

Mechanical, Electrical, Plumbing Seal

DIVISION 20 - FACILITY SERVICES GENERAL REQUIREMENTS INDEX

SECTION	DESCRIPTION
20 00 00	FACILITY SERVICES GENERAL REQUIREMENTS INDEX
20 05 00	CODES AND STANDARDS
20 05 01	SCOPE OF WORK
20 05 02	DESIGN CRITERIA
20 05 03	BASIC DIVISION 20-28 REQUIREMENTS
20 05 04	SCHEDULE OF SUBMITTAL DATA
20 05 05	GENERAL DIVISION 20-28 MATERIALS AND METHODS
20 05 08	DEMOLITION AND WORK WITHIN EXISTING BUILDINGS
20 05 14	ELECTRONIC VARIABLE SPEED DRIVES
20 05 33	PIPE HEAT TRACING
20 05 48	NOISE AND VIBRATION ISOLATION
20 07 00	THERMAL INSULATION
20 08 00	COMMISSIONING

END OF INDEX

SECTION 20 05 00 - CODES AND STANDARDS

PART 1 - GENERAL

1.01 **RELATED DOCUMENTS**

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

1.02 **CODES: DIVISIONS 20 - 28**

A. Code Design Basis: The following codes and ordinances were used in the design of the project and shall be complied with during construction of the project.

1. Refer to each discipline's cover sheet per school for codes and ordinances followed.

1.03 **STANDARDS**

A. Refer to Division 1 for general administrative/procedural requirements related to compliance with applicable standards. This Work and all materials shall meet the standards set forth in the applicable portions of the following recognized standards:

1. ADC..... Air Diffusion Council
2. AEIC..... Association of Edison Illuminating Companies
3. AGA..... American Gas Association
4. AHRI..... Air Conditioning, Heating, and Refrigeration Institute
5. AMCA..... American Movement and Control Association
6. ANSI..... American National Standards Institute
7. ASHRAE ... American Society of Heating, Refrigerating, and Air Conditioning Engineers
8. ASME ..... American Society of Mechanical Engineers
9. ASPE..... American Society of Plumbing Engineers
10. ASSE..... American Society of Sanitary Engineering
11. ASTM ..... American Society for Testing and Materials
12. AWS ..... American Welding Society
13. AWWA..... American Water Works Association
14. CBM ..... Certified Ballast Manufacturers
15. CDA..... Copper Development Association
16. CE ..... Corps of Engineers (U.S. Department of the Army)
17. CISPI..... Cast Iron Soil Pipe Institute
18. EIA..... Electronic Industry Association
19. EPA ..... Environmental Protection Agency
20. ETL..... Electrical Testing Laboratory
21. FAA ..... Federal Aviation Administration (U.S. Department of Transportation)
22. FCC..... Federal Communications Commission
23. FM ..... Factory Mutual Engineering Corporation
24. FS..... Federal Specification (General Services Administration)
25. ICEA..... Insulated Cable Engineering Association
26. IEEE ..... Institute of Electrical and Electronics Engineers
27. IES..... Illuminating Engineering Society of North America
28. IRI..... Industrial Risk Insurers
29. LPI..... Lightning Protection Institute
30. MCAA..... Mechanical Contractors Association of America
31. MIL ..... Military Standardization Documents (U.S. Department of Defense)
32. MSS ..... Manufacturers Standardization Society of the Valve and Fittings Industry
33. NAIMA..... North American Insulation Manufacturers Association

34. NEC..... National Electrical Code (by NFPA)
35. NECA ..... National Electrical Contractor Association
36. NEMA..... National Electrical Manufacturers Association
37. NFPA..... National Fire Protection Association
38. OSHA ..... Occupational Safety Health Administration (U.S. Department of Labor)
39. PDI ..... Plumbing and Drainage Institute
40. SMACNA... Sheet Metal and Air Conditioning Contractor's National Association
41. UL..... Underwriters' Laboratories, Inc.

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION (NOT APPLICABLE)

END OF SECTION

SECTION 20 05 01 - SCOPE OF WORK

PART 1 - GENERAL

1.01 **RELATED DOCUMENTS**

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, and Drawings apply to all Work herein.

B. Refer to Specification Section 20 05 00 for related required Codes and Standards.

C. Refer to Specification Section 20 05 04 for related required Schedule of Submittal Data.

D. Requirements of Division 20 apply to all Work of Divisions 20-28.

1.02 **SCOPE**

A. General: Provide all labor, materials, tools, machinery, equipment, supplies, transportation, storage, utilities, appliances, drayage, hauling, hoisting, excavation, backfill, supervision, and services necessary to complete the Fire Suppression, Plumbing, Heating, Ventilating, and Air Conditioning, Automation, Electrical, Communications, and Electronic Safety Work under this Contract. Pay all fees, tap charges, meter charges, permits, licenses, inspections, and special fees assessed by the local utilities and local authorities having jurisdiction. Coordinate Work with the Work of the other trades so as to resolve conflicts without impeding job progress.

B. Examine the Architectural, Structural, Mechanical, Plumbing, and Electrical Drawings and other Divisions, and Sections of the Specifications in order to determine the extent of Work required to be completed. Failure to examine all the Contract Documents for this Project will not relieve the Contractors of the responsibility to perform all the Work required for a complete, fully operational and satisfactory installation.

C. Project Location: The Work to be performed under this Contract is all in connection with the construction and erection of a new building or renovations in an existing building located in Fort Bend County, Texas.

D. Work Included: The Work includes but is not limited to the following systems, equipment, and services:

1. Tagging and identification of equipment, valves, piping, and conduit, etc.
2. Radiation protection for ductwork, piping, and conduit penetration of walls surrounding various radiotherapy department rooms.
3. Connection of all equipment furnished under other Divisions and/or by the Owner.
4. All water services for the building, including all required fees.
5. All electric services for the building, including all required fees.
6. Furnishing of Shop Drawings, Product Data and Samples.
7. Furnishing of Record Drawings.
8. Start-up, testing, balancing, and adjusting of systems as specified in Divisions 20-28.
9. Furnishing of operating and maintenance books.
10. Miscellaneous items as required for complete and functioning systems as specified, as indicated on the Drawings, and as required.
11. All systems, equipment, and services specified shall be furnished and installed completely and ready to use.
12. Performance and acceptance testing of equipment and systems as specified and as required by Authorities Having Jurisdiction. Refer to Sections in Divisions 20-28 titled "Start-up, Testing, Balancing, and Adjusting" for additional requirements. Participate in

and provide labor as required for "off-hour" testing of equipment and systems if required by job conditions or by the Authorities Having Jurisdiction and as required to obtain the "Certificate of Occupancy (CO)".

1.03 **WORK OF OTHER DIVISIONS**

A. The following is a partial list of work not included in Divisions 20-28:

1. Factory finish painting is included in the work of these Divisions. Prime, protective, and field finish painting is included in the work of Division 9, except as otherwise specified herein. The Work of these Divisions includes coordinating the painting of Division 20-28 systems with the Division 9 contractor.
2. Motors and motor controllers that are an integral part of the equipment are furnished under the Division with the driven equipment. All other motor controllers, electrical wiring and connections are included in the work of Division 26.
3. Concrete housekeeping pads, equipment pads, fill for equipment inertia bases, and water curbs are specified under Division 3. Dimensions and locations of pads, inertia bases, and curbs for equipment furnished under Divisions 21-28 are included in the Work of the respective Division.
4. Installing access doors. Provision of access doors are included in the Work of Divisions 21-28.
5. Owner and General Contractor furnished equipment. Fire Suppression, Plumbing, Heating, Ventilating, and Air Conditioning, Automation, Electrical, Communications, and Electronic Safety provisions, including rough-in and final connections, are included in the Work of the respective Division.
6. Metal louvers.
7. Cooling tower supporting structure to be provided by the contractor.

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION (NOT APPLICABLE)

END OF SECTION

SECTION 20 05 02 - DESIGN CRITERIA

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

1.02 DESIGN CONDITIONS:

A. General:

1. Range of indoor design goals for sound control for all occupied spaces shall have an NC criteria curve range not to exceed NC 40.
2. Approximate grade elevation above Sea Level: 45 ft.
3. Standards: Refer to Division 1 for general administrative/procedural requirements related to compliance with applicable standards. This Work and all materials shall meet the standards set forth in the applicable portions of the recognized standards listed in Section 20 05 00 Codes and Standards.
4. The design wind load shall be based on an ultimate design wind speed of 139 mph, roughness class C, as per IBC section 1609. If the design wind load in the architectural or structural documents differs, the more stringent requirements shall apply.

B. Division 22 Plumbing

1. Outside design conditions are as follows: Dry Bulb °F

   a. Winter Outside Air Temperature 28

2. Schedule of Working Pressures: Working Pressure

   a. Domestic Cold-Water System: 150
   b. Domestic Hot Water System: 150
   c. Natural Gas System: 150
   d. Medical Gas and Vacuum Systems: 100

C. Division 23 Heating, Ventilating, and Air Conditioning

1. Outside design conditions are as follows: Dry Bulb °F Wet Bulb °F

   a. Summer Outside Air Temperature 96 80
   b. Winter Outside Air Temperature 28 ---

2. Cooling inside design conditions are as follows:

   a. Offices, Lobbies, Corridors 75 61
   b. Elevator Machine Rooms 85 ---
   c. Machine Rooms 85 ---

3. Heating inside design conditions are as follows:

   a. Inside Temperature Throughout 75 ---
   b. Penthouse and Machine Rooms 60 ---

4. Schedule of Working Pressures:		Working Pressure	Normal Operating Temperature Range
a.	Chilled Water System:	150	42°F to 60°F
b.	Condenser Water System:	150	86°F to 96°F
c.	Heating Hot Water System:	150	150°F to 180°F
d.	Steam System:		
1)	High Pressure	250	406°F
2)	Medium Pressure	50	298°F
3)	Low Pressure	5	228°F

D. Division 25 Integrated Automation

1. Outside design conditions are as follows:		Dry Bulb °F	Wet Bulb °F
a.	Summer Outside Air Temperature	96	80
b.	Winter Outside Air Temperature	27	---

2. Cooling inside design conditions are as follows:

a.	Offices, Lobbies, Corridors	74	61
b.	Elevator Machine Rooms	85	---
c.	Mechanical Rooms	85	---

3. Heating inside design conditions are as follows:

a.	Inside Temperature Throughout	75	---
b.	Machine Rooms	60	---

5. Schedule of Working Pressures:		Working Pressure	Normal Operating Temperature Range
a.	Chilled Water System:	150	42°F to 58°F
b.	Condenser Water System:	150	86°F to 96°F

E. Design Conditions: Division 26 Electrical

1. Not Applicable

F. Design Conditions: Division 27 Communications

1. Not Applicable

G. Design Conditions: Division 28 Electronic Safety

1. Not Applicable

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION (NOT APPLICABLE)

END OF SECTION

SECTION 20 05 03 - BASIC DIVISION 20-28 REQUIREMENTS

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

1.02 COMPLETE PERFORMANCE

A. The Contractor shall furnish and install all items specified herein and as indicated on the Drawings. The Contractor shall also furnish and install all items necessary to make the systems function which may be reasonably implied as essential, whether mentioned in the Contract Documents or not.

B. Each Contractor for Divisions 20-28 shall provide competent, experienced full time superintendents who are authorized to make decisions on behalf of the Contractor.

C. Work shall be executed in strict accordance with the best practice of the trades in a thorough, substantial and workmanlike manner by competent workmen.

1.03 SITE FAMILIARIZATION

A. General: Become familiar with the Drawings and Specifications, examine the premises, and understand the conditions under which the Contract shall be performed, prior to submitting a bid.

B. Site: Be informed of the site conditions, verify locations of new and existing equipment, and determine exact requirements for connections.

C. Coordination: Tender of a proposal for this project infers that the Contractor has visited the site and has become familiar with the Drawings, Specifications, and site conditions and has included in his proposal, all work necessary to properly install complete and functioning systems on the project. Failure to comply with this requirement shall not be considered justification for the omission or faulty installation of any Work covered by the Contract Documents.

1.04 CODES AND STANDARDS

A. General: All Work shall comply with the most recently revised versions of all applicable laws, rules, regulations and ordinances of all Federal, State and Local Authorities and applicable Utilities. None of the terms or provisions of this Specification shall be construed as waiving any part of the laws, rules, regulations or requirements of these Authorities.

B. Asbestos: Be aware of and comply with Asbestos NESHAP (National Emission Standard for Hazardous Air Pollutants) regulations, as well as all other applicable codes, laws, and regulations.

C. Conflict: In the event of conflict between the Contract Documents and the local enforcing authority, the latter shall rule. Any modifications resulting therefrom shall be made without any additional cost to the Owner or Architect/Engineer. This Contractor shall report any such modifications to the Architect/Engineer and secure his approval prior to proceeding with the work.

D. Precedence: Where Contract Document requirements exceed the requirements of the Codes and Standards, the Contract Documents shall take precedence provided they are not in conflict with those Codes and Standards.

E. Approval Labels: All items of equipment and all materials for which approved standards have been established by Underwriters' Laboratories, Inc. (UL), Factory Mutual (FM), Certified Ballast Manufacturer (CBM), Electrical Testing Laboratory (ETL), National Manufacturers Association (NEMA), American Standard Codes, ASME, AGA, AMCA, ASA, ANSI, ASHRAE, and ARI shall be so approved and shall bear approval labels attesting to same.

1.05 DRAWINGS AND SPECIFICATIONS

A. Drawings: The Drawings are schematic in nature and indicate approximate locations of the heating, ventilating, and air conditioning systems, fire protection systems, plumbing equipment, fixtures and piping systems, and electrical items, except where specific locations are noted and dimensioned on the Drawings. All items are shown approximately to scale. The intent is to show how these items shall be integrated into the construction. Locate all items by on the job measurements and in accordance with the Contract Documents. Coordinate with other trades.

B. Location: Prior to locating diffusers, grilles, plumbing fixtures, fire hose cabinets, plumbing items, outlets, switches, fixtures, fire alarm devices, sprinkler heads, and other exposed devices, obtain the Architect's approval as to exact location. Locations shall not be determined by scaling Drawings. Mount plumbing fixtures, fire hose racks, cabinets, outlets, switches, and other wall-mounted devices at heights as directed by the Architect. Contractor shall be responsible for costs of redoing work of trades necessitated by failure to comply with this requirement.

C. Specifications: The specifications are intended to supplement the Drawings and it is not in the scope of the Specifications to mention any part of the work that the Drawings are competent to fully explain. Conversely, any part of the work that the specifications are competent to fully explain may not be mentioned on the Drawings. Drawings and Specifications are complimentary/supplementary documents to each other.

D. Disagreement: Disagreement between the Drawings and Specifications or within the Drawings or Specifications shall be estimated and/or bid using the better quality or greater quantity of material or installation, and a clarification request for information shall be made to the Architect/Engineer in a timely manner after the Project is under contract.

1.06 DISCREPANCIES

A. Clarification: Clarification of significant cost matters shall be obtained before submitting a proposal for the Work under Divisions 20-28 as to discrepancies or omissions from the Contract Documents or questions as to the intent thereof.

B. Detailed Instructions: Should it appear that the work hereby intended to be done or any of the materials relative thereto is not sufficiently detailed or explained in the Drawings or Specifications, then the Contractor shall apply in a timely manner to the Engineer for clarification or explanations as may be necessary, allowing a reasonable time for the Engineer to respond. The Contractor shall conform to this additional information as a part of the Contract without additional cost to the Owner or Engineer.

C. Interpretations: Should any doubt or question arise respecting the true meaning of Drawings or Specifications, reference shall be made to the Engineer, whose written decision shall be final and conclusive. No alleged statement by the Engineer will be accepted as an excuse for non-compliance or inferior work.

D. Contractor Agreement: Consideration will not be granted for misunderstanding of the amount of work to be performed. Tender of a proposal conveys full Contractor agreement of the items and conditions specified, shown, scheduled, or required by the nature of the project, and all costs are included in the proposal.

1.07 **REQUESTS FOR INFORMATION (RFI)**

A. General: Submit all Contractor Requests for Information (RFI) in writing to the Architect/Engineer for response. Submit RFI on a standard form that has a space for the requested information and the Architect/Engineer's response. Electronic submissions shall be sent to RFI@wylieeng.com.

B. Solution Proposal: In general, the Contractor shall propose solutions to identified problems for review and approval of the Architect/Engineer. The RFI shall include hand sketches, marked drawing prints, equipment cutsheets, drawing and specification references, and any other back-up information, etc., as required to sufficiently explain the problem and proposed solution.

1.08 **QUALITY ASSURANCE**

A. General: Materials and equipment shall be new, of best grade and quality, and standard products of reputable manufacturers regularly engaged in the production of such materials and equipment.

B. Workmanship: Work shall be executed, and materials installed in accordance with the best practice of the trades in a thorough, substantial, workmanlike manner by competent workmen, presenting a neat appearance when completed.

C. Judgment: In all cases, the Engineer shall be the sole judge of the quality and equivalence of manufacturers, products, materials, and methods.

D. Manufacturers/Products/Materials/Methods: Manufacturers, products, materials, and methods described in the various sections of the Specifications and indicated on the Drawings are intended to establish a standard of quality only. It is not the intention of the Engineer to discriminate against any manufacturer, product, material, or method that is equal to the standards as indicated and/or specified, nor is it intended to preclude open, competitive bidding. The fact that a specific manufacturer is listed as an acceptable manufacturer shall not be interpreted to mean that the manufacturer's standard product will meet the requirements of the project design, Specifications, and space constraints.

1. Wherever a definite manufacturer, product, material, or method is specified and there is not a statement that another manufacturer, product, material, or method will be acceptable, it is the intention of the Engineer that the specified manufacturer, product, material, or method is the only one that shall be used without Prior Approval.
2. Wherever a definite manufacturer, product, material, or method is specified as "NO SUBSTITUTE", it is the intention of the Engineer that the listed item is the only one acceptable.

E. Alternate Manufacturers/Products/Materials/Methods: Products by Alternate reliable manufacturers, products, materials, or methods may be accepted provided they have equal capacity, construction, and performance.

1. Wherever a definite material or manufacturer's product is specified and the Specification states that products of listed manufacturers may be provided, it is the intention of the Engineer that Alternate products of manufacturers that are specified (i.e., listed) are the only products that will be acceptable and that products of non-listed manufacturers will not be considered for Substitution without Prior Approval.

F. Substitute Manufacturers/Products/Materials/Methods: Products by Substitute reliable manufacturers, products, materials, or methods may be accepted provided they have equal capacity, construction, and performance.

1. Wherever the expression "Or Approved Equal" is used in the Contract Documents, it is the intention of the Engineer that Substitute manufacturers, products, materials, and methods may be used only with Prior Approval. Under no circumstances shall any Substitution of manufacturers, products, materials, or methods be made without the prior written approval of the Engineer.

G. Coordination: Where Alternate or Substituted equipment is used on the project, it shall be the responsibility of the Contractor or Subcontractor involved to verify that the equipment will fit in the space available, including all required Code and maintenance clearances, and to coordinate all equipment requirements and provisions with the System Design, all affected Divisions, and all other Contractors. Where the use of Alternate or Substitute materials affects the cost of provisions made by other Contractors, the Contractor providing the Alternate or Substitute shall be responsible for the other Contractor's cost adjustment. There shall be no additional cost to the Owner or Architect/Engineer due to the use or acceptance of any Alternate or Substitute manufacturer, product, material, or method.

1.09 **PRIOR APPROVAL**

A. General: Contractors wishing to Substitute manufacturers, products, materials, or methods from those indicated, or specified, shall submit such requests to the Architect in writing ten (10) calendar days prior to the General Contractor’s bid. Requests for Prior Approval sent directly to the Engineer will not be considered. Requests for permission to make Substitutions after that time will not be considered. An approved Substitution will receive a written approval only in the form of an issued Specification change.

B. Submittal: Requests shall consist of two (2) sets of descriptive literature and performance data covering each item of equipment or material. The submittal shall include the following:

1. Name of the Architect, Engineer, Project, Sub-Contractor, and General Contractor.
2. Reference to Specification Section and Page Number.
3. A list of all variations from the Contract Document requirements.
4. Dimensional drawings.
5. Sufficient information on the specified product for which approval is sought. All technical performance data and construction materials shall be clearly noted.

C. Samples: Provide, upon request of the Architect/Engineer, samples of materials and equipment for review.

D. Conditions: The Contractor's Substitution request will be received and considered by the Architect/Engineer when the following conditions are satisfied:

1. Extensive revisions to Contract Documents are not required.
2. Proposed changes are in keeping with the general intent of Contract Documents.
3. The request is timely, fully documented, and properly submitted.
4. The request is directly related to an "or equal" clause or similar language in the Contract Documents or as permitted in the section QUALITY ASSURANCE.
5. One or more of the following conditions:

   a. The specified product or method of construction cannot be provided within the Contract Time. The request will not be considered if the product or method cannot be provided as a result of failure to pursue the Work promptly or coordinate activities properly.
   b. The specified product or method of construction cannot receive necessary approval by a governing authority, and the requested substitution can be approved.

c. A substantial advantage is offered the Owner, in terms of cost, time, energy conservation, or other considerations of merit, after deducting offsetting responsibilities the Owner may be required to bear. Additional responsibilities for the Owner may include additional compensation to the Architect/Engineer for redesign and evaluation services, increased cost of other construction by the Owner or separate Contractors, and similar considerations.

d. The specified product or method of construction cannot be provided in a manner that is compatible with other materials, and where the Contractor certifies that the substitution will overcome the incompatibility.

e. The specified product or method of construction cannot be coordinated with other materials, and where the Contractor certifies that the proposed substitution can be coordinated.

E. Shop Drawings, Product Data, and Samples: The Contractor's submittal and Engineer's acceptance of Shop Drawings, Product Data, or Samples that relate to construction activities not complying with the Contract Documents does not constitute an acceptable or valid request for Substitution, nor does it constitute approval.

F. Division 1: The requirements for Prior Approval listed herein supersede the requirements for Substitutions listed in Division 1 of the Specifications.

1.10 **CONFERENCE PRIOR TO START OF WORK**

A. Immediately upon the award of this Contract, but prior to commencing any Work, the Contractor, together with designated major subcontractors, shall confer with the Architect and Engineer concerning the Work under this Contract.

B. The conference will be at a mutually agreed place and acceptable time.

1.11 **UTILITIES**

A. General: Location, inverts and sizes of water lines, gas lines, fire hydrants, sewer lines, manholes, capacity and voltage of electric lines, and location of telephone lines, etc., are shown if available. This data is accurate to the best knowledge of the Engineer.

B. Coordination: The Contractor shall be responsible for field verification of the actual location of site utilities and shall make modifications necessary for connection to or construction around those utilities at no additional cost to the Owner or Engineer.

C. Temporary Power Services:

1. Temporary electrical power for construction operations shall be derived from a new temporary service from the Power Company. The Electrical Contractor shall provide the necessary conductors, connections, service switches, poles, protective devices, lighting fixtures, lamps, outlet devices, disconnect switches, etc., required for temporary lighting and single and three phase power of voltage levels required by the construction of the project.
2. All such temporary equipment shall remain the property of the Contractor and shall be removed when permanent connections have been completed.
3. Temporary connections shall be safe and in accordance with applicable codes. The Contractor shall be responsible for any damage or injury to equipment, materials, or personnel caused by improperly protected temporary installations.
4. All costs for materials and installation for distribution of temporary electrical facilities shall be at the expense of the Electrical Contractor.

5. No conductors, bus, nor any other electrical equipment which is part of the permanent electrical system may be used for temporary electrical service for construction operations, unless approved by the Architect/Engineer.
6. Power Company costs for temporary and permanent power usage (during construction) until date of occupancy will be born by the General Contractor.
7. In addition, it is the responsibility of the Electrical Contractor to coordinate with the local power company the installation and activation of permanent power to the building, in a timely manner to avoid construction delays.

1.12 **CHANGE ORDERS**

A. Refer to Division 1 for requirements concerning Change Orders.

1.13 **ALTERNATES**

A. General: Refer to Division 1 for information concerning Alternates.

1.14 **UNIT PRICES**

A. General: Refer to Bid Form for information on required Unit Prices.

1.15 **SPACE LIMITATIONS**

A. General: Determine in advance of purchase that the equipment and materials proposed for installation will fit into the confines indicated, leaving adequate clearances for adjustments, repair, or replacement. Allow adequate space for clearance in accordance with requirements of the Code, local inspection department, and equipment manufacturer.

B. Scheduled Equipment: The design shown on the Drawings is based on the equipment scheduled. Equipment has been chosen which will fit into the physical spaces provided and indicated, allowing ample room for access, servicing, removal and replacement of parts, etc.

C. Responsibility: Since space requirements and equipment arrangement vary according to each Manufacturer, the responsibility for initial access and proper fit rests with the Contractor.

D. Review: Final arrangements of equipment to be installed shall be subject to Architect/Engineer review.

1.16 **COORDINATION**

A. Each Contractor shall be responsible for the coordination of all items that will affect the installation of the Work of his Division. The coordination shall include, but not be limited to, voltage, ampacity, capacity, electrical/piping connections, structural supports, space requirements, locating devices in Architectural finish elements, staging the construction and building requirements, and special conditions.

B. By submitting shop drawings on the project, this Contractor is indicating that all necessary coordination has been completed and that the systems, products and equipment submitted can be installed in the building and will operate as specified and intended, in full coordination with all other disciplines.

C. Holes or other openings required in surfaces with special Architectural finishes (stone, cloth, finished wood, etc.) shall be reviewed and approved by the Owner or Architect prior to any cutting or drilling.

1.17 **SHOP DRAWINGS AND SUBMITTALS**

A. General: After the Contract is awarded but prior to proceeding with the Work requiring Shop Drawing review, the Contractor shall obtain complete shop drawings and product data from the manufacturers, suppliers, vendors, and Sub-Contractors for all materials and equipment specified herein and make formal submission to the Architect. A minimum period of two (2) weeks should be allowed in the Construction Schedule for the Engineers review.

B. Certification: Each Contractor responsible for the Work shall review and certify the shop drawing, submittal and/or product data to be in full compliance with the requirements of the Contract Documents.

C. The Engineer's review of shop drawings and submittal data shall not relieve the Contractor of the responsibility for dimensions or errors that may be contained therein, or for deviations from any requirements of the Contract Documents. It shall be clearly understood that the Engineers noting some errors but overlooking some others does not grant the Contractor permission to proceed in error. Regardless of any information contained in the shop drawing or product data, the Contract Documents shall govern the Work and are neither waived nor superseded in any way by the review of shop drawings, product data and samples.

D. A SUBMITTAL SHALL NOT CONTAIN INFORMATION FROM MORE THAN ONE SPECIFICATION SECTION. A specification section can be subdivided into separate submittals for items that are listed in the section.

E. ELECTRONIC SUBMITTAL: Each submittal shall contain the following items in a suitable electronic document or file:

1. Electronic Submittals shall be sent to the Architect for distribution to the proper Design Team recipients.
2. The Architect shall provide Electronic Submittals to Engineer at Submittals@wylieeng.com. Submittals sent to individual Wylie Engineers only will not be accepted.
3. Electronic submittals shall be sent via email in searchable PDF form with electronic marks. At no point shall a submittal be printed and scanned prior to emailing. Submittals required to be printed for review are to be provided via hard copy. Submittals scanned from hard copies with handwritten marks are not acceptable.
4. Any electronic submittals deemed not readable will be automatically rejected.

F. Each submittal shall contain the following items:

1. A cover sheet with the names and addresses of the Project, Architect, MEP Engineer, General Contractor and the Subcontractor making the submittal.
2. The Specification Section Number or Drawing Reference Number covering the items being submitted and the product name or description.
3. An index page listing all data within the submittal including the product name and description.
4. A specification compliance review. This shall consist of a reproduction of the applicable specification section(s) from the contract documents. Each line in the specification shall be marked either “Comply”, “Deviate”, or “N/A”, as appropriate. An explanation shall be provided for Deviate and N/A items.
5. Dimensional data and actual sketches as applicable to show that the submitted equipment will fit into the space available with all required Code and maintenance clearances.
6. Identification of each item of material or equipment matching that indicated on the Drawings.

7. Sufficient performance data, capacity, sound data where applicable, diagrammatic data and descriptive information to show its compliance with the requirements of the Contract Documents. Any options or special requirements shall be clearly highlighted. All applicable information shall be clearly highlighted. All non-applicable data shall be crossed out.

G. Submittals will be marked with one of the following levels of status:

1. NO EXCEPTIONS
2. FURNISH AS NOTED
3. REVISE AND RESUBMIT
4. REJECTED AS NOTED
5. NO ACTION

H. NO EXCEPTIONS: The submittal was reviewed and general compliance with the design concept and general requirements of the Contract Documents was noted.

I. FURNISH AS NOTED: The submittal was reviewed and found to have minor deviations from the requirements of the Contract Documents or missing information. The contractor shall correct deviations or missing information when ordering materials or equipment and shall provide a corrected submittal in the O&M Manual.

J. REVISE AND RESUBMIT: The submittal was reviewed and major deviations from the requirements of the Contract Documents were noted. The shop drawing or product data shall be revised to eliminate the deviations. A complete resubmittal is required with a written response to each review comment.

K. REJECTED AS NOTED: The submittal was found to be in direct conflict with the requirements of the Contract Documents and was not reviewed further. A complete submittal on the product specified is mandatory.

L. NO ACTION: This status is assigned to O & M Manuals, Record Drawings, and non-applicable submittals made to the Engineer. Should there be comments with this status, the contractor shall address and satisfy them all via written correspondence.

M. Materials and equipment which are purchased or installed without a "NO EXCEPTIONS" shop drawing review shall be at the risk of the Contractor and the cost for removal and replacement of such materials and equipment and related work which is judged unsatisfactory by the Architect/Engineer for any reason shall be at the expense of the Contractor.

N. Shop Drawings shall be complete and certified by the Contractor prior to submission to the Engineer for review. Where more than two reviews are required for a given submittal to obtain a status of "NO EXCEPTIONS", the owner shall be reimbursed by the Contractor for any expense in connection with more than the two submittals set forth herein.

1.18 **CERTIFICATIONS AND TEST REPORTS**

A. Submit a detailed schedule for completion and testing of each system indicating scheduled dates for completion of system installation and outlining tests to be performed and schedule date for each test. This detailed completion and test schedule shall be submitted at least thirty (30) days before the projected project completion date.

B. Test result reporting forms shall be submitted for review prior to submittal of the completion and test schedule.

C. Submit an electronic copy of all certifications and test results to the Architect/Engineer for review in sufficient advance of the completion schedule to allow for any remedial work required to correct any deficiencies discovered in equipment and systems.

D. Certifications and completed test reports to be submitted electronically, and shall include, but not be limited to those items outlined in Sections titled "Startup, Testing, Adjusting and Balancing", and "Testing".

1.19 OPERATING AND MAINTENANCE MANUALS

A. Bind together electronically or in 3-ring binders, four (4) sets (if hard copy is selected) of all approved shop drawings, submittals, bulletins, wiring diagrams, and operating and maintenance instructions on every piece of equipment furnished under this Division. All Sections shall be organized into Sections, typed, labeled and indexed for ease of reference. All pertinent information required for proper operation and maintenance of equipment supplied by the respective Division shall be clearly and legibly written and shall be bound with the O & M's.

B. The following information shall be provided for all equipment:

1. Identifying name, name tag designation and location of all equipment.
2. Valve tag lists with valve number, type, location, service and color-coding.
3. Fuse and motor heater size information.
4. Equipment and motor nameplate data.
5. Manuals shall only contain submittals with a status of "No Exceptions Taken" or have written responses.
6. Fabrication drawings.
7. Equipment and device bulletins and catalog cut sheets clearly highlighted to show pertinent information about the product installed in the Project. Include also all performance curves and capacity data.
8. Maintenance instructions clearly highlighted to show all required periodic maintenance and lubrication.
9. Wiring diagrams.
10. Operating instructions clearly highlighted.
11. Exploded parts views and parts lists for all equipment and devices.
12. Location and listing of all spare parts and special keys and tools furnished to the Owner.
13. Vendor source name, address, and phone number for replacement parts.
14. Copies of all certified test results and other required certifications.
15. Color-coding charts for all painted equipment and conduit.
16. Operating and Maintenance Manuals shall be delivered to the Architect/Engineer at least fourteen (14) days prior to the beginning of the operator's training period.

1.20 RECORD DRAWINGS

A. The Contractor shall maintain, on a daily basis, a complete set of black line record prints clearly stamped "Record Drawings" on the job site on which he shall note all details and alterations required to be made to meet actual site conditions and Changes made by Change Order notices. All deviations from the Contract Documents shall be noted on the Record Drawings. This requirement shall not be construed as authorization for the Contractor to make changes in the layout or Work without definite instructions from the Architect. These drawings shall be kept available for inspection by the Architect/Engineer at all times. Refer to Division 1 for additional requirements concerning Record Drawings.

B. The Record Drawings shall indicate accurate dimensions in two directions from a column for all buried or concealed Work and for recording any deviations from the Work indicated on the Contract Documents as a result of coordination.

C. Within thirty (30) days of completion of the Work, the Contractor shall transfer all marks from the Record Drawings to a set of Record CAD or BIM files and shall submit the Record CAD or BIM files and three (3) sets of black line prints to the Architect/Engineer for review.

D. The reproducible Record CAD or BIM files shall have the Engineer's name and seal completely removed. Each Drawing shall be marked with an impression identical to the example below and signed on each sheet as follows:

CERTIFIED RECORD DRAWINGS

DATE: _____

(NAME OF GENERAL CONTRACTOR)

BY: _____

(NAME OF SUBCONTRACTOR)

BY: _____

1.21 **EXECUTION AND COORDINATION OF WORK**

A. The Drawings attempt to show reasonable indications of the locations of ductwork, piping, conduit, and equipment without always indicating elevations and dimensions. The Contractor shall perform field measurements of actual structural conditions prior to fabricating ductwork, piping, and conduit. All piping systems that require grading shall be coordinated with all trades. Exact locations of equipment and connections thereto shall be coordinated with "No Exceptions Taken" shop drawings, equipment drawings, rough-in drawings, building conditions and all other trades. Any reasonable changes in the locations indicated on the Contract Documents, up to a distance of three (3) feet, shall be made by the Contractor without any additional cost to the Owner.

B. All ducts, pipes, and conduit, except those in the various equipment rooms, in unfinished spaces or where specifically designated herein or on the Drawings shall be run concealed in furrings, plenums and chases.

C. Interferences with other trades shall be resolved by giving precedence to systems required to be sloped for drainage or proper operation. Where space requirements conflict, the following order of precedence shall be observed:

1. Building lines.
2. Structural members.
3. Soil and drain piping.
4. Steam and condensate piping.
5. Sprinkler piping.
6. Vent piping.
7. Supply ductwork.
8. Exhaust ductwork.
9. HVAC water piping.
10. Domestic water piping.
11. Electrical conduit.

D. Manufacturer's Recommendations: With exceptions as specified and/or indicated on the Drawings or in the Specifications, apply, install, erect, use, clean, and condition, manufactured articles, materials, and equipment per Manufacturer's current printed recommendations. Keep copies of such printed recommendations at job site and make them available as required.

E. Architectural Approval: Devices exposed to occupant view or mounted on walls, ceilings, floors, etc. in finished spaces shall:

1. Be located in exact locations shown on the Architectural Drawings or locations approved by the Architect.
2. Have appearances acceptable to the Architect.

1.22 **CONTRACTOR'S COORDINATION DRAWINGS/BUILDING INFORMATION MODEL (BIM)**

A. The Contractor shall coordinate efforts of all trades and shall furnish (in writing, with copies to the Architect and Owner) any information necessary to permit the Work of all trades to be installed satisfactorily and with the least possible interference or delay.

B. The Contractor and all Subcontractors shall prepare a complete set of construction coordination drawings ("Coordination Drawings") indicating all of the equipment actually purchased and the exact routing and elevations for all lines such as piping, busway, conduit, ductwork, etc., including conduit embedded in concrete and openings, sleeves, etc., required in the structure, walls, partitions, etc. The Coordination Drawings shall be submitted complete for review to the Architect, Engineer and Owner in accordance with the specifications. The Coordination Drawing preparation and completion shall comply with the requirements of the Schedule. Prior to commencing the Work, the Subcontractor shall obtain from the Architect or Engineer the Building Information Model (BIM) file in Revit® and/or a set of AutoCAD compatible format Architectural and Engineering Drawings, to be used to produce the Coordination Drawings. The Subcontractor shall give to the Architect and Engineer a written release acceptable to the Architect and Engineer signed by a corporate officer of the Subcontractor, prior to receipt of the compact disks. The sheet metal Drawings, prepared on electronic media using BIM software at a scale not less than 1/4" = 1'-0", shall serve as the base Drawings to which all other Subcontractors will overlay and add their Work. The Mechanical Subcontractor shall be designated as the lead contractor in the development of the composite modeling process and shall be responsible for electronically incorporating the various trade models into the final composite Building Model. Each trade shall draw their Work on separate layers represented by individual colors. Each Coordination Drawing shall be completed and signed off by the other Subcontractors and the Contractor prior to the installation of the Work in the area covered by the specific Coordination Drawing. The Subcontractors Work shall be installed in accordance with the Shop Drawings and the Coordination Drawings and shall include the required maintenance access space and the code clearance space. If the Contractor allows one trade to install their Work before coordinating with the Work of other trades, the Contractor shall make necessary changes to correct the condition without extra cost to the Owner. The Coordination Drawings indicating piping, conduit, busway and equipment support points, and loads exceeding 1,000 lb. imposed on the building structure shall be submitted to the Architect for review and approval. The elevation, location, support points, static, dynamic and expansion forces and loads imposed on the structure at support and anchor points and the size of all lines shall be indicated. All beam penetrations, slab penetrations, and sleeves shall be indicated, sized and coordinated with all other Work. All required code clearance space and required maintenance access space shall be indicated and coordinated with all other work. All Work routed underground or embedded in concrete shall be indicated by dimension to column and building lines and shall be coordinated. This requirement for Coordination Drawings shall not be construed as authorization for the Contractor or Subcontractor to make any unauthorized changes to the Drawings. All space allocations shown on the Drawings shall be maintained, such as ceiling height, seven (7) inch high zone directly above the ceiling reserved for tenant build out and flexibility, chase walls, equipment room size, etc., unless prior written authorization is received from the Architect to change them. Prior to final

acceptance of the Work, the Contractor shall give the BIM in Revit® or AutoCAD 3D 2018 or later compatible format on electronic media storage, containing the Contractor's coordination documentation, to the Owner.

1.23 SUPERVISION

A. A competent Superintendent approved by the Architect/Engineer, shall be kept by the Contractor at the building to receive instructions and to act for the Contractor. Once the Superintendent has been approved, no change shall be made without approval of Architect/Engineer. Representatives of the Owner, Architect/Engineer shall have the right to observe the work at any time. The Contractor shall have a representative available when his work is being observed and he shall give assistance as may be required to the Architect/Engineer's representative.

B. The project shall be constructed by employees of the Contractor or by workers under his supervision. Any subcontractors employed by the Contractor shall be approved by the Owner's Representative. The Contractor shall be responsible for all equipment, material and work performed by any subcontractor.

1.24 SAFETY REGULATIONS

A. All Work shall be performed in compliance with all applicable and governing safety regulations. All safety lights, guards and signs required for the performance of the Work shall be provided and operated by the respective Contractor.

1.25 STORAGE AND PROTECTION OF MATERIALS

A. The Contractor shall properly store all material and equipment at the jobsite and protect it from the elements and from damage. Any equipment damaged due to improper protection shall be replaced by the Contractor at his expense.

B. It shall be the responsibility of the Contractor to provide a watertight installation throughout the construction process.

C. All large pieces of equipment which are to be installed in the building and which are too large to permit access through doorways, stairways or shafts shall be brought to the job by the Contractor and shall be placed in the spaces before enclosing structure is completed. All apparatus shall be cribbed up from the floor.

D. The Contractor shall protect the work, equipment, and material of all other trades from damage by his work or other workmen and shall make good all damage thus caused.

E. The Contractor shall be responsible for all work, materials, and equipment until finally inspected, tested, and accepted; protect work against theft, injury or damage; and carefully store material and equipment received on site which are not immediately installed. Close open ends of work with temporary covers or plugs during construction to prevent entry of obstructing material. The Contractor shall cover and protect in an acceptable manner to the Owner, all his equipment and materials from damage due to water, spray-on fireproofing, construction debris, etc.

F. If any item of equipment is received prior to the time it is required, the Contractor shall be responsible for its proper storage and protection until such time as it may be required. The Contractor shall pay for all costs of demurrage or storage.

1.26 SCAFFOLDING

A. The Contractor shall provide his own scaffolding and ladders to facilitate the necessary adjustment and balancing of the system.

1.27 DRAYAGE AND HAULING

A. The Contractor shall keep the jobsite free from the accumulation of trash and construction debris, regardless of which subcontractor may be responsible.

1.28 EXCAVATION AND BACKFILL

A. The Contractor shall make all necessary excavations, cutting of paving, concrete, etc., and do all backfilling and temporary patch type paving repairs necessary for the proper execution of the Work. Remove all dirt and debris out and away from the building as directed.

B. Backfill shall be compacted and repairs to paving or concrete shall be accomplished to the satisfaction of the Architect and the Local Authorities having jurisdiction.

1.29 SLEEVES, CUTTING, PATCHING AND FIRESAFING

A. Where it becomes necessary to cut through any wall, floor or ceiling to permit the installation of any Work, or to repair any defects that may appear, the cutting shall be performed under the supervision of the General Contractor. Inform the Owner's representative before any work commences. No structural member shall be altered without the written permission of the Structural Engineer.

B. The Contractor shall be responsible for the timely placing of sleeves for all piping passing through walls, partitions, beams, floors, and roofs while the same are under construction.

C. Seal all material and system support penetrations of fire rated construction with factory-built devices or with manufactured fill, void or cavity materials "Classified" by Underwriter's Laboratories, Inc. for use as a Through-Penetration Firestop.

D. If holes and/or sleeves are not properly installed and cutting and patching becomes necessary, it shall be done at no additional expense to the Owner.

E. Unused sleeves shall be sealed with fire-stop devices and systems to maintain the fire rating of the construction penetrated.

F. This Contractor shall be responsible for patching fire proofing on steel and concrete structural members where it has been removed or disturbed for the installation of his hangers, braces or brackets.

1.30 LUBRICATION

A. All equipment shall be properly filled with lubricating oil prior to initial startup.

B. All parts of equipment requiring the regular preventive maintenance of lubrication shall be equipped with an appropriate Zerk fitting and/or extension tube to an accessible location.

1.31 EQUIPMENT NOISE AND VIBRATION

A. It is the intent to specify and for the Contractor to install systems that are quiet and free of vibration. Equipment shall be balanced, and vibration isolated to meet the requirements specified herein for both the equipment itself and conditions within occupied spaces. Each Contractor is responsible for obtaining and installing equipment that is quiet in operation as compared to other available equipment of its size, capacity, and type.

B. Equipment not meeting these requirements shall be corrected by the Contractor to an acceptable level but within the requirements of the Specifications at no cost to the Owner, Architect or Engineer.

C. Air distribution equipment shall be sound tested at the design operating conditions and shall not exceed an NC of 35 at rated CFM.

D. Noise Level: Unless noted otherwise herein or on the Drawings, the noise level in all occupied spaces shall not exceed the "lowest value in the range" of the noise criteria curves published in the current Fundamentals edition of the ASHRAE Guide and Data Book. The noise criteria curves shall be based on ANSI Standard S1.6-1967 octave bands and a sound pressure level in decibels referenced to 0.002 microbars. Sound levels in occupied spaces must meet the design criteria with all construction in place.

E. Verification: Should a question arise regarding the acceptable level of noise or vibration in a particular space or piece of equipment, the Contractor shall be responsible for providing the services of an approved acoustical consultant to determine actual noise/vibration conditions.

1.32 **START-UP**

A. The Contractor shall furnish the services of factory-trained specialists to supervise the installation and start-up of all major systems and equipment.

1.33 **FINAL COMPLETION AND TESTING**

A. Near the completion of the Work, all equipment and systems specified herein to receive individual testing shall be demonstrated by the Contractor to the Engineer to operate in accordance with the requirements of the Contract Documents. Should any piece of equipment fail to meet those requirements, it shall be either repaired in a timely manner or replaced.

B. The date for the final acceptance test shall be sufficiently in advance of the Contract completion date to permit the execution of the test and make any remedial repairs prior to the expiration of the Contract. Any adjustments and/or alterations that the final acceptance tests indicate as necessary for the proper functioning of all equipment shall be completed prior to the expiration of the Contract. Retests shall not relieve the Contractor of completion data responsibility. See individual Sections and Sections titled "Startup, Testing, Adjusting and Balancing", and "Testing", for extent of testing required.

C. The Contractor shall provide a detailed schedule of completion indicating when each system is to be completed and outlining when tests will be performed. Completion schedule shall be submitted for review at least thirty (30) days prior to the anticipated project completion date.

D. Replace all air filters immediately prior to final acceptance by the Owner.

E. Equipment and material shall satisfactorily serve continuous loads.

F. Clean all new lighting fixtures and diffusers immediately prior to final acceptance.

G. Touch up and/or refinish all scratched equipment and devices immediately prior to final acceptance by the Owner.

1.34 **OPERATOR INSTRUCTIONS**

A. The Contractor shall provide the services of factory trained specialists to supervise the installation, start-up, testing, and operation of major equipment and systems as specified herein and in other individual specification Sections and to instruct the Owner's operators for a five-day

operating instruction period. The operating instruction period shall be defined as straight time working hours and shall not include nights, weekends, or travel time to and/or from the Project. See individual Specification Sections for additional instructions by Manufacturer's trained specialists.

B. The Owner shall be notified in writing at least five (5) days before each operating instruction period begins. The Contractor shall commence no instruction period until the Owner has issued his written acceptance of the starting time.

1.35 **FINAL REVIEW**

A. At a time, designated, the entire system shall be reviewed for compliance with the Contract Drawings and Specifications. The Contractor shall be present at this review.

B. The entire system shall be operating properly with all systems balanced and all controls adjusted.

C. Certificates and Documents required herein shall be in order and presented to the Architect at least two (2) weeks prior to the review.

D. After the review, any changes or corrections noted as necessary for the Work to comply with these Specifications and the Drawings shall be accomplished without delay in order to secure final acceptance of the Work.

1.36 **WARRANTIES AND GUARANTEES**

A. General: Contractor shall guarantee all material and equipment installed by him against defects in workmanship and material for a period of twelve (12) months after final acceptance of the Work by the Owner, and he shall repair or replace any materials or equipment developing such defects within that time, promptly on due notice given him by the Owner and at Contractor's sole cost and expense.

B. Equipment: All equipment bearing a manufacturer's guarantee shall be construed to have an extended guarantee to the Owner by the manufacturer. Any such equipment that proves defective in materials or workmanship within the guarantee period is to be replaced by the Contractor in accordance with the manufacturer's guarantee.

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION

3.01 **SUBMITTALS**

A. Submittals shall include, but not be limited to the following:

1. List of proposed manufacturers and subcontractors for major equipment and systems.
2. Test Result Reporting Forms.
3. Detailed completion and test schedule.
4. Operating and maintenance manuals.
5. Record drawings.
6. Operator instruction schedule.

END OF SECTION

SECTION 20 05 04 - SCHEDULE OF SUBMITTAL DATA

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20 Sections apply to this section:

1. Scope of Work - Section 20 05 01
2. Basic Division 20-28 Requirements - Section 20 05 03
3. General Division 20-28 Materials and Methods - Section 20 05 05

1.02 SCOPE

A. Furnish submittals consisting of shop drawings, product data, brochures, samples, etc., as indicated on the Drawings, as specified herein, and as required by other sections of these specifications.

1.03 SUBMITTALS REQUIRED

A. The submittals to be furnished for this Project shall comply with the Specifications herein. The referenced Sections scheduled here are for general information purposes only and shall not be construed to be limiting to the submittal data scheduled and/or required within the individual Sections of these Specifications.

B. Division 20 Submittals are required for, but not limited to, the following items:

1. 20 05 05 .....GENERAL DIVISION 20-28 MATERIALS AND METHODS
2. 20 05 08 .....DEMOLITION AND WORK WITHIN EXISTING BUILDINGS
3. 20 05 14 .....ELECTRONIC VARIABLE SPEED DRIVES
4. 20 05 33 .....PIPE HEAT TRACING
5. 20 05 48 .....NOISE AND VIBRATION ISOLATION
6. 20 07 00 .....THERMAL INSULATION
7. 20 08 00 .....COMMISSIONING

C. Division 22 Submittals are required for, but not limited to, the following items:

1. 22 05 25 .....MISCELLANEOUS EQUIPMENT
2. 22 05 93 .....STARTUP, TESTING, ADJUSTING AND BALANCING
3. 22 08 00 .....PLUMBING COMMISSIONING
4. 22 11 16 .....PLUMBING PIPING AND ACCESSORIES

D. Division 23 Submittals are required for, but not limited to, the following items:

1. 23 05 10 .....HVAC WATER PIPING ACCESSORIES
2. 23 05 93 .....START-UP, TESTING, ADJUSTING AND BALANCING
3. 23 05 93.13 .....SUPPLEMENTAL BALANCING AND ADJUSTMENTS
4. 23 08 00 .....MECHANICAL COMMISSIONING
5. 23 09 16 .....BUILDING CONTROL AND AUTOMATION SYSTEM (BCAS)
6. 23 21 13 .....HVAC WATER PIPING
7. 23 21 23 .....HVAC PUMPS
8. 23 64 33 .....WATER CHILLING UNITS - AIR COOLED

E. Division 25 Submittals are required for, but not limited to, the following items:

1. 25 06 01 .....STRUCTURED CABLING INFRASTRUCTURE
2. 25 07 01 .....NETWORK AND CENTRAL HARDWARE
3. 25 09 01 .....INSTALLATION, TESTING, AND TRAINING
4. 25 09 02 .....PANELS AND CONTROLLERS
5. 25 09 03 .....DAMPERS, VALVES AND ELECTRONIC CONTROL AND AUTOMATION HARDWARE
6. 25 09 16 .....BUILDING CONTROL AND AUTOMATION SYSTEM (BCAS) SOFTWARE
7. 25 09 93 .....SEQUENCE OF OPERATION

F. Division 26 Submittals are required for, but not limited to, the following items:

1. 26 05 07 .....TESTING
2. 26 05 19 .....CONDUCTORS
3. 26 05 23 .....MOTOR AND CONTROL WIRING
4. 26 05 26 .....GROUNDING
5. 26 05 33 .....CONDUIT
6. 26 05 34 .....OUTLET BOXES
7. 26 08 00 .....ELECTRICAL COMMISSIONING
8. 26 27 26 .....WIRING DEVICES
9. 26 28 13 .....FUSES
10. 26 28 16.16 .....SAFETY AND DISCONNECT SWITCHES
11. 26 29 13 .....INDIVIDUAL MOTOR CONTROLLERS
12. 26 51 13 .....LIGHTING FIXTURES

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION (NOT APPLICABLE)

END OF SECTION

SECTION 20 05 05 - GENERAL DIVISION 20 MATERIALS AND METHODS

PART 1 - GENERAL

1.01 **RELATED DOCUMENTS**

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20 Sections apply to this section:

1. Scope of Work - Section 20 05 01
2. Basic Division 20-28 Requirements - Section 20 05 03
3. Schedule of Submittal Data - Section 20 05 04
4. Demolition and Work Within Existing Buildings - Section 20 05 08

C. Requirements of Division 20 apply to all Work of Divisions 20-28.

1.02 **SCOPE**

A. Provide and install general Division 20-28 materials and methods as shown, scheduled, specified, and required.

PART 2 - PRODUCTS

2.01 **PIPING SYSTEM MATERIALS**

A. Refer to other Division 21-28 Sections.

2.02 **PIPE HANGERS AND SUPPORTS**

A. Refer to Section 20 05 05, Part 3, Execution.

2.03 **CABINETS AND PULL BOXES**

A. Refer to Section 20 05 05, Part 3, Execution.

2.04 **PIPE CLEANING AND STERILIZATION CHEMICALS**

A. Refer to Section 20 05 05, Part 3, Execution.

2.05 **SLEEVES**

A. Refer to Section 20 05 05, Part 3, Execution.

2.06 **FIRESTOP DEVICES, SYSTEMS, AND MATERIALS**

A. Refer to Section 20 05 05, Part 3, Execution.

2.07 **EQUIPMENT PADS**

A. Refer to Section 20 05 05, Part 3, Execution.

2.08 **ACCESS DOORS**

A. Refer to Section 20 05 05, Part 3, Execution.

2.09 **CURBS AND SUPPORTS**

A. Refer to Section 20 05 05, Part 3, Execution.

PART 3 - EXECUTION

3.01 **PIPING INSTALLATION**

A. Erection: Piping shall be properly supported, and adequate provisions shall be made for expansion, contraction, slope and anchorage. Piping measurements are the responsibility of the Piping Contractor. Piping shall be worked into place without springing or forcing. All pipes shall have burr and cutting slag removed by reaming or other approved cleaning methods. All changes in direction shall be made with fittings.

B. Concealed and Exposed Piping: All piping in finished areas shall be concealed, unless otherwise noted. Piping exposed in mechanical rooms and other locations as noted shall be installed in an orderly manner and parallel with or perpendicular to building lines. Exposed piping in occupied areas shall be routed tight to the structure or as high as is possible.

C. Electrical Equipment and Electrical Room Precautions: In general, Contractor shall not install piping for heating, refrigeration, plumbing, fire protection, process piping, or any piping systems not included as part of the electrical work, in any switchgear, transformer, elevator equipment, telephone, or electrical equipment room. No piping shall be installed above switchboards, panelboards, control panels, motor control centers, individual motor controllers, etc.

D. Grading: All piping shall be carefully installed so as to eliminate traps and pockets in pressurized lines and to maintain flow in gravity flow lines. Where air pockets and traps cannot be avoided, provide valved hose connections for water traps and valved automatic air vents for air traps. The Contractor shall consider the pipe grading requirements when coordinating pipe routing for the project. Pipe slope shall be maintained throughout the project. Waste and vent piping shall be sloped in accordance with applicable codes. Pressurized plumbing piping systems shall be sloped to drain points. HVAC water piping systems shall be graded up 1/16" per 10 lineal foot of horizontal run to air vent locations and down 1/16" per 10 lineal feet of horizontal run to drain locations.

E. Arrangement: Flanges or unions, shall be provided in the piping at connections to all items of equipment. All valves and specialties shall be placed to permit easy and proper operation and access, and all valves shall be regulated, packed and glands adjusted at the completion of the work before final acceptance. Eccentric reducers shall be used wherever changes in pipe sizes occur in horizontal mains. The use of bull head tees or other high pressure drop configurations will not be permitted. Devices installed in the piping systems such as thermowells, gages, etc., shall be installed in positions such that any condensation will drip away from, not into the insulation.

F. Welding: All welded joints on piping shall be continuous metallic arc or gas fusion welds connecting pipe ends which are beveled to 37-1/2 degrees before welding. The use of backing rings will not be acceptable. All taps shall be made using proper weld fitting. No "burn-ins" will be allowed. Gas torch cuts shall be true and free from burned metal. Clean pipe surfaces to be welded immediately prior to welding. Welded pipe joints shall be properly aligned with no weld material or bead projection into the pipe. All weld procedures shall be in accordance with requirements of the American Welding Society and shall be performed by certified welders. Documentation of welder certification shall be available if requested. All welding operations shall

conform to the latest recommendations of the American Welding Society and to ASME B31.9 Piping Code. All qualifying tests, welding and stress relieving procedures, shall, moreover, be in accord with Standard Qualification for WELDING PROCEDURES, WELDERS AND WELDING OPERATORS, APPENDIX A, SECTION 6 of the Code, current edition. In no cases shall Schedule 40 pipe be welded with less than three passes including one tack, one filler, and one lacer. Schedule 80 pipe shall be welded with not less than four passes including one tack, two fillers and one lacer. Welds lacking penetration shall be removed. Internal and external cracks shall be ground down and removed. Finished welds shall be buffed and spray painted with lacquer.

1. All weld fittings shall be factory made wrought carbon steel butt-welding fittings conforming to ASTM A234 and ASME/ANSI B16.9 latest edition, as made by Anvil, Tube Turn, Hackney, Taylor Forge, or Ladish Company. Long radius fittings shall be provided for all 90 degree and 45-degree elbows. Each fitting shall be stamped as specified by ASME/ANSI B16.9 and, in addition, shall have the laboratory control number metal stenciled on each fitting for ready reference as to physical properties required for any fitting selected at random. Complete test reports may be required for any fittings selected at random. Only one manufacturer of weld fittings will be approved for each project. Fittings that have been machined, remarked, or painted will not be acceptable. Each fitting shall have the manufacturer's trademark permanently identified in accordance with MSS SP-25. Markings shall be placed on the fittings at the farthest point from the edge to be welded to prevent disfiguring from the welding process.
2. Piping and fittings shall be welded and fabricated in accordance with ASME/ANSI and the latest edition of Standard B31.9 from the Code for Pressure Piping for all systems. Machine beveling in shop is preferred. Field beveling may be done by flame cutting to recognized standards.
3. Ensure complete penetration of deposited metal with base metal. Contractor shall provide filler metal suitable for use with base metal. Keep inside of fittings free from globules of weld metal.
4. Align piping and equipment so that no part is offset more than 1/16". Set all fittings and joints square and true and preserve alignment during welding operation. Use of alignment rods inside pipe is prohibited.
5. Do not permit any weld to project within the pipe so as to restrict it. Tack welds, if used, must be of the same material and made by the same procedure as the completed weld, otherwise, remove tack welds during welding operation.
6. Contractor shall not split, bend, flatten or otherwise damage piping before, during or after installation. Remove dirt, scale, and other foreign matter from inside piping before tying in sections, fittings, valves or equipment.
7. In no case shall Schedule 40 pipe be welded with less than three passes including one stringer/root, one filler and one lacer. Schedule 80 pipe shall be welded with not less than four passes including one stringer/root, two fillers and one lacer. In all cases, however, the weld must be filled before the cap weld is added.
8. All welds are subject to visual inspection for compliance with specifications. The Owner will, at the Owners option, provide employees or employ a testing laboratory for the purposes of performing said inspections and/or X-ray testing. Initial visual and X-ray inspections will be provided by the Owner. The Contractor shall be responsible for all labor, material and travel expenses involved in the re-inspection and retesting of any welds found to be unacceptable. In addition, the Contractor shall be responsible for the costs involved in any and all additional testing required or recommended by ASME/ANSI Standards due to the discovery of poor, unacceptable, or rejected welds.
9. Welds lacking penetration, containing excessive porosity of cracks, or is found to be unacceptable for any reason, must be removed and replaced with an original quality weld as specified herein. All qualifying tests, welding, and stress relieving procedures shall, moreover, be in accord with Standard Qualification for Welding Procedures, Welders and Welding Operators, Appendix A, Section 6 of the Code, current edition.

G. Screw Pipe Fittings: All screw joints shall be made with taper threads, properly cut. Joints shall be made tight with Teflon applied to the pipe threads only and not to fittings. When threads are cut on pipes, the ends shall be carefully reamed to remove any burrs. Before installing pipe that has been cut and threaded, the lengths of pipe shall be upended and hammered to remove all shavings and foreign material.

H. Assembling Other Joints: Procedures for assembling joints in cast iron and copper lines have been set forth elsewhere in these Specifications. For any special materials, consult the manufacturers for the recommended procedures in assembling the joints.

I. Expansion and Contraction: Expansion and contraction of piping shall be provided by expansion loops, bends, or expansion joints, to prevent injury to connections, piping, equipment or the elements of the building. Pipe guides shall be provided and installed on piping as shown on Drawings and as necessary to properly fulfill function of expansion loops.

J. Anchors: Pipe anchors shall be provided and installed at each end of piping runs which require expansion loops or joints, and where indicated on Drawings. Anchors shall be fabricated of rigid structural steel members firmly secured to the building structure.

K. Escutcheons: Spring clamp plate escutcheons shall be provided where pipes are exposed in finished locations of the building and run through walls, floors, or ceilings. Plates shall be chrome plated spun brass of plain or approved pattern and shall be set tight on the pipe and to the building surface.

L. Unions: Shall be installed on all bypasses, ahead of all traps, at all connections to equipment, where shown on the Drawings and where required to facilitate removal of equipment. Unions shall also be provided in welded lines at the connections to items of equipment, where equipment flanges are not provided. Unions in steel lines assembled with screwed fittings shall be malleable iron screwed pattern unions with bronze seats. Unions in copper or brass lines shall be all brass, threaded pattern unions. Where unions are required by the above in steel lines assembled by welding, they shall consist of two mating welding flanges.

M. Protection: All open ends of pipes and equipment shall be properly capped or plugged during construction to keep dirt and other foreign materials out of the system. Plugs of rags, wool, cotton, waste or similar materials are not acceptable.

N. Dissimilar Pipe Materials: Connections between copper and steel pipes shall be made with dielectric couplings, flanged dielectric unions, or nylon bushings temperature and pressure rated for the service at the point of installation. Connections between copper and steel pipes shall be located in accessible locations or access shall be provided by the installation of access doors.

3.02 HANGERS AND SUPPORTS

A. General: Provide pipe and conduit hangers and support materials as specified herein. All horizontal and vertical piping shall be thoroughly and substantially supported in accordance with ASME B31.9 Standard Code for Pressure Piping and Manufacturers' Standardization Society MSS SP-69 Pipe Hangers and Supports - Selection and Application. The design, type, spacing and application of all hangers, supports, anchors and guides shall comply with the above standards. Hanger rods shall be galvanized, or cadmium plated. Hanger rod clamps and inserts shall be as recommended by the clamp or insert manufacturer for the intended use and shall be approved in writing by the Structural Engineer. All methods of attachment to the structure and the use of after-set inserts shall be approved in writing by the Structural Engineer. The load and spacing on each hanger and/or insert shall not exceed the safe allowable load for any component of the support system, including the concrete that holds the inserts. Reinforcement at inserts shall be provided as required to develop the strength required. The Contractor shall patch

fireproofing on steel and concrete structural members where it has been removed or disturbed for the installation of his hangers, braces, or brackets, etc.

B. MSS Standard Compliance: Provide pipe hangers and supports of materials, design, and manufacture which comply with ANSI/MSS SP-58, SP-59, SP-69, SP-89, and SP-90.

C. Acceptable Manufacturers: The model numbers listed in the Specification establish a level of quality and material. The following manufactures are acceptable subject to compliance with the requirements of this Specification:

1. Anvil International
2. B-Line
3. Central Iron Manufacturing Company
4. F & S Manufacturing Company
5. The Michigan Hanger Company

D. Inserts: Provide Anvil Fig. 282 or equal inserts for all pipe and equipment suspended from new concrete construction. Where inserts are placed in the bottom faces of concrete joists which are too narrow to provide adequate strength of concrete to hold insert properly or where a larger insert would require displacement of the bottom joist steel, the hanger rod shall be suspended from the center of a horizontal angle iron, channel iron, I-beam, and similar items spanning across two adjacent joists. The horizontal support shall be bolted to nonadjustable concrete inserts of the "spot" type, of physical size small enough to avoid the bottom joist steel.

E. Fasteners: Fastening of pipes, conduits, and similar items in the building shall be as follows: To wood members - by wood screw; to masonry - by threaded metal expansion screws, or welding (when specifically permitted or directed), or bolts, and to new concrete by suitable insert anchored to reinforcing steel and poured in place unless other means are indicated on the plans. Power-actuated fasteners (shooting) will not be acceptable under any circumstances.

F. Piping in Multiple Parallel Runs: Provide structural channels or angles with Anvil Fig. 137 or equal U-bolt clamps, supported as trapeze hangers where multiple parallel runs of piping are shown. Select and size members for weights to be carried and span dimensions between supports.

G. Piping in Single Runs: Provide Anvil Fig. 260 or equal adjustable clevis hangers with a nut above and below the hanger on the hanger rod.

H. Copper Pipe Hangers: Hangers supporting and contacting brass or copper lines 3" in size and smaller shall be Anvil Fig. CT 99C or equal, adjustable plastic-coated copper-plated tubing rings. Hangers supporting and contacting brass or copper lines 4" and larger shall be Anvil Fig. 260 or equal, adjustable clevis, with a nut above and below the hanger, and approved neoprene isolating material between pipe (or tubing) and hanger on the support rod. For insulated copper or brass domestic water lines, hangers for all sizes of pipe shall be Anvil Fig. 300 or equal, adjustable clevis, with a nut above and below the hanger, and approved neoprene isolating material between pipe (or tubing) and hanger on the support rod. Isolate all copper or brass lines from ferrous metals with electrical tape or other dielectric materials to prevent electrolytic action.

I. Hanger Rod: Provide cadmium-coated or galvanized hanger rods of required length. All hanger rods shall be trimmed neatly so that no more than one inch (1") of excess hanger rod protrudes beyond the hanger nut. In the event a rod is intentionally but temporarily left excessively long (for slope or insulated lines for example), the Contractor shall take appropriate measures to protect the pipe or other materials from damage. Rod diameters shall be as follows:

PIPE SIZES	ROD DIAMETER
3/4" - 2"	3/8"
2-1/2" - 3"	1/2"
4" - 5"	5/8"
6"	3/4"
8" - 12"	7/8"
14" - 18"	1"

J. Riser Clamps: Provide Anvil Fig. 261 or equal riser clamps with equal bearing on each end. Riser clamps for copper-plated tube shall be copper-plated.

K. Pipe Supports in Chases and Partitions: Horizontal and vertical piping in chases and partitions, shall be supported by hangers or other suitable support. Pipes serving plumbing fixtures and equipment shall be securely supported near the point where pipes penetrate the finish wall. Supports shall be steel plate, angles or special channels such as Unistrut mounted in vertical or horizontal position. Pipe clamps such as Unistrut P2426, P2008, P1109 or other approved clamps shall be attached to supports. Supports shall be attached to wall or floor construction with clip angles, brackets, or other approved methods. Supports may be attached to cast iron pipe with pipe clamp or other approved method.

L. Saddles and Shields:

1. Saddles for Horizontal Insulated Piping Without Vapor Barrier: At each hanger or support on horizontal runs, provide Anvil Fig. 160 or equal saddles, as applicable. Shields as described below may be used instead of the saddles. On heating water systems below 140°F (60°C), hangers may be sized for the pipe size and of material compatible with the pipe. Where dissimilar materials are used, provide dielectric separation. Carry insulation over hanger and seal where hanger is sized for pipe.
2. Shields for Horizontal Insulated Water Piping with Vapor Barrier: At each hanger or support for water piping, provide a half section of preformed cellular glass or rigid calcium silicate blocking, with jacket of adjacent insulation brought across unbroken, supported on Anvil Fig. 167 or equal semicircular galvanized steel shields. Shields for pipe 4" and smaller shall be 12" long; shields for pipe 5 to 8" shall be 18" long; and shields for larger pipe shall be 24" long.

M. Roller Supports: Provide Anvil Fig. 177 or equal adjustable pipe roll supports for support of horizontal piping installed in racks, beam supports, and where shown on the Drawings.

N. Independent Support: Support fire sprinkler and standpipe piping independently of other piping in accordance with NFPA-approved methods and local codes and standards, using UL-listed and labeled support components.

O. Provisions for Movement:

1. Movement: Install hangers and supports to allow controlled movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate the action of expansion joints, expansion loops, expansion bends, and similar units.

2. Load Distribution: Install hangers and supports so piping live and dead loading and stresses from movement will not be transmitted to any pipe or connected equipment. Pipe supports shall properly transmit the weight of the pipe and its contents to the building structure, or to independent posts, piers, or foundations.
3. Pipe Slopes: Install hangers and supports to provide the indicated pipe slopes so maximum pipe deflections allowed by ANSI B31 are not exceeded.

P. Guides: Install pipe guides complying with the manufacturers published product literature. Where not otherwise indicated install pipe guides near expansion loops, expansion joints, and ball joints.

Q. Anchors: Install anchors at the proper locations to prevent stresses from exceeding those permitted by ANSI B31 and to prevent the transfer of loading and stresses to connected equipment. Anchors shall include vibration isolation in accordance with the pipe support system specified. Where the piping system is floating, the anchors shall be termed restraints or braces.

1. Where expansion compensators are indicated, install anchors in accordance with the expansion unit manufacturers written instructions, to limit movement of piping and forces to the maximums recommended by the manufacturer of each unit.
2. Where not otherwise indicated, install anchors at the ends of principal pipe runs and at intermediate points in pipe runs between expansion loops and bends. Make provisions for preset of anchors as required to accommodate both expansion and contraction of piping.

R. Leveling: Adjust hangers and supports and place grout as required under supports to bring piping to proper levels and elevations.

S. Hangers: Refer to Section 20 05 48, Noise and Vibration Isolation, for additional information and support requirements. Pipe hangers made of wood, wire, or sheet iron shall not be permitted.

T. Non-Isolated Riser Supports: Vertical piping shall be secured at sufficiently close intervals to keep the pipe in alignment and carry the weight of the pipe and contents.

1. Cast iron soil pipe shall be supported at the base and at each story level, but in no case at intervals greater than 10 ft.
2. Steel pipe shall be supported at the base and at not less than every other story level, but in no case at intervals greater than 25 ft., except that grooved-piping system shall be supported at each pipe section.
3. Copper tube shall be supported at each story level, but in no case at intervals greater than 10 ft.
4. CPVC pipe shall be supported at each floor level with mid-level guide.

U. Miscellaneous Steel: All miscellaneous steel required for pipe and duct supports, anchors, guides, and similar items shall be galvanized for indoor use or hot dipped galvanized for outdoor use and where exposed to ambient conditions and shall be sized and provided by the Mechanical Contractor unless specifically indicated to be provided by others. The support members and their connection to the building structure shall be designed by a registered professional Structural Engineer.

V. Finish: All steel and iron hangers for piping including clevis hangers, rods, inserts, clamps, stanchions, brackets, etc., shall be hot dip galvanized after fabrication for exterior applications and interior applications that are not in an air-conditioned space or air-conditioned return air plenum. Rods shall be electro-galvanized, or cadmium plated after threading for indoor applications and hot dip galvanized after fabrication for outdoor applications. Universal concrete inserts shall be hot dip galvanized.

3.03 **PIPE CLEANING AND STERILIZATION**

A. HVAC Piping: All HVAC piping shall be cleaned following pressure testing of pipe. Piping shall be completely drained following pressure testing and then filled with clear water and alkaline pipe cleaning treatment (Garratt-Callahan Company 247-L or approved equal) to the suppliers recommended concentration. Provide copies of chemical treatment MSDS Sheets to the Owner. The system shall then be circulated per the supplier's recommendations. Following cleaning, each system shall be drained, refilled, and then continuously flushed until clean water is obtained. All strainers shall be cleaned prior to the system's final operation. Building pumps shall not be used for system flushing or cleaning. All pumps, piping, valves, fittings, etc. needed for flushing, filling and draining, shall be provided as required. After the system has been pressure tested, treated with pipe cleaning treatment and rinsed with clear water to remove the cleaning treatment, a 5 micron in-line filter may be installed in the system, in lieu of continuous water flushing, to clear the piping of construction debris. Each system being filtered shall be pumped continuously and the filter shall be cleaned once every 24 hours until no visible filtered matter is present in the filter after 24 hours of circulation. After the cleaning process is complete, the filters shall be removed from the system and all strainers shall be cleaned prior to putting the piping system into operation.

B. Potable Water Piping: All potable water piping system components shall, after pressure testing, be thoroughly flushed with clear water and then sterilized. Sterilization shall be with either liquid chlorine or chlorine gas of adequate volume to give a concentration of 50 ppm based upon the volume of the system being treated. A minimum residual chlorine level of 5 ppm shall remain in each system for a minimum of 24 hours. After sterilization, all piping shall be thoroughly flushed. The above are minimum requirements and all sterilization procedures shall be in strict accordance with all local codes and authorities having jurisdiction.

C. Fire Suppression Water Piping: All fire suppression water piping system components shall, after pressure testing, be thoroughly flushed with clear water.

3.04 **SLEEVES**

A. General: This Contractor shall be responsible for the timely placement of sleeves in construction. If sleeves are not placed during construction, this contractor shall secure written permission to perform a core drill or cut and patch installation at no cost to the Owner. No piping shall pass through obstructions without sleeves, unless noted otherwise. Furnish and install sleeves around all piping passing through masonry, CMU and concrete walls and partitions, suspended slabs, plaster or drywall ceilings, structural members, other building features and where shown on the drawings.

B. Partitions: Sleeves shall be required for piping passing through rated drywall and plaster partitions where required by the U.L. Classification for the Through-Penetration Firestop used. Sleeves shall be installed in accordance with the Firestop U.L. Classification. Sleeves are not required for piping passing through non-rated drywall or plaster partitions. Non-isolated piping shall be mudded in and isolated piping shall have the opening muddied to within 1/2" of the pipe and an elastomeric caulk shall be installed in the opening around the pipe or insulation. Sleeves shall be secured to partitions as required by local Codes.

C. Storm, Waste, and Vent Piping: Sleeves shall not be required for storm, waste or vent piping through slabs on grade or for piping passing through precast structure. Where piping passes vertically through pre-cast structures without sleeving, adequate provisions shall be made to prevent water leakage through slabs where applicable.

D. Sizing Sleeves: Sleeves shall be one size larger than the pipe passing through the sleeve, except where larger sizes are required for mechanical seals. Where insulated piping passes through non-fire rated construction, sleeves shall be one size larger than the outside diameter of

the insulation. All sleeves in floors shall extend 2 inches above the finished floor. Do not cut fire stop assemblies, such as ProSet or Hilti cast-in devices, off flush at slab level.

E. Materials:

1. Non-Supporting Vertical Construction: Provide minimum 18-gauge galvanized steel sleeves.
2. Non-Supporting Horizontal Construction: Provide minimum 16-gauge galvanized steel sleeves.
3. Horizontal Construction Supporting Risers 3" and Smaller: Provide Schedule 40 galvanized pipe sleeves.
4. Horizontal Construction Supporting Risers 4" and Larger: Provide Thunderline "Link-Seal" Model WS galvanized steel wall sleeves or Schedule 40 galvanized pipe sleeve with four, six (6) inch long, 3/8" diameter reinforcing rods welded radially to the sleeve on 90-degree centers, set in concrete.
5. Exterior Building Construction: For exterior concrete construction above and below grade, and exterior brick or masonry above grade, provide Thunderline "link-seal" Model WS galvanized wall sleeves or Schedule 40 black steel pipe with 1/4" thick steel plate secured to the piping with continuous fillet weld. The plate shall be located in the middle of the wall and shall be four inches wider all around than the sleeve it encircles. The entire assembly shall be hot dipped galvanized after fabrication. Seal off annular opening between piping and sleeve with "Link Seal" Casing Seal: Thunderline Corporation, Livonia, Michigan; “Pipe Linx”: Mason-Dallas, Inc.
6. The piping sleeve shall be sized to accommodate the casing seal. Casing seals shall be Series 300 for piping sizes 3/4" through 4", Series 400 for piping 5" through 24", and Series 500 for piping 30" and larger.

F. Installation: At no point shall the pipe or its insulation touch the sleeve it passes through. Clearance around piping shall not be less than 1/2" or more than 1". Seal all sleeves that are not in exterior construction below grade or rated construction with an approved non-hardening mastic. Seal sleeves through fire rated construction as specified herein and as detailed on the Drawings. Sleeves below grade shall be sealed with Thunderline "Link-Seal" model LS or Mason-Dallas “Pipe Linx” mechanical seals.

G. Option: At the contractor's option, waterproof, fire rated Sleeve/Coupling Penetrations: ProSet Systems, Inc., may be used for non-isolated piping systems in lieu of galvanized sleeves specified hereinabove.

3.05 CUTTING AND PATCHING

A. Where it becomes necessary to cut through any wall, floor or ceiling to permit the installation of any Work, or to repair any defects that may appear, the cutting shall be performed under the supervision of the General Contractor. Inform the Owner's representative before any work commences. No structural member shall be altered without the written permission of the Structural Engineer.

B. Patching of all openings cut by this Contractor or repairing of any damage to the work of other trades occasioned by cutting operations, or occasioned by the failure of any part of work installed under this Contract, shall be performed by the trade whose work is involved, but shall be paid for by this Contractor.

C. Any openings cut through exterior walls or roofs shall be provided with suitable covers while they are left open to protect the property or materials involved. Any openings cut through walls below grade shall be properly protected to prevent entrance of water or other damaging elements.

D. Water Stops: Provide water stops at new penetrations of existing floors. Water stops shall be at least 16 gauge and be sized as specified herein for sleeves. Water stops shall be securely attached to the top of the floor slab with a waterproof mastic applied between the bottom flange of the water stop and the floor slab. The thickness of the firesafing system shall not exceed the existing floor thickness.

3.06 **FLASHING**

A. Flash around all vent pipes passing through the roof with sheet lead not less than 4 lbs. per square foot, built a minimum of 8" into the roofing in all directions from the outside of the pipe, running up the pipe, and turned over into the pipe cavity.

3.07 **FIRESTOPPING**

A. Where Division 20-28 materials and system supports pass through fire or smoke rated construction, they shall be fire stopped with a factory-built UL Classified Through-Penetration Firestop Device, or with manufactured Fill, Void, or Cavity Materials Classified by Underwriters Laboratories, Inc. for use in a UL Classified Through-Penetration Firestop System to prevent the spread of smoke, fire, toxic gas, or water.

B. The Firestop Devices, Materials, and Systems shall meet all the fire test and hose stream test requirements of ASTM E119, "Standard Test Methods for Fire Tests of Building Construction and Materials", or ASTM E814, "Standard Test Method for Fire Tests of Through-Penetration Fire Stops".

C. "F" ratings of the Firestop used shall be not less than the required fire resistance rating of the wall or floor penetrated. "T" ratings shall be as required by local code for the type of building construction.

D. Fill, Void, or Cavity Materials shall only be installed in accordance with UL classified system numbers.

E. All firestop Devices and Systems shall be approved for such use by the authority having jurisdiction.

F. Excessive shrinkage of the fire stopping materials that would permit the transmission of smoke or water prior to exposure to a fire condition is unacceptable. Where mastic is used to seal the surface of the firestop, the mastic shall be non-hardening. Firestop Systems for isolated piping systems shall be non-hardening except that non-hardening putty will not be acceptable. The Firestop System used shall accommodate expansion and contraction of the floating mechanical piping systems without damaging the firestop or reducing its effectiveness as a barrier to the passage of smoke, fire, toxic gas, or water.

G. Submittal data for Firestop Materials shall include the U.L. System Numbers listed in the U.L. Fire Resistance Directory under which the material was tested in accordance with ASTM E 814 (UL 1479) or ASTM E119.

H. If it complies with these Specifications, firestop Devices, Systems, and Materials manufactured by one of the following manufacturers will be acceptable:

1. Tremco Fire-Resistive Joint System using Dymeric sealant and Cerablanket-FS mineral filler
2. 3M Fire Barrier Penetration Sealing Systems (Electro Products Division)
3. GE Pensil 1851 Silicone RTM by General Electric
4. ProSet Systems, Inc.
5. The Rectorseal Corporation

6. STI
7. Hilti

3.08 **PAINTING**

A. Field painting will be provided under Division 9 utilizing these guidelines.

B. All machinery and equipment not finished at the factory shall be given a prime coat and then finish painted with two coats of enamel in colors as directed by the Architect/Engineer or Owner's Representative. No nameplates on equipment shall be painted, and suitable protection shall be afforded such plates to prevent their being rendered illegible during the painting operations.

C. All un-insulated black steel pipe, hangers and supports shall be given two (2) coats of zinc-epoxy primer. Where exposed to outdoor weather or public view, these items shall be primed and finished with two coats of epoxy in colors as indicated in the Piping System Identification Table. Outdoor insulated piping shall be primed prior to application of insulation.

D. All un-insulated black steel pipe direct buried shall be given two coats of primer and then coated with 3M Scotchwrap Pipe Insulation #50 applied in strict accordance with manufacturer's published recommendations (machine wrapping of pipe is acceptable) prior to burial in the ground.

E. All insulated piping exposed to view shall have the finished insulation painted with two coats of acrylic in colors as indicated in the Piping System Identification Table. Piping concealed in furrings, chases, or above suspended ceilings, need not be painted.

F. All grilles and registers will be furnished with a factory-applied finish. Should the plans indicate that certain grilles and registers be furnished with a factory-applied prime coat for field painting, the cores shall be removed for painting under another Division. The frames, after installation, shall be given two coats of enamel. The cores shall be spray painted with two coats of enamel and shall be reinstalled in the frames only after both cores and frames are thoroughly dry. In such cases the color of the enamel finish shall be as directed by the Architect/Engineer.

G. Before painting, all surfaces to be painted shall be suitably prepared. This shall include removing all oil, rust, scale, dirt, and other foreign material. Surfaces shall be made smooth by grinding, filing, brushing, or other approved method. In the painting operations, the primer for metal surfaces shall be of the zinc dust type, and where finish painting is specified for a finish, it shall be painted as specified in another Division.

H. Except where specific materials and colors are designated above, the various piping systems, hangers, supports, equipment items, machinery and appurtenances shall be painted using materials and colors approved by the Architect/Engineer.

I. Piping System Identification Table (Also refer to Section 23 21 13)

PIPE MARKERS CLASSIFICATION LEGEND				
PIPING SYSTEM	**COLOR PIPE**	**COLOR FIELD**	**COLOR LETTERS**	**DIRECTIONAL ARROWS**
CONDENSER WATER SUPPLY	Light Green	Green	White	Yes
CONDENSER WATER RETURN	Dark Green	Green	White	Yes
CHILLED WATER SUPPLY	Dark Blue	Green	White	Yes
CHILLED WATER RETURN	Light Blue	Green	White	Yes
HOT WATER HEAT SUPPLY	Dark Red	Yellow	Black	Yes

PIPE MARKERS CLASSIFICATION LEGEND				
PIPING SYSTEM	**COLOR PIPE**	**COLOR FIELD**	**COLOR LETTERS**	**DIRECTIONAL ARROWS**
HOT WATER HEAT RETURN	Light Red	Yellow	Black	Yes
DOMESTIC COLD WATER	Brown	Green	White	No
HOT WATER SUPPLY 120°	Tan	Yellow	Black	Yes
HOT WATER RETURN 120°	Tan	Yellow	Black	Yes
250 PSI STEAM SUPPLY	Orange	Yellow	Black	Yes
100 PSI STEAM SUPPLY	Orange	Yellow	Black	Yes
25 PSI STEAM SUPPLY	Orange	Yellow	Black	Yes
PUMPED STEAM CONDENSATE RETURN	Light	Yellow	Black	Yes
GRAVITY STEAM CONDENSATE RETURN	Light	Yellow	Black	Yes
HOT WATER SUPPLY 140°	Tan	Yellow	Black	Yes
HOT WATER RETURN 140°	Tan	Yellow	Black	Yes
WASTE AND VENT	Black	Green	White	Yes
FUEL OIL	Safety	Yellow	Black	Yes
OXYGEN	Light Green	Green	White	No
NITROGEN	Black	Green	White	No
NITROUS OXIDE	Light Blue	Yellow	Black	No
MEDICAL AIR	Light Yellow	Blue	White	No
VACUUM	Silver	Yellow	Black	Yes
NATURAL GAS	Safety	Yellow	Black	No
COMPRESSED AIR		Yellow	Black	
FIRE PROTECTION	Red	Red	White	No

3.09 IDENTIFICATION AND LABELING OF ELECTRICAL EQUIPMENT

A. Equipment: All service entrance equipment, distribution equipment, and distribution panelboards, including their associated branch circuit devices, and each new major item of electrical equipment including lighting and power panelboards, motor starters, transfer switches, and disconnect switches, shall be properly identified by the attachment of engraved nameplates constructed from laminated plastic, at least 1/16-inch-thick 3-ply, with black surfaces and white core. Emergency power equipment nameplates shall have red surfaces and white core.

1. Engraving shall be condensed gothic, at least 1/4 inch high. The engraved nameplates shall be securely attached to the device or panelboard using non-corroding screws. The use of adhesive or tape attachment is not acceptable.
2. Labeling shall include the name of equipment the device feeds, the source panel, the source circuit number, and the voltage. Consult the Mechanical, Electrical and Plumbing drawings for label nomenclature.
3. Transfer Switches: Transfer switch nameplates shall include the name and circuit number for the normal and emergency power sources to the transfer switch.
4. Fire Pump: Fire pump controller, transfer switch, emergency power source, and overcurrent protection device shall be labeled as per NFPA-20.

B. Miscellaneous Switch Plates or Device Plates: Device and switch plates for all 20-amp devices circuited to "emergency" circuits, special purpose outlets, pilot lights, remote operated light switches, devices in critical care areas of healthcare facilities, and all remote-control devices shall be identified by engraving the switch plate or device plate.

1. Nomenclature shall include the panel and circuit of the outlet or switch, or the indication of the pilot, or the area of control, or equipment served. Consult the Architect/Engineer for label nomenclature.
2. Plates shall be stainless steel or as otherwise specified.
3. Engraving shall be 3/16-inch condensed gothic and shall be filled with black enamel.

C. Conduits: All exposed conduits shall have the voltage marked on 50-foot centers, at least one in each room and at all junction boxes and electrical devices. Markers shall be Brady B-500 vinyl cloth with black letters on an orange background or an approved equal. Emergency power conduits shall also by labeled to indicate the type of service. Designations shall be approved by the Architect/Engineer.

D. Emergency Power Panelboards: Engraved red nameplates for panelboards serving emergency power loads shall indicate the "Branch" of the Essential Electric System served. The nameplate shall also identify the voltage, circuit number, and equipment name from which the incoming feeder circuit was derived.

3.10 IDENTIFICATION AND LABELING OF EQUIPMENT, PIPING, VALVES, AND ACCESS DOORS

A. Equipment: Rooftop equipment, air handling units, pumps, water heaters, supply fans, duct heaters, exhaust fans, water chilling units, boilers, cooling towers, terminal units and any other equipment designated by the Architect/Engineer shall be labeled with permanently attached engraved nameplates constructed from laminated phenolic plastic, at least 1/16-inch-thick, 3-ply, black surfaces and white core. Engraving shall be condensed gothic at least 3/8 inch high. Engraving shall include equipment name and number and electrical panel and circuit that serve the equipment. Consult the Drawings for label nomenclature.

B. Valves: All valves at major equipment and in all equipment, rooms shall be marked with 1-1/2" diameter aluminum or engraved plastic tags securely attached to valve stems with "S" hooks.

C. Piping: Piping at major equipment and in all equipment, rooms shall be identified by color-coded markers as to type of use, service and direction of flow as indicated within the Piping System Identification Table. Markers shall be located at each valve, at entries through walls, and on 20 ft. centers on straight runs of pipe. Piping concealed in accessible locations shall be marked on 50-foot centers on straight runs of pipe, at all changes in direction, and at least one location above each room having partitions to structure. Labels shall be as manufactured by Brady, Brimar, Seton, Marking Services, Inc., or Westline.

D. Access Doors: Access doors provided for access and servicing of fire and smoke dampers shall be labeled as to type of damper (fire, smoke, combination fire and smoke) served.

E. Equipment nameplates and valve designation data shall be recorded on Record Drawings, and on itemized listing by equipment types and valve number sequence. Itemized listings shall include designation, device description and device location.

3.11 PIPING SYSTEM LEGEND LETTER SIZING TABLE

OUTSIDE DIAMETER OF PIPE OR COVERING - INCH	LENGTH OF COLOR FIELD - INCH	SIZE OF LETTER - INCH
3/4 to 1-1/4	8	1/2
1-1/2 to 2	8	3/4
2-1/2 to 6	12	1-1/4

OUTSIDE DIAMETER OF PIPE OR COVERING - INCH	LENGTH OF COLOR FIELD - INCH	SIZE OF LETTER - INCH
8 to 10	24	2-1/2
OVER 10	32	3-1/2

3.12 WARNING SIGNS

A. Provide warning signs where there is a hazardous exposure associated with access to or operation of mechanical facilities. Provide text of sufficient clarity and lettering of sufficient size to convey adequate information at each location. Mount warning signs permanently in an appropriate and effective location in the space, at equipment, and on piping and ductwork.

B. Comply with recognized industry standards for color and design.

3.13 EXPOSED PIPING

A. All exposed piping in finished areas shall be polished chrome plated unless noted otherwise on the Drawings. This shall include piping, fittings and valves. Polished chrome plated sleeves may be used over piping provided that the finished installation presents the appearance of a fully chrome plated system.

3.14 EQUIPMENT PADS AND ACCESSORIES

A. Equipment Housekeeping Pads and Anchor Bolts: Concrete pads for equipment will be furnished under another Division. Pads shall be provided in equipment rooms, and in other locations with major equipment installed. Pads shall nominally be 3-1/2" high and shall generally conform to the shape of the piece of equipment it supports with a minimum of 3" margin around the equipment and supports. Height of pads for air handling units shall consider whether the units have internal or external vibration isolation to permit proper installation of the condensate drain p-trap.

B. Pad Materials: Pads shall be minimum 2500 psi (28 day) concrete reinforced with 6 x 6 #6 welded wire mesh. Tops and sides of pads shall be hard troweled smooth with a 3/4" bullnose on all external corners. Furnish galvanized anchor bolts according to the equipment layout templates for installation in equipment pads. Bolts shall be of the size and quantity recommended by the manufacturer and where vibration isolators are used, they shall be anchor bolted to the equipment pad.

C. Equipment Guards: Provide easily removable expanded metal guards for all belts, couplings, exposed fan inlets and outlets and other moving parts of machinery. Provide tachometer openings in motor and fan shaft guards at least 2" diameter on all belt drive and variable speed equipment.

D. Belt Drives: Select belt drives as accurately as possible, based upon the design conditions. Whenever, in the course of balancing a system, it is determined that a drive change is required, the Contractor shall furnish one complete drive change without additional cost to the Owner or Architect/Engineer. Multiple belt drives shall have matched belt sets.

E. Supports: The Contractor shall support all work and equipment furnished under his Division. The Contractor shall study thoroughly all Architectural, Structural, Mechanical, Plumbing, Fire Suppression, and Electrical drawings, shop drawings and catalog data to determine how equipment is to be supported, mounted or suspended, and shall provide all bolts, inserts, pipe stands, brackets and accessories for proper support.

3.15 ACCESS DOORS

A. Access doors shall be provided by Division 20-28 Contractors for access to valves, balancing dampers, fire dampers, motors, duct cleanouts or any other item which may require servicing or adjusting, and which is concealed behind an inaccessible surface such as spline ceilings and plaster walls or ceilings. Doors shall be factory finished as noted below and turned over to the General Contractor for installation and painting. Doors shall be as manufactured by Inryco/Milcor or an approved equal in the following styles:

1. Drywall construction (vertical partition surface) - Milcor Style DW with gray prime finish.
2. Drywall construction (ceiling horizontal surface) - Milcor Style ATR with door design for drywall insert.
3. Finished acoustical ceiling tile - Milcor Style AT with door design for tile insert.
4. Finished plaster ceiling or walls - Milcor Style AP with door designed for finish plastering.
5. Masonry or tile walls - Milcor Style M with gray prime finish.
6. Fire rated walls - Milcor Fire Rated Access Door with gray prime finish.
7. Fire rated ceiling or ceiling assembly - Milcor Style ATR with door designed for tile insert.

B. Access doors shall be furnished with a continuous piano hinge with screwdriver operated flush locks and shall be a minimum of 12" x 12". Larger sizes shall be furnished where required for proper access. Access doors shall not be installed until location and style have been approved by the Architect.

3.16 TRENCHING AND BACKFILLING

A. All underground pipes and conduit shall be laid open in trench. All field measurements, layouts, grade establishments, etc., shall be done by Registered Public Surveyor in the employ of the Contractor. The Contractor's Surveyor shall be on-the-job during all underground Work. The Architect will provide a "Bench Mark" reference for use by the Contractor.

B. Pipes shall be laid and maintained at required lines and grades during the course of the Work. All joints shall be aligned and complete.

C. The trench shall be excavated to alignment and depth as required. Trench shall be properly braced and dewatered. The trenches shall be kept free of water at all times during installation, testing of pipe and/or conduit, and back filling. The Contractor shall provide proper facilities for discharging water into natural drainage channels. No water shall be discharged onto a street without approval by the Architect.

D. All exterior underground piping and conduit shall be installed with a minimum of 18" of earth or equivalent cover, except where specifically shown otherwise or required by the Architect/Engineer.

E. The trench shall be at least 18" wider than the diameter of the largest bell on the pipe duct bank, and conduit. If the pipe has no bells, the trench shall be at least 18" wider than the maximum diameter of the pipe. Pipe or conduit shall be laid in the center of the trench. The trench shall be excavated to a depth sufficient to provide for pipe/conduit cushions as specified herein.

F. Sheet pile and brace excavations wherever necessary to prevent cave-in. Trench width may be increased as required and piling left in place until sufficient compacted backfill is in place. The Contractor shall properly sheet and brace all open trenches to render them secure and shall remove all such sheeting and bracing before completing the backfill. The quantity of the excavation required to install sheeting and the installation and removal of sheetings and bracings will not be regarded as extra Work and all costs incurred for this excavation and the installation of sheeting shall be included in the Contract price.

G. Trenching may be done with trench digging machinery unless hand digging is required to avoid damage to existing structures or apparatus both above or below grade.

H. Pipe Cushion/Select Fill: Upon completion of excavation and prior to the laying of the pipe or conduit, the trench bottom shall be brought up to the required elevation with a pipe cushion, except where the cushion has been eliminated by the Architect. Pipe and conduit cushions shall be selected material deposited in the trench, and shall be compacted, leveled off, and shaped to obtain a smooth compacted bed along the laying length of the pipe. Material for pipe and conduit cushion shall comply with local codes and shall be placed in accordance with the Earthwork section of the specifications. In absence of local code requirements, the cushion shall be select fill with a PI of between 10 and 20. Any select fill used shall pass a one-inch screen.

I. Pipes and conduit shall not be laid in water or when trench condition is unsuitable.

J. As sections of pipe and conduit are installed, they shall be temporarily sealed until remaining sections of the piping have been installed to complete the system.

K. Cast iron pipes subject to potential heads of 15 feet of water or more shall have concrete anchors at each change in direction and/or as directed. Any change in direction exceeding 15 degrees shall be anchored. Concrete anchors shall rest against solid (virgin) ground with the required area of bearing on pipe and ground to provide suitable anchoring.

L. Trenches shall be backfilled only after piping has been inspected, tested, and approved by the Architect/Engineer. All backfill material shall be placed in the trench either by hand or by approved mechanical methods. The compaction of backfill material shall be accompanied by tamping with hand tools or approved pneumatic tampers, by using vibratory compactors, or by any combination of these. The method of compaction shall be approved, and all compaction shall be done in accordance with requirements of the Earthwork section of the Specifications. Backfill completely around pipe or conduit, including 18" above the pipe or conduit, with select fill, tamped in 8" layers under, around, and over pipe or conduit. The remainder of the backfill for all pipes or conduit shall be select backfill material tamped at intervals of no more than 12" depths, to attain Proctor Compaction Density required. If in the opinion of the Architect or the Geotechnical Consultant, the excavated material does not meet the requirements for select fill, the Contractor shall be required to screen the material prior to its use as select fill material. Material used in the upper portion of the backfill or sub-grade shall not contain stone, rock, or other material larger than six inches in its longest dimension. No wood, vegetable matter, or other material, which in the opinion of the Architect or Geotechnical Consultant, are unsuitable shall be included in the backfill. Backfill shall be brought up to finish grade identified on the Architectural Drawings and include additional backfill required to offset settlement during consolidation.

M. At building perimeter where pipe or conduit exits the building, mix a granular pellet form of Bentonite with select fill and completely fill trench for 8 feet inside and outside building exterior to create a vertical hydraulic barrier.

N. When removal of unsuitable excavated material creates a shortage of backfill material, the Contractor shall, at no cost to the Owner, furnish material as specified in this Section in the amount required to complete the backfill.

O. Existing street, driveways, and sidewalks damaged during the excavation work shall be restored to acceptable condition, subject to approval by the Architect.

P. Provide all street and sidewalk excavations with approved barricades, warning lights, and cover plates as required by the Authorities Having Jurisdiction.

Q. Submit complete installation and test procedures of the excavation and backfill work for approval by Architect prior to commencing any work.

3.17 CURBS AND SUPPORTS - ROOF MOUNTED EQUIPMENT

A. Where required, curbs and supports shall be of box section design, heavy gauge galvanized steel or aluminum construction, continuous mitered and welded corner seams, integral base plate, factory installed wood nailer, and shall be insulated with 1-1/2" thick, rigid fiberglass board insulation. Curbs and supports shall be mounted and flashed according to manufacturer's recommendations. Curbs for sloping roof surfaces shall be custom fabricated such that supported equipment is level. Curbs and Support: Pate Company of the style as outlined below or approved equal.

1. Utility Fan Curbs: Shall be style PC-1A, 12" high.
2. Duct Curbs: Where ducts are required to penetrate the roof without passing through an equipment curb, Pate style PC-1A, 12" high curbs shall be used.
3. Piping Curbs: Where piping penetrates the roof without passing through an equipment curb, Pate style PCA-1, 12" high curbs shall be used.
4. Equipment Supports: Roof mounted equipment shall be supported using Pate style ES-1A equipment supports with provisions for securing equipment as required. Equipment curbs shall be at least 12" high. Curbs for sloping roof surfaces shall be custom fabricated such that supported equipment is level.
5. Pipe and Ductwork Supports: Piping and ductwork routed on roofs shall be suspended using support products as manufactured by Portable Pipe Hangers, Inc. of Stafford, Texas. Supports shall consist of reinforced pre-cast concrete bases, tubular steel frame, and hangers as specified in HANGERS AND SUPPORTS. The tubular steel frame and rollers shall be hot dipped galvanized to prevent rust. Threaded rods, nuts, washers, etc., shall be cadmium plated. Pipe hangers shall be adjustable in height to provided appropriate pipe slope where required and equally distribute the piping load. Pipes and ducts shall be suspended a minimum of 18" above the roof surface. The entire support system shall be designed by a factory-authorized engineer and shall consist of standard and custom hanger arrangements as required for proper support. The support system shall accommodate piping expansion/contraction and for pumped water systems shall accommodate system vibrations. See Section 20 05 48, Noise and Vibration Isolation. The design shall be coordinated with the pipe and duct fabrication drawings, building structure, and actual roof construction. Provide protection pads such as Siplast Trafbloc composed of chopped rubber particles and synthetic binders under each pre-cast concrete base. Use polyurethane caulking where the frame fits into the base to prevent water migration into the insert. Install the piping support system in accordance with the manufacturers written installation instructions.

B. Roof mounted equipment shall be designed and constructed to sustain vertical and horizontal loads due to wind as prescribed by the building code. In the absence of specific building code requirements, the design wind load shall be based on an ultimate wind speed of based on an ultimate design wind speed of 139 mph, roughness Class C, as per IBC Section 1609. Manufacturer shall submit a curb or support design that is sealed by an Engineer licensed in the state where the project is to be located. Documentation shall be provided indicating that the equipment casing and components are designed to sustain the prescribed wind loading.

3.18 SUBMITTALS

A. Submit shop drawing information on the following Basic Materials:

1. Link Seal mechanical seals and sleeves.
2. Pipe Cleaning and Sterilizing methods and materials.
3. Pipe Hangers, Supports, Saddles, Insulation Shields and Anchors for attaching hangers and supports to the building structure.
4. Fire Stop Materials with manufacturers recommended installation details.

5. Miscellaneous Curbs and Supports.
6. Equipment (housekeeping) Pad drawings.
7. Identification, Labeling and Warning Signs.
8. Access Doors.
9. Pipe Fabrication Drawings.
10. Roof Mounted Equipment Curbs and Supports.
11. Cabinets and Pull Boxes.
12. Additional requirements as outlined in Section 20 05 03.

END OF SECTION

SECTION 20 05 08 - DEMOLITION AND WORK WITHIN EXISTING BUILDINGS

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20 Sections apply to this section:

1. Scope of Work - Section 20 05 01
2. Basic Division 20-28 Requirements - Section 20 05 03
3. General Division 20-28 Materials and Methods - Section 20 05 05

1.02 SCOPE

A. Existing buildings and their facilities must remain functional while the Work under this Contract is performed. All system shutdowns and outages must be minimized and coordinated with the Owner.

1.03 DEMOLITION AND WORK WITHIN EXISTING BUILDINGS

A. General: During the construction and remodeling, portions of the project shall remain in service. Construction equipment, materials, tools, extension cords, and similar items shall be arranged so as to present minimum hazard or interruption to the occupants of the building. Make every effort to minimize damage to the existing building and the Owner's property. Repair, patch, or replace, as required, any damage that might occur as a result of work at the site. Care shall be taken to minimize interference with the Owner's activities during construction. Cooperate with the Owner and other trades in scheduling and performance of the work.

B. Loss or Damage: The Contractor shall be responsible for loss or damage to the existing facilities caused by him and his workmen and shall be responsible for repairing or replacing such loss or damage. The Contractor shall send proper notices, make necessary arrangements, and perform other services required for the care, protection and in-service maintenance of all mechanical services for the new and existing facilities. The Contractor shall erect temporary barricades, with necessary safety devices, as required to protect personnel from injury, removing all such temporary protection upon completion of the work.

C. Operational Continuity: The Contractor shall provide temporary or new services to all existing facilities as required to maintain their proper operation when normal services are disrupted as a result of the work being accomplished under this project.

D. Utility Access: Where existing construction is removed to provide working and extension access to existing utilities, Contractor shall remove doors, piping, air conditioning ductwork, conduit, and equipment, and similar items to provide this access and shall reinstall same upon completion of work in the areas affected.

E. Demolition of Architectural/Structural Elements: Where partitions, walls, floors, or ceiling of existing construction are indicated to be removed and reinstalled, this Contractor shall remove and reinstall, in locations approved by the Architect, all devices required for the operation of the various systems installed in the existing construction.

F. Scheduled Service Outages: Outages of services as required by the new installation will be permitted but only at a time approved by the Owner. The Contractor shall allow the Owner two

(2) weeks in order to schedule required outages. The time allowed for outages will not be during normal working hours unless otherwise approved by the Owner. All costs of outages, including overtime charges, shall be included in the contract amount.

G. Pre-Demolition Salvage Survey: The Contractor shall modify, remove, and/or relocate all materials and items so indicated or as required by the installation of new facilities. All removals and/or dismantling shall be conducted in a manner as to produce maximum salvage. Survey the project with the Owner's Representative before demolition begins and determine all materials that the Owner specifically chooses to be salvaged. Pre-establish with the Owner locations where salvaged materials are to be stored. Salvage materials shall remain the property of the Owner and shall be delivered to such destination as directed by the Owner. Materials and/or items scheduled for relocation and that are damaged during dismantling or reassembly operations shall be repaired and restored to good operating condition. The Contractor may, at his discretion and upon the approval of the Owner, substitute new materials and/or items of like design and quality in lieu of materials and/or items to be relocated.

H. Relocated Equipment: All items that are to be relocated shall be carefully removed in reverse to original assembly or placement and protected until relocated. The Contractor shall clean and repair and provide all new materials, fittings, and appurtenances required to complete the relocations and to restore to good operative order. All relocations shall be performed by workmen skilled in the work and in accordance with standard practice of the trades involved.

I. Damaged Materials/Equipment to be Reused: When items scheduled for relocation are found to be in damaged condition before work has been started on dismantling, the Contractor shall call the attention of the Owner to such items and receive further instructions before removal. Items damaged in repositioning operations are the Contractor's responsibility and shall be repaired or replaced by the Contractor as approved by the Owner, at no additional cost to the Owner.

J. Termination of Utility Services: Service lines and piping to items to be removed, salvaged, or relocated shall be removed to points indicated on the Drawings, specified, or acceptable to the Owner. Service lines and wiring not scheduled for reuse shall be removed to the points at which reuse is to be continued or service is to remain. Such services shall be sealed, capped, or otherwise tied-off or disconnected in a safe manner acceptable to the Owner. All disconnections or connections into the existing facilities shall be done in such a manner as to result in minimum interruption of services to adjacent occupied areas. Services to existing areas or facilities that must remain in operation during the construction period shall not be interrupted without prior specific approval of the Owner as hereinabove specified.

K. Nighttime Shifts: Certain work during the demolition and alteration phase of construction may require overtime or nighttime shifts or temporary evacuation of the occupants. Coordinate times with the Owner.

L. Include in the contract price all rerouting of existing ductwork, piping, air devices, fixtures, and similar items and the reconnecting of existing fixtures and devices as necessitated by field conditions to allow the installation of the new systems regardless of whether or not such rerouting, reconnecting or relocating is shown on the Drawings. Furnish all temporary ductwork and piping, and similar items as required to maintain service for the existing areas with a minimum of interruption.

M. Include in the contract price all rerouting of existing conduit, fixtures, and similar items and the reconnecting of existing fixtures and devices as necessitated by field conditions to allow the installation of the new systems regardless of whether or not such rerouting, reconnecting or relocating is shown on the Drawings. Furnish all temporary conduit, circuits, and similar items as required to maintain service for the existing areas with a minimum of interruption.

N. All existing air devices materials, equipment and appurtenances not included in the remodel or alteration areas are to remain in place and shall remain in service.

O. All existing electrical devices, materials, equipment and appurtenances not included in the remodel or alteration areas are to remain in place and shall remain in service.

P. Mechanical equipment and building systems equipment, and similar items that are to remain but are served by piping that is disturbed by the remodeling work, shall be reconnected in such a manner as to leave it in proper operating condition.

Q. Electrical equipment and building systems equipment, and similar items that are to remain but are served by conduit and circuits disturbed by the remodeling work, shall be reconnected in such a manner as to leave it in proper operating condition.

R. Existing plumbing fixtures, registers, grilles, and diffusers shown to be removed and indicated to be reused, shall be cleaned, repaired and provided with such new accessories as may be needed for the proper installation in their new locations.

S. Existing lighting fixtures, outlets, switches, and panelboards shown to be removed and indicated to be reused, shall be cleaned, repaired and provided with such new accessories as may be needed for the proper installation in their new locations.

T. Within the remodeled or alteration areas where existing ceilings are being removed and new ceilings are installed, all existing air devices, other ceiling mounted devices and their appurtenances shall be removed and reinstalled into the new ceiling, unless otherwise shown or specified.

U. Within the remodeled or alteration areas where existing ceilings are being removed and new ceilings are installed, all existing light fixtures, fire alarm devices, and other ceiling mounted devices and their appurtenances shall be removed and reinstalled into the new ceiling, unless otherwise shown or specified.

V. Within the remodeled or alteration areas where existing walls are being removed, all existing fixtures, thermostats, other materials and equipment and their appurtenances shall be removed and relocated if necessary, where required by the remodel work either shown or specified.

W. Within the remodeled or alteration areas where existing walls are being removed, all existing outlets, switches, other materials and equipment and their appurtenances shall be removed and relocated if necessary, where required by the remodel work either shown or specified.

X. Any salvageable equipment as determined by the Owner, shall be delivered to the Owner, and placed in storage at the location of his choice. All other debris shall be removed from the site immediately.

Y. Equipment, materials or other potential hazards to the public and working occupants of the building shall not be left overnight outside of the designated working or construction areas.

Z. All existing air handling equipment that is shown as being reused shall have coils cleaned and shall be equipped with new filters and belts by this Contractor.

AA. No portion of the fire protection or alarm systems shall be turned off, modified or changed in any way without the express knowledge and written permission of the Owner's representative.

BB. Refer to Architectural "Demolition" and "Alteration" plans for actual location of walls, ceiling, and similar items being removed and/or remodeled.

CC. Drawings do not fully indicate conditions or existing obstructions or utilities. Visit the site and examine work to be removed and become familiar with conditions affecting work.

DD. Asbestos removal is not part of this Contract.

EE. Floor Sleeves: Sleeves are not required where new openings are core-drilled into existing construction, unless noted otherwise on the Drawings. Provide water stops at new penetrations of existing floors.

FF. Wall Sleeves: In the remodel of existing areas, the Contractor shall install new sleeves and seal existing piping penetrations through new walls with materials specified herein.

GG. Water Stops: Provide water stops at new penetrations of existing floors. Water stops shall be 1-1/2" tall, at least 16 gauge, and be sized as specified in Section 20 05 05 for sleeves. Water stops shall be securely attached to the top of the floor slab with waterproof mastic applied between the bottom flange of the water stop and the floor slab. Pipe supports for riser piping shall be elevated sufficiently on spacers to prevent crushing water stops. The thickness of the firesafing system shall not exceed the existing floor thickness.

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION (NOT APPLICABLE)

END OF SECTION

SECTION 20 05 14 - ELECTRONIC VARIABLE SPEED DRIVES

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20 Sections apply to this section:

1. Scope of Work - Section 20 05 01
2. Basic Division 20-28 Requirements - Section 20 05 03
3. Schedule of Submittal Data - Section 20 05 04
4. General Division 20-28 Materials and Methods - Section 20 05 05

1.02 SCOPE

A. Provide and install electronic variable speed drives (VSD) as shown, scheduled, and specified.

B. Types: Variable frequency motor speed controllers.

C. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. HVAC Pumps - Section 23 21 23
2. Fans - Section 23 34 10
3. Water Chilling Units - Centrifugal - Section 23 64 16
4. Cooling Towers - Section 23 65 19
5. Air Handling Units - Section 23 73 00

1.03 QUALITY ASSURANCE

A. Manufacturers: If they comply with these specifications and requirements, products of the following manufacturers will be acceptable:

1. ABB
2. Danfoss

B. Codes and Standards:

1. Products shall be designed, manufactured, tested and installed in compliance with the following standards, as applicable:

   a. UL or ETL listed.

2. At a minimum, the drives shall have internal impedance equivalent to 5% to reduce the harmonics to the power line. 5% impedance may be from dual (positive and negative DC link) chokes, or AC line reactor. Drives with only one DC link choke shall add an AC line reactor. The entire system shall comply with IEEE 519-2014 & IEEE 519-1992 for distortion within the building and at the point of common coupling. Provide a harmonic analysis to prove compliance.
3. For initial pricing purposes prior to final bid, assume all drives greater than or equal to 50HP shall be ultra low harmonic type equal to ABB ACH580-ULH series.

4. VSD design and construction shall comply with all applicable provisions of the National Electric Code.

C. Factory Testing: To ensure quality, the VSD shall be subject to the following factory tests:

1. Unit shall be factory tested while fully loaded.
2. The drive manufacturer shall certify in writing that the selected driven machine, motor and drive assembly operate together as a system without excessive electrical distortion, motor overheating, physical noise or vibration.

D. Warranty: Include full parts and labor warranty for turnkey resolution with no cost to the Owner for repair or replacement for a period of two (2) years, starting on the date of Certificate of Substantial Completion.

PART 2 - PRODUCTS

2.01 **ELECTRONIC VARIABLE SPEED DRIVES**

A. General: Provide electronic IGBT based pulse-width modulated variable speed drives for control of standard or high-efficiency NEMA Design B induction motors on air handling units, fans, and pumps where specified herein, scheduled or shown on the Drawings.

B. Operation: Each variable speed drive shall convert available utility power to adjustable voltage/frequency, 3-phase, AC power for stepless motor control from 25 to 110% of motor 60 Hz speed.

1. The variable speed drive (VSD) shall produce an adjustable AC voltage/frequency output for complete motor speed control. Speed control shall be stepless throughout the range under a variable torque load on a continuous basis. The VSD shall be automatically controlled by an external control signal.
2. The VSD maximum output current rating shall be greater than or equal to the motor nameplate full load. The input power factor of the controller shall be 0.95 or greater under all speed and load conditions and the unit shall be rated for 100% operation at full rated current, voltage and frequency.
3. A dedicated line filter shall be provided at the input of the VSD to limit EMI and voltage distortion from interference with vital electrical equipment. Voltage line notching is not acceptable. DC Bus chokes may be provided in lieu of line filters if they perform their intended function.
4. All drives on the project shall utilize the same keypad user interface.

C. Components: Each controller shall include, but not be limited to, an input rectifier, constant voltage DC link, filter, sine-weighted pulse width modulation inverter and accessory sections with each section modularized for ease of troubleshooting. Controller shall be protected with I^2T fuses or circuit breakers per the manufacturer's design and specification. All components shall be factory mounted and wired on a dead-front, grounded, free-standing or wall-mounted minimum NEMA 1 enclosure arranged for top or bottom conduit entry. The free-standing enclosure shall be suitable for mounting on a steel platform or on a concrete housekeeping pad.

1. The controller enclosure shall be provided with the manufacturer's illustrated operating instructions and parts list mounted inside the enclosure door, manual speed control potentiometer, three position mode selector switch (manual-off-auto), "power on" light, diagnostic/frequency display, auxiliary relays, and contacts for interlock and control wiring.
2. Controllers located outdoors for cooling tower applications shall have NEMA 4 enclosures.

D. Features: VSD features shall include, but not be limited to, the following:

1. Input Power: 460 volts AC ±10%, 60 Hz, ±1.8 Hz. Input power factor shall be 0.95 or greater from full motor speed to zero speed for any motor load.
2. SEMI-F47 certified: The drive must tolerate voltage sags to 50% for up to 0.2 seconds, sags to 70% for up to 0.5 seconds, and sags to 80% for up to one second.
3. Output Power: Three phase, 0-460 volts, 2-60 Hz.
4. Ambient Temperatures:

    a. Operating: 0ºC to 40ºC (32ºF to 104ºF).
    b. Storage: -20ºC to 60ºC (-4ºF to 140ºF).

5. Frequency Stability: Output frequency will be held to ±0.1% of maximum frequency regardless of load, ±10% input voltage change or temperature changes within the ambient specification.
6. Disconnect: Locking input disconnect switch or circuit breaker with external operating handle suitable for 100,000 amp SCCR drive rating.
7. Bypass: Provide manual bypass which isolates the drive from the circuit and allows motor operation at full across-the-line speed. Bypass shall include motor contactor, drive isolation contactors, motor overload protection, fused control power transformer and front panel mounted bypass controls.
8. Current Limit: To limit output current to 110% of that of the drive rating. The current limit shall be designed to function automatically to prevent overcurrent trip due to momentary overload conditions, allowing the drive to continue operation.
9. Instantaneous Overcurrent Trip: To safely limit the output current in under 50 microseconds due to short circuit or severe overload conditions.
10. Undervoltage Trip: To protect the drive due to non-momentary power of phase loss. The undervoltage trip will activate automatically when line voltage drops 15% below rated input voltage.
11. Overvoltage Trip: To protect the drive due to voltage levels in excess of its rating.
12. Ground Fault Protection: Fuseless electronic power protection for ground fault protection. Isolation transformers for ground fault protection are not acceptable. Ground fault shall not cause fuses to open.
13. Overload Protection: Electronic output overload protection shall be provided to eliminate the use of bimetallic overloads. The drive shall not be phase sequence sensitive. The overload protection shall also protect the motor when it is operated at full speed in the bypass mode.
14. Over-Temperature Trip: To protect the drive from elevated temperatures in excess of its rating. An indicating light shall be provided to alert the operator to an over-temperature condition. When the over-temperature trip point is reached, this light will be continuously illuminated.
15. Automatic Reset/Restart: The drive shall be equipped such that a trip condition resulting from overcurrent, undervoltage, overvoltage or over-temperature shall be automatically reset, and the drive shall automatically restart upon removal, or correction of the causative condition. The number of reset/restart attempts for undervoltage, overvoltage, over temperature and overcurrent shall be limited to five. If, in five attempts, a reset/restart is not successful, the drive shall shut down safely, requiring a manual restart. If, within five attempts, a successful reset/restart occurs, the Auto Reset/Restart circuit will reset the attempts counted to zero after approximately 10 minutes of continuous operation.
16. Power Interruption: In the event that an input or output power contactor is opened or closed while the drive is activated, no damage to the drive shall result.
17. Short Circuit Protection: In the event of a phase-to-phase short circuit the drive shall be designed to shut down safely without component failure.
18. Single Phase Protection: In the event of a loss of any phase, the drive shall be designed to shut down safely without component failure.

19. Sustained Power Loss: In the event of a sustained power loss, the drive shall be designed to shut down safely without component failure. Upon return of power, the systems shall be designed to automatically return to normal operation.
20. Momentary Power Loss: In the event of a momentary power loss, the drive shall be designed to ride-through a power interruption up to five cycles and shut down safely without component failure. Upon a more extended momentary power loss, the system shall be designed to automatically return to normal operation upon return of power.
21. Stand Alone Operation: To facilitate startup troubleshooting, the drive shall be designed to operate without a motor, or any other equipment connected to the drive output.
22. Start/Stop Control: The drive may be started or stopped by any one of the following:

    a. A contact closure.
    b. The speed control signal dropping below or rising above minimum.
    c. An external 24 Volt dc signal.
    d. Keypad interface

23. Speed Control: Minimum of (2) analog inputs. The drive will adjust the output frequency in proportion to a 0-10-volt or 4-20 ma analog signal.
24. Minimum and Maximum Speed Control: Adjustable minimum and maximum digital parameters or speed potentiometers for all speed signals. Minimum range shall be 0-80%, field set at 40%. Maximum range shall be 100-0%, field set at 100%.
25. Signal Gain and Offset: Adjustable signal gain (1:1 to 10:1 range) and offset (0-50% of input signal for all speed signals.
26. Automatic Reversing: Reversing terminals to automatically reverse the rotation of the motor(s) shall be available for customer use if so desired. When a contact closure is made across these terminals, the motor shall decelerate from its operating speed to zero at the preset deceleration rate. Upon reaching zero, it shall reverse direction and accelerate to the set speed at the present acceleration rate.
27. Adjustable Accel/Decel: Independently adjustable acceleration and deceleration digital parameters or time potentiometers from at least 30-199 seconds, field set at 90 seconds.
28. Control Isolation: Low voltage logic and 115-volt control circuits shall be electrically isolated from the power circuits. Signal circuit common shall be grounded.
29. Control Adjustments: All control adjustments shall be made without the necessity of an extender board or specialized meters, and from front accessible controls.
30. Diagnostics: A diagnostic fault detection center shall be integral to each VSD, providing an indication of the following fault conditions:

    a. External fault
    b. Processor line voltage
    c. Low ac line voltage
    d. High ac line voltage
    e. Current overload
    f. High dc bus voltage
    g. VSD output fault

31. Status Lights: Status lights for indications of conditions described in items 1 through 5 shall be provided. An SPDT contact for remote indication of items 2 through 5 shall be provided. Additionally, status lights to show "Power On", "Zero Speed", and "Drive Enabled" shall be provided. All status lights shall be self-contained in the front panel of the unit and shall be duplicated for ease of troubleshooting on the inside of the unit. Status lights shall be red, light-emitting diode type for high visibility and reliability. Status information may be provided by a digital read-out message center.
32. Indicating Lights: Provide indicating lights or a digital read-out message center with selector keypad to display the following information.

    a. Power On: Lights any time input power is applied to the drive

b. Zero Speed: Illuminates whenever the drive is at zero frequency
c. Enabled: Lights to indicate that the drive has a start command
d. Over Temperature: Upon reaching the over temperature trip point, the light is continuously illuminated
e. Current Limit: Indicates that the Accel, Decel or Run Limit circuit is in operation
f. Undervoltage: Indicates that an undervoltage trip has occurred
g. Overvoltage: Indicates that an overvoltage trip has occurred
h. Overcurrent: Indicates that the current rating of the drive has been exceeded and the overcurrent trip circuit has been activated

33. External Alarm Contacts: Single pole, double throw contacts rated 115-volt ac, 28-volt ac, 1 Amp resistive, shall be available for external monitoring. Contacts will change state when any trip condition has occurred.
34. Network Communications: The drive shall have an EIA-485 port with removable terminal blocks. The onboard protocols shall include BACnet MS/TP. Communication cards for BACnet/IP and LonWorks shall be available. Reference Division 25 specifications for the required protocol.
35. Speed Reference Signal: An adjustable signal shall be provided for customer use. This signal shall vary in direct proportion to the drive speed. 0-10V or 4-20mA.
36. User Interface: The VSD shall have the following door mounted user interface devices:

    a. "Power On" light
    b. Hand/Off/Auto (or equivalent) selector switch
    c. Speed potentiometer or keypad control
    d. Digital Readout with keypad for Frequency information and Diagnostic Display

37. Cooling: The VSD shall be convection-cooled or fan-cooled. The unit shall have high temperature protection.
38. Control Power: A 24-volt dc, control power shall be available for customer use whenever drive input power is applied.
39. External Safeties: Fire alarm interface, safety and temperature control interlock terminals with door mounted "external fault" light.

E. System Operation:

1. Selector switch in the "off" position - the controller run circuit will be open and the system will not operate.
2. Selector switch in the "hand" position - the speeds of the motor will be controlled by the manual speed potentiometer or keypad.
3. Selector switch in the "auto" position - operation will be via the external control input signal with the output speed proportional to the input signal.

PART 3 - EXECUTION

3.01 **SUBMITTALS**

A. Shop drawing submittals shall include, but not be limited to, the following:

1. Cut sheets of individual speed controllers with construction, dimensions, weights, ratings, voltage, poles, options, and all associated accessories clearly indicated
2. Wiring diagrams for the drive power, bypass and control sections
3. A detailed description of drive operation and adjustable parameters
4. Additional information as required in Section 20 05 03

3.02 INSTALLATION OF ELECTRONIC VARIABLE SPEED DRIVES

A. General: Install electronic variable speed drives where shown, in accordance with the manufacturer's written instructions, the applicable requirements of the NEC and the NECA's "Standard of Installation", and recognized industry practices to ensure that products serve the intended function.

B. Supports: Provide all electronic variable speed drives with galvanized angle or other suitable supports where mounting on wall or other rigid surface is impractical. Drives shall not be supported by conduit alone. Where drives are mounted on equipment served, the drive shall not inhibit removal of any service panels or interfere with any required access areas. All drives shall be installed plumb and aligned in the plane of the wall in/on which they are installed.

C. VFD Output Power Wiring: Provide dedicated output conduits for each VFD to each motor unless otherwise indicated on drawings.

D. Coordination: The Division 20-28 Contractor shall coordinate electronic variable speed drive selection and installation including, but not limited to, the following:

1. Coordinate power wiring to electronic variable speed drives and served motors with the Division 26 Contractor.
2. Coordinate selection of variable speed drives and served motors to ensure compatibility.
3. Coordinate variable speed drive control interface with controls and sequence of operation specified in Section 25 09 16 and Section 25 09 93.

3.03 STARTUP/TESTING

A. Pre-Energize Check: The Division 26 Contractor shall check electronic variable speed drive power wiring for continuity of circuits and for short circuits.

B. Startup Services: A representative of the variable speed drive manufacturer shall provide startup services for each drive including, but not limited to, the following:

1. Check out of drive control and power wiring.
2. Startup drive and demonstrate proper manual, automatic, and bypass operation.
3. Adjust variable speed drive overload protection and other adjustable parameters to suit project requirements.

C. Motor/Controller Coordination Documentation: Provide motor/controller coordination documents including, but not limited to, the following information in the Operation and Maintenance manuals.

1. Motor size in horsepower
2. Motor full load amps
3. Motor efficiency
4. Motor service factor
5. Size and manufacturer's catalog number of electronic variable speed drives.
6. Setting of electronic variable speed drive overload protection and other adjustable parameters

D. Motor Rotation: Verify that motor rotation is correct as connected. Where rotation must be changed, the Division 26 Contractor shall reconnect phase conductors to motor leads at motor junction box.

END OF SECTION

SECTION 20 05 33 - PIPE HEAT TRACING

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20 Sections apply to this section:

1. Scope of Work - Section 20 05 01
2. Design Criteria - Section 20 05 02
3. Basic Division 20-28 Requirements - Section 20 05 03
4. Schedule of Submittal Data - Section 20 05 04
5. General Division 20-28 Materials and Methods - Section 20 05 05

1.02 SCOPE

A. General: Furnish and install pipe heat tracing cable systems as shown, scheduled, and specified.

B. Freeze Protection: All chilled water, domestic water, water-filled fire protection, makeup water, condensate, and sanitary drain piping routed in unheated spaces and where exposed to freezing conditions shall be heat traced and insulated.

C. Coordinate with Division 20 the circuit quantities and locations that are required, whether shown on the Drawings or not.

D. The Electrical Contractor shall properly ground the piping system being heat traced in accordance with Article 250 of the NEC. The Electrical Contractor shall make the final power connection to the heat trace cable at the junction box and shall test the operation of the cable to ensure proper electrical connection and grounding.

E. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. Thermal Insulation - Section 20 07 00
2. Plumbing Piping and Accessories - Section 22 11 16
3. HVAC Water Piping Accessories - Section 23 05 10
4. HVAC Water Piping - Section 23 21 13

1.03 QUALITY ASSURANCE

A. Manufacturers: If they comply with these specifications and requirements, products of the following manufacturers will be acceptable:

1. Chromalox
2. Nelson
3. Raychem
4. Thurmon

B. Codes and Standards: The installation and materials furnished shall meet the N.E.C. requirements and be Underwriters' Laboratories listed and conform to ANSI/IEEE Standard 515.1-2005 for the application.

PART 2 - PRODUCTS

2.01 PIPE HEAT TRACING (FREEZE PROTECTION)

A. General: Heat tracing cable shall be self-regulating at a watt density per lineal foot required to prevent pipe from freezing down to an ambient temperature of 15ºF and a wind velocity of 20 miles per hour. Cables shall be provided in the lengths, wattages, voltages, and resistance ratings as required to meet the design performance specified.

B. Electrical: Electrical characteristics shall be 120V or 208V (as provided for on the electrical Drawings), 60 HZ, single phase with NEMA 4 enclosed thermostat with ambient sensing bulb, adjustable set point and contacts rated as required for each group of cables.

C. Cable: Heat tracing cable shall consist of twin copper conductors encased in a radiation cross-linked polyolefin semi conductive heating core matrix whose resistance varies with temperature. The cable shall be capable of varying its heat output for the surrounding conditions along the entire length of the circuit, allowing the cable to crossover itself without overheating. When the outer jacket temperature decreases, the core heat output increases and as the jacket temperature increases, the core heat output decreases. The core matrix shall be covered with a flame-resistant thermoplastic elastomer (TPE) jacket.

D. Accessories: Provide all required accessories including thermostats, termination kits, cold lead kits, end seal kits, splice and tee kits, heat transfer foil, stainless steel banding straps, fiberglass tape, aluminum tape (for nonmetallic pipe), and “Electric Heat Tracing” labels all as recommended by the cable manufacturer.

E. Control and Monitoring: Provide a microprocessor-based control and monitoring panel with the following adjustable parameters: low temp alarm, high temp alarm, low current alarm, high current alarm, ground fault alarm (30-100mA adjustable), ground fault trip on/off. Provide capability for monitoring at building automation system via (2) Form C dry contacts or communications port.

PART 3 - EXECUTION

3.01 SUBMITTALS

A. Shop drawing submittal shall include, but not be limited to, the following:

1. Cut sheets on all pipe heat tracing equipment specified herein, clearly marked to show sizes, construction features, capacities and other pertinent information
2. Drawings showing extent of Heat Traced Piping
3. Calculations to determine Heat Tracing Loads
4. Megohmeter Test Results
5. Additional information as required in Section 20 05 03

3.02 INSTALLATION

A. Install all materials in accordance with manufacturer's written installation instructions and design guides, applicable standards, and recognized industry practices.

B. The entire length of the exposed pipe including all valves, fittings, and accessories shall be traced and insulated. Where a heat traced pipe enters or exits a building or penetrates from below grade to above grade, the heating cable and insulation shall extend into the building a minimum of 12 inches or the distance necessary to protect the pipe between the surface and the frost line.

C. Heat trace cable shall be secured to the traced pipe in the 5 o'clock or 7 o'clock position with fiberglass tape on 12-inch centers. For nonmetallic pipe, the cable shall be secured using

aluminum tape, directly on the cable. Cable at valves, flanges, unions, and pipe supports shall be looped to allow adequate slack cable such that the valves, flanges, unions, and pipe supports can be removed without removing the heat tracing cable from the traced pipe run. The thermostat shall be set to energize the heat tracing cable at 35ºF ambient air temperature. Pipe labels on heat traced piping shall indicate that the labeled pipe is electrically heat traced.

3.03 **TESTING**

A. Heat trace cable shall be tested with a megohmeter between the heating cable bus wires and the metallic ground braid with a 2500 VDC megohmeter. This test shall be performed a minimum of three times:

1. Prior to installation while the cable is still on the reel(s)
2. After installation of heat trace cable and completion of circuit fabrication kits, but prior to installation of thermal insulation
3. After installation of thermal insulation but prior to connection to power

B. The minimum acceptable level for the megohmeter readings is 20 megohms, regardless of circuit length.

C. Results of the megohmeter readings shall be recorded and submitted for review.

END OF SECTION

SECTION 20 05 48 - NOISE AND VIBRATION ISOLATION

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20 Sections apply to this section:

1. Scope of Work - Section 20 05 01
2. Basic Division 20-28 Requirements - Section 20 05 03
3. Schedule of Submittal Data - Section 20 05 04
4. General Division 20-28 Materials and Methods Section 20 05 05

1.02 SCOPE

A. General: Furnish and install vibration isolation supports for all equipment and piping as required to prevent transmission of vibration and noise to the building structure.

B. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. All Pump Equipment and Piping Sections
2. All Air Handling Equipment Sections

1.03 QUALITY ASSURANCE

A. Expected noise levels in various parts of the building shall conform to noise criteria recommendations as set forth in the ASHRAE 2023 Applications Handbook, Chapter 49, Table 1. Refer to ASHRAE 2023 Applications Handbook, Chapter 49, Figures 5 and 6 for NC and RC curves. The mid-point of the range of NC criteria curves shall apply. It shall be the Contractor's responsibility to select and install vibration isolators that enable the noise criteria standards to be met to the extent that the noise can be controlled by vibration isolators.

B. All vibration isolation devices, including auxiliary steel bases and pouring forms, shall be designed and furnished by a single manufacturer and supplier.

C. Manufacturers: If they comply with these specifications and requirements, products of the following manufacturers will be acceptable:

1. Amber/Booth Company, Inc. (Proco Products)
2. Kinetics Noise Control
3. Mason Industries
4. VMC/Korfund
5. Vibration Eliminator
6. Vibro Acoutics

PART 2 - PRODUCTS

2.01 GENERAL

A. Unless otherwise noted, equipment driven by motors 2 HP and smaller shall be isolated by means of elastomeric mounts or hangers properly sized for 1/2" deflection.

B. Unless otherwise noted, spring type vibration isolators shall be used for all equipment driven by motors of 3 HP and larger. Deflections as tabulated are minimums and it shall be the responsibility of the isolation manufacturer to determine the amount of spring deflection required for each isolator to achieve optimum performance, prevent the transmission of objectionable vibration and meet the noise criteria referenced herein.

C. All spring isolators shall be completely stable in operation and shall be designed for not less than 50% reserve deflection beyond actual operating conditions. Open spring isolators shall be designed such that the KX/KY ratio shall be 1.0 or greater. Spring shall be welded both to the baseplate and the compression plate.

D. All elastomeric isolators shall be of neoprene or high-quality synthetic rubber with anti-ozone and anti-oxidant additives.

E. Steel components shall be cleaned and painted. All nuts, bolts, and washers shall be zinc-electroplated. Structural steel bases shall be thoroughly cleaned of welding slag and primed with zinc-chromate or metal etching primer.

F. Height saving brackets used with isolators having 2.5" deflection or greater shall be of the pre-compression type to limit exposed bolt length.

G. All isolators exposed to the weather shall have PVC, cadmium, or neoprene coated springs and hot dipped galvanized steel components. Aluminum components shall be etched and painted. Nuts, bolts and washers may be zinc-electroplated.

H. Isolators for equipment installed outdoors shall be designed to provide adequate restraint due to normal wind conditions and to withstand wind loads of 30#/sq. ft. applied to any exposed surface of the isolated equipment.

I. Axial flow fans operating at 2" of static pressure and above shall be furnished with type TRK isolation thrust resisters to limit displacement to 1/4".

2.02 EQUIPMENT ISOLATION (TABLE 20 05 48-A)

A. The following table represents the isolator and base types required for various equipment.

TABLE 20 05 48-A

EQUIPMENT		ISOLATOR TYPE	MINIMUM DEFLECTION (IN.)	BASE TYPE
AIR HANDLING UNITS (Externally Isolated)				
FLOOR MOUNTED:	UP TO 15 HP 20 HP AND OVER	SW SW	1.0 2.0	HKP HKP
SUSPENDED:	UP TO 15 HP 20 HP AND OVER	BSRA BSRA	1.5 2.5	—- ----
CURB MOUNTED:		SW	(1.0) (2.0) (3.0)	RTIR
AIR HANDLING UNITS (Internally Isolated)				
FLOOR MOUNTED:	UP TO 15 HP	SP-NRE	0.15	HKP
FAN COIL UNITS				
SUSPENDED:		BSRA	0.50	----
FANS - CENTRIFUGAL				

TABLE 20 05 48-A

EQUIPMENT		ISOLATOR TYPE	MINIMUM DEFLECTION (IN.)	BASE TYPE
FLOOR MOUNTED:	UP TO 15 HP 20 HP AND OVER	SW SW	1.5 3.0	HKP CPF/HKP
SUSPENDED:	UP TO 15 HP 20 HP AND OVER	BSRA BSRA	1.5 2.5	—- ----
FANS - AXIAL				
FLOOR MOUNTED:	UP TO 15 HP 20 HP AND OVER	SW SW	1.5 3.0	HKP CPF/HKP
SUSPENDED:	UP TO 15 HP 20 HP AND OVER	BSRA BSRA	1.5 2.5	—- ----
FANS - WALL OR CURB MOUNTED		ISOLATORS FURNISHED WITH EQUIPMENT		
IN-LINE PUMPS		NONE	----	----
FLOOR MOUNTED PLUMBING PUMPS		NONE	----	HKP
PACKAGED DOMESTIC WATER PUMPING SYSTEM		SP-NRE	0.15	HKP
FIRE PROTECTION PUMPS		NONE	----	HKP
HVAC PUMPS				
FLOOR MOUNTED:	UP TO 5 HP 7-1/2 HP AND OVER	RSW RSW	1.0 2.0	CPF/HKP CPF/HKP
ROOF MOUNTED:	UP TO 5 HP 7-1/2 HP AND OVER	SP-NRE SP-NRE	0.15 0.15	HKP HKP
AIR COMPRESSORS		SW	2.0	HKP
MEDICAL AIR COMPRESSOR		SP-NRE	0.15	HKP
MEDICAL AIR COMPRESSOR		SW	2.0	CPF/HKP *
MEDICAL VACUUM PUMP		SP-NRE	0.15	HKP
MEDICAL VACUUM PUMP		SW	2.0	CPF/HKP *
WATER CHILLING UNITS		SP-NRE	0.15	HKP
WATER CHILLING UNITS		CT	2.0	HKP *
AIR COOLED CONDENSING UNITS				
ROOF MOUNTED:	UP TO 5 TONS 7-1/2 TONS - 20 TONS ABOVE 20 TONS	SP-NRE CT CT	0.15 1.0 2.0	RTIR RTIR RTIR
WATER HEATERS		----	----	HKP
BOILERS		----	----	HKP
HEAT EXCHANGERS		----	----	HKP
COOLING TOWER				
	UP TO 499 TONS 500 TO 1,000 TONS OVER 1,000 TONS	CT CT CT	3.0 3.5 4.5	SEE STRUCTURAL DRAWINGS

* WHERE MOUNTED ON FLOOR SLAB OVER OCCUPIED SPACE.

2.03 ISOLATOR TYPES

A. General: Isolator types shall be one or more of the following. Model numbers of Amber/Booth products are included for identification.

B. Type SW: An adjustable, freestanding, open-spring mounting with combination leveling and equipment fastening bolt. The spring shall be welded to the spring mounting baseplate and compression plate for stability. The isolator shall be designed for a minimum KX/KY of 1.0. An elastomeric pad having a minimum thickness of 1/4" shall be bonded to the baseplate. Nuts, adjusting bolts and washers shall be zinc-electroplated to prevent corrosion.

C. Type RSW: An adjustable, freestanding, open-spring for recessed mounting in a Type CPF base. The isolator shall be designed for a minimum KX/KY of 1.0. An elastomeric pad having a minimum thickness of 1/4" shall be bonded to the spring base plate. Nuts, bolts and washers shall be zinc-plated to prevent corrosion.

D. Type RVD: An elastomeric mounting having a steel baseplate with mounting holes and a threaded insert at the top of the mounting for attaching equipment. All metal parts shall be completely embedded in the elastomeric material. Mounting shall be designed for approximately 1/2" deflection.

E. Type SP-NRE: A pad type mounting consisting of two layers of 3/8" thick ribbed or waffled elastomeric pads bonded to a 16-gauge galvanized steel separator plate. Pads shall be sized for approximately 20 to 40 psi load and a deflection of 0.12" to 0.16".

F. Type CT: An adjustable, open-spring isolator having one or more coil springs attached to the top compression plate and a baseplate. An elastomeric pad having a minimum thickness of 1/4" shall be bonded to the baseplate. Nuts, adjusting bolts and washers shall be zinc-electroplated to prevent corrosion. The spring assembly shall be removable and shall fit within welded steel enclosure consisting of a top plate and rigid lower housing, which serves as a blocking device during installation. Isolated restraining bolts which shall not be engaged during normal operation shall connect the top plate and lower housing to prevent the isolated equipment from rising when drained of water.

G. Type PBSR: A combination spring and elastomeric hanger consisting of a rectangular steel box capable of 200% minimum overload without visible deformation, with the addition of a load transfer plate to hold the equipment or piping at a fixed elevation during installation and to permit transferring the load to the spring after installation, a coil spring, spring retainers and elastomeric element.

H. Type BSA: A spring hanger consisting of a rectangular steel box capable of 200% minimum overload without visible deformation, coil spring, spring retainers, neoprene impregnated fabric washer, and steel washer. This isolator shall incorporate a 30º angularity feature that will permit up to a 15º misalignment of the hanger rod from the vertical without shorting out to the hanger box.

I. Type BSRA: A combination spring and elastomeric hanger consisting of a rectangular steel box capable of 200% minimum overload without visible deformation, coil spring, spring retainers, and elastomeric element. This isolator shall incorporate a 30º angularity feature that will permit up to a 15º misalignment of the hanger rod from the vertical without shorting out to the hanger box.

J. Type PBSA: A spring hanger consisting of a rectangular steel box capable of 200% minimum overload without visible deformation, with the addition of a load transfer plate to hold the equipment or piping at a fixed elevation during installation and to permit transferring the load to the spring after installation, a coil spring, spring retainers, neoprene impregnated fabric washer, and steel washer. This isolator shall incorporate a 30º angularity feature that will permit up to a 15º misalignment of the hanger rod from the vertical without shorting out to the hanger box. Alternately, the hanger shall be of the pre-positioned configuration.

K. Type PBSRA: A combination spring and elastomeric hanger consisting of a steel box capable of 200% minimum overload without visible deformation, with the addition of a load transfer plate to

hold the equipment or piping at a fixed elevation during installation and to permit transferring the load to the spring after installation, a coil spring, spring retainers, and elastomeric element. This isolator shall incorporate a 30º angularity feature that will permit up to a 15º misalignment of the hanger rod from the vertical without shorting out to the hanger box. Alternately, the hanger shall be of the pre-positioned configuration.

2.04 **BASE TYPES**

A. Type HKP: A concrete equipment housekeeping pad as specified in Section 20 05 05.

B. Type CPF: A concrete inertia base, consisting of perimeter steel concrete pouring form (CPF), with reinforcing bars and isolators welded in place. The perimeter steel members shall have a minimum depth of 1/12” of the longest span, but not less than 6" deep. The base shall be sized with a minimum overlap of 4" around the base of the equipment and, in the case of belt-driven equipment, 4" beyond the end of the drive shaft. Fan bases are to be supplied with NEMA standard motor slide rails. The bases for pumps shall be sized to support the suction elbow of horizontal split-case pumps. The bases shall be T-shaped where necessary to conserve space. The CPF base shall be installed over a concrete equipment (housekeeping) pad as specified in Section 20 05 05.

C. Type RTIR: An extended aluminum rail base for rooftop air conditioning units consisting of a pair of weatherproofed aluminum rails for fastening to equipment and to the roof curb incorporating wind restraints and a continuous air and water seal which is protected from accidental puncture and direct sunlight by an aluminum weather shield. Rails shall incorporate non-adjusting Type SW spring isolators properly spaced around the perimeter according to load distribution of the supported equipment.

D. Type CURB: An equipment roof curb as specified in Section 20 05 05.

2.05 **PIPING ISOLATION**

A. All piping for the systems listed herein shall be isolated by means of spring type vibration isolation hangers or floor mounts as may be required to create the effect of a completely floating system. It shall be the responsibility of the vibration isolation manufacturer to coordinate the selection of piping supports with equipment supports to provide for a carefully engineered system designed to accommodate expansion and contraction while isolating and supporting the pipe and equipment. Piping for the following systems shall be isolated:

1. All piping four (4) inches in diameter and larger, and all piping two inches in diameter within 100 ft. of the pump for pumped domestic water.
2. All piping two inches in diameter and larger for all other pumped water, air, steam, gas, and engine exhaust systems.
3. Piping shown in tunnels on the Drawings to be installed on rollers does not require vibration isolation.

B. Riser diagrams shall be prepared by the vibration isolation manufacturer and submitted for approval. These diagrams shall show anticipated vertical expansion and contraction; initial and final loads on the building structure; initial and final deflections at each support point; spring deflection changes; operating temperatures; and temperature changes. Isolators shall be selected for minimum deflections equal to four (4) times the calculated thermal movement at each support point to minimize load shifts on the structure. If flexible connectors or expansion loops to relieve stress are required in the riser system, they shall be furnished whether shown or not at no additional expense to the Owner or Architect/Engineer. Submittal data shall include certification that the piping system (horizontal and vertical) has been examined for excessive stresses and that none will exist in the design proposed when installed in accordance with the submittals and these specifications.

C. Hangers for horizontal piping shall be installed at regular intervals as specified in Section 20 05 05. Isolated pipe risers up through 8" shall be supported at intervals of every third floor of the building and every second floor for risers 10" and over, and as shown on the riser schematics on the plans.

D. The first two piping supports away from any given piece of externally isolated equipment to which piping is connected shall be vibration isolators selected for an operating spring deflection equal to that specified for the equipment isolators. This shall apply whether the remainder of the piping system is or is not isolated by means of spring type vibration isolators.

E. Condenser Water Piping: The first two supports for condenser water connecting to cooling towers shall have isolators of the same type and deflection as those specified for the towers.

F. The first three horizontal piping supports away from a riser connection shall have deflections selected to adequately accommodate the riser thermal movement.

G. Provide Type 301 acoustic seals where isolated piping passes through non-fire rated wall, ceiling or floor openings from equipment rooms into adjoining occupied spaces. The acoustic seals shall consist of an S-shaped molded synthetic rubber seal attached with stainless steel clamps to the pipe wall sleeves and to carrier piping.

H. Domestic water systems shall have flexible connections where shown.

2.06 PIPING ISOLATOR TYPES

A. Type PBSA - for first two hangers in suspended horizontal piping adjacent to isolated equipment and for all hangers on 8" and larger pipe.

B. Type BSA - for remaining hangers in horizontal piping.

C. Type SW - for pipe risers. Isolator base plates shall be provided with holes for bolting and isolation grommets.

2.07 FLEXIBLE CONNECTORS (NON "FLOATING" SYSTEMS)

A. Install full line size flexible connectors at the suction and discharge connection of each pump and at other locations as shown on the drawings. All connectors shall be suitable for use at the pressure and temperature encountered at point of operation. End fitting of connectors shall conform to pipe fitting types specified elsewhere and are to be of the following types, as applicable. All flexible connectors shall be Amber/Booth or an approved equal by Mason, Metraflex or Vibration Mountings.

B. Water Service

1. Flanged (2-1/2" and larger), Type 2800 - A flanged spherical arch rubber expansion joint constructed of molded reinforced neoprene with integral steel floating flanges, suitable for pressure up to 214 psi (working) and 850 psi (burst) and temperatures up to 180ºF. Connectors shall have minimum movement capability of 1/2" compression, 1/2" control units shall be furnished for sizes up through 8" to limit thrust elongation to 3/8". For 10" and larger, the control rods shall be fitted with neoprene bushings for isolation.
2. Threaded (2" and smaller), Type SS-PM - A metal hose connector constructed of stainless-steel hose and braid with carbon steel NPT threaded end fittings. Minimum lengths shall conform to the following table:

    a. 1-1/2" diameter and smaller: 10" long

b. 2" diameter and larger: 12" long

C. Steam and Condensate Service

1. Flanged (2-1/2" and larger), Type SS-FP - A flanged metal hose connector constructed of stainless-steel hose and braid with carbon steel plate flanges. Minimum lengths shall conform to the following table:

a. 2-1/2" through 4": 9" long
b. 5" and 6" diameter: 11" long
c. 8" diameter: 12" long
d. 10" diameter: 13" long

2. Threaded (2" and smaller), Type SS-PM - Same as for water service.

2.08 **DUCTWORK ISOLATION**

A. Ductwork suspended above or below public spaces shall be isolated from the structure by Type BSRA vibration isolators sized for 3/4” deflection. These public spaces, include but are not limited to:

1. Ballroom
2. Meeting Rooms
3. Boardroom
4. Lobby
5. Pre-Function Room
6. Dining Room

B. Ductwork supported from floors above these areas shall be isolated from structure by Type RSW vibration isolators sized for 3/4” deflection.

PART 3 - EXECUTION

3.01 **SUBMITTALS**

A. Upon startup of internally isolated equipment, shipping restraints shall be released from internal springs to ensure proper function. Verification of operation shall be confirmed by the Vibration Isolation manufacturer, or qualified representative, as described in Paragraph B. below.

B. Shop drawings submittal data shall include, but not be limited to, the following information:

1. A complete listing of proposed types of isolators for each specified application, including size and deflection information
2. Selection calculations for all isolators
3. Vertical isolation riser diagrams with expansion/contraction calculations
4. Cut sheets for each isolator type to be utilized on the project
5. A clearly outlined procedure for installation and adjusting all isolators
6. Cut sheets on all furnished bases and frames
7. Cut sheets on all flexible connectors and application data as required
8. Piping drawing submittal shall show all isolator locations and types
9. Additional information as specified in Section 20 05 03
10. Additional information as may be required for proper evaluation of the proposed vibration isolation system

3.02 **INSTALLATION**

A. The vibration isolation manufacturer, or his qualified representative, shall be responsible for providing such supervision as may be necessary to assure correct installation and adjustment of the isolators and flexible connectors. Upon completion of the installation and after the system is put into operation, the manufacturer or his representative shall make a final inspection and submit his report in writing certifying the correctness of installation and compliance with approved submittal data.

END OF SECTION

SECTION 20 07 00 - THERMAL INSULATION

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20 Sections apply to this section:

1. Scope of Work - Section 20 05 01
2. Basic Division 20-28 Requirements - Section 20 05 03
3. Schedule of Submittal Data - Section 20 05 04
4. General Division 20-28 Materials and Methods - Section 20 05 05

1.02 SCOPE

A. Furnish and install thermal insulation for systems as specified in this Section and as shown on the Drawings.

B. Insulation Protection: All piping and/or duct insulation subject to damage, exposed to the outdoor elements, and/or within parking garage drive lanes shall be covered with factory applied aluminum laminate or 0.016" thick smooth aluminum jacket utilizing longitudinal "zee" closures. Jacket shall be secured at butt joints with 2" wide aluminum straps containing a permanently plastic sealant. Straps shall be centered over butt joints of jacket. Provide 1/2" wide aluminum bands applied on 12" centers. Install the longitudinal joint facing downward to shed water. Furnish end closure and caps to cover completely all valves, fittings, etc. Aluminum jacket for insulated grooved pipe fittings shall be as manufactured by Pro-Tec-T-Kotes, Inc., or approved equal. At the contractor's option, all ductwork insulation (including elastomeric type) exposed to the outdoor elements and/or within parking garage drive lanes may be covered with VentureClad Plus 1579CW-CE, clear embossed 13-ply laminate as manufactured by Venture Tape Corporation. All rigid insulation in unconditioned, ventilated attics open to the outdoors shall be covered with VentureClad 1579CW-CE, clear embossed 13-ply laminate in accordance with the manufacturer's written installation instructions. Venture Clad is not acceptable for pipe covering.

C. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. Miscellaneous Piping - Section 20 21 16
2. Plumbing Piping and Accessories - Section 22 11 16
3. Plumbing Fixtures and Trim - Section 22 42 10
4. HVAC Water Piping Accessories - Section 23 05 10
5. HVAC Water Piping - Section 23 21 13
6. HVAC Pumps - Section 23 21 23
7. Refrigerant Piping - Section 23 23 00
8. Ductwork and Sheet Metal - Section 23 31 13
9. Air Distribution Devices and Dampers - Section 23 33 10

1.03 QUALITY ASSURANCE

A. Manufacturers: If they comply with these specifications and requirements, products of the following manufacturers will be acceptable:

1. Insulation:

   a. Armacell LLC
   b. CertainTeed Corporation
   c. Knauf Insulation
   d. Johns Manville
   e. Owens/Corning
   f. Thermal Ceramics
   g. Resolco
   h. K-Flex
   i. Polyguard Products, Inc.

2. Adhesives/Sealants:

   a. Childers
   b. Foster
   c. Vimasco
   d. Armacell
   e. K-FLex

B. Codes and Standards:

1. Fire/Smoke Ratings: Fire and smoke hazard rating as tested by Procedure ASTM E84, NFPA 255, and UL Classified under UL 723 shall not exceed Flame Spread 25, Smoke Developed 50:
2. Specifications:

   a. Preformed fiberglass - ASTM C547
   b. Fiberglass Blanket - ASTM C553
   c. Polyisocyanurate board - ASTM C591
   d. Expanded closed cell elastomeric - ASTM C534
   e. Preformed Calcium silicate block - ASTM C533, Type I
   f. Cellular glass - ASTM C552
   g. Phenolic foam - ASTM C1126
   h. Fiberglass internal duct liner - ASTM C1071, Type I or II
   i. High Temperature Blanket - ASTM E119 & E814
   j. Aluminum jacket - ASTM B209
   k. Vapor barrier jacket - ASTM C1136
   l. Fiberglass insulation adhesive- ASTM C916
   m. Thermal efficiency test method - ASTM C177
   n. Dimensional standard - ASTM C585

PART 2 - PRODUCTS

2.01 **PREFORMED FIBERGLASS INSULATION**

A. General: Insulation material shall be Johns Manville Micro-Lok APT, Owens-Corning ASJ/SSL, or Knauf Earthwool 1000 Degree Pipe Insulation preformed glass fiber pipe insulation.

B. Conductivity: Preformed glass fiber pipe insulation shall have an average thermal conductivity (K factor) not to exceed 0.23 BTU • IN/HR • SF • ºF at 75ºF mean temperature and a temperature limit of at least 850ºF.

C. Jacket: The insulation shall include an all-service jacket (ASJ) consisting of a high density, white kraft bonded to aluminum foil and reinforced with fiberglass yarn. The jacket shall include a

longitudinal lap with a pressure sensitive tape lap sealing system and matching ASJ butt wraps. Jacket shall comply with ASTM C 1136 Type I.

2.02 **FIBERGLASS BLANKET INSULATION**

A. General: Insulation shall be Johns-Manville Microlite EQ100, Owens-Corning Type SoFTR 100, or CertainTeed Type 100, or Knauf Atmosphere 1 PCF duct wrap 1-pound FSK flexible glass fiber blanket.

B. Conductivity: Insulation shall have an average thermal conductivity (K-value) of no more than 0.27 BTU • IN/HR • SF • ºF at 75ºF mean temperature and a 250ºF temperature limit.

C. Jacket: Insulation shall be furnished with a factory applied foil-scrim-kraft facing consisting of 0.35 mil aluminum foil reinforced with glass yarn mesh and laminated to 40 pound chemically treated and fire resistant white kraft paper. Jacket shall comply with ASTM C 1136 Type II.

2.03 **HIGH TEMPERATURE BLANKET INSULATION**

A. General: Insulation shall be Thermal Ceramics, FireMaster Duct Wrap, FireMaster Duct Wrap+, Unifrax FyreWrap Elite 1.5, or approved equal 2300ºF, high temperature, foil encapsulated, blanket insulation, 6-pound density. Core material shall be composed of alumina and silica or biosoluble, low biopersistence, alkaline-earth silicate wool.

B. Conductivity: Insulation shall have an average thermal resistance (R-value) of 4.5 per inch at 70ºF mean temperature.

C. Fire Protection: Where used for the fire protection of PVC conduit or kitchen hood exhaust ductwork, insulation shall be installed in accordance with the manufacturers written installation instructions to provide 1-hour protection (PVC conduit) or 2-hour protection (hood exhaust duct).

2.04 **PIPE INSULATION ACCESSORIES**

A. Protection Shields: Provide protection shields at all clevis hangers as specified in Section 20 05 05, Basic Division 20 Materials and Methods.

B. Protection Shield Inserts: Where protection shields are used, provide an insert between the piping and the shield 2" longer and 2" wider than the shield, having the same thickness and contour as the adjoining insulation. Inserts shall be minimum 8.0-pound density, minimum 100 psi compressive strength.

1. Owens-Corning Foamglas cellular glass
2. Johns-Manville Thermo-12 Gold calcium silicate
3. Resolco Insul-phen phenolic foam
4. Polyguard Products, Inc. Polyphen Phenolic Foam

C. Banding: Pipe insulation 2" and larger shall be banded with either of the following:

1. A.J. Gerrard & Company "Steel-Binder" 0.02" thick by 1/2" wide aluminum bands or approved equal.
2. Thomas & Betts "TY-RAP" nylon ties or approved equal.

2.05 **ADHESIVES/SEALANTS/COATINGS**

A. Elastomeric Adhesives:

1. Armacell 520 or 520 BLV (for low VOC)

2. K-Flex 720-LVOC
3. Foster 85-75
4. Childers CP-82

B. Fiberglass Insulation Adhesive: Adhesives shall comply with ASTM C916, Standard Specification for Adhesives for Duct Thermal Insulation. Adhesive VOC content shall not exceed limits set forth in SCAQMD Rule #1168.

1. Foster (H.B. Fuller Co.) 85-60
2. Childers CP-127

C. Phenolic/Polyisocyanurate Foam Adhesive:

1. Foster 81-33/81-84
2. Childers CP-96

D. Vapor Barrier Coatings: Indoor applications, water-based vapor barrier coating for service -20oF to 180oF, permeance 0.013 perms or less at 43 mils dry thickness per ASTM E 96, Procedure B. Coating VOC content shall not exceed limits set forth in GS-11. Coating must also meet MIL 19565C, Type II as be listed on Qualified Products Database (QPD).

1. Childers CP-38
2. Foster (H.B. Fuller Co.) 30-80
3. Vimasco 749
4. Armcell WB Finish
5. K-Flex 374

E. Insulation Joint Sealant: Sealant used with phenolic, polyisocyanurate and cellular glass on cold service. Sealant VOC content shall not exceed limits set forth in SCAQMD Rule #1168 categorized as “other”.

1. Foster 95-50
2. Childers CP-76
3. Pittsburgh Corning CW (for cellular glass)

F. Metal Jacketing/Flashing Sealant: Sealant VOC content shall not exceed limits set forth in SCAQMD Rule #1168 categorized as “other”.

1. Foster 95-44
2. Childers CP-76
3. Pittsburgh Corning PC 727

G. Reinforcing Mesh: Mesh used in conjunction with mastics/coating as reinforcement. Fiberglass or synthetic fiber, 10 x 10 or 9 x 8 strands per square inch

1. Foster Mast a Fab
2. Childers Chil Glas #10
3. Pittsburgh Corning PC 79

H. Fungicidal Coating: Water based, fungicidal coating used inside ducts on duct liners.

1. Foster 40-20

2.06 **LAVATORIES AND SINKS**

A. Supply Pipes: The 3/8" supply pipes and risers to lavatory and sink fixtures exposed beneath the counter, lavatory, or sink, shall be insulated with 1/2" thick insulation. Handi-Lav-Guard insulation kits manufactured by Truebro will be an acceptable alternate.

B. Waste Piping: All exposed lavatory and sink waste piping beneath the counter, lavatory, or sink, shall be insulated as required by Federal, State, and Local requirements for handicap lavatories. Insulation shall be provided with fitted cover to give a finished appearance, color by Architect. Handi-Lav-Guard insulation kits manufactured by Truebro will be acceptable. Method of insulation and sample shall be submitted to Architect for approval.

2.07 **INSULATION SCHEDULE**

A. General: Insulation thickness shall be at least the minimum value scheduled. Thickness shall be increased where required to prevent condensation or to comply with governing energy code requirements.

1. Piping Systems: (2013 ASHRAE 90.1 and 2015 IECC Requirements)

EQUIPMENT/SYSTEM SURFACE	TYPE	THICKNESS
CHILLED WATER INDOORS / OUTDOORS, 1/2" – 1-1/2"	CELLULAR GLASS	1” / 2”
CHILLED WATER 2" AND LARGER INDOORS / OUTDOORS	CELLULAR GLASS	1-1/2" / 2”
HEATING HOT WATER 1-1/4" AND SMALLER (140ºF AND BELOW)	PREFORMED FIBERGLASS	1"
HEATING HOT WATER MAINS 1-1/2" AND LARGER (140ºF AND BELOW)	PREFORMED FIBERGLASS	1-1/2"
HEATING HOT WATER MAINS 1-1/4" AND SMALLER (141ºF AND ABOVE)	PREFORMED FIBERGLASS	1-1/2"
HEATING HOT WATER MAINS 1-1/2" AND LARGER (141ºF AND ABOVE)	PREFORMED FIBERGLASS	2"
STEAM 3” AND SMALLER (250ºF AND BELOW)	PREFORMED FIBERGLASS	2-1/2”
STEAM 4" AND LARGER (250ºF AND BELOW)	PREFORMED FIBERGLASS	3”
STEAM CONDENSATE 1-1/4" AND SMALLER (250ºF AND BELOW)	PREFORMED FIBERGLASS	1-1/2"
STEAM CONDENSATE 1-1/2" AND LARGER (250ºF AND BELOW)	PREFORMED FIBERGLASS	2"
STEAM CONDENSATE VENT PIPING	PREFORMED FIBERGLASS	1"
REFRIGERANT AND HOT GAS	ELASTOMERIC	1"
CONDENSATE (COOLING COILS)	PREFORMED FIBERGLASS	1/2"
CONDENSATE (ROOFTOP UNITS)	ELASTOMERIC	1"
DOMESTIC HOT WATER 1-1/4" AND SMALLER	PREFORMED FIBERGLASS	1"
DOMESTIC HOT WATER 1 1/2" AND LARGER	PREFORMED FIBERGLASS	1-1/2"
REFRIGERATED DRINKING WATER	PREFORMED FIBERGLASS	1"
HORIZONTAL STORM DRAIN PIPING*	PREFORMED FIBERGLASS	1"
ROOF DRAIN BODY (UNDERSIDE)*	FIBERGLASS BLANKET	2”
OVERFLOW ROOF DRAIN BODY (UNDERSIDE)*	FIBERGLASS BLANKET	2”

EQUIPMENT/SYSTEM SURFACE	TYPE	THICKNESS
HORIZONTAL AREAWAY DRAIN PIPING*	PREFORMED FIBERGLASS	1"
AREAWAY DRAIN BODY (UNDERSIDE)*	FIBERGLASS BLANKET	2”
FLOOR DRAIN/HUB DRAIN PIPING***	PREFORMED FIBERGLASS	1/2"
FLOOR DRAIN/HUB DRAIN TRAPS, BODIES***	FIBERGLASS BLANKET	2”
DRINKING FOUNTAIN DRAIN PIPING (TO JUNCTION WITH MAIN RISER)***	PREFORMED FIBERGLASS	1/2"
EXPOSED LAVATORY/SINK STOPS/RISERS	MOLDED VINYL	3/16"
EXPOSED LAVATORY/SINK TRAP/TAILPIECE	MOLDED VINYL	3/16"
ENGINE EXHAUST AND MUFFLER	PREFORMED CALCIUM SILICATE BLOCK	2 @ 1-1/2"
EXISTING PVC WASTE, VENT, STORM PIPING IN RETURN AIR PLENUMS	HIGH TEMPERATURE BLANKET	1-1/2” (1hr)
UNDERGROUND PIPING	(SEE SECTION 23 21 13)	
ICE MACHINE DRAIN PIPING	PREFORMED FIBERGLASS	2"
CHILLED WATER PIPING – HEAT TRACED OR EXPOSED TO FREEZING TEMPERATURES	CELLULAR GLASS	2”
WATER FILLED PIPING OTHER THAN CHILLED WATER _ HEAT TRACED OR EXPOSED TO FREEZING TEMPERATURE	PREFORMED FIBERGLASS	2"
FIRE SPRINKLER PIPES IN: MECHANICAL ROOMS, IDF, MDF, AND MAIN ELECTRICAL ROOMS; REFER TO PLANS	PREFORMED FIBERGLASS	2"

***** Where located in air-conditioned spaces and plenums only.
****** Where located in non-air conditioned spaces and plenums only.
******* Systems that receive cooling coil condensate, refrigerated drinking water only, or drainage from ice Machines, or other fluids that can cause piping to condensate.

PART 3 - EXECUTION

3.01 SUBMITTALS

A. Insulation submittals shall include, but not be limited to, the following:

1. Cut sheets on all insulation products, shield insert blocks, fitting covers, protection jackets, straps, bands, etc., to be used.
2. Cut sheets on all mastic, adhesives, sealants, coatings, anti-microbial agents, etc., and other products to be used with insulation products.
3. Cut sheets on covering and aluminum jacketing materials.
4. Manufacturer's pre-printed installation instructions for all products.

3.02 INSTALLATION

A. General:

1. Install thermal insulation on clean, dry surfaces after all leakage testing and inspection is completed. Any leaking equipment shall be brought to the attention of the Contractor who shall cause these conditions to be corrected. Thermal insulation installation shall be in strict accordance with these Specifications, the Midwest Insulation Contractors Association (MICA) Commercial and Industrial Insulation Standards, recognized industry practice, and the manufacturer's printed installation instructions.

2. Where there is evidence of vapor stop failure or "wet" insulation after installation, the insulation shall be removed, and the surface shall be cleaned, dried, and properly reinsulated.
3. The insulation shall be handled and applied in a manner that will not adversely affect its structural, insulating, or vapor permeability properties.

B. Piping:

1. Condensate Drains:

   a. All drain lines, including but not limited to sanitary or storm, receiving condensate shall be insulated to a point three feet past vertical connection or according to local codes whichever is more stringent.
   b. Equipment drains, receiving condensate from cooling coil, shall be fully insulated.

2. Drain Bodies: The substitution of ductwrap insulation for piping insulation is prohibited except on drain bodies.
3. Miscellaneous Valves and Fittings:

   a. All valve operators, "Pete's Plugs", drain valves, meter and gauge fittings, and other items, which must protrude through the pipe insulation, shall be suitably insulated with removable insulation caps. Bevel and seal insulation and joints at removable caps. Chilled water riser support plates shall be suitably insulated.
   b. Fittings, flanges, strainers, unions, and valves shall be insulated with pre-molded rigid glass fiber or phenolic foam insulation and finished with two brush coats of vapor barrier mastic with reinforced glass fabric tape embedded in between each coat.

4. Protection Shield Inserts: Protection shield insert blocking shall be thoroughly vapor sealed and finished to match pipe insulation.
5. Protective Jacketing: All piping insulation subject to damage, exposed to the outdoor elements, and/or within parking garage drive lanes shall be covered with factory applied aluminum laminate or 0.016" thick smooth aluminum jacket utilizing longitudinal "zee" closures. Jacket shall be secured at butt joints with 2" wide aluminum straps containing a permanently plastic sealant. Straps shall be centered over butt joints of jacket. Provide 1/2" wide aluminum bands applied on 12" centers. Install the longitudinal joint facing downward to shed water. Furnish end closure and caps to cover completely all valves, fittings, etc.
6. Banding: Band insulation on 24" centers and install at least two (2) bands per section of insulation.
7. Installation of Cellular Glass Insulation: Bore coat insulation with Hydrocal B11. For cold service, apply joint sealant and vapor stop using PITTSEAL CW. Secure insulation with 0.5”x0.016” 304 SS bands. Jacket shall be PITTWRAP CF for straight piping. At fittings, valves and other locations, finish insulation with PITTCOAT 404 coating and PC Fabric 79.
8. Installation of Preformed Fiberglass and Phenolic Foam Insulation: An approved vapor retarder mastic compatible with the insulation shall be applied to all joints and fittings around the edges of the adjoining pipe/fitting insulation overlapping seam. The preformed fitting insulation shall be finished with two brush coats of vapor barrier mastic with reinforced glass fabric tape embedded in between each coat.

   a. Longitudinal and Butt Joint Vapor Seal: For Cold Service, longitudinal self-sealing laps and butt joint 3" wide self-sealing strips of the insulation jacket shall be further sealed by applying one coat of fire-resistant vapor barrier coating over the entire joint surface. For Hot Service longitudinal joints on insulation systems utilizing factory applied Self Seal or dual factory applied adhesive strips, such as

Owens-Corning SSL II, need not be further sealed or banded as required above. For Self-Seal and factory applied adhesive systems, firmly rub all longitudinal and circumferential joints using a squeegee or sealing tool.

b. Butt Joint Vapor Stop/Seal: Provide an isolating vapor stop between pipe insulation jacket and the pipe at butt joints of insulation at fittings, flanges, valves, and hangers and at 21-foot intervals on continuous runs using vapor barrier coating. Extend the vapor barrier coating 2" along the insulation jacket, across the face of the insulation, and 4" along the pipe.

9. Installation of Elastomeric Pipe Insulation: Insulation shall be installed in continuous lengths over piping and glued with adhesive at butt joints. Horizontal suspended piping shall be provided with protection shields at hangers. All elastomeric piping insulation exposed to weather or ultra-violet light shall be protected by aluminum jacket or by a factory applied cladding consisting of a laminate of aluminum and polyester with a white finish. Insulation installed indoors but exposed to view shall be finished with two (2) coats of Elastomeric Coating.
10. Installation of Phenolic Foam Pipe Insulation: Install insulation in half sections wherever possible. Seal joints with Childers CP-76 or Foster 95-50 Flextra Sealant. Joints shall be butted tightly. Apply 3" wide 2 mil foil tape to all joints and openings. Fittings shall be 2-piece pre-formed phenolic insulation secured with fiber reinforced tape. Finish fittings, valves, etc., with scrim reinforced vapor retarder mastic which overlaps adjacent jacket by 2". Cover edges with butt strips. Preformed fitting insulation covers may be used as specified herein.
11. Installation of Preformed Calcium Silicate Block Insulation:

    a. All protrusions through the insulation shall be wrapped and/or packed with refractory fiber. All joints and cracks over 1/8" wide shall be sealed with Ryder "V" one Coat.
    b. Insulation shall be held in place with 20-gauge galvanized wire on 9" centers.
    c. Horizontal hangers shall be installed inside the calcium silicate insulation and shall be insulated with glass fabric and Foster 46-50 or Childers CP-10/11 weather barrier mastic coated calcium silicate and fiberglass where exposed to possible contact.
    d. Provide expansion joints in the insulation and aluminum jacket where provided, as recommended by the manufacturer to allow for differential expansion between the exhaust pipe, or flue, insulation, and jacket.
    e. Engine Exhaust Piping: Entire engine exhaust pipe from exhaust manifold expansion connection to outside terminal shall be enclosed in two layers of insulation.

        1) Joints for the first and second layers shall be staggered.
        2) Apply a third outer layer of 1" thick fiberglass pipe insulation. Finish as required for fiberglass insulation.
        3) Insulate exhaust muffler in the same manner as the exhaust piping.

12. Heat Traced Insulated Piping: All chilled water, domestic water, fire protection, make-up water, condensate, and sanitary drain piping exposed to weather and cold outdoor temperatures (i.e., open truck docks, open parking garages, outdoors, etc.) subject to freezing shall be heat traced and insulated.

END OF SECTION

SECTION 20 08 00 - COMMISSIONING

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20 Sections apply to this section:

1. Scope of Work - Section 20 05 01
2. Basic Division 20-28 Requirements - Section 20 05 03
3. Schedule of Submittal Data - Section 20 05 04
4. General Division 20-28 Materials and Methods - Section 20 05 05

1.02 SCOPE

A. Furnish and install commissioning work as specified herein and in the Commissioning Agent's Specifications.

B. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. All Division 20-28 Sections
2. Division 1, General Commissioning Requirements (01 91 13)

1.03 COMMISSIONING

A. A complete checkout and test shall be performed to demonstrate and certify that the HVAC systems (Divisions 20-28) are 100% operational and adjusted upon completion of the installation, and that they comply with all applicable codes and specification requirements. Testing shall be performed in two (2) parts and two-way radios for use by test observers shall be provided. The first part of the test shall be a full test of all system components, function, and alarms. All affected subcontractors shall participate in this test. All tests shall be witnessed and acknowledged by written signature of the General Contractor's supervising representative. The Owner's building engineer may elect to observe this first part testing. The first part test results shall be certified and submitted to the Engineer and Owner's Commissioning Agent. The second part of the test shall be a 100% demonstration of basic system functions and alarms for the Engineer, Owner's Commissioning Agent, and Owner's Representative.

B. The General Contractor shall coordinate the test schedule with the Owner's Commissioning Agent, BCAS Contractor, Electrical Contractor, Mechanical Contractor, Fire Protection Contractor, Fire Alarm Contractor, and other Contractors required to be present for a complete and functional test.

C. The system checkout and test shall be a comprehensive 100% inspection and functional test of all equipment and software and shall include, but not be limited to, the following:

1. Testing to verify that all control functions specified in the sequence of operation are provided and fully functional as specified and required.
2. Verification of manual and program control of all start/stop and alarm points, including status indication and alarms.
3. Verification of all controlled points including setpoint and actual point readouts, remote setpoint change and point alarm.

4. Verification that all system annunciation text and messages are correct and appropriate.
5. Functional test of the normal and emergency power building start-up and shutdown routines.
6. Testing to verify that all systems on emergency power operate as specified in the sequence of operation.
7. Testing to verify that all specified software is provided and fully implemented.
8. Display and demonstrate such data entry template and show site specific customizing capability. Demonstrate parameter changes.
9. Execute menu tree.
10. Display graphics, demo update.
11. Execute digital and analog commands in English and graphic mode.
12. Demonstrate all specified diagnostics.
13. Demonstrate DDC loop precision and stability via trend logs of inputs and outputs.
14. Demonstrate BCAS performance via trend logs and command printouts.
15. Demonstrate scan, update, and alarm responsiveness.
16. Other testing required by Section 23 05 93.
17. Other testing required by the Commissioning Agent's Specifications.

D. Fire Alarm System Interface Testing: Testing of the BCAS interface with the fire alarm system for smoke management, air handling unit shutdown, fire/smoke damper control, duct smoke detector annunciation and other specified interfaces shall be coordinated with the Division 28 fire alarm testing and certification.

E. Emergency Power Operation Testing: Testing of BCAS operation under emergency shall be coordinated with the Division 26 Contractor such that the testing is conducted along with the Division 26 emergency power system testing and certification.

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION (NOT APPLICABLE)

END OF SECTION

DIVISION 22 - PLUMBING INDEX

SECTION	DESCRIPTION
22 00 00	PLUMBING INDEX
22 05 01	SCOPE OF WORK
22 05 25	MISCELLANEOUS EQUIPMENT
22 05 93	STARTUP, TESTING, ADJUSTING AND BALANCING
22 08 00	PLUMBING COMMISSIONING
22 11 16	PLUMBING PIPING AND ACCESSORIES

END OF INDEX

SECTION 22 05 01 - SCOPE OF WORK

PART 1 - GENERAL

1.01 **RELATED DOCUMENTS**

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Refer to Specification Section 20 05 00 for related required Codes and Standards.

C. Refer to Specification Section 20 05 02 for related required Design Criteria.

D. Refer to Specification Section 20 05 04 for related required Schedule of Submittal Data.

E. Requirements of Division 20 apply to all Work of Divisions 20-28.

1.02 **SCOPE**

A. General: Provide all labor, materials, tools, machinery, equipment, supplies, transportation, storage, utilities, appliances, drayage, hauling, hoisting, excavation, backfill, supervision, and services necessary to complete the Plumbing Work under this Contract. Pay all fees, tap charges, meter charges, permits, licenses, inspections, and special fees assessed by the local utilities and local authorities having jurisdiction. Coordinate Work with the Work of the other trades, so as to resolve conflicts without impeding job progress.

B. Examine the Architectural, Structural, Fire Suppression, Plumbing, Mechanical and Electrical Drawings and other Divisions, and Sections of the Specifications in order to determine the extent of Work required to be completed under this Division. Failure to examine all the Contract Documents for this Project will not relieve the Contractors of the responsibility to perform all the Work required for a complete, fully operational and satisfactory installation.

C. Project Location: The Work to be performed under this Contract is all in connection with the construction and erection of **renovations in existing buildings located in Tomball, The Woodlands, and Spring, Harris County, Texas.**

D. Work Included: The Work includes but is not limited to the following systems, equipment, and services:

1. Plumbing system consisting of all items indicated on the Drawings and/or specified herein, such as:

    a. Plumbing fixtures and trim
    b. Domestic hot water piping
    c. Domestic cold-water piping
    d. Electric drinking fountains
    e. Electric water heaters
    f. Packaged gas water heaters
    g. Sanitary waste piping
    h. Storm drain piping
    i. Vent piping
    j. Steam to domestic hot water heat exchangers
    k. Water surge and house tanks
    l. Domestic water pumps and controls
    m. Roof and floor drains

n. Oil interceptors
o. Grease interceptors
p. Sewer and water main extensions to 5'-0" beyond perimeter foundation walls
q. Insulation, controls, safety devices, vibration isolation, etc.
r. Natural gas piping
s. Medical gas systems
t. Brine storage tanks, pumps, piping, and controls
u. Water softeners
v. De-ionized water system
w. Distilled water system
x. Acid resistant waste and vent piping
y. Diesel fuel oil storage tanks, pumps, piping, and controls
z. Main water meter, vault, and piping extension to the building

1.03 **WORK OF OTHER DIVISIONS**

A. The following is a partial list of work not included in Division 22:

1. Electrical connections to motors.
2. Engine-driven generator remote fuel storage day tank. Installations of remote fuel storage day tanks are included in the Work of this Division.
3. Utility mains and piping 5 feet beyond the foundation walls unless shown otherwise on the Drawings.

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION (NOT APPLICABLE)

END OF SECTION

SECTION 22 05 25 - MISCELLANEOUS EQUIPMENT

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Design Criteria - Section 20 05 02
2. Basic Division 20-28 Requirements - Section 20 05 03
3. Schedule of Submittal Data - Section 20 05 04
4. General Division 20-28 Materials and Methods - Section 20 05 05
5. Scope of Work - Section 22 05 01
6. Start-up, Testing, Adjusting, and Balancing - Section 22 05 93

1.02 SCOPE

A. Furnish and install miscellaneous equipment as shown on the Drawings, scheduled, and specified.

PART 2 - PRODUCTS

2.01 DOMESTIC COLD-WATER PRESSURE REDUCING VALVE ASSEMBLIES

A. Domestic water pressure reducing assemblies shall be provided where indicated on the Drawings. The pressure reducing assemblies shall have the capacities indicated in the schedule on the Drawings and shall maintain a constant downstream pressure with the varying inlet pressure indicated over the minimum to maximum flow range listed in the Schedule. The pressure reducing valves shall be selected to provide stable flow conditions without cavitation or valve chatter over the entire flow range specified. PRV piping, valves, and strainers shall be full size to maximum flow velocity or 10 feet/sec. Valve shall be sized as scheduled or noted on the Drawings.

B. ***(OPTION 1)*** PRV WITH BLOCK VALVE:

1. The high flow pressure reducing valve shall be a hydraulically operated, pilot-controlled diaphragm-type ductile iron (ASTM A-536) globe valve with stainless steel trim and suitable for a working pressure as indicated on the Drawings. The pressure-reducing valve shall have an adjustable outlet pressure range suitable for the scheduled valve outlet pressure. The valve shall be stem center guided or guided at both ends and have a single removable seat and resilient disc. The pilot control shall be 316 Stainless Steel or a bronze ASTM B-61 direct-acting, adjustable, spring-loaded, normally open diaphragm valve designed to permit flow when controlled pressure is less than the spring setting. The control system shall include a fixed orifice and .. a pilot control system completely factory piped (stainless steel) with shut-off cocks to isolate the pilot system . The pressure-reducing valve shall be Clayton 90G-01AS, Charles M. Bailey Company No. 400, Bermad Model BC-720-P/Victaulic Series 972 or approved equal.
2. The low flow pressure-reducing valve shall be selected to operate at flow rate below the minimum flow rate of the high flow valve and the minimum flow rate indicated in the Schedule on the Drawings. The low flow pressure-reducing valve shall be a pilot operated or spring-loaded direct acting globe valve suitable for a working pressure as indicated on the Drawings. The outlet pressure setting shall be field adjustable. The

pressure-reducing valve shall be Watts #223, Bermad BC-720-P/Victaulic Series 972 or approved equal.

3. Furnish and install relief valves suitable for a working pressure where required and as indicated on the Drawings. Relief valve size shall be as required by the applicable code, and as indicated on the Drawings. Domestic cold-water pressure reducing assembly relief valve shall have an adjustable range of 20 to 200 psig and remote indication to the Building Control and Automation System (BCAS) Bermad model BC-73Q-P/ Victaulic 973-Q Section 23 09 16.
4. Provide and install pilot operated shutoff valves with solenoid actuation , as detailed on the Drawings in the inlet to each pressure reducing valve station. This valve shall close upon activation of the pressure relief valve for its zone. Valve shall be Bermad BC-710-P-/Victaulic 971 or Cla-Val Model 131-KX, 120-volt, 60 hertz.
5. Provide additional pressure reducing valve with on off solenoid control on the redundant bypass. Valve shall remain closed during normal operation, and open upon command from the control box by passing PRV station. Pressure reducing valve shall open automatically according to pilot setting. Valve shall be Bermad BC-720-55-P/Victaulic Series 972-55, Cla-Val Model 131-KX, 120-volt, 60 hertz.

C. ***(OPTION 2)*** PRV WITH WATCHDOG:

1. Pressure Reducing System with “Watchdog” Hydraulic Backup Valve (Pilot Operated): shall automatically reduce a higher upstream pressure and maintain a constant lower downstream pressure regardless of varying flow rate and/or varying inlet pressure. The system shall also include an integral hydraulic backup that protects the system should the primary pressure reducing valve fail open. When the backup is activated, the valve shall take over pressure control and trigger an alarm. 1½” through 16”, factory assembled valve with either Groove x Groove ends (1½-8”), NPT threaded ends (1½-3”), and Class 150# and 300# flanged ends (1½”-16”) with a maximum pressure rating of 400 psi/2557 kPa (250 psi/ 1723 kPa for ANSI Class 150# flanges), hydraulically operated, diaphragm actuated globe style with double-chambered actuator, full bore "Y" pattern type with a V-port throttling plug and semi-straight (no right angles) flow through the valve. Valve body and cover shall be ductile iron to ASTM A536, electro- statically applied fusion bonded epoxy coating. The interior trim shall be stainless steel, tin bronze bearing, SAE 316 external nuts and bolts, NBR disc seal, EPDM nylon fabric bonded rubber diaphragm and EPDM O-rings. 316 stainless steel pilot control, accessories, tubing & fittings. The primary valve will operate independent of valve differential pressure, utilizing a 2-way control principle using a spring-loaded pilot valve. The backup valve shall utilize a 3-way control principal with a double chamber actuator to ensure immediate response when activated. A full range of pilot spring settings shall be available in ranges of 3 to 430 psi (21 to 2965 kPa) with a standard range of 15-145 psi (103-1000 kPa). The complete valve shall be certified to NSF/ANSI 61 and 372 for contact with drinking water. All necessary repairs shall be possible without removing the valve from the line, the entire actuator assembly shall be removable from the valve as a single, integral unit. Basis of Design: Bermad Model BC-72S-H-P/Victaulic Series 972S-H.
2. The low flow bypass shall be the same design as the main branch described above. The low flow branch shall be a smaller line size to meet the system demand. Basis of Design: Bermad Model BC-72S-H-P/Victaulic Series 972S-H.
3. Furnish and install relief valves suitable for a working pressure where required and as indicated on the Drawings. Relief valve size shall be as required by the applicable code, and as indicated on the Drawings. Domestic cold-water pressure reducing assembly relief valve shall have an adjustable range of 20 to 200 psig and remote indication to the Building Control and Automation System (BCAS) or Victaulic 973-QS Section 23 09 16.
4. System Basis of Design: Victaulic Series 386C/D.

D. ***(OPTION 3)*** SINGLE BRANCH PRV SYSTEMS:

1. Victaulic Series 386A/B-SB Single Branch PRV Station with Integral Low-Flow Bypass: Factory assembled, single branch pressure reducing valve (PRV) Station consisting of a Victaulic Style 972-2B PRV with an integral low-flow bypass with a Victaulic style 935-H DPRV. Assembly shall include required Schedule 10S, type 304L, stainless steel pipe conforming to ASTM A312, with Victaulic stainless steel fittings, (2) Victaulic Series 461 butterfly valves for isolation, a wye pattern strainer style 968-F upstream of the PRV, joined with Victaulic installation-ready rigid couplings, Style 107N. Where the ratio of the inlet to outlet pressure is greater than 3, a 972-PD Proportional PRV shall be added for a double stage reduction. PRV Station shall be UL classified to ANSI / NSF-61 for potable water service and shall be certified to the low lead requirements of NSF-372.
2. Victaulic Series 386C/D-SB Single Stage, Single Branch PRV Station with Integral Low-Flow Bypass & Emergency Downstream Over-Pressure Guard “Watchdog”: Factory assembled, single branch pressure reducing valve (PRV) Station consisting of a Victaulic Style 972S-2B-H PRV Watchdog valve combo with a mechanical limit switch for BMS alert on the main branch and with an integral low-flow bypass with a Victaulic style 935-H DPRV. Assembly shall include required Schedule 10S, type 304L, stainless steel pipe conforming to ASTM A312, with Victaulic stainless steel fittings, (2) Victaulic Series 461 butterfly valves for isolation, a wye pattern strainer style 968-F upstream of the PRVs, joined with Victaulic installation-ready rigid couplings, Style 107N. Where the ratio of the inlet to outlet pressure is greater than 3, a 972-PD Proportional PRV shall be added for a double stage reduction. PRV Station shall be UL classified to ANSI / NSF-61 for potable water service and shall be certified to the low lead requirements of NSF-372.

PART 3 - EXECUTION

3.01 SUBMITTALS

A. Shop drawing submittal shall include, but not be limited to, the following:

1. Cut sheets on all miscellaneous equipment specified herein, clearly marked to show sizes, construction features, connection and installation details, capacities and other pertinent information.
2. Additional information as required in Section 20 05 03.

3.02 INSTALLATION

A. General: Install all materials in accordance with manufacturer's written installation instructions, applicable standards, and recognized industry practices.

B. The PRV Station manufacturer’s factory trained representative shall provide on-site training for contractor’s field personnel in the use of the PRV Station and installation. The representative shall periodically visit the job site and review contractor is following best recommended practices in PRV Station installation. (A distributor’s representative is not considered qualified to conduct the training or jobsite visit(s).)

END OF SECTION

SECTION 22 05 93 - START-UP, TESTING, ADJUSTING AND BALANCING

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Design Criteria - Section 20 05 02
2. Basic Division 20-28 Requirements - Section 20 05 03
3. Schedule of Submittal Data - Section 20 05 04
4. General Division 20-28 Materials and Methods - Section 20 05 05
5. Scope of Work - Section 22 05 01

1.02 SCOPE

A. Hydrostatic pressure testing of all pressure piping systems

1.03 RELATED SECTIONS

A. All Division 22 Sections

1.04 QUALITY CONTROL

A. Testing of equipment requiring starting procedures may be performed by the Contractor, where manufacturer representatives are not required.

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION

3.01 EXAMINATION

A. Before commencing work, verify that systems are complete and operable to the following extent:

1. Equipment is operable and in a safe and normal condition
2. Proper thermal overload protection is in place for electrical equipment
3. Access doors are closed
4. Piping systems have been flushed, sterilized, and filled
5. Correct pump rotation
6. Proper strainer baskets are clean and in place
7. Service and balance valves are open

B. Report any defects or deficiencies noted during performance of services to Engineer.

C. Promptly report abnormal conditions in mechanical systems or conditions which prevent system balance.

D. If, for design reasons, system cannot be properly balanced, report as soon as observed.

E. Beginning of work means acceptance of existing conditions.

3.02 **PREPARATION**

A. Provide all material, equipment and personnel, including factory personnel where specified or required, to fully check out and start up all equipment and systems as specified in accordance with manufacturer's requirements.

B. No water piping systems shall be "pumped" until all piping has been hydrostatically tested, flushed, cleaned and water treated as applicable.

C. Lubrication and fluid levels shall be checked prior to equipment start-up. Alignment on all motor driven equipment shall be checked and adjusted prior to start-up.

3.03 **TESTING PROCEDURES**

A. Tests shall be made during the course of construction as specified and as required by authorities having jurisdiction.

B. Test submittals shall include a preliminary submittal of all proposed test procedures and recording forms for engineer's review prior to any testing and four (4) copies of all certified test results and completed reporting forms for approval.

C. Vibration Testing: Where a piece of equipment exhibits, in the Engineers opinion, excessive noise or vibration, the service of a certified acoustic Consulting Engineer shall be provided to perform noise and vibration testing on the equipment or system involved. The Consulting Engineer shall provide a written report concerning the noise and vibration of the equipment or system involved and the Contractor involved shall make changes or modifications as recommended by the Consulting Engineer. The above services and retroactive corrections shall be provided at no cost to the Owner or Engineer.

D. Hydrostatic Testing: All pressurized piping (not listed herein) shall be leak tested prior to enclosure or cover-up. Piping shall be leak tested for 24 hours under a hydrostatic pressure of 150% of the system design working pressure. The Engineer shall be notified prior to all hydrostatic tests and may elect to witness any of the tests. Water shall not be drawn off of the piping, and the piping shall not be covered up until it has been observed by the Engineer. Care shall be taken to protect any equipment which may be damaged by hydrostatic testing.

E. Completion Reports: Before the final inspection, but after all testing, balancing and adjusting, the Contractor shall furnish all labor, materials and devices necessary to prepare a completion report with the following information.

1. Motor data on all motors installed on the project. Motors shall be listed by the device on which they are installed, and information provided shall include:

    a. Horsepower
    b. Speed
    c. Type
    d. Location
    e. Rated full load amperage
    f. Rated voltage
    g. Actual measured amperage for each leg
    h. Actual measured voltage for each leg

2. Belt and drive data for all belt driven equipment installed on the project. Data shall be listed by the device on which the belts and drive are installed, and information provided shall include: number of belts, size of belts, size and type of drive installed, motor RPM and driven device RPM.

END OF SECTION

SECTION 22 08 00 - PLUMBING SYSTEMS TECHNICAL COMMISSIONING REQUIREMENTS

PART 1 – GENERAL

1.01 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. Specifications throughout all Divisions of the Project Manual are directly applicable to this Section, and this Section is directly applicable to them.

1.02 SUMMARY

A. The purpose of this Section is to define responsibilities in the Commissioning Process. Additional system testing is required within individual Specification Sections.

B. Commissioning requires the participation of the Contractor to ensure that all systems are operating in a manner consistent with the Contract Documents. General Commissioning requirements and coordination are detailed in Division 01. Division 20-25 Contractors shall be familiar with all parts of Division 01 and the Commissioning Plan issued by the Owner's CxA, shall execute all Commissioning responsibilities assigned to them in the Contract Documents and include the cost of Commissioning in the Contract price.

C. Plumbing systems to be commissioned include the following:

1. Domestic Water Heaters
2. Domestic Water Circulation Pumps

1.03 DEFINITIONS

A. Refer to the General Commissioning Requirements for definitions.

1.04 SUBMITTALS

A. Contractor shall provide Owner and/or CxA with documentation required for Commissioning Work. At minimum, documentation shall include: Detailed Start-up procedures, full sequences of operation, Operating and Maintenance data, performance data, control drawings, and details of Owner-contracted tests.

1. Shop drawings and product submittal data related to systems or equipment to be commissioned.

B. Contractor shall submit to Owner and/or CxA installation and checkout materials actually shipped inside equipment and actual field checkout sheet forms used by factory or field technicians.

C. Where installation testing may be performed in a progressive manner (i.e., piping hydrostatic testing), the Contractor shall prepare and submit to the Owner, A/E team and CxA a testing plan that details how the progressive testing will be performed, documented and presented for approval prior to the start of any testing activities.

D. Contractor shall provide any additional documentation needed to complete the requirements of the Commissioning Process

1. Factory Performance Test Reports: Review and compile all factory performance data to assure that the data is complete prior to executing the FPTs.
2. Installation testing reports such as piping hydrostatic testing, piping chemical treatment and flushing, bolt flange torquing, and any documentation associated with local code authority inspections or authorizations.
3. Pre-functional Performance Checklists: review and compile all information associated with the piece of equipment to be commissioning ensure the equipment is ready for final commissioning.
4. Completed equipment Start-up certification forms along with the manufacturer's field or factory performance and Start-up test documentation.
5. Operating and Maintenance (O&M) information per requirements of the Technical Specifications and Division 01 requirements.

PART 2 - PRODUCTS

2.01 GENERAL

A. All materials and installation shall meet or exceed all applicable referenced standards, federal, state and local requirements, and conform to codes and ordinances of authorities having jurisdiction.

B. Refer to the General Commissioning Requirements for other work products related to the Commissioning Process

C. Contractor is required to follow all applicable industry and site specific safety practices, lockout / tagout requirements, specialized PPE requirements, and provide qualified, trained personnel to execute Commissioning Process requirements.

2.02 TEST EQUIPMENT

A. Contractor shall provide all specialized tools, test equipment and instruments required to execute Start-up, checkout, and testing of equipment.

B. All specialized tools, test equipment, and instruments required to execute Start-up, checkout, and testing of equipment shall be of sufficient quality and accuracy to test and/or measure system performance within specified tolerances. A testing laboratory must have calibrated test equipment within the previous twelve (12) months. Calibration shall be NIST traceable. Contractor must calibrate test equipment and instruments according to manufacturer's recommended intervals and whenever the test equipment is dropped or damaged. Calibration tags must be affixed to the test equipment or certificates readily available.

PART 3 - EXECUTION

3.01 CONSTRUCTION PHASE

A. In each purchase order or subcontract that is written for changes in scope, include the appropriate requirements for submittal data, Commissioning documentation, testing assistance, Operating and Maintenance (O&M) data, and training, as a minimum.

B. Attend Pre-Commissioning Meeting(s), Pre-Installation Meeting(s), and other Project meetings scheduled by the Owner, CxA or Contractor to facilitate the Commissioning process.

C. Provide manufacturer's data sheets and shop drawing submittals of equipment.

D. Provide additional requested documentation to the Owner and/or CxA, prior to O&M manual submittals, for development of System Verification Checklists and Functional Performance Testing procedures.

1. Typically, this will include detailed manufacturer's installation and Start-up, operating, troubleshooting and maintenance procedures, full details of any Owner-contracted tests, full factory testing reports, if any, and full warranty information.
2. In addition, the installation, Start-up, and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Contractor and/or CxA.
3. This information and data request may be made prior to normal submittals.

E. During the installation, Start-up and initial checkout process, execute and document related portions of the System Verification Checklists for all commissioned equipment according to the procedures indicated in the Commissioning Plan.

F. Factory Start-ups: Factory Start-ups are specified for certain equipment. Factory Start-ups generally are Start-up related activities that will be reviewed and checked prior to Functional Performance Tests. All costs associated with factory Start-ups shall be included with the contract price unless otherwise noted. Notify the Commissioning Team of the factory Start-up schedule and coordinate these factory Start-ups with witnessing parties. The Commissioning Team members may witness these Start-ups at their discretion.

G. Independent Testing Agencies: For systems that specify testing by an independent testing agency, the cost of the test shall be included in the Contract price unless otherwise noted. Testing performed by independent agencies may cover aspects required in the System Verification Checklists, Start-ups, and Functional Performance Tests. Coordinate with the independent testing agency so that CxA, Owner and/or A/E can witness the test to ensure that applicable aspects of the test meet requirements.

H. Incorporate manufacturer's Start-up procedures with System Verification Checklists (SVC).

I. Provide skilled technicians to execute starting of equipment and to assist in execution of Functional Performance Tests. Ensure that they are available and present during the agreed upon schedules and for a sufficient duration to complete the necessary tests, adjustments, and problem solving.

J. Correct deficiencies (differences between specified and observed performance) as interpreted by the Owner's Project Manager and A/E and retest the system and equipment.

1. CxA shall participate in one retesting effort at no cost to the Owner nor contractor. Should a 2nd retesting effort be required due to system indicating the same or similar issue, then the contractor shall be charged for their effort and the Owner retains the right to withhold the cost of the CxA's additional attendance from the contractor retainage at a maximum of $2,500 per occurrence.

K. During construction, maintain as-built marked-up Drawings and Specifications of all Contract Documents and Contractor-generated coordination Drawings. Update after completion of Commissioning activities (include deferred tests).

L. Provide training of the Owner's operating personnel as specified.

M. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.

3.02 **WARRANTY PHASE**

A. Execute seasonal or deferred tests, witnessed by the CxA and Owner, according to the Specifications

1. Complete deferred tests as part of this Contract during the Warranty Period. Schedule this activity with the Owner.

B. Correct deficiencies and make necessary adjustments to O&M manuals, Commissioning documentation, and as-built drawings for applicable issues identified in any deferred or seasonal testing.

3.03 **INSTALLATION**

A. Installation shall meet or exceed all applicable federal, state and local requirements, referenced standards and conform to codes and ordinances of authorities having jurisdiction.

B. All installation shall be in accordance with the Project Documents.

3.04 **TRAINING**

A. Refer to the individual section of this Specification for specific training requirements on each system.

B. Refer to the General Commissioning Requirements and Division 01 for overall training requirements related to the Commissioning process and this project.

END OF SECTION

SECTION 22 11 16 - PLUMBING PIPING AND ACCESSORIES

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Scope of Work - Section 22 05 01
5. Start-up, Testing, Adjusting, and Balancing - Section 22 05 93

1.02 SCOPE

A. The Work of this Section shall include, but not be limited to:

1. Securing and installing plumbing services for the building.
2. A complete domestic hot and cold-water distribution system.
3. A complete sanitary soil waste and vent system.
4. A complete storm water piping system.
5. Miscellaneous plumbing equipment and specialties required for a complete plumbing system as specified.

B. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. Owner and Contractor Furnished Equipment - Section 20 05 06
2. Pipe Heat Tracing - Section 20 05 33
3. Noise and Vibration Isolation - Section 20 05 48
4. Thermal Insulation - Section 20 07 00

1.03 QUALITY ASSURANCE

A. Codes and Standards: All materials, fixtures or devices used or entering into the construction of the plumbing system shall be listed for Uniform Plumbing Code (UPC) or shall conform to Alternate Standards recognized as "equal" by the Authorities Having Jurisdiction.

B. All grooved components including couplings, fittings, valves, gaskets, and specialties shall be of one manufacturer. All castings shall be dated stamped for quality assurance and traceability.

C. NSF Compliance: All components used in potable water systems shall be NSF 61 certified and shall be NSF/ANSI 61-G and/or NSF/ANSI 372 certified for lead content. Components for domestic water shall be 3rd Party Certified.

D. All piping shall be manufactured in the United States of America.

1.04 **PLUMBING SERVICES**

A. The Plumbing Contractor shall be responsible for securing all plumbing services necessary for the project as shown on the Drawings.

1. Securing water connection permit from the authority having jurisdiction.
2. Tapping, or arranging for tapping of the city main in accordance with the authority having jurisdiction.
3. Extending water service to meter.
4. Installation of water meter and meter box in accordance with authority having jurisdiction.
5. Extending water services from meter box to building entry.
6. Securing sanitary sewer connection permit from the authority having jurisdiction.
7. Connecting, or arranging for the connection of the sanitary lines(s) into the sanitary sewer in accordance with the authority having jurisdiction.
8. Securing storm sewer connection permit from the authority having jurisdiction.
9. Connection of or arranging for the connection of the storm drain(s) into the storm sewer system in accordance with the authority having jurisdiction.
10. Installing all drainage systems with the proper slope as required by code.
11. Boring and jacking existing streets, driveways, sidewalks, etc., in the city right-of-ways as is necessary. (Where this stipulation cannot be met, it shall be the responsibility of the Plumbing Contractor to secure all necessary permits at his cost to do whatever is required to secure the service from the city or local authority and make whatever repairs necessary after the service is secured.)
12. Arranging with the gas company to have the necessary gas service and properly sized gas meter station located where shown on Drawings.
13. Extending gas service from the gas meter station to the building entry.

B. The Plumbing Contractor shall be responsible for coordinating plumbing services and site utility work as shown on the Plumbing and Civil Utility Drawings with the General Contractor to determine what work is included in the scope of the Plumbing Subcontract.

1.05 **PIPING FABRICATION DRAWINGS**

A. Piping fabrication drawings shall be submitted for all piping in the Central Plant, Mechanical Rooms, and Penthouse and for Equipment connections and all other areas requiring coordination with other trades.

B. Pipe fabrication drawings shall be double line drawings to scale on 1/4" scale building floor plans and shall indicate pipe size, fittings, valves, accessories, connections, system type, insulation, support requirements, isolator locations and types, pipe elevations and other information required for coordinating with other trades and fabrication of piping.

C. Pipe fabrication drawings shall be coordinated with other trades and building construction prior to submittal for approval.

1.06 **EXPOSED PIPING**

A. All exposed piping for supply, waste, and vent connections to plumbing fixtures and connected equipment in finished areas shall be polished chrome plated unless noted otherwise on the drawings. This shall include piping, fittings and valves. Polished chrome plated sleeves may be used over supply, waste and vent piping provided that the finished installation presents the appearance of a fully chrome plated system.

1.07 **PIPE HEAT TRACING (FREEZE PROTECTION)**

A. The Plumbing Contractor shall furnish and install heat tracing cable as specified in Section 20 05 33, where shown on the Drawings, and where piping is exposed to freezing conditions. The entire length of the exposed pipe including all valves, fittings and accessories shall be traced and insulated. Refer to Section 20 07 00 for insulation requirements.

1.08 **NO LEAD**

A. Lead Free: Refers to the wetted surface of pipe, fittings and fixtures in potable water systems that have a weighted average lead content ≤0.25% per Safe Drinking Water Act as amended January 4, 2011, Section1417. All materials and components used in potable water systems shall be lead free.

PART 2 - PRODUCTS

2.01 **DOMESTIC WATER PIPING**

A. General: The domestic water system in the building shall be designed for pressures up to 150 psi for distribution piping and risers.

B. Water Service Piping: Water service piping shall be ductile iron, mechanical joint water pipe (ANSI C-110) or Tyton joint water pipe (ANSI C-151) and shall be installed in accordance with manufacturer's recommendations. Water service to the building shall be routed and installed as detailed on the Drawings. No main water service piping shall be permitted under the slab. Water service piping shall have a minimum 24" cover from top of pipe in non-paved areas and 30" cover in paved areas.

C. Underground Protection: Underground metallic water piping shall be coated with 3M Scotchwrap Pipe Wrap Insulation No. 50, or Tapecoat CT, applied in strict accordance with the manufacturer's recommendations. Machine wrapping of piping is acceptable. Concrete thrust blocks shall be poured at all turns and offsets of mechanical joint piping.

D. Underslab Piping: Piping underground and piping under the building slab for hose bibbs and equipment stubs shall be no larger than 1" and shall be Type "K" soft drawn copper tubing (ASTM Standard B-88). Piping shall be run continuous from slab penetration to penetration and there shall not be any fittings or connections below the slab. Piping shall have minimum 24" cover in non-paved areas. Underground piping up to 3" inches above slab penetrations shall be protected as described herein above.

E. Underground Piping: In general, all underground piping shall be buried in a trench with minimum 24” of cover from top of pipe insulation jacket, and at minimum 12” wider than the combined O.D. of all piping systems within the trench. All backfill material shall be cleaned bank sand.

F. 3" and Smaller Inside Piping: Water piping, 3" and smaller inside the building shall be type "L" hard drawn copper tubing (ASTM B-88) with wrought copper fittings (ASME B16.22, or ASME B16.18), roll-grooved ends with Victaulic copper grooved end couplings, or copper press fittings Viega ProPress or Nibco NibPress System. Clean and de-burr the insides of all fittings and pipe carefully before joining. Solder shall be Bridgit solder or Silver Brite 100 using Bridgit burn resistant soldering flux. No acids sweating joints. Press fittings shall employ an EPDM o-ring seal and shall be pressed using the tool approved by the system manufacturer. The use of drilled-T connections is not permitted. Press fittings manufactured by Viega or Nibco shall be acceptable if they comply with these specifications.

G. 4" and Larger Inside Piping: Water piping 4" and larger inside the building shall be Class 250, Schedule 40 galvanized steel domestic water pipe conforming to ASTM A-53 and ANSI B125.2.

All piping shall be manufactured by one of the manufacturers listed in the latest edition of the American Petroleum Institute (API) approved manufacturer listing.

H. Grooved CPVC Pipe Option for 2” and Larger Inside Piping: At the contractor's option only with prior approval by the engineer, CPVC pipe meeting the requirements of ASTM F441 and ASTM D1784 - minimum cell classification 23447 may be provided within the limits of Residential Dwelling Units and Residential Main Riser only. Provide schedule 80 CPVC (ASTM D-2241, ASTM D-1785) with Victaulic grooved fittings and coupling connections only. Solvent welded fittings shall not be used. Reduced pressure ratings must be considered for hot water temperature applications. Refer to the manufacturer’s requirements prior to installation.

I. Fittings:

1. Pipe fittings 4" and larger shall be galvanized malleable iron fittings, or galvanized cast iron flanged fittings per ASME B16.1. Fittings shall be Class 150 for pressures up to 150 psi and Class 250 for pressures above 150 psi and up to 250 psi.
2. Grooved Piping Option:

    a. For galvanized steel pipe, a grooved piping connection system with "roll grooves or cut-grooves" may be used. All couplings shall be Victaulic Style 807N Installation-Ready Rigid Couplings with angled bolt-pads to achieve rigidity and shall require visual verification only for proper installation without torque requirements. Rigid couplings shall be used at valves and in other areas where piping system rigidity meeting ASME B31 hanging requirements. Victaulic Style 877N Installation-Ready® Flexible Couplings may be used in approved locations to accommodate vibration, deflection or expansion/contraction as designed within accordance of the manufacturers’ recommendations and shall be reviewed by Victaulic Engineering Services. All gaskets shall be grade “P” Fluoroelastomer compound with red and blue color code designed for operating temperatures from 0 deg F to +180 deg F.

3. Taps to mains shall be made using Victaulic Style 72 or Style 920, galvanized mechanical tees. Mechanical tee couplings with U-bolts such as Victaulic style 921 shall not be permitted. Flanged connections shall be made using Victaulic Style 741. Fittings for elbows, tees, reducers, etc. shall be Victaulic galvanized full flow fittings. All grooved piping connection materials shall be utilized with the manufacturer's recommended groove cutting tool. All grooved piping couplings and fittings used in conjunction with companion grooved fittings shall be by the same manufacturer. The use of boltless couplings and reducing couplings is prohibited. All wetted surfaces in the piping system shall be hot dip galvanized and all proposed grooved piping connection materials shall be suitable for domestic water use at the temperatures and pressures at the point of application. Painted couplings may be used where they meet the above requirements.

    a. Manufacturers: If they comply with these Specifications, all grooved piping products shall be manufactured by Victaulic only. No substitutions will be allowed. Installation: The grooved coupling manufacturer’s factory trained representative shall provide on-site training for contractor’s field personnel in the use of grooving tools and installation of grooved joint products. The representative shall periodically visit the jobsite and review contractor is following best recommended practices in grooved product installation. (A distributor’s representative is not considered qualified to conduct the training or jobsite visit(s).

J. Copper Option: Copper pipe type “L” hard drawn in sizes 2-1/2”, 3", 4", and 6" for 150 psig systems may be used and assembled with Victaulic style 607N couplings. All fittings shall be Victaulic style 600 series with =Grade “P” Fluoroelastomer compound with red and blue color

code designed for operating temperatures up to +180 deg F full flow with grooved ends manufactured to copper-tube dimensions. (Flaring of tube or fitting ends to accommodate alternate size couplings is not permitted). Piping shall be roll grooved utilizing the grooving system manufacturer's roll-grooving machine. Couplings and fittings shall be of one manufacturer.

K. Water Hammer Arrestors (Shock Arrestors): The following water hammer arrestors are designed for installation in sealed walls without an access panel. Water hammer arrestors shall be provided on both hot and cold-water lines serving fixtures or equipment using flush valves or quick-closing valves. Water hammer arrestors are to be sized according to the number of fixture units and installed per manufacturer's recommendations. Contractor fabricated pipe type air chambers are not allowed. Check applicable codes which may require access in walls or ceilings. Verify size of unit in conformance to PDI Standards.

1. Precision Plumbing Products, Inc. Model Series SC, PDI WH-201, piston actuated, factory sealed, seamless hard drawn Type "L" copper barrel with threaded ends.
2. Sioux Chief Manufacturing Company, Inc. Model Series 650, PDI WH-201, piston actuated, factory sealed, seamless hard drawn Type "L" copper barrel with threaded ends.

L. Minimum Size: The minimum size of water piping on the project shall be 1/2" on fixture drops and 3/4" on risers. Final fixture connection sizes shall be a specified or shown on the drawings.

M. Isolation Valves: Each fixture, device or connection to equipment shall have a stop valve to isolate that fixture without shutting down any other portion of the system.

2.02 **VALVES**

A. Furnish and install valves as required, specified and shown on the drawings.

B. Gate valves or Butterfly valves shall be used for all riser shutoff and zone isolation applications. Gate, Butterfly, or Ball valves shall be used for fixture bank isolation, equipment isolation and other local isolation applications. Globe valves shall be used for throttling and balancing applications unless noted otherwise on the Drawings.

C. Bonze bodied valves, involving internal components, shall contain no more than 15% zinc. Where a brass valve is specifically called out in the specifications or drawings, the valve body and all internal components shall be resistant to dezincification and stress corrosion cracking as defined in NSF/ANSI Standard 14. Submittals shall include a report indicating the results of testing conducted in accordance with ISO 6509 “Corrosion of metal and alloys - Determination of dezincification resistance of brass”.

D. Acceptable Manufacturers:

1. Globe, Gate, and Check Valves:

a. Nibco
b. Rigid
c. Viega ProPress
d. Keystone

2. Ball Valves, Butterfly Valves:

a. Nibco
b. Kitz
c. Hammond

d. Stockham
e. Apollo
f. Jomar
g. Grinnell
h. Victaulic
i. Milwaukee Valve

3. Balancing Valves:

a. Armstrong
b. Victaulic
c. Taco
d. Nibco

E. Globe Valves:

1. Globe valves 2" and smaller shall be Class 125 bronze globe valves with screw-in bonnet, integral seat and removable disc. Valves shall be rated for 200 psi CWP or 300 WOG and shall conform to MSS SP-80. Valves shall be Milwaukee Valve 1502, or equal by listed manufacturer.
2. Globe valves 2-1/2" and larger shall be bronze mounted Class 125 iron body, outside screw and yoke globe valves with bolted bonnets and renewable seat and disc. Valves shall be rated for 200 psi CWP or 200 psi WOG and shall conform to MSS SP-85. Valves shall be Milwaukee F-2981M, or equal by listed manufacturer.

F. Gate Valves:

1. Gate Valves 2" and smaller shall be Class 125 bronze gate valves with screw-in bonnet, non-rising stem and solid wedge. ASTM B584 C87850 or C89833 Alloy. Valves shall be rated for 200 psi CWP or 300 psi WOG and shall conform to MSS SP-80. Valves shall be Nibco S/T-113-LF, Milwaukee Valve UP105 or UP115, or equal by listed manufacturer.
2. Gate valves 2-1/2" and larger shall be bronze mounted Class 125 iron body, outside screw and yoke gate valves with bolted bonnets and solid wedges. Valves shall be rated for 200 psi CWP or 200 psi WOG and shall conform to MSS SP-70. Valves shall be Nibco F-637-33, Milwaukee F-2885M, or equal by listed manufacturer.

G. Butterfly Valves:

1. Butterfly valves 2-1/2” to 6” shall be lever operated and provide bi-directional dead-end service without a downstream flange, and bubble tight shutoff at 200 psi. Valves shall be constructed of ductile iron with an aluminum bronze disc. Valve shall include a molded-in EPDM liner and a stainless-steel stem with copper bushings. Valve shall be rated for 200 psi CWP and designed to meet MSS-SP-67. Valve will carry the NSF/ANSI 372/61 rating for lead-free. Valve shall be NIBCO 2D-2000-3 or equal, by listed manufacturer.
2. Butterfly valves 6” and larger shall be gear operated and provide bi-directional dead-end service without a downstream flange, and bubble tight shutoff at 200 psi. Valves shall be constructed of ductile iron with aluminum bronze disc. Valve shall include a molded-in EPDM liner and a stainless-steel stem with copper bushings. Valve shall be rated for 200 psi CWP and designed to meet MSS-SP-67. Valve will carry the NSF/ANSI 372/61 rating for lead-free. Valve shall be NIBCO 2D-2000-5 or equal, by listed manufacturer.
3. Grooved End Butterfly valves for galvanized, copper, CPVC, or stainless steel grooved piping systems 2-1/2" meeting the specification requirements shall be used. Valves 2 ½” to 4” shall be lever operated. 6” and larger shall be gear operated. Valve shall be rated for 300 psi maximum pressure rating. Valves shall be Victaulic, selected for the appropriate piping system as specified. Where grooved systems are installed, grooved

Victaulic valves shall be installed. The use of flange adapters on lug or wafer style butterfly valves shall not be allowed.

a. For Copper Grooved Systems: Valve shall be constructed of cast brass body to UNS C87850. (Alloy code shall be cast or stamped into the valve body.) Aluminum bronze disc to UNS C95500, with pressure responsive Grade “P” fluoroelastomer seat. Stem shall be offset from the disc centerline to provide complete 360-degree circumferential seating. Bubble tight, dead-end or bi-directional service, with memory stop for throttling, metering or balancing service. Valve may be automated with electric, pneumatic, or hydraulic operators. Valve shall be certified to NSF 61 Hot/Cold and NSF 372 Low Lead. Vavles shall be Victaulic Series 608N.

b. For Stainless Steel, Galvanized Carbon Steel, and CPVC Grooved Systems: Valve construction and performance shall meet or exceed MSS-SP-67 requirements. Valve body and disc shall be constructed of stainless steel to ASTM A351 Grade CF8M, with pressure responsive Grade “P” fluoroelastomer seat. Stem shall be offset from the disc centerline to provide complete 360-degree circumferential seat. Bubble tight, dead-end or bi-directional service, with memory stop for throttling, metering or balancing service. Valve shall be certified to NSF 61 Hot/Cold and NSF 372 Low Lead. Valves shall be Victaulic Series 861.

H. Ball Valves:

1. Ball valves 2" and smaller shall be two-piece body bronze valves of a full port design, reinforced two-piece Teflon seat, blow-out proof stem, stainless steel ball and stem. ASTM B584 Alloy C87600 or C89833. Valves shall be rated for 600 psi CWP or 600 psi WOG and shall conform to Federal Specification WW-V-35B. Valves shall be Nibco S/T-585-66-LF, Watts, or Rigid.

I. Check Valves:

1. Check valves 2" and smaller shall be Class 125 bronze spring loaded in-line. B584 C87850 or C89833 Alloy. Valves shall be rated for 200 psi CWP or 300 psi WOG and shall conform to MSS SP-80. Valves shall be Nibco 480 series, or Watts 600 series.
2. Check valves 2-1/2" and larger shall be stainless steel mounted Class 125 ductile or cast-iron body swing check valves with bolted bonnets and renewable seat and disc. Valves shall be rated for 200 psi CWP or 200 psi WOG and shall conform to MSS SP-71, Type 1. Valves shall be Nibco F-908 series, or Watts 410 series.
3. Manual Balancing Valves: Balancing valves for the domestic hot water system shall be ANSI/NSF 61 Hot/Cold and ANSI/NSF 372 low lead certified Nibco or Watts balancing valves. Valves shall be Y-pattern globe type with fixed orifice, low lead brass CC768S body construction, brass plug with EPDM O-ring seat seal. Valve shall include metering test ports and calibrated hand wheel with position readout and memory stops. Valve shall be rated for a maximum temperature of 248°F and a maximum pressure of 400 psi. The Contractor shall furnish a differential pressure gauge for Contractor use in balancing the hot water system. After balancing and verification is complete, the differential pressure gauge shall be turned over to the Owner at the time of Substantial Completion.

J. Backflow Prevention and Cross Contamination:

1. A backflow control unit shall be installed at all locations in the domestic water system as follows:

a. Where a cross connection or potential cross connection could result in introduction of a health contaminant or non-health pollutant into the domestic water supply system.
b. Where required by the authority having jurisdiction.
c. Where recommended by the American Water Works Association (AWWA) Manual M14.
d. Where shown on the Drawings.

2. Backflow shall be controlled by one of the following methods or types of assemblies:

a. Air gap (AG)

3. The domestic water system shall be protected at terminations and equipment connections by methods and devices shown in AWWA Manual M14, Table 4-1.
4. Building premises isolation from the Utility shall utilize devices listed in AWWA Manual M14, Table 4-2.
5. Backflow prevention products manufactured by Watts, are acceptable provided they meet or exceed test standards of American Society of Sanitary Engineers (ASSE).
6. All new pipes, fittings, and related products must conform to American National Standards Institute/National Sanitation Foundation ANSI/NSF Standard 61 (including Annex G) and must be certified by an organization accredited by ANSI.
7. Underground Systems: Routing and crossing underground water and sanitary lines shall follow rules established by the local authority having jurisdiction for prevention of cross contamination.

K. Relief Valves:

1. Furnish and install relief valves where required and as indicated on the Drawings. Relief valve capacity shall be as required by the applicable code and as scheduled or as shown on the Drawings.
2. Relief valves shall be suitable for the working pressure and temperature of the system in which they are installed. Refer to Section 20 05 02, Design Criteria.
3. Inlet and outlet piping from the relief valve shall be at least the size of the valve connections unless otherwise indicated on the Drawings.
4. Liquid relief valves shall be direct spring-loaded type with a cast iron, bronze or steel body and stainless steel or bronze trim, lifting lever, and ASME Unfired Pressure Vessel Code stamp. Valves shall be selected for a maximum overpressure of 10%.
5. If they comply with these Specifications, relief valves manufactured by Kunkel, Watts, Armstrong or Consolidated will be acceptable.

L. Solenoid Valves: Cold water solenoid valves shall be similar to ASCO Red-Hat Series 8210, 120/1/60, brass body with Buna "N" Seals and Discs, 150 psi operating pressure. Valves shall be normally open or normally closed as called for in drawings.

M. If it complies with these specifications, valves manufactured by one of the manufacturers listed above will be acceptable.

2.03 **SERVICE WATER METERS**

A. Water meters shall be of the turbine type with magnetic drive and hermetically sealed register. Meter body casting shall be bronze. Trim shall be stainless steel.

B. Flow shall be straight through the meter at all flow rates. All water measured by the meter shall be recorded on a single totalizing register.

C. Meters shall meet or exceed AWWA Standard C-701-78 for Class II turbine meters at both normal flow ranges and sustained flow limits and must be approved for potable water use by the City Water Department. Meters shall be certified compliant with NSF61 Annex G, and shall comply with NSF61 Annex F.

D. Meter shall be installed in accordance with the manufacturer's written recommendations. Provide a minimum of seven (7) pipe diameters of straight pipe immediately in front of the meter assembly and a minimum of five (5) pipe diameters of straight pipe immediately downstream of the meter assembly. Throttling valves, control valves, check valves, backflow preventers, or pressure reducing valves shall not be installed upstream of any domestic water meter regardless of pipe separation. Reducer connections to water meter assemblies where used shall be of the tapered concentric type. Reducing flanges and eccentric step-type reducers are unacceptable.

E. Meters shall be furnished for various locations as noted below and shall be approved equal to the Sensus Model numbers listed:

1. Main Domestic Water Service: Neptune HP Turbine (flanged connections).
2. Cooling Tower Make-up: Neptune HP Turbine with flanged ends and 3" bronze strainer.
3. Cooling Tower Blowdown: Neptune HP Turbine with flanged ends and 2" bronze strainer.

F. Manufacturers: If they comply with these Specifications, water meters manufactured by Hersey, Sensus, Badger, Neptune, or an approved equal will be acceptable.

G. Remote Readout: Provide one (1) water meter remote readout at location indicated on the Drawings. Architect to detail minimum 6" x 6" x 2" deep weatherproof enclosure suitable for installation of remote readout.

H. Provide pulse to D.C. converter with 4-20 mA output proportional to flow rate for remote monitoring by the Building Control and Automation System (BCAS).

2.04 PLUMBING PIPING HANGER SPACING

A. Maximum spacing between piping hangers shall be in accordance with the following table:

SIZE OF PIPING	DISTANCE BETWEEN SUPPORTS	
	COPPER/GALVANIZED STEEL	CAST IRON/GLASS
3/4"	6'	5'
1"	7'	5'
1-1/4"	8'	5'
1-1/2"	9'	5'
2" AND LARGER	10'	5'

B. Supports shall be arranged so as to be near the weakest point of the span such as joints, turns and at the base of all vertical to horizontal offsets and at all waste traps.

2.05 CHASE AND WALL PIPING SUPPORTS

A. All piping whether sanitary or water shall be rigidly installed in all chases or walls.

B. Support inside the chase or wall for Sanitary Waste and Vent Piping shall be accomplished by utilizing fixture carrier bolt-downs, "UNI-STRUT" or similar structural bracing system, "U-bolts", nuts and lock-washers, all bolted to the floor and to the piping system.

C. Support for Water Piping or other similar service piping shall be accomplished by using a "system" designed for that purpose. An approved system shall consist of preformed steel supports which shall be installed between studs or joints and preformed nonmetallic pipe holder inserts which are designed to rigidly support or hold the piping to the steel supports.

D. In no case shall Sanitary Sewer Waste or Vent Piping depend on blocks, brick, stone or wood sleepers for its final support. In no case shall Water Piping or similar service piping depend on its final support on "tie-wires", soldering or brazing to metal studs or joints.

E. Support system shall be as manufactured by "HOLDRITE" or an approved equal.

2.06 **DRAIN PANS**

A. Furnish and install galvanized sheet metal drain pans under piping where shown on the Drawings and under all domestic water, waste, and storm drain piping installed in the ceiling space in the following locations:

1. Utility Company Transformer Vault
2. Electrical Rooms
3. Telephone Equipment Rooms
4. IDF Rooms
5. Audio/Visual Equipment Rooms
6. Food Preparation Areas
7. Food Serving Areas
8. Food Storage Areas
9. Intensive Care Rooms
10. Imaging Rooms

B. Drain pans shall be 3" deep, minimum 16-gauge galvanized steel with watertight solder joints. Drain pans shall be 3" wider in each dimension than the piping protected and shall be chain suspended. Pans shall be cross-broken or sloped to a 1/2" coupling welded to the pan for drain line connection.

C. Route 1/2" copper or galvanized steel drain lines from each drain pan and terminate through the ceiling in "tell-tale" fashion above the nearest general use plumbing fixture. Drain pan and "tell-tale" locations shall be shown on the Record Drawings. A chrome escutcheon shall be provided where the drain line passes through the ceiling.

PART 3 - EXECUTION

3.01 **SUBMITTALS**

A. Submittals shall include, but not be limited to, the following:

1. Cut sheets for the following plumbing products:

a. Domestic water pipe, fittings, solder, etc.
b. Valves
c. Backflow preventers
d. Water meters
e. Sanitary soil waste and vent pipe and fittings
f. Sanitary soil waste and vent piping joint material

g. Storm water piping and fittings
h. Storm water piping and joint materials
i. Grease traps and sampling wells
j. Oil separators
k. Chase and wall pipe supports
l. Drain pans

2. Piping fabrication drawings.
3. Additional information as required by Section 20 05 03.
4. Grooved products shall be shown on drawings and product submittals and shall be specifically identified with the applicable style or series number.

3.02 **INSTALLATION**

A. General: Route all piping parallel or perpendicular to building lines. Grade piping for drainage and install hose connection drain valves at all system low points.

B. Copper Pipe: All copper water piping shall be completely isolated from metal hangers, metal studs or any other electrically conductive building components. Provide dielectric unions at all connections between copper and galvanized pipe.

C. CPVC Pipe: At the contractor's option the use of CPVC piping as a contractor's option for domestic water systems shall be approved prior by the engineer of record and shall be installed using the Victaulic PSG-300 grooved CPVC couplings, fittings and valves in accordance with the manufacture's requirements and specifications herein. Solvent welded or other joining methods shall not be allowed.

D. Manufacturer's Instructions: Install all materials in accordance with the manufacturers written installation instructions.

E. Domestic water piping shall be hydrostatically tested at 1.5 times system design pressure as specified in Section 22 05 93.

F. Refer to Section 20 05 05 for domestic water pipe cleaning and sterilization.

3.03 **CLEANING AND ADJUSTING**

G. This Contractor shall furnish all labor, tools, instruments and supervision required in the performance of all tests as specified in Section 22 05 93. All fixtures shall be cleaned and in good working order at project completion.

END OF SECTION

DIVISION 23 - HEATING, VENTILATING, AND AIR CONDITIONING INDEX

SECTION	DESCRIPTION
23 00 00	HEATING, VENTILATING, AND AIR CONDITIONING INDEX
23 05 01	SCOPE OF WORK
23 05 10	HVAC WATER PIPING ACCESSORIES
23 05 93	START-UP, TESTING, ADJUSTING AND BALANCING
23 05 93.13	SUPPLEMENTAL BALANCING AND ADJUSTMENTS
23 08 00	MECHANICAL COMMISSIONING
23 09 16	BUILDING CONTROL AND AUTOMATION SYSTEM (BCAS)
23 21 13	HVAC WATER PIPING
23 21 23	HVAC PUMPS
23 64 33	WATER CHILLING UNITS - AIR COOLED

END OF INDEX

SECTION 23 05 01 - SCOPE OF WORK

PART 1 - GENERAL

1.01 **RELATED DOCUMENTS**

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Refer to Specification Section 20 05 00 for related required Codes and Standards.

C. Refer to Specification Section 20 05 04 for related required Schedule of Submittal Data.

D. Requirements of Division 20 apply to all Work of Divisions 20-28.

1.02 **SCOPE**

A. Work Included: The Work includes but is not limited to the following systems, equipment, and services:

1. A chilled water-cooling system consisting of all items indicated on the Drawings and/or specified herein, such as:

a. Water chilling units
b. Chilled water pumps
c. Chilled water piping
d. Water treatment
e. Insulation, controls, safety devices, vibration isolation, etc.

2. Energy management and automatic temperature control systems (BCAS) consisting of all items indicated on the Drawings and/or specified herein, such as:

a. Pneumatic control devices
b. Electric control devices
c. Electronic control devices
d. Computer control devices
e. Various relays
f. Valves, dampers, and sensors
g. Pneumatic piping, air compressors, air driers, etc.
h. Computer head-end equipment and communications network
i. Building Control and Automation System (BCAS)
j. Control system wiring

1.03 **WORK OF OTHER DIVISIONS**

A. The following is a partial list of work not included in Division 23:

1. Electrical connections to motors.

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION (NOT APPLICABLE)

END OF SECTION

SECTION 23 05 10 - HVAC WATER PIPING ACCESSORIES

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Scope of Work - Section 23 05 01
5. Start-up, Testing, Adjusting, and Balancing - Section 23 05 93

1.02 SCOPE

A. General: Furnish and install HVAC water piping system accessories as specified herein and as shown on the Drawings.

B. Types: Provide accessories of the following types:

1. Thermometers
2. Gauges
3. Pressure/Temperature Test Plugs
4. Valves
5. Pressure Reducing Valves
6. Suction Diffusers
7. Strainers
8. Pressure Relief Valves
9. Balancing Kits
10. Expansion Tanks
11. Air Separators
12. Air Vents
13. Auxiliary Drain Pans and Drain Lines
14. Venturi Flow Tubes

C. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. Thermal Insulation - Section 20 07 00
2. HVAC Water Piping - Section 23 21 13

PART 2 - PRODUCTS

2.01 THERMOMETERS

A. Furnish and install thermometers and thermometer wells for the following:

1. Entering chilled water at each chiller.
2. Leaving chilled water at each chiller.
3. Entering condenser water at each chiller.
4. Leaving condenser water at each chiller.

5. Entering hot water at each boiler.
6. Leaving hot water at each boiler.
7. Entering hot water at each heat exchanger.
8. Leaving hot water at each heat exchanger.
9. Chilled water supply main to the building riser.
10. Chilled water return main to the building riser.
11. Hot water supply main to the building riser.
12. Hot water return main to the building riser.
13. Chilled water supply to each air handling unit chilled water coil.
14. Chilled water return from each air handling unit chilled water coil.
15. Hot water supply to each air handling unit heating coil.
16. Hot water return from each air handling unit heating coil.
17. Where shown on the Drawings.

B. Thermometers shall be Moeller Instruments Company Style AJ, or approved equal, with a minimum 9" scale length and minimum 2ºF scale divisions. Thermometers shall be adjustable angle, hinge assembly type with red or blue appearing triple distilled mercury column. Scale shall have white background with black scale, heat stamped, and permanently embossed. Case shall be extruded aluminum with powder-coated finish. Phenol or other plastics are unacceptable case materials. Lens shall be Plexiglas or double strength glass. Stems shall be aluminum with well connections. Bulb chamber shall be a rounded bevel union seat to provide maximum sensitivity. Temperature ranges shall be 0-100ºF for chilled and condenser water, and 30-240ºF for heating hot water.

C. Thermometer wells shall be brass or stainless steel with pressure and temperature ratings suitable for their application. Wells for insulated piping shall have a 2-1/2" lagging protrusion and all wells shall be filled with silicon and be provided with a cap and chain.

D. Thermometers and wells shall have the following insertion lengths:

PIPE DIAMETER	ORIENTATION	INSERTION LENGTH
4"	HORIZONTAL	2-1/2"
4", 6"	VERTICAL	5"
6", 8"	HORIZONTAL	5"
8", 10"	VERTICAL	8"
8"	HORIZONTAL	8"
10"	VERTICAL	14"

E. Thermometers manufactured by Moeller Instrument Company, Trerice, or Weksler will be acceptable if they comply with these specifications.

2.02 **GAUGES**

A. Furnish and install gauges for the following:

1. Suction side of each pump inlet suction diffuser or strainer.
2. Suction side of each pump.
3. Discharge side of each pump.
4. Entering water side of each chiller, boiler, and heat exchanger.
5. Leaving water side of each chiller, boiler, and heat exchanger.
6. Entering water side of each air handling unit hot water and chilled water coil.
7. Leaving water side of each air handling unit hot water and chilled water coil.
8. Where shown on the Drawings.

B. Gauges shall be Moeller Instrument Company Vantage Series, or approved equal, with 4-1/2" dial face, 1/4" IPS connection, bourdon tube type, phosphor bronze soldered to brass socket and tip. Case shall be stainless steel with stainless steel ring. Pointer shall be adjustable. Movement shall be stainless steel or bronze bushed and gear operated. Accuracy shall be 1% of full scale over middle half of range. Window shall be glass. Dials shall be white with black markings, heat stamped, and permanently embossed. Provide Moeller or an approved equal needle valve, suitable for the pressure and temperature rating of the system.

C. Pressure gauges installed outdoors shall be bourdon tube type, 316 stained steel tube and socket. Cases to be 304, stainless steel, 4" minimum face, dry, glycerin or silicone filled. Pointer to be micrometer type adjustable. Movement shall be stainless steel. Accuracy shall be 1% of full scale. Window shall be glass. Gauge shall have a pressure relief plug.

D. Differential pressure gauges for strainers shall be Orange Research Series 1201 with 0-5 psid range.

E. Provide Trerice Series 870 or approved equal Moeller or Weksler impulse dampeners in-line between all gauge valves and pressure gauges. Provide Trerice Series 855 or approved equal Moeller or Weksler coil siphons between gauge valves and impulse dampers on all steam pressure gauges.

F. Provide gauges with ranges and intervals appropriate to pressure conditions at the point of application.

G. Gauges manufactured by Moeller Instrument Company, Trerice, or Weksler will be acceptable if they comply with these specifications.

2.03 PRESSURE/TEMPERATURE TEST PLUGS

A. Provide pressure and temperature test plugs at the supply, bypass, and return connections to all coils (in addition to all other thermometers and wells specified) and as indicated on the Drawings. Test plugs shall be Peterson Engineering Pete's Plug, 1/2" NPT, brass with Nordel core, Model 710. In addition, the Contractor shall supply the Owner with four pressure gauge adapters with 1/8" O.D. probe and four 5" stem pocket testing thermometers: Two 25-120ºF, and two 0-220ºF.

B. If it complies with these Specifications, pressure temperature test plugs manufactured by Peterson Engineering, Sisco, MG Piping Products Company, or Texas Fairfax Company will be acceptable.

2.04 VALVES

A. Ball and butterfly valves shall be used for isolation and throttling service on HVAC water systems. All valves shall be of non-blow-out construction. Where valves are installed in insulated piping, valves shall have stem extensions. All valves more than 8' above the floor shall be gear operated with chain operators.

B. Ball valves 2" and smaller shall be two- or three-piece body bronze (no more than 15% zinc), of a full port design. Stainless steel ball and stem. Valves shall be rated for 600 psi WOG and shall conform to MSS-SP-110. Ball valves installed in chilled water piping shall have insulating handles, such as NIBCO NIB-Seal. Valves to be:

1. Nibco No. T-585-70-66
2. Watts B6800 SS

C. Ball valves for copper piping up to and including 2-1/2” shall be two or three piece body bronze (no more than 15% zinc) of a full part design. Stainless steel ball and stem. Valves shall be rated for 600 psi WOG and shall conform to MSS-SP-110. NIBCO S-585-70-66 or equal by Watts.

D. Butterfly valves 2-1/2” and larger shall be ductile iron or cast iron lug body, molded-in EPDM (EPT) seat, aluminum bronze or stainless steel disc, 400 series stainless steel upper and lower stems (stems shall be positively connected to the valve disc), EPDM stem seals, lever operators on valves 5" and smaller, and gear operators with wheel for valves 6" and larger. Lever operators shall have memory stops and gear operators shall have waterproof, enclosed, factory worm gear operators with mechanical stops. All valves more than 8' above the floor (except where concealed above ceilings) shall be gear operated with chain operators. Butterfly valves shall be certified bubble-tight with bi-directional dead-end service without need of downstream flange and shall be listed by the manufacturer for continuous throttling service. Valves shall be:

1. Nibco LD-2000 or GD 4765
2. Watts (submit for approval)

* Indicates type of valve operators (see above requirements).

E. Butterfly valves for copper piping using grooved joint option shall have cast brass bodies, conforming to UNS c87850 with aluminum-bronze cast disc (UNSC95500)EPDM seat, EPDM seals, and 316 stainless steel trim. Valves shall be rated for working pressures up to 300 PSIG for bi-directional dead-end service. Handles and operators shall be as specified for ductile and cast iron butterfly valves. Valves shall be Victaulic Series 608N or approved equal.

F. High Performance Butterfly Valves shall be ASTM-A216WCB steel lug body with reinforced PTFE garter spring type seal, blowout proof stainless steel stem, stainless steel disc, PTFE packing, and seal retaining ring. Valve shall be certified bubble-tight with bi-directional dead-end service without the need of downstream flange. Valves shall be Class 150 or Class 300 (ANSI B16.5), as per project requirements and shall meet MSS-SP-67 for double offset design. Valves smaller than 6” shall have lever handle, and valves 6” and larger shall have gear operators.

1. Class 150 Valves:

   a. NIBCO LCS6822
   b. Or Watts approved equal

2. Class 300 Valves:

   a. NIBCO LCS7822
   b. Or Watts approved equal

G. Silent check valves shall be used on HVAC water systems. Silent check valves 2-1/2" and larger shall be non-slam globe type iron body, bronze disc with stainless steel seat and spring, full lug or flanged body style spring check valves with renewable seats and discs. Valves shall be ASA Class 125 rated, conforming to MSS-SP-125, and shall be:

1. Nibco F-910-B
2. NIBCO T/S-480Y
3. Watts (approved equal)

2.05 **PRESSURE REDUCING VALVE**

A. The pressure reducing and pressure sustaining valve shall be installed where shown on the drawings. The valve is a single seated, hydraulically-operated, pilot-controlled, diaphragm type globe valve. Valve body shall be cast iron ASTM-A48, main valve trim shall be 303 stainless

steel, pilot controls shall be bronze ASTM B-61, pilot control trim shall be 303 stainless steel. The valve shall have adjustment pressure ranges of 15 to 75 psi downstream and 0 to 75 psi upstream. The valve shall be ASA Class 125 rated and shall be:

1. Watts
2. Approved Equal

2.06 SUCTION DIFFUSERS

A. Pump Suction Diffusers shall be Taco Series 300, Bell & Gossett, Armstrong, Aurora and Grundfos rated for 150 psi WOG and shall consist of an angle body with inlet vanes and a combination, 304 stainless steel diffuser strainer with 3/16" diameter openings. Flow direction shall be from inside the strainer to outside. The diffuser body shall fit the pump and connecting piping size and shall be provided with an adjustable support foot. Suction diffusers shall be factory drilled and tapped for field installation of a pressure gauge and gauge cock as shown on the drawings. A valve and cap shall be installed at the blowdown connection.

B. A disposable fine mesh screen shall be installed in the strainer and shall be removed after the first 30 days of system operation. Strainers shall be cleaned after initial start-up, after 30 day of operation and at final acceptance.

2.07 STRAINERS

A. Strainers shall be as manufactured by the Mueller Steam Specialty Company, Crane, Victaulic Style 732, McAlear, Zurn, or Keckley. Strainers for 2" and smaller piping shall be Mueller No. 11M, 400 #WOG, iron body with perforated 20 mesh, 304 stainless steel screen with cleanout and screwed ends. Strainers for piping 2-1/2" and larger shall be Mueller No. 758, 150 # WOG or Mueller No. 752, 500# WOG, with perforated 304 stainless steel screen with 1/16" perforations for sizes through 4" and 5/32" perforations for sizes 5" and larger, with blowdown connection and Class 125 ANSI B16.1 flanges ends. A valve and cap shall be installed at the blowdown connection. Where pump suction diffusers with integral strainers are provided, separate strainers shall not be required. Strainers shall be cleaned after initial start-up, after thirty (30) days of operation and at final acceptance.

2.08 PRESSURE RELIEF VALVES

A. Relief Valves:

1. Furnish and install relief valves where required and as indicated on the Drawings in all closed piping systems. Relief valve capacity shall be as required by the applicable code and as scheduled or as shown on the Drawings.
2. Relief valves shall be suitable for the working pressure and temperature of the system in which they are installed. Refer to Section 23 05 02, Design Criteria.
3. Inlet and outlet piping from the relief valve shall be at least the size of the valve connections unless otherwise indicated on the Drawings.
4. Liquid relief valves shall be direct spring-loaded type with a cast iron, bronze or steel body and stainless steel or bronze trim, lifting lever, and ASME Unfired Pressure Vessel Code stamp. Valves shall be selected for a maximum overpressure of 10%.
5. If they comply with these Specifications, relief valves manufactured by Kunkel, Watts, or Consolidated will be acceptable.

2.09 PRESSURE REDUCING VALVES

A. Pressure Reducing Valves shall be Watts, Cla-Val, Wilkins, Victaulic/ Bermad or an approved equal. Watts No. U5LP for sizes to 2", No. 223S for 2-1/2"and 3" and No. 2300 for 4" and larger.

Pressure reducing valves shall be provided for all system fill connections and shall be selected and set for 10 psi above system static head at the fill point.

2.10 MANUAL BALANCING KITS

A. Pipe sizes 2” and smaller globe style: 300 psi, threaded or sweat ends, non-ferrous Ametal® brass copper alloy body, EPDM o-ring seals. 4 turn digital readout handwheel for balancing, hidden memory feature with locking tamper-proof setting. Basis of Design Victaulic /TA Series 787 STAD or Series 786 STAS. Suitable for operating temperatures to 250°F.

B. Pipe sizes 2-1/2” and larger globe style: grooved or flanged ends, ASTM A536 ductile iron body, all other metal parts of Ametal® brass copper alloy, EPDM O-ring seals. 8, 12 or 16 turn digital readout handwheel for balancing, hidden memory feature with locking tamper-proof setting. Basis of Design: Victaulic/TA Hydronics Series 789 STAG or Series 788 STAF. Suitable for operating temperatures to 250°F.

C. Koil-Kit™ Components: Install Victaulic Series 799 Koil Kit Components, Series 78U 400 psi forged DZR brass body with manual air vent port and pressure/temperature port, with EPDM seals. Series 78Y strainer/ball valve up to 400 psi Ametal® copper alloy body consisting of a full port ball valve and strainer with pressure and temperature measuring ports. Ball valve shall be complete with Teflon packing, plated ball, blow-out proof stem, handle extension and steel handle with vinyl grip. Strainer shall be Y-pattern, with 20 mesh stainless steel screen and blowdown port. 78T ball valve/union combination with handle extension. Body of valve to be made of DZR Brass. Series 78k balancing/shutoff valve 300 psi, threaded or sweat ends, non-ferrous Ametal® EPDM o-ring seals. 4 turn digital readout handwheel for balancing, hidden memory feature with locking tamper-proof setting. Suitable for operating temperatures to 250°F.

2.11 EXPANSION TANKS

A. Each closed loop pressurized water system shall include a diaphragm-type expansion tank with replaceable bladder. Each tank shall accommodate the expanded water of the system generated within the normal operating temperature range, limiting the pressure increase at all components in the system to the maximum allowable pressure at those components. It shall maintain minimum operating pressure necessary to eliminate all air. The only air in the system shall be the permanent sealed-in air cushion contained in the diaphragm-type tank. Tank size shall be as indicated on the Drawings.

B. Each expansion tank shall be welded steel, construction tested and stamped in accordance with Section VIII of the ASME Code for a working pressure of 125 psi and pre-charged to the required minimum operating pressure. Prior to filling each tank, the tank shall be charged to a pressure approximately 5 psi above the system static pressure at the point of connection.

C. If it complies with the Specifications, tanks manufactured by Amtrol, Armstrong, Taco, or Wood Industrial will be acceptable.

2.12 AIR SEPARATORS

A. All free air originally contained in each closed water system, and all entrained air bubbles carried by system water shall be eliminated at all system points as indicated on the Drawings.

B. The air separator shall be cast iron or welded steel, constructed, tested and stamped in accordance with Section VIII of the ASME Code for a working pressure or 125 psi.

C. Size shall be as shown on the drawings or required.

D. If it complies with the Specifications, air separators manufactured by Amtrol, Armstrong, Taco, or Wood Industrial will be acceptable.

2.13 **AIR ELIMINATION VALVES (AIR VENTS)**

A. Air shall be eliminated to the atmosphere as fast as it is separated from system water, through float activated, remote pressure operated, automatic air elimination valves installed on top of an air separator, at the top of each riser, and at all other intermediate high points in closed piping systems.

B. Air elimination valves shall be Sarco Type 13W, 150 psi WOG rated or an approved equal and shall be suitable for the system in which they are installed including the system pressure and temperature.

C. Each air elimination valve shall have a high removal rate at low pressure differentials and shall be fully open for the removal of air at all pressures in the operating range from 2 to 150 psig. It shall be tightly sealed against loss of system water and prevent entrance of air in negative pressure situations. Each air elimination valve shall be constructed of metal and all working parts shall be non-corrosive.

D. Provide 3/8" OD hard drawn Type L copper tubing from the vent outlet to a suitable drain. Provide 3/4" stop valve in vent line for air vent servicing.

E. If they comply with these specifications, air elimination valves as manufactured by Sarco, Taco, or Woods Industrial will be acceptable.

2.14 **AUXILIARY DRAIN PANS AND AUXILIARY DRAIN LINES**

A. Furnish and install 3" deep galvanized sheet metal auxiliary drain pans under any equipment where shown on the Drawings and under all horizontal air handling units, duct mounted chilled water coils, horizontal suspended fan coil units and suspended domestic water heaters located above ceilings.

B. Drain pans shall be minimum 16-gauge galvanized steel with watertight soldered joints. Drain pans shall be at least 2" larger in each dimension than the equipment served and shall extend under control and isolation valves. Chain-suspend drain pans under equipment served. Pan shall have a welded coupling of the same size as the unit condensate drain (minimum 3/4" FPT). Pan bottom shall be cross-broken and sloped to the drain connection.

C. Auxiliary drain lines shall be as specified hereinabove for drain piping but shall be uninsulated and shall be routed through the ceiling in "tell-tale" fashion above the nearest general use plumbing lavatory or janitors sink. An escutcheon shall be provided.

PART 3 - EXECUTION

3.01 **SUBMITTALS**

A. Shop drawing submittals shall include, but not be limited to, the following:

1. Cut sheets marked to clearly indicate all piping system materials to be used.
2. Cut sheets clearly marked to show all HVAC piping accessories.
3. Valve samples as specified herein or requested.
4. Manufacturer's installation recommendations and instructions.

END OF SECTION

SECTION 23 05 93 - START-UP, TESTING, ADJUSTING AND BALANCING

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. HVAC Testing, Adjusting, and Balancing - Section 01 45 23.01
2. Basic Division 20-28 Requirements - Section 20 05 03
3. Schedule of Submittal Data - Section 20 05 04
4. General Division 20-28 Materials and Methods - Section 20 05 05
5. Scope of Work - Section 23 05 01

1.02 SCOPE

A. Testing, adjusting, and balancing of all air systems.

B. Testing, adjusting, and balancing of all hydronic (and steam) systems.

C. Hydrostatic pressure testing of all pressure piping systems.

D. Sound measurement of equipment operating conditions.

1.03 RELATED SECTIONS

A. All Division 23 Sections.

1.04 QUALITY CONTROL

1. Refer to Specification Section 01 45 23.01.

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION

In addition to all items listed in Section 01 45 23.01, the contractor shall perform the following.

3.01 EXAMINATION

A. Before commencing work, verify that systems are complete and operable to the following extent:

1. Equipment is operable and in a safe and normal condition.
2. Temperature control systems are installed complete and operable.
3. Proper thermal overload protection is in place for electrical equipment.
4. All air filters are clean and in place. If required, install temporary media in addition to final filters.
5. Correct fan rotation.
6. Fire, smoke, and volume dampers are in place and open.
7. Coil fins have been cleaned and combed.
8. Access doors are closed, and duct end caps are in place.
9. Air outlets are installed and connected.

10. Duct system leakage is below specified level.
11. Hydronic systems have been flushed, filled, and vented.
12. Correct pump rotation.
13. Proper strainer baskets are clean and in place.
14. Service and balance valves are open.

B. Report any defects or deficiencies noted during performance of services to Architect/Engineer.

C. Promptly report abnormal conditions in mechanical systems or conditions that prevent system balance.

D. If, for design reasons, system cannot be properly balanced, report as soon as observed.

E. Beginning of work means acceptance of existing conditions.

3.02 **PREPARATION**

A. Provide all material, equipment, and personnel, including factory personnel where specified or required, to fully check out and start up all equipment and systems as specified in accordance with manufacturer's requirements.

B. No water piping systems shall be "pumped" until all piping has been hydrostatically tested, flushed, cleaned and water treated as applicable.

C. Lubrication and fluid levels shall be checked prior to equipment start-up. Alignment on all motor driven equipment shall be checked and adjusted prior to start-up.

3.03 **TESTING PROCEDURES**

A. Tests shall be made during the course of construction as specified and as required by authorities having jurisdiction.

B. Test submittals shall include a preliminary submittal of all proposed test procedures and recording forms for Engineer's review prior to any testing and four (4) copies of all certified test results and completed reporting forms for approval.

C. Gas Fired Boiler Safety Testing: Fire each gas-fired boiler make sure all safety devices are functioning properly. Run up temperature and pressure to relief valve settings and make them relieve pressure and shut off gas valve. Do not raise arm on relief valve for checking. Make sure all other safety devices for gas fired appliances and air conditioning equipment are functioning properly and fail safe.

D. Vibration Testing: Where a piece of equipment exhibits, in the Engineers opinion, excessive noise or vibration, the service of a certified acoustic Consulting Engineer shall be provided to perform noise and vibration testing on the equipment or system involved. The Consulting Engineer shall provide a written report concerning the noise and vibration of the equipment or system involved and the Contractor involved shall make changes or modifications as recommended by the Consulting Engineer. The above services and retroactive corrections shall be provided at no cost to the Owner or Architect/Engineer.

E. Hydrostatic Testing: All pressurized piping (not listed herein) shall be leak tested prior to enclosure or cover-up. Piping shall be leak tested for 24 hours under a hydrostatic pressure of 150% of the system design working pressure. The Engineer shall be notified prior to all hydrostatic tests and may elect to witness any of the tests. Water shall not be drawn off of the piping, and the piping shall not be covered up until it has been observed by the Engineer. Care shall be taken to protect any equipment that may be damaged by hydrostatic testing.

F. Refrigerant Leak Testing: Leak test and check refrigerant systems at final acceptance and at the end of the warranty period. Repair any leaks found and properly charge affected systems with refrigerant. Ensure refrigerant systems are properly charged and free from leaks at final acceptance and at the end of warranty (1 year from final acceptance).

G. Water Testing: Provide water analysis and testing as specified in Section 23 25 10.

H. Fire, Smoke and Fire/Smoke Damper Testing: Provide fire, smoke and fire/smoke damper testing and certification as specified in Section 23 33 10.

I. Fire Alarm System Interface: Provide testing, in conjunction with the Fire Alarm System functional testing specified in Section 28 31 00, to verify that all Fire alarm related HVAC control functions and shutdowns operated as specified in Section 23 09 16, Division 28, and as shown on the drawings.

J. Duct Leakage: Medium pressure low velocity duct: Duct leakage shall be tested and shall be less than 2% of the duct system flow up to 4" W.G. maximum duct pressure. Ductwork failing this test shall be reworked, resealed, and retested by this Contractor until it passes this test.

K. Air Balance: Upon completion of the installation of air system components, the outside, supply, exhaust and return air volume for each air handling unit, supply fan and exhaust fan; and the supply, exhaust or return air volume for each air distribution device shall be adjusted to within 5% of "design" air flow. The amount of air indicated on the drawings through ceiling outlets etc. includes a 5% allowance for duct leakage. "Design" air-flow is thus 95% of the value indicated on the drawings. Air handling unit and fan volumes shall be adjusted by changing fan speed and adjusting volume dampers associated with the unit.

L. Air Distribution Device Volume shall be adjusted using the spin-in tap damper for flexible duct connected devices and/or the device OBD for duct connected devices. Air distribution devices shall be balanced with air patterns as specified. Duct volume dampers shall be adjusted to provide air volume to branch ducts where such dampers are shown.

M. Water Balance:

1. After initial start-up of the chilled water, condenser, and heating hot water systems, each system shall be balanced to provide proper water volume from all pumps and through all loops, heat exchangers, coils, bypass links, and cooling tower cells to within 5% of the volume shown on the drawings.
2. The balanced position on all valves shall be permanently marked in the valve body insulation.

N. Automatic Temperature Control Adjustment: Adjust and calibrate all thermostats, dampers, operators, controllers, and other devices, as required to put the Temperature Control system in proper working order as designed and specified.

O. Completion Reports: Before the final inspection, but after all testing, balancing and adjusting, the Contractor shall furnish all labor, materials and devices necessary to prepare a completion report with the following information.

1. Motor data on all motors installed on the project. Motors shall be listed by the device on which they are installed, and information provided shall include:

   a. Horsepower
   b. Speed
   c. Type

d. Location
e. Rated full load amperage
f. Rated voltage
g. Actual measured amperage for each leg
h. Actual measured voltage for each leg

2. Belt and drive data for all belt-driven equipment installed on the project. Data shall be listed by the device on which the belts and drive are installed, and information provided shall include: number of belts, size of belts, size and type of drive installed, motor RPM and driven device RPM.

END OF SECTION

SECTION 23 05 93.13 - SUPPLEMENTAL BALANCING AND ADJUSTMENTS

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Design Criteria - Section 20 05 02
2. Basic Division 20-28 Requirements - Section 20 05 03
3. Schedule of Submittal Data - Section 20 05 04
4. General Division 20-28 Materials and Methods - Section 20 05 05
5. Scope of Work - Section 23 05 01
6. Start-up, Testing, Adjusting, and Balancing - Section 23 05 93

1.02 SCOPE

A. Adjusting and balancing of all hydronic systems.

B. Sound measurement of equipment operating conditions.

1.03 RELATED SECTIONS

A. All Division 23 Sections.

1.04 QUALITY CONTROL

A. All balancing work shall be completed by a certified, independent N.E.B.B. balancing contractor. The Contractor shall provide a complete air and water balance of the entire building and central plant systems.

B. The Balancing Contractor will act as liaison between the Owner, Architect, Engineer, and the General Contractor and inspect the installation of mechanical piping system, sheet metal work, temperature controls and other component parts of the heating, air conditioning and ventilating systems.

C. Measurements and recorded readings of air, water, and electricity that appear in the reports will be done by the permanently employed technicians or engineers of the balancing contractor.

D. The Balancing Contractor shall make inspections in the building during the opposite season from that in which the initial adjustments were made. At the time, make necessary modifications to the initial adjustments required to produce optimum operation of system components to affect the proper conditions as indicated on the Drawings. At time of opposite season check-out, the Owner's representative will be notified before readings or adjustments are made.

E. In fan systems, the air quantities indicated on the Drawings may be varied as required to secure a maximum temperature variation of two degrees within each separately controlled space, but the total air quantity indicated for each zone must be obtained. It shall be the obligation of the balancing contractor to adjust fan drives and motors as necessary, without cost to the Owner, to attain the specified air volumes.

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION

3.01 EXAMINATION

A. Before commencing work, verify that systems are complete and operable to the following extent:

1. Equipment is operable and in a safe and normal condition.
2. Temperature control systems are installed complete and operable.
3. Proper thermal overload protection is in place for electrical equipment.
4. All air filters are clean and in place. If required, install temporary media in addition to final filters.
5. Hydronic systems have been flushed, filled and vented.
6. Correct pump rotation.
7. Proper strainer baskets are clean and in place.
8. Service and balance valves are open.

B. Report any defects of deficiencies noted during performance of services to Architect/Engineer.

C. Promptly report abnormal conditions in mechanical systems or conditions which prevent system balance.

D. If, for design reasons, system cannot be properly balanced, report as soon as observed.

E. Beginning of work means acceptance of existing conditions.

3.02 PREPARATION

A. Provide all material, equipment and personnel, including factory personnel where specified or required, to fully check out and start up all equipment and systems as specified in accordance with manufacturer's requirements.

B. Lubrication and fluid levels shall be checked prior to equipment adjustment. Alignment on all motor driven equipment shall be checked and adjusted.

3.03 TESTING PROCEDURES

A. Before the final acceptance of the report is made, the Balancing Contractor will furnish the Owner the following data to be approved by the Owner, Architect, and Engineer:

1. Summary of main supply return and exhaust duct pitot tube traverses and fan settings indicating minimum value required to achieve specified air volumes.
2. A listing of the measure air quantities at each outlet corresponding to the temperature tabulation as developed by the Engineer.
3. Air quantities at each return and exhaust air handling device.
4. Static pressure readings entering and leaving each supply fan, exhaust fan, filter, coil, balancing dampers and other components of the systems included in the retrofit Work. These readings will be related to performance curves in terms of the CFM handled if available.
5. Motor current readings at each equipment motor on load side of capacitors. The voltages at the time of the reading shall be listed.
6. The final report shall certify test methods and instrumentation used, final velocity reading obtained, temperatures, pressure drops, RPM of equipment, amperage of motors, air balancing problems encountered, recommendations and uncompleted punch list items. The test results will be recorded on standard forms.

7. A summary of actual operating conditions shall be included with each system outlining normal and ventilation cycles of operation. The final report will act as a reference of actual operating conditions for the Owner's operating personnel.

3.04 **SYSTEM BALANCING**

A. General:

1. Place all equipment into full operation and continue the operating during each working day of balancing and testing.
2. The Contractor shall submit detailed balancing and recording forms for approval. After the approval by the Architect/Engineer, prepare complete set of forms for recording test data on each system. All instruments used shall be accurately calibrated to within 1% of scale and maintained in good working order.
3. Upon completion of the balancing and testing, the Balancing Contractor shall compile the test data in report forms, and forward five copies to the Architect/Engineer for evaluation.
4. The final report shall contain logged results of all tests, including such data as:

    a. Tabulation of air volume at each outlet.
    b. Outside dry bulb and wet bulb temperature.
    c. Inside dry bulb and wet bulb temperatures in each conditioned space room or area.
    d. Actual fan capacities and static pressures. Motor current and voltage readings at each fan.

5. Automatic temperature controls shall be calibrated and all thermostats and dampers, adjusted so that the control system is in proper operating condition, subject to the approval of the Architect.
6. The Air Balance Contractor shall report to the Architect/Engineer all air distribution devices or other equipment that operate noisily so that corrective measures may be implemented by the Mechanical Contractor.

B. Water System Balance:

1. After initial start-up of the chilled water, condenser, and heating hot water systems, each system shall be balanced to provide proper water volume from all pumps and through all loops, heat exchangers, coils, bypass links, and cooling tower cells to within 5% of the volume shown on the drawings.
2. The balanced position on all valves shall be permanently marked in the valve body insulation.

END OF SECTION

SECTION 23 08 00 - HVAC SYSTEMS TECHNICAL COMMISSIONING REQUIREMENTS

PART 1 - GENERAL

1.01 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. Specifications throughout all Divisions of the Project Manual are directly applicable to this Section, and this Section is directly applicable to them.

1.02 SUMMARY

A. The purpose of this Section is to define responsibilities in the Commissioning Process. Additional system testing is required within individual Specification Sections.

B. Commissioning requires the participation of the Contractor to ensure that all systems are operating in a manner consistent with the Contract Documents. General Commissioning requirements and coordination are detailed in Division 01. Division 20-25 Contractors shall be familiar with all parts of Division 01 and the Commissioning Plan issued by the Owner's CxA, shall execute all Commissioning responsibilities assigned to them in the Contract Documents and include the cost of Commissioning in the Contract price.

C. HVAC systems to be commissioned include the following (some may not apply – refer to the Plans and other sections of the specifications for the scope of work):

1. Chillers
2. Pumps
3. HVAC / Building Automation System and Integrations

D. The TAB Contractor will perform control sequence verification on each terminal unit shall independently verify each sensor and point and document the results to be included in the Final TAB Report. The CxA will commission approximately 25% of the terminal units once TAB is complete with the CSV and point verification of the terminal units. Contractor to provide personnel and all support necessary for this effort.

1.03 DEFINITIONS

A. Refer to the General Commissioning Requirements for definitions.

1.04 SUBMITTALS

A. Contractor shall provide Owner and/or CxA with documentation required for Commissioning Work. At minimum, documentation shall include: Detailed Start-up procedures, full sequences of operation, Operating and Maintenance data, performance data, control drawings, and details of Owner-contracted tests.

1. Shop drawings and product submittal data related to systems or equipment to be commissioned.

B. Contractor shall submit to Owner and/or CxA installation and checkout materials actually shipped inside equipment and actual field checkout sheet forms used by factory or field technicians.

1. Where installation testing may be performed in a progressive manner (i.e., piping hydrostatic testing, ductwork pressure testing, etc.), the Contractor shall prepare and submit to the Owner, A/E team and CxA a testing plan that details how the progressive testing will be performed, documented, and presented for approval prior to the start of any testing activities.

C. Contractor shall provide any additional documentation needed to complete the requirements of the Commissioning Process

1. Factory Performance Test Reports: Review and compile all factory performance data to assure that the data is complete prior to executing the FPTs.
2. Pre-functional Performance Checklists: review and compile all information associated with the piece of equipment to be commissioning ensure the equipment is ready for final commissioning.
3. Installation testing reports such as ductwork pressure testing, piping hydrostatic testing, piping chemical treatment and flushing, bolt flange torquing, and any documentation associated with local code authority inspections or authorizations.
4. Completed equipment Start-up certification forms along with the manufacturer's field or factory performance and Start-up test documentation.
5. Operating and Maintenance (O&M) information per requirements of the Technical Specifications and Division 01 requirements.

PART 2 - PRODUCTS

2.01 GENERAL

A. All materials and installation shall meet or exceed all applicable referenced standards, federal, state and local requirements, and conform to codes and ordinances of authorities having jurisdiction.

B. Refer to the General Commissioning Requirements for other work products related to the Commissioning Process

C. Contractor is required to follow all applicable industry and site-specific safety practices, lockout / tagout requirements, specialized PPE requirements, and provide qualified, trained personnel to execute Commissioning Process requirements.

2.02 TEST EQUIPMENT

A. Contractor shall provide all specialized tools, test equipment and instruments required to execute Start-up, checkout, and testing of equipment.

B. All specialized tools, test equipment, and instruments required to execute Start-up, checkout, and testing of equipment shall be of sufficient quality and accuracy to test and/or measure system performance within specified tolerances. A testing laboratory must have calibrated test equipment within the previous twelve (12) months. Calibration shall be NIST traceable. Contractor must calibrate test equipment and instruments according to manufacturer's recommended intervals and whenever the test equipment is dropped or damaged. Calibration tags must be affixed to the test equipment or certificates readily available.

PART 3 - EXECUTION

3.01 **CONSTRUCTION PHASE**

A. In each purchase order or subcontract that is written for changes in scope, include the appropriate requirements for submittal data, Commissioning documentation, testing assistance, Operating and Maintenance (O&M) data, and training, as a minimum.

B. Attend Pre-Commissioning Meeting(s), Pre-Installation Meeting(s), and other Project meetings scheduled by the Owner, CxA or Contractor to facilitate the Commissioning process.

C. Provide manufacturer's data sheets and shop drawing submittals of equipment.

D. Provide additional requested documentation to the Owner and/or CxA, prior to O&M manual submittals, for development of System Verification Checklists and Functional Performance Testing procedures.

1. Typically, this will include detailed manufacturer's installation and Start-up, operating, troubleshooting and maintenance procedures, full details of any Owner-contracted tests, full factory testing reports, if any, and full warranty information.
2. In addition, the installation, Start-up, and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Contractor and/or CxA.
3. This information and data request may be made prior to normal submittals.

E. With input from the BAS vendor and A/E, clarify the operation and control of commissioned equipment in areas where the Specifications, BAS control drawings, or equipment documentation are not sufficient for writing detailed test procedures.

F. During the installation, Start-up and initial checkout process, execute and document related portions of the System Verification Checklists for all commissioned equipment according to the procedures indicated in the Commissioning Plan.

G. Factory Start-ups: Factory Start-ups are specified for certain equipment. Factory Startups generally are Start-up related activities that will be reviewed and checked prior to Functional Performance Tests. All costs associated with factory Start-ups shall be included with the contract price unless otherwise noted. Notify the Commissioning Team of the factory Start-up schedule and coordinate these factory Start-ups with witnessing parties. The Commissioning Team members may witness these Start-ups at their discretion.

H. Independent Testing Agencies: For systems that specify testing by an independent testing agency, the cost of the test shall be included in the Contract price unless otherwise noted. Testing performed by independent agencies may cover aspects required in the System Verification Checklists, Start-ups, and Functional Performance Tests. Coordinate with the independent testing agency so that CxA, Owner and/or A/E can witness the test to ensure that applicable aspects of the test meet requirements.

I. Incorporate manufacturer's Start-up procedures with System Verification Checklists (SVC).

J. Air and water test, adjust and balance shall be completed with discrepancies and problems remedied before Functional Performance Tests of the respective air or water related systems are executed.

K. Provide skilled technicians to execute starting of equipment and to assist in execution of Functional Performance Tests. Ensure that they are available and present during the agreed-

upon schedules and for a sufficient duration to complete the necessary tests, adjustments, and problem solving.

L. Correct deficiencies (differences between specified and observed performance) as interpreted by the Owner's Project Manager and A/E and retest the system and equipment.

a. CxA shall participate in one retesting effort at no cost to the Owner nor contractor. Should a 2nd retesting effort be required due to system indicating the same or similar issue, then the contractor shall be charged for their effort and the Owner retains the right to withhold the cost of the CxA's additional attendance from the contractor retainage at a maximum of $2,500 per occurrence.

M. During construction, maintain as-built marked-up Drawings and Specifications of all Contract Documents and Contractor-generated coordination Drawings. Update after completion of Commissioning activities (include deferred tests).

N. Provide training of the Owner's operating personnel as specified.

O. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.

3.02 **WARRANTY PHASE**

A. Execute seasonal or deferred tests, witnessed by the CxA and Owner, according to the Specifications.

B. Complete deferred tests as part of this Contract during the Warranty Period. Schedule this activity with the Owner and/or CxA.

C. Correct deficiencies and make necessary adjustments to O&M manuals, Commissioning documentation, and as-built drawings for applicable issues identified in any deferred or seasonal testing.

3.03 **INSTALLATION**

A. Installation shall meet or exceed all applicable federal, state and local requirements, referenced standards and conform to codes and ordinances of authorities having jurisdiction.

B. All installation shall be in accordance with the Project Documents.

3.04 **TRAINING**

A. Refer to the individual section of this Specification for specific training requirements on each system.

B. Refer to the General Commissioning Requirements and Division 01 for overall training requirements related to the Commissioning process and this project.

END OF SECTION

SECTION 230916 - BUILDING CONTROL AND AUTOMATION SYSTEM (BCAS)

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Design Criteria - Section 20 05 02
2. Basic Division 20-28 Requirements - Section 20 05 03
3. Schedule of Submittal Data - Section 20 05 04
4. General Division 20-28 Materials and Methods - Section 20 05 05
5. Scope of Work - Section 23 05 01
6. Start-up, Testing, Adjusting, and Balancing - Section 23 05 93

1.02 DESCRIPTION OF WORK

A. General: Provide a fully integrated Building Control and Automation System (BCAS) incorporating Direct Digital Control (DDC), energy management hardware and software, equipment monitoring and control. This Section requires the furnishing and installing of all items Specified herein, and as indicated on the Drawings, or reasonably inferred as necessary for safe and proper operation; Including every article, device, or accessory (whether or not specifically called for by item) necessary to facilitate each system's functioning as indicated by the design, the equipment specified, and the sequence of operation specified. Elements of the work include, but are not limited to, materials, labor, engineering, supervision, supplies, equipment, transportation, storage, utilities, services, programming, testing, and all required permits and licenses.

B. Drawings: Refer to the Mechanical and Plumbing Drawings for graphic representations, equipment schedules, and notations showing elements of building control and automation work.

C. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. Sequence of Operation - See Control Diagram Drawings
2. Input/Output Point Schedule - See Control Diagram Drawings
3. Conduit - Section 26 05 33
4. Conductors - Section 26 05 19

D. Work included: The work includes, but is not limited to, the following systems, equipment, and services:

1. A complete system of coordinated Building Control and Automation as specified and required.
2. All necessary controls, wiring and installation shall be provided and installed. Provide a complete system of devices to perform the sequences and programs including, but not limited to:

a. Electric, electronic, and computer control for all items shown on the Drawings, to provide the specified Sequence of controls as specified hereinafter including thermostats, sensors, relays, and motors.

b. Electric damper operators and control valves furnished to the appropriate trade as specified under the Work of other Sections.
c. Control panels as specified hereinafter and as shown on the Drawings.
d. Complete instrument air systems including air compressors and receivers, refrigerated air dryers, appropriate accessories and distribution piping.
e. PC based central computer, associated peripherals, and software as specified to function as the operator interface for the BCAS. All hardware and software required for interface to the communications network and peripheral devices shall be included.
f. The Building Control and Automation System (BCAS) system shall consist of a high-speed, peer-to-peer network of DDC controllers, a control system server, and a web-based operator interface.
g. System software shall be based on a server/thin-client architecture, designed around the open standards of web technology. The control system server shall be accessed using a Web browser over the control system network, the owner's local area network and (at the owner's discretion) over the Internet. The server shall also act as a "workstation" when running as a server/client platform. Additional clients shall have concurrent access to the "workstation" in this mode.
h. The intent of the thin-client architecture is to provide operators complete access to the control system via a Web browser. No special software other than a Web browser shall be required to access graphics, point displays, and trends, configure trends, configure points and controllers, or to download programming into the controllers.
i. System shall use BACnet protocol for communication between the control modules and web server. Communication between the web server and the user's browser shall be HTTP or HTTPS protocol utilizing HTML5. Use of Adobe Flash technology is not acceptable.

3. Other miscellaneous control system components as shown on the Drawings, specified herein, and/or required.

E. Work of Other Sections:

1. Control valves, automatic dampers, temperature sensors, flow switches, pressure switches, and other duct and piping system sensors and control devices shall be furnished under this Section for installation by the Division 23 Contractor.
2. The Division 23 Contractor shall:

a. Install immersion wells, pressure taps and any associated shut-off cocks.
b. Install flow switches and sensors.
c. Install automatic control valves.
d. Install level switches.
e. Furnish and install venturi flanges.
f. Install venturi and flow sensors.
g. Furnish and install automatic valve flanges, flange gaskets, increasers, reducers, nuts, and bolts as required.
h. Furnish and install flare nuts for unitary valves.
i. Furnish and install union fittings where required in unitary equipment for service of automatic valves, including necessary transitions.
j. Install automatic control dampers.
k. Provide and install necessary transitions and blank-off plates required to install automatic control dampers that are different than duct size.
l. Assemble multiple section dampers with required interconnecting linkages and extend required number of shafts through duct for external mounting of damper motors.

m. Provide and install necessary sheet metal baffle plates to eliminate stratification and provide air volumes specified. Locate baffles by experimentation and affix and seal permanently in place only after stratification problem has been eliminated.
n. Provide, install, and label access door or other approved means of access through ducts for service to control equipment.
o. Provide and install necessary duct transitions to provide velocities as recommended by airflow station manufacturers.
p. Install airflow measurement stations as indicated on the Drawings, specified, or required.
q. HVAC terminal units provided by Division 23 shall have velocity transducer, controllers and damper actuators provided by the BCAS subcontractor for installation by the terminal unit manufacturer.

3. The Division 26 Contractor shall:

a. Provide control power source circuits only where BCAS control panel locations are shown on the Electrical Drawings. Division 26 shall provide the power supply to the temperature control air compressors (where supplied). All other BCAS control wiring and control power source circuits required but not shown on the Electrical Drawings shall be included in the work of this Section.
b. Fire alarm interface relays and addressable input devices shall be provided by Division 28. Interface relays shall be mounted adjacent to motor starters. Control wiring to these relays from the fire alarm system shall be by Division 28 and wiring of HVAC control circuits shall be by this Contractor.

F. System Capacity: The BCAS system shall have adequate front-end capacity to accommodate a 50% increase in connected points, in excess of those specified, without the addition of any new hardware or software. Each stand-alone DDC Panel and controller as defined herein shall have minimum of 20% spare points (i.e. AI/AO/DI/DO, etc.), in excess of those specified.

1.03 COORDINATION WITH OTHER TRADES

A. The BCAS Contractor shall be responsible for coordinating the Work of this section with the Work of other sections and Divisions 20-28 and providing all materials and labor required for installation of the Building Control and Automation System, which is not specified to be provided under another Division.

B. During the course of construction, the BCAS Contractor shall be responsible for coordinating BCAS provisions by other Divisions and shall be responsible for the proper installation of all provisions. Where provisions are not properly coordinated and are shown in the contract documents (i.e. BACnet interface included in equipment, etc.), it shall be the responsibility of this Division to correct the provisions at the expense of the BCAS Contractor. If new provisions are required by other Divisions, the contractor shall submit an RFI to determine course of action and shall follow the project issue-resolution procedure prior to performing the additional scope.

C. The BCAS Contractor shall be responsible for reviewing the Division 20-28 Drawings and Specifications to determine the BCAS provisions and interface points provided under those Divisions and coordinating the work of this Section as required to interface properly.

D. Coordination Deliverables: Provide a Responsibility Matrix identifying Furnish/Install/Terminate/Power/Test for each device class (sensors, actuators, VFDs, packaged equipment gateways, FA interfaces).

E. Coordination Meetings: Participate in weekly MEP/IT coordination through rough-in and panel placement; submit updated network riser (VLANs, IP ranges, BBMDs) and I/O schedules with ≥20% spare.

F. Access & Labeling: Coordinate access doors and service clearances; provide device and panel labels matching the drawings and point names.

1.04 **MANUFACTURERS**

A. Products and installation by the following manufacturers is acceptable contingent upon compliance with all aspects of the Specifications:

1. Automated Logic Corporation
2. Johnson Controls, Inc. (factory branch)
3. Trane

1.05 **QUALITY ASSURANCE**

A. General: All of the following Quality Assurance requirements shall be met:

1. All BCAS work shall be furnished and installed by the temperature control system Contractor. The work shall be performed by skilled technicians under the direction of experienced engineers, all of whom shall be properly trained and qualified for this work. Installer shall have an established working relationship with the Control System Manufacturer and have, as a minimum, 5 years demonstrated experience with installation and support of the manufacturer's product.
2. Installer shall have successfully completed Control System Manufacturer's control system training. Upon request, Installer shall present record of completed training including course outlines.
3. All materials and equipment used shall be standard catalogued components, regularly manufactured for use in HVAC control systems, and not custom designed for this project. All systems and components shall be manufacturer's latest standard design and have been thoroughly tested and proven in actual use.
4. Single source responsibility of the BCAS Contractor shall be the complete installation and proper operation of the BCAS and shall include debugging and proper calibration of each component in the entire system.
5. The BCAS Contractor shall have an established support facility within 50 miles of the project site with factory trained technical staff, spare parts inventory, and all necessary test and diagnostic equipment and provide on-site response within 24 hours for functional issues during startup/warranty
6. Post-Warranty Service: Offer an annual maintenance program including software updates (within major version), database backups, and health checks.
7. The specification covers minimum requirements and is not intended to preclude provisions of equipment or methods that exceed the requirements.
8. All electronic equipment shall conform to the requirements of FCC regulation Part 15, Section 15 governing radio frequency electromagnetic interference and be so labeled.
9. Electrical work and safety requirements shall comply with NFPA 70 and all applicable local and state codes.
10. The system shall use an open protocol standard such as BACnet, as the communications protocol from node to node and from nodes to the operator workstations. System level integration shall be via TCP/IP over an the Owner's BCAS VLAN with NTP time sync. Communication between web server and user's browser shall be HTTP or HTTPS protocol utilizing HTML5 or above. Use of Adobe Flash technology shall be approved by the Owner in writing and shared with the entire project team first. BTL listing is required. Modbus RTU/TCP or LON may be used only for equipment-level integration where shown on schedules, via gateways furnished under this Section..

11. Control system components shall be new and in conformance with the following applicable standards for products specified:

    a. American Society for testing materials, ASTM
    b. Institute of Electrical and Electronic Engineers, IEEE
    c. National Electrical Manufacturers Association, NEMA
    d. Underwriters Laboratory, UL (UL 916)
    e. FCC Regulation, Part 15, Section 156
    f. National Fire Protection Association, NFPA
    g. Local building codes
    h. BACnet Standard ASHRAE/ANSI 135 and approved addenda

12. Environmental Conditions of Operation:

    a. DDC controller and I/O equipment shall be designed to operate in ambient temperatures from 32°F to 122°F and relative humidity from 10% to 95% non-condensing.
    b. Sensors and Operating Devices: The environment that they are sensing or controlling but not less severe than for controller and I/O devices.

13. Ratings: All equipment shall be rated for continuous operation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified or normally encountered at the installed location.

14. Cybersecurity: Provide HTTPS/TLS 1.2+ for operator access, unique per-user credentials with role-based access, password policy (min length, rotation, lockout), disable default accounts, and backup/restore procedures verified during commissioning. All servers/controllers shall sync to Owner's NTP.

B. Manufacturers:

1. Provide principal control and automation system equipment and materials produced by the BCAS Manufacturer. All equipment shall be supplied by and be the responsibility of that manufacturer.
2. Where the BCAS Manufacturer does not have all required equipment available, provide sensors, transducers, switches, and similar equipment and material produced by one of the following:

    a. W.E. Anderson
    b. Badger Meter
    c. Barton
    d. Bristol
    e. Daniel
    f. Dwyer
    g. Emerson
    h. General Signal Corporation
    i. Kele and Associates
    j. Mamac Systems
    k. McDonnell and Miller
    l. Onicon
    m. Pre-Con Corporation
    n. Taylor

3. Where the BCAS Manufacturer does not have all required equipment available, provide control valves, actuators, PE switches, EP valves and similar equipment and materials produced by one of the following:

a. Honeywell, Inc.
b. Johnson Controls, Inc.
c. KMC Controls
d. Keystone and Spartan Control Valves (by Emerson)
e. Landis and Staefa Controls (by Siemens)
f. Robertshaw

C. Electrical Standards: Provide electrical products which have been tested, listed, and labeled by Underwriters' Laboratories, Inc. (UL) and which comply with National Electrical Manufacturers' Association (NEMA) standards.

1. Local Control Panels and Standalone Controls used to sequence dampers and control equipment associated with the Fire Alarm smoke purge sequence shall have the following UL listing:

a. UL 864 UUKL (Smoke Evacuation)
b. UL 916 PAZX

2. Equipment that is not listed for Smoke Removal/Evacuation may not be used to sequence dampers, Air Handlers and Exhaust Fans without hardwired interlocks to the Fire Alarm System.

D. Accuracy Standards:

1. Sensing elements and associated controllers or readout devices shall be field-adjustable to provide the minimum operating throttling range possible without control loop hunting. Variation from control point setting through the full control range shall be no more than 1/2 the throttling range. Space temperature control throttling range shall not exceed 2°F and overall control system accuracy (end-to-end) shall be as listed below from set point for each control function, including the control element, air piping loss, wiring, relays, submaster devices, and similar items. All accuracy's defined as percentage shall be percentage of the actual reading within the specified range:

a. ± 0.5°F for space temperature in the 0 to 130°F range.
b. ± 0.5°F for duct temperatures in the 40 to 130°F range.
c. ± 0.5°F for outside air temperatures in the -30 to 230°F range.
d. ± 0.5°F for water temperatures in the 30 to 230°F range.
e. ± 0.25°F for water temperatures used in BTU calculations.
f. ± 1% for KWH and kW monitoring.
g. ± 2% for relative humidity in the 5 to 95% range.
h. ± 0.1 inch for static pressure in the 0 to 5-inch water gauge range.
i. ± 0.1 inch for filter status differential in the 0 to 2-inch range.
j. ± 1% for pressure switches.
k. ± 1% for air flow from 10 to 150% of maximum flow.
l. ± 1.5% for water flow from 10 to 150% of maximum flow.
m. ± 1% for differential water pressure from 10 to 150% of maximum flow.

2. Accuracy standards for individual sensors, transducers, devices, and systems shall be as specified for the individual components and systems.

1.06 SUBMITTALS

A. General: Shop drawings, product data, spec compliance and submittals required for this project shall include, but not be limited to, the following:

1. Shop Drawings and Product Data Submittals.
2. Certifications and Test Reports.
3. Operating and Maintenance Manuals.
4. Warranties (Guarantees).
5. Specification Compliance.
6. Additional Requirements of Section 20 05 03.

B. Shop Drawings and Product Data Submittals: In addition to the requirements of Section 20 05 03, the contractor shall provide shop drawings and product data on hardware, software, and equipment to be installed or provided. No work may begin on any segment of this project until submittals have been approved for conformity with design intent. Provide submittal data in a digital format on suitable digital media such as a USB drive. The submittal data shall be in standard Microsoft (Word, Excel, etc.) or PDF file formats. The shop drawings shall be formatted to fit on 11" x 17" pages and hardware/software product data shall be formatted to fit on 8.5" x 11" pages. When manufacturer's cutsheets apply to a product series rather than a specific product, the data specifically applicable to the project shall be highlighted or clearly indicated by other means. Each submitted piece of literature and drawing shall clearly reference the specification and/or drawing that the submittal is to cover. General catalogs shall not be accepted as cutsheets to fulfill submittal requirements. Select and show submittal quantities appropriate to scope of work. Submittal approval does not relieve Contractor of responsibility to supply sufficient quantities to complete work. Submittals shall be provided within 12 weeks of contract award. The Shop Drawings shall include, but not be limited to:

1. All equipment, hardware and software to be installed and/or provided.
2. Network & BACnet Package: Project-specific network riser showing servers, supervisors, routers/BBMDs, IP subnets/VLAN IDs, BACnet/IP UDP ports, NTP sources, and firewall/ACL touchpoints. Provide IP addressing plan, hostname convention, and BACnet Device ID/instance ranges with no duplicates.
3. BTL Compliance: BACnet Protocol Implementation Conformance Statement (PICS) and device profiles for all controllers/routers (B-BC/B-AAC/B-ASC as applicable) and operator interface.
4. Master Points Register (CSV/Excel): For every point—Tag, Equipment, BACnet Object Type & Instance, Units, Engineering Range, Writable (Y/N), Alarm Class/limits/delay, Trend interval/retention, Graphic binding.
5. Graphics/UI Package: System graphics showing all monitored or controlled systems, data (connected and calculated) point addresses, and operator notations.
6. BCAS central system configuration complete with all direct digital controllers (controller panels), peripheral devices, batteries, power supplies, diagrams, Operator interface equipment, and similar items with interconnection diagrams.
7. Provide a flow diagram depicting the program control algorithms and how they are implemented on this project with specific input and output points shown.
8. One-line diagrams from sensor and control points to I/O boards and controllers, including all components, signal values and cables.
9. Test Reports: Description of test exercise events and results of measurements and observations.
10. Site Acceptance Test (SAT): Point-to-point check forms, alarm routing tests, trend performance (interval/retention), and network failover/BBMD tests.
11. A complete bill of material of equipment used indicating quantity, manufacturer, model number, and relevant technical.
12. Technical specification data sheets of each system component and devices, with products to be furnished specifically highlighted or noted (marked). Data sheets shall show adjustment capabilities, performance criteria, and accuracy limits for each specific application.
13. Licensing agreement for each licensed software module.

14. A written sequence of operation for each controlled or monitored system and control function.
15. Complete control drawings showing all control components with control wiring diagrams, control power requirements, Fire Alarm System interface, and other information required for review of the system. Cut sheets on wiring materials shall be submitted.
16. A control valve selection chart with system type, controlled equipment, gpm, CV, and pressure drop noted for each valve selection. Pressure ratings, leakage ratings, and dead-end isolation pressure ratings for all valves.
17. Reports or information requiring certification shall be certified by an authorized office of the manufacturer or testing agency.
18. Equipment and material submittals shall show sufficient data including all performance curves, sound data, recommended installation details, and sufficient data to indicate complete compliance with the Contract Documents, including proper sizes, clearances, materials, and finishes.
19. Record floor plan drawings showing proposed locations of all wall-mounted and return air path space temperature sensors, and all field panels.
20. Additional information as required in Section 20 05 03.

C. Samples: Submit samples, upon request, of control and automation devices and materials for review by the Architect/Engineer. Samples will be returned upon written request of the Contractor.

D. Operating and Maintenance Manuals: As a minimum, the following information shall be provided (provide both searchable PDF manuals and as-built system package) as follows:

1. General description and specifications for all components.
2. Principles and theory of operation.
3. Detailed schematics and assembly drawings and detailed alignment and calibration procedures for all components.
4. Upon completion of installation, submit record (as-built) documents for approval before final completion. Provide record documents in a digital format on suitable digital media such as a USB drive. The record documents shall be in standard Microsoft (Word, Excel, etc.) or PDF file formats except as noted below. Record documentation shall include the following:

    a. Project Record Drawings
    b. Testing and Commissioning Reports and Checklists.
    c. Operation and Maintenance (O&M) Manual.
    d. As-built versions of submittal product data.
    e. Names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems.
    f. Operator’s manual with procedures for operating control systems: logging on and off, handling alarms, producing point reports, trending data, overriding computer control, and changing setpoints and variables.
    g. Programming manual or set of manuals with description of programming language and syntax, of statements for algorithms and calculations used, of point database creation and modification, of program creation and modification, and of editor use.
    h. Engineering, installation, and maintenance manual or set of manuals that explains how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware.
    i. Documentation of programs operating in the system and object database that can be viewed using technician software tools furnished with system.
    j. Graphic files, programs, and database to be viewed using technician software tools furnished with system.

k. List of recommended spare parts with part numbers and suppliers.
l. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
m. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation or web server software, and graphics software.
n. Licenses, guarantees, and warranty documents for equipment and systems.
o. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.

5. Fully detailed parts lists, including all numbered parts and recommended spare parts, of each item of equipment and apparatus provided under this section.
6. Manufacturer's printed instructions describing operation, service, maintenance, and repair of each item of equipment and apparatus.
7. Typewritten record of tests made of materials, equipment, and systems included under this section. Such records shall state the dates the tests were conducted, name(s) of person(s) making and witnessing the tests and citing any unusual conditions relevant to the tests.
8. Temperature control wiring diagrams complete with instructions outlining each sequential step in the start up and shutdown of the heating/cooling system. Include precautions and instructions for servicing each item of the system.
9. Identifying names, name tags designations and locations for all equipment.
10. Valve tag lists with valve number, type, color coding, location, and function.
11. Copy of all approved Shop Drawing submittals.
12. Fabrication drawings.
13. Equipment and device bulletins and cutsheets clearly highlighted to show equipment on the project and including performance curves and data as applicable.
14. Maintenance instructions clearly highlighted to show all required periodic maintenance and lubrication. Complete trouble-shooting procedures, diagrams, and guidelines.
15. Wiring diagrams.
16. Operator's Manual: Complete instruction with keyboard pictures and step-by-step procedures annotated to properly describe the system and its operation as installed. Provide index and tabbed sections for each operator function.

    a. Operator's Manual shall be provided with graphic explanations of keyboard and mouse use for all operator functions specified under Operator Training, including graphic mode. Although operator functions are to be self-instructional, and menu-interactive from the keyboard terminal, this manual shall be for off-line study and refresher use.

17. Programmer's Manual: A Programmer's Manual shall be provided with graphic descriptions of all keyboard functions required for software modifications and development specified under Programmer Training. Although high-level languages may be required to be usable on the system, full language manuals and training are not required. The use and installation of high-level type programs shall be included in this manual.
18. Provide one copy of the final version of all software in a digital format on suitable digital media such as USB drive.
19. Document all user-performed maintenance, including inspection, preventive maintenance, fault diagnosis and repair/replacement of defective components. Provide properly identified ordering number for each system components and source of supply. Provide a list of recommended spare parts needed to minimize downtime of the DDC control system.

20. Interconnection wiring diagrams and wire lists of the complete field installed system with ordering number for each component.
21. An operator's reference table listing the addresses of all connected input points, output points, and unguarded software parameters. Settings shall be shown where applicable.
22. Flow charts of the energy management software programs utilized in the system.
23. Flow charts of the custom software programs utilized in the system.
24. A complete program listing file and parameter listing for all programs.
25. The BCAS contractor shall maintain computer file copies of all data file and application software for reload use in the event of a system crash or memory failure, including all special and custom programs. One copy shall be delivered to the Owner during training session and one copy shall be archived in the BCAS manufacturer's local software vault.
26. Exploded parts views showing modular parts and parts lists for all equipment and devices and part sources for all parts.
27. Location and listing of all spare parts and special keys and tools furnished to the Owner.
28. Load into the control system for access by the operator through any operator workstation closeout documentation. There shall be a menu or navigation tab to access the documentation. The documentation can be loaded into the control system in a pdf format. The following documentation shall be included:

    a. As-built control diagrams including wiring diagrams and sequences of operations for each controller/piece of equipment.
    b. All IOM data as follows:

        1) IOM from each equipment manufacturer for each piece of equipment (AHUs, FCUs, Chillers, pumps etc.)
        2) IOM for each control module and end device installed in the system.

29. Training Materials: Provide course outline and materials for each class at least six weeks before first class. Training shall be furnished via instructor-led sessions, computer-based training, or web-based training. Engineer will modify course outlines and materials if necessary to meet Owner’s needs. Engineer will review and approve course outlines and materials at least three weeks before first class.
30. Other requirements of Section 20 05 03.

E. Any items missing in the submittal, whether reviewed and returned by the engineer with or without revise and resubmit, does not relinquish the requirement from the contractor to provide all parts, pieces, programming required for a functional and maintainable system.

1.07 CALIBRATION, LOOP TUNING, AND ADJUSTMENTS

A. General: Coordinate with Section 23 05 93 – Testing, Adjusting, and Balancing. TAB is responsible for air and hydronic balancing; BAS Contractor is responsible for sensor calibration, controller/loop tuning, sequence verification, and setpoint implementation required for proper operation per drawings, specifications, manufacturer recommendations, and Section 25 09 93 (Sequences). Calibration, testing, and adjustments shall be completed prior to Site Acceptance Testing (SAT/FPT). Activities shall be witnessed by the Owner’s Building Engineer or designee when scheduled with ≥ 5 business days’ notice.

B. Scope (BAS):

1. Sensor Calibration & Documentation: Calibrate space/duct/water temperature, RH, pressure, and flow sensors per manufacturer methods. Record as-found and as-left values and apply only the minimum offset necessary; upload offsets to the database. Provide NIST-traceable certificates for metering-grade devices (power/BTU/ultrasonic flow).

2. Loop Tuning: Tune PID loops to achieve: ≤ 10% overshoot, ≤ 10 minutes settling to ± 1.0°F (space) or as scheduled, and stable steady-state without sustained hunting.
3. Setpoints & Schedules: Implement all normal/override setpoints, resets, holidays, and exception schedules per Section 25 09 93; verify min/max limits.
4. Equipment Functional Adjustments: Verify proper actuator stroke, fail position, end-switch operation, and VFD min/max speed, ramp times, and start/stop sources.
5. Legacy Pneumatics (If Indicated): *Only where shown on drawings.* Verify compressor operation, dryer performance, and pressure-reducing setpoints; record control air pressures upstream/downstream of each station.

C. The contractor shall furnish a single set of all tools necessary to interface to the control system for test and balance purposes.

D. The contractor shall provide training in the use of these tools. This training will be planned for a minimum of 4 hours.

E. In addition, the contractor shall provide a qualified technician to assist in the test and balance process, until the first 20 terminal units are balanced.

F. The tools used during the test and balance process will be returned at the completion of the testing and balancing

G. Evidence of Completion: Provide a Master Points Register signed by the BAS Contractor certifying 100% point-to-point and graphic binding verification, loop tuning worksheet(s), and calibration records.

H. Certification: Submit a digital certification letter stating the BAS is installed, adjusted, and calibrated to operate as specified, with attachments listed in 1.7.C.

I. Completion Report: Prior to final inspection and after TAB/BAS adjustments and testing, submit a Completion Report including: (1) Master Points Register, (2) calibration/as-left records, (3) loop tuning results, (4) updated setpoint/schedule list, and (5) corrected drawings reflecting device locations & labels. *(Refer also to 23 05 93.)*

1.08 BCAS TESTING AND CERTIFICATION

A. A complete BCAS checkout and test shall be performed to demonstrate and certify that the BCAS is 100% operational and adjusted upon completion of the installation, and that it complies with all applicable codes and specification requirements. The system checkout and test shall be performed within thirty (30) days of the completion of system installation, adjustment, and commissioning. Testing shall be performed in two (2) parts and two-way radios for use by test observers shall be provided. The first part of the test shall be a full test of all system components, function, and alarms. All affected subcontractors shall participate in this test. All tests shall be witnessed and acknowledged by written signature of the Owner's Building Engineer. Test results shall be certified and submitted to the Engineer. This test shall be the basis for the System Acceptance document specified in this Section. The second part of the test shall be a demonstration of basic system functions and alarms for the Engineer and Owner's Representative.

B. This Contractor shall coordinate the test schedule with the General Contractor, Electrical Contractor, Mechanical Contractor, Fire Protection Contractor, Fire Alarm Contractor, and other Contractors required to be present for a complete and functional test.

C. The system checkout and test shall be a comprehensive 100% inspection and functional test of all equipment and software and shall include, but not be limited to, the following:

1. The contractor shall furnish all labor and test apparatus required to calibrate and prepare for service of all instruments, controls, and accessory equipment furnished under this specification.
2. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
3. Enable the control systems and verify calibration of all input devices individually. Perform calibration procedures according to manufacturers' recommendations.
4. Verify that all binary output devices (relays, solenoid valves, two-position actuators and control valves, magnetic starters, etc.) operate properly and that the normal positions are correct.
5. Verify that all analog output devices (I/Ps, actuators, etc.) are functional, that start and span are correct, and that direction and normal positions are correct. The contractor shall check all control valves and automatic dampers to ensure proper action and closure. The contractor shall make any necessary adjustments to valve stem and damper blade travel.
6. Verify that the system operation adheres to the sequences of operation. Simulate and observe all modes of operation by overriding and varying inputs and schedules. Tune all DDC loops.
7. Alarms and Interlocks:
8. Check each alarm separately by including an appropriate signal at a value that will trip the alarm.
9. Interlocks shall be tripped using field contacts to check the logic, as well as to ensure that the fail-safe condition for all actuators is in the proper direction.
10. Interlock actions shall be tested by simulating alarm conditions to check the initiating value of the variable and interlock action.
11. Other testing required by Section 23 05 93.

D. Fire Alarm System Interface Testing: Testing of the BCAS interface with the fire alarm system for smoke management, air handling unit shutdown, fire/smoke damper control, duct smoke detector annunciation and other specified interfaces shall be coordinated with the Division 28 fire alarm testing and certification.

E. Emergency Power Operation Testing: Testing of BCAS operation under emergency shall be coordinated with the Division 26 Contractor such that the testing is conducted along with the Division 26 emergency power system testing and certification.

1.09 SYSTEM ACCEPTANCE

A. The BCAS Manufacturer shall issue a report upon completion stating that the system is complete, has been adjusted, has had all hardware and software functions verified, and is operating in accordance with the specifications. Any deviations from specified settings or operations necessitated during system adjustment shall be specifically noted. A demonstration of complete system operation shall be made to the Engineer and Owner's Representative.

B. Upon receipt of a detailed punch list from the Engineer or Owner's Representative, an installation inspection report shall be prepared by the BCAS Contractor showing, by system, each outstanding item on the punch list. After all items appearing on the installation inspection report are completed, a second written request for system approval shall be made to the Owner's Representative. As each or all items are approved, an appropriate notation shall be entered on the system report at the time of joint inspection, with counter signature by the Owner's Representative and date. A copy of this report shall be made for the Owner's Representative.

C. Where it is required for the BCAS Contractor to modify, alter, add, or remove hardware or software programs of the building automation system or related accessories for the purpose of eliminating punch list items, off-line operation and testing to implement them shall be done as required by the BCAS Contractor until such time acceptance performance of the building automation system has been established.

D. Problems that occur within hardware or software shall be corrected in an appropriate fashion under guarantee. Any such occurrence shall not void previous approval; however, the BCAS Contractor shall be responsible to attend to and remedy such items within a reasonable amount of time. Appropriate logs, schedules, and reports shall be maintained to reflect these items and their redress.

1.10 CLEANING

A. The contractor shall clean up all debris resulting from his/her activities daily. The contractor shall remove all cartons, containers, crates, etc., under his/her control as soon as their contents have been removed. Waste shall be collected and placed in a designated location.

B. At the completion of work in any area, the contractor shall clean all work, equipment, etc., keeping it free from dust, dirt, and debris, etc.

C. At the completion of work, all equipment furnished under this section shall be checked for paint damage, and any factory-finished paint that has been damaged shall be repaired to match the adjacent areas. Any cabinet or enclosure that has been deformed shall be replaced with new material and repainted to match the adjacent areas.

1.11 OWNER TRAINING

A. General: This Contractor and appropriate factory-trained representatives shall instruct the Owner's personnel in the proper operation and maintenance of all systems and equipment and shall explain all warranties.

B. Outline: Prior to instruction of Owner Personnel, prepare a typed outline, listing the subjects that will be included in this instruction.

C. Certification: At the conclusion of the instruction period obtain the signature of each person being instructed on each copy of the approved outline to signify that he has a proper understanding of the operation and maintenance of the systems.

D. Training shall enable students to accomplish the following objectives.

1. Day-to-day Operators:

   a. Proficiently operate the system
   b. Understand control system architecture and configuration
   c. Understand DDC system components
   d. Understand system operation, including DDC system control and optimizing routines (algorithms)
   e. Operate the workstation and peripherals
   f. Log on and off the system
   g. Access graphics, point reports, and logs
   h. Adjust and change system set points, time schedules, and holiday schedules
   i. Recognize malfunctions of the system by observation of the printed copy and graphical visual signals
   j. Understand system drawings and Operation and Maintenance manual
   k. Understand the job layout and location of control components
   l. Access data from DDC controllers and ASCs
   m. Operate portable operator’s terminals

2. Advanced Operators:

    a. Make and change graphics on the workstation
    b. Create, delete, and modify alarms, including annunciation and routing of these
    c. Create, delete, and modify point trend logs and graph or print these both on an ad-hoc basis and at user-definable time intervals
    d. Create, delete, and modify reports
    e. Add, remove, and modify system's physical points
    f. Create, modify, and delete programming
    g. Add panels when required
    h. Add operator interface stations
    i. Create, delete, and modify system displays, both graphical and others
    j. Perform DDC system field checkout procedures
    k. Perform DDC controller unit operation and maintenance procedures
    l. Perform workstation and peripheral operation and maintenance procedures
    m. Perform DDC system diagnostic procedures
    n. Configure hardware including PC boards, switches, communication, and I/O points
    o. Maintain, calibrate, troubleshoot, diagnose, and repair hardware
    p. Adjust, calibrate, and replace system components

3. System Managers/Administrators:

    a. Maintain software and prepare backups
    b. Interface with job-specific, third-party operator software
    c. Add new users and understand password security procedures

E. Organize the training into sessions or modules for the three levels of operators listed above. (Day-to-Day Operators, Advanced Operators, System Managers and Administrators). Students will receive one or more of the training packages, depending on knowledge level required.

F. Provide course outline and materials according to the "Submittals" article in Part 1 of this specification. Provide one copy of training material per student.

G. The instructor(s) shall be factory-trained and experienced in presenting this material.

H. Classroom training shall be done using a network of working controllers representative of installed hardware.

I. Day to day Operator and System/Manager/Administrator training shall be in a classroom format at the project site and shall be scheduled at the Owners convenience. Class size shall be approximately but not limited to eight per session. All dates are coordinated with the Owner during construction and acceptance phases.

J. Advanced Operator training shall be for minimum two (2) Owner personnel and shall be scheduled by the Owner with two (2) week notice anytime during the warranty period.

K. Other Requirements: Refer to other Division 23 Sections for additional Operator Training requirements.

L. Contractor to provide minimum 120 hours of training for the Owner between turnover and Warranty phase to accommodate all the requirements shown above.

1.12 WARRANTIES AND GUARANTEES

A. General: Contractor shall guarantee all material and equipment installed by him against defects in workmanship and material and provide service for a period of sixty (60) months after final acceptance of the work by the Owner and he shall repair or replace any materials or equipment developing such defects within that time, promptly on due notice given him by the Owner and at Contractor's sole cost and expense. This encompasses full parts and labor warranty for the 5-year period as indicated above.

B. Service shall be accomplished, and guarantee fulfilled by qualified employees of the BCAS Contractor.

C. Indirect temperature control service by independent contractors, distributors and franchised installers will not be acceptable.

D. Warranty servicing shall include, but not limited to, the following:

1. Replacing defective parts and components as required.
2. Servicing by factory-trained and locally employed service representative of system contractor.
3. Maintaining of system programming to ensure application programs operate in accordance with the original sequence of operation.

1.13 OWNERSHIP OF PROPRIETARY MATERIAL

A. Project-specific software and documentation shall become Owner’s property. This includes, but is not limited to:

1. Graphics
2. Record drawings
3. Database
4. Application programming code
5. Documentation

1.14 PRODUCTS FURNISHED BY OTHERS AND INTEGRATED INTO BAS:

A. General: The BAS shall be capable of integrating to any third party equipment using the following standard open protocols:

1. BACnet (IP, SC, Arcnet, or MS/TP)
2. Modbus (RTU or IP)

B. The third party equipment provider shall provide the details of the proposed interface including PICS for BACnet equipment, hardware and software identifiers for the interface points, network identifiers, wiring requirements, communication speeds, and required network accessories.

C. The third party equipment provider is responsible for furnishing and installing their interface pre-programmed and configured with the correct parameters to integrate with the BAS. These parameters include, but are not limited to the following:

1. Communication protocol
2. Correct communication protocol baud rate
3. Points required to be viewed through the BAS. This includes ensuring the points are “in service” and visible to the BAS.
4. Addressing of controller/interface. The BAS provider shall furnish the address.

D. The third party equipment manufacturer shall include a minimum of 16 hours of onsite technical support for integration into the BAS.

PART 2 - PRODUCTS

2.01 GENERAL

A. Provide temperature control products in the size, capacities, and quality indicated by these Specifications and as required, conforming to manufacturer's standard materials and components as published in their product information, designed, and constructed as recommended by the manufacturer, and as required for the application indicated or required. These Specifications shall be considered minimum standards in all situations.

B. Provide all sensors, thermostats, relays, switches, control valves, dampers, operators, instrumentation, and other devices required for operation and interface of the Building Control and Automation System (BCAS).

2.02 COMMUNICATION

A. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork. Controller and operator interface communication shall conform to ANSI/ASHRAE Standard 135, BACnet.

B. All IP based controllers shall be capable of providing IPv4 or IPv6 protocol standards as defined by the Internet Data Communications Standard.

C. The BMS contractor shall provide all communication media, connectors, repeaters and network switches/routers, and network devices necessary to provide a complete and workable control network.

D. Each controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.

E. Internetwork operator interface and value passing shall be transparent to internetwork architecture.

1. An operator interface connected to a controller shall allow the operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, and control algorithms shall be viewable and editable from each internetwork controller.
2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the internetwork. Program and test all cross-controller links required to execute specified sequences of operations. An authorized operator shall be able to edit cross-controller links by typing a standard object address or by using a point-and-click interface.

F. Building Control Panels and Controllers with real-time clocks shall use the BACnet Time Synchronization service. System shall automatically synchronize system clocks daily from an operator-designated device via the internetwork. The system shall automatically adjust for daylight saving and standard time as applicable.

G. System shall be expandable to at least twice the required BACnet objects. No additional licensing/software fees shall be required to add controllers, associated devices, and wiring.

H. System shall support Web services data exchange with any other system that complies with XML (extensible markup language) and SOAP (simple object access protocol) standards. Web services support shall as a minimum be provided at the workstation or web server level and shall enable data to be read from or written to the system.

1. System shall support Web services read data requests by retrieving requested trend data or point values (I/O hardware points, analog value software points, or binary value software points) from any system controller or from the trend history database.
2. System shall support Web services write data request to each analog and binary object that can be edited through the system operator interface by downloading a numeric value to the specified object.
3. For read or write requests, the system shall require user name and password authentication and shall support TLS (Transport Layer Security) or equivalent data encryption.
4. System shall support discovery through a Web services connection or shall provide a tool available through the Operator Interface that will reveal the path/identifier needed to allow a third party Web services device to read data from or write data to any object in the system which supports this service.

2.03 OPERATOR INTERFACE

A. Operator Interface. The web server shall reside on a high-speed network with the building controllers. Web pages generated by this server shall be compatible with the latest versions of Microsoft Edge, Google Chrome, Mozilla Firefox, and Apple Safari browsers. Any of these supported browsers connected to the server shall be able to access all system information. Mobile devices shall be recognized by the web server and shall supply the appropriate system content as needed. The Operator Interface (web server with client devices) shall conform to the BACnet Operator Workstation (B-OWS) or BACnet Advanced Workstation (B-AWS) device profile as specified in ASHRAE/ANSI 135 BACnet Annex L. This includes the ability to configure and/or reconfigure the system from the client device (change programs, graphics, labels, etc.).

B. Communication. Web server and controllers shall communicate using the BACnet protocol. Web server and control network backbone shall communicate using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing as specified in ANSI/ASHRAE 135, BACnet Annex J. Communication between the web server and client (workstation) shall be HTTP or HTTPS protocol utilizing HTML5 language. Use of Adobe Flash in any part of the communication infrastructure is not acceptable.

C. Hardware:

1. Web server and/or workstation. Industry-standard hardware shall meet or exceed DDC system manufacturer's recommended specifications and shall meet response times specified elsewhere in this document. The web server may also be configured in client/server fashion to accommodate a "workstation" definition. In "workstation" configuration, the workstation will also perform as a server supplying additional clients as needed. The following hardware requirements apply:

a. System storage shall have sufficient memory to accommodate:

1) All required system software.
2) A DDC database to accommodate, as a minimum, twice the size of the delivered system database.
3) Two years of archival trend data based on the points specified to be trended at their specified trend intervals.

b. Provide additional hardware (communication ports, video drivers, network interface cards, cabling, etc.) to facilitate all control functions and software requirements specified for the DDC system.
c. Minimum hardware configuration shall include the following:

1) Quad Core Processor
2) 4-24 GB RAM (size dependent on size of system)
3) 500 GB hard disk providing data at 3.0 Gb/sec (size dependent on historical data storage requirements)
4) 16x DVD+/-RW drive
5) Qwerty Keyboard
6) Optical Mouse
7) 24-inch LED Color monitor with 75Hz refresh rate and 1080P resolution to provide a minimum screen resolution of 1920 x 1080 pixels.
8) Serial (USB) and network communication ports, with cables as required for proper DDC system operation

D. System Software:

1. Operating System. Web server shall have an industry-standard professional-grade operating system. Operating system shall meet or exceed the BMS manufacturer's minimum requirements to support their software. Acceptable systems include the most recent version of a Microsoft Windows Server, Red Hat Enterprise Linux, or Ubuntu Desktop, or Owner's preferred/selected system.
2. Security. The web server application shall support Transport Layer Security (TLS) 1.3 capable of encryption of up to 256 bit elliptical curve for transmitting private information over the Internet using HTTPS. Additionally, the web server shall have SHA-2 certificate support capability.
3. Database. System shall support any JDBC (Java DataBase Connectivity) compliant engine. This includes: MS SQL, My SQL, Apache Derby, PostgreSQL and Oracle.
4. The BMS system shall allow an unlimited number of concurrent users.
5. The BMS manufacturer shall provide all software and tools necessary to provide the following capabilities:

a. Create and/or edit any programming used in controllers
b. Create and/or edit any graphics used in the system
c. Software shall not be subscription based and be given to owner at time of turnover. If software is subscription based, manufacturer shall include 10 years of subscription service.
d. The owner shall have the ability to install software on a minimum of five (5) additional owner furnished computers without additional licenses or fees.

6. System Graphics. The operator interface software shall be graphically based and shall include at least one graphic per piece of equipment or occupied zone, graphics for each chilled water and hot water system, and graphics that summarize conditions on each floor of each building included in this contract. Indicate thermal comfort on floor plan summary graphics using dynamic colors to represent zone temperature relative to zone setpoint.

a. Minimum graphics resolution shall be 1920 x1080 for display of detailed system graphics.
b. Floor Plan Graphics. Floor plan graphics shall be capable of allowing the floor plan graphic to dynamically size relative to the end user's monitor resolution.
c. Functionality. Graphics shall allow operator to monitor system status, to view a summary of the most important data for each controlled zone or piece of equipment, to use point-and-click navigation between zones or equipment, and to edit setpoints and other specified parameters.

d. Animation. Graphics shall be able to animate by displaying different image files for changed object status.
e. Alarm Indication. Indicate areas or equipment in an alarm condition using color or other visual indicator.
f. Format. Graphics shall be saved in an industry-standard format such as BMP, JPEG, PNG, GIF, or SVG. Web-based system graphics shall be viewable on browsers compatible with World Wide Web Consortium browser standards. Web graphic format shall require no plug-in) or shall only require widely available no-cost plug-ins (such as Active-X or Adobe Flash).

7. Custom Graphics. Custom graphic files shall be created with the use of a graphics generation package furnished with the BMS system. The graphics generation package shall be a graphically based system to create and modify graphics that are saved in the same formats as are used for system graphics..
8. Graphics Library. Furnish a complete library of standard HVAC equipment graphics such as chillers, boilers, air handlers, terminals, fan coils, and unit ventilators. This library also shall include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork. The library shall be furnished in a file format compatible with the graphics generation package program.

E. System Applications. System shall provide the following functionality to authorized operators as an integral part of the operator interface or as stand-alone software programs. If furnished as part of the interface, the tool shall be available from each workstation or web browser interface. If furnished as a stand-alone program, software shall be installable on standard PC type personal computer with no limit on the number of copies that can be installed under the system license.

1. Automatic System Database Configuration. Each workstation or web server shall store on its hard disk a copy of the current system database, including controller firmware and software. Stored database shall be automatically updated with each system configuration or controller firmware or software change.
2. Manual Controller Memory Download. Operators shall be able to download memory from the system database to each controller.
3. System Configuration. The workstation software shall provide a method of configuring the system. This shall allow for future system changes or additions by users under proper password.
4. On-Line Help. Provide a context-sensitive, on-line help system to assist the operator in operating and editing the system. On-line help shall be available for all applications and shall provide the relevant data for that particular screen. Additional help information shall be available through the use of hypertext.
5. Security. Each operator shall be required to log on to the system with a user name and password in order to view, edit, add, or delete data.

a. Operator Access. The user name and password combination shall define accessible viewing, editing, adding, and deleting privileges for that operator. Users with system administrator rights shall be able to create new users and edit the privileges of all existing users. System Administrators shall also be able to vary and deny each operator’s privileges based on the geographic location, such as the ability to edit operating parameters in Building A, to view but not edit parameters in Building B, and to not even see equipment in Building C.
b. Password Policy Rules. System administrator shall invoke policies for minimum password strength, including number of characters, special characters and numbers, upper and lower case, etc.
c. Automatic Log Out. Automatically log out each operator if no keyboard or mouse activity is detected. This auto logoff time shall be user adjustable.
d. Encrypted Security Data. Store system security data including operator passwords in an encrypted format. System shall not display operator passwords.

6. System Diagnostics. The system shall automatically monitor the operation of all building management panels and controllers. The failure of any device shall be annunciated to the operator
7. Alarm Processing. System input and status objects shall be configurable to alarm on departing from and on returning to normal state. Operator shall be able to enable or disable each alarm and to configure alarm limits, alarm limit differentials, alarm states, and alarm reactions for each system object. Configure and enable alarm points as required by sequences of operation. Alarms shall be BACnet alarm objects and shall use BACnet alarm services. BMS system shall be capable of assigning alarm sources to categories such as HVAC Critical, or HVAC General. The BMS shall include at a minimum HVAC and FDD categories. BMS system shall allow user to create custom alarm categories.
8. Alarm Messages. Alarm messages shall use the English language descriptor for the object in alarm in such a way that the operator will be able to recognize the source, location, and nature of the alarm without relying on acronyms or mnemonics.
9. Alarm Reactions. Operator shall be able to configure (by object) what, if any actions are to be taken during an alarm. As a minimum, the workstation or web server shall be able to log, print, start programs, display messages, send e-mail, send SMS text, and audibly annunciate.
10. Alarm and Event log. Operators shall be able to view all system alarms and changes of state from any location in the system. Events shall be listed chronologically. An operator with the proper security level may acknowledge and delete alarms, and archive closed alarms to the workstation or web server hard.
11. Trend Logs. The operator shall be able to configure trend sample or change of value (COV) interval, start time, and stop time for each system data object and shall be able to retrieve data for use in spreadsheets and standard database programs. Controller shall sample and store trend data and shall be able to archive data to the hard disk. Configure trends as required by the sequences of operations. Trends shall be BACnet trend objects. As a minimum, all physical points in the system shall be trended within the local controller (AAC, ASC, BC) for at least 277 samples per point. Selected points, as desired, shall be available for historical archiving within the server. The historical archiving capability cannot be less than 2 years.
12. Object and Property Status and Control. Provide a method for the operator to view, and edit if applicable, the status of any object or property in the system. The status shall be available by menu, on graphics, or through custom programs.
13. Reports and Logs. Operator shall be able to select, to modify, to create, and to print reports and logs. Operator shall be able to store report data in a format accessible by standard spreadsheet and word processing programs.
14. Audit and Security Detail. All users accessing the system shall have their actions recorded. Information recorded shall include:

    a. Login/logout time and date
    b. System modifications – with before and after values;
    c. Ability to report user activity based on individual and/or date and time.

15. Standard Reports. Furnish the following standard system reports:

    a. Objects. System objects and current values filtered by object type, by status (in alarm, locked, normal), by equipment, by geographic location, or by combination of filter criteria.
    b. Alarm Summary. Current alarms and closed alarms. System shall retain closed alarms for an adjustable period.
    c. Logs. System shall log the following to a database or text file and shall retain data for an adjustable period:

1) Alarm History.
2) Trend Data. Operator shall be able to select trends to be logged.

16. Custom Reports. Operator shall be able to create custom reports that retrieve data, including archived trend data, from the system, that analyze data using common algebraic calculations, and that present results in tabular or graphical format. Reports shall be launched from the operator interface. Operator shall be able to schedule reports to automatically run and be emailed to recipients on a recurring basis from the BMS system.
17. Semantic Tagging. The BMS system shall include a semantic tagging engine that uses the Project Haystack library of descriptive tagging for building equipment and systems used in the BMS. The Project Haystack naming tags used by the BMS shall be a library that includes a comprehensive list of standard tag names to address common equipment, building systems, and device types. The library tag of names shall include at a minimum the tag names listed in ASHRAE Standard 223P.

F. Workstation Application Editors. Each PC or browser workstation shall support editing of all system applications. The applications shall be downloaded and executed at one or more of the controller panels.

1. Controller. Provide a full-screen editor for each type of application that shall allow the operator to view and change the configuration, name, control parameters, and set points for all controllers.
2. Scheduling. An editor for the scheduling application shall be provided at each workstation. Provide a method of selecting the desired schedule and schedule type. Exception schedules and holidays shall be shown clearly on the calendar. The start and stop times for each object shall be adjustable from this interface.
3. Custom Application Programming. Provide the tools to create, edit, debug, and download custom programs. System shall be fully operable while custom programs are edited, compiled, and downloaded. Programming language shall have the following features:

a. Language. Language shall be graphically based or English oriented. If graphically based, language shall use function blocks arranged in a logic diagram that clearly shows control logic flow. Function blocks shall directly provide functions listed below, and operators shall be able to create custom or compound function blocks. If English language oriented, language shall be based on the syntax of BASIC, FORTRAN, C, or PASCAL, and shall allow for free-form programming that is not column-oriented or “fill-in-the-blanks.”
b. Programming Environment. Tool shall provide a full-screen, cursor-and-mouse-driven programming environment that incorporates word processing features such as cut and paste. Operators shall be able to insert, add, modify, and delete custom programming code, and to copy blocks of code to a file library for reuse in other control programs.
c. Independent Program Modules. Operator shall be able to develop independently executing program modules that can disable, enable and exchange data with other program modules.
d. Debugging and Simulation. Operator shall be able to step through the program observing intermediate values and results. Operator shall be able to adjust input variables to simulate actual operating conditions. Operator shall be able to adjust each step’s time increment to observe operation of delays, integrators, and other time-sensitive control logic. Debugger shall provide error messages for syntax and for execution errors.
e. Conditional Statements. Operator shall be able to program conditional logic using compound Boolean (AND, OR, and NOT) and relational (EQUAL, LESS THAN, GREATER THAN, NOT EQUAL) comparisons.

f. Mathematical Functions. Language shall support floating-point addition, subtraction, multiplication, division, and square root operations, as well as absolute value calculation and programmatic selection of minimum and maximum values from a list of values.

g. Variables. Operator shall be able to use variable values in program conditional statements and mathematical functions.

1) Time Variables. Operator shall be able to use predefined variables to represent time of day, day of the week, month of the year, and date. Other predefined variables or simple control logic shall provide elapsed time in seconds, minutes, hours, and days. Operator shall be able to start, stop, and reset elapsed time variables using the program language.

2) System Variables. Operator shall be able to use predefined variables to represent status and results of Controller Software and shall be able to enable, disable, and change setpoints of Controller Software as described in Controller Software section.

2.04 CONTROLLER SOFTWARE

A. All controller software applications shall reside and operate in the system controllers.

B. All application software in controllers furnished by BMS manufacturer shall be editable through operator workstation, web browser interface, or workstation.

C. Each controller furnished by BMS manufacturer shall have all of its local on board software applications backed up and saved to the BMS web server. In the event of a controller failure, the BMS server shall download backed up software applications to replacement controller. Controllers furnished by others and integrated into the BMS are not required to be backed up to BMS server.

D. Furnish the following applications for building and energy management:

1. System Security.
2. Scheduling. Provide the capability to execute control functions according to a user created or edited schedule. Each schedule shall provide the following schedule options as a minimum:
3. Weekly Schedule. Provide separate schedules for each day of the week. Each schedule shall be able to include up to 5 occupied periods (5 start-stop pairs or 10 events).
4. Exception Schedules. Provide the ability for the operator to designate any day of the year as an exception schedule. Exception schedules may be defined up to a year in advance. Once an exception schedule has executed, the system shall discard and replace the exception schedule with the standard schedule for that day of the week.
5. Holiday Schedules. Provide the capability for the operator to define up to 24 special or holiday schedules These schedules will be repeated each year. The operator shall be able to define the length of each holiday period. System Coordination. Operator shall be able to group related equipment based on function and location and to use these groups for scheduling and other applications.
6. Binary Alarms. Each binary object shall have the capability to be configured to alarm based on the operator-specified state. Provide the capability to automatically and manually disable alarming.
7. Analog Alarms. Each analog object shall have both high and low alarm limits. The operator shall be able to enable or disable these alarms.
8. Alarm Reporting. The operator shall be able to determine the action to be taken in the event of an alarm. An alarm shall be able to start programs, print, be logged in the event log, generate custom messages, and display on graphics.

9. Remote Communication. System shall automatically contact operator workstation or server on receipt of critical alarms. If no network connection is available, system shall use a modem connection.
10. Demand Limiting.

    a. The demand-limiting program shall monitor building power consumption from a building power meter (provided by others) which generates pulse signals or a BACnet communications interface. An acceptable alternative is for the system to monitor a watt transducer or current transformer attached to the building feeder lines.
    b. When power consumption exceeds adjustable levels, system shall automatically adjust setpoints, de-energize low-priority equipment, and take other programmatic actions to reduce demand as specified in sequences of operation. When demand drops below adjustable levels, system shall restore loads as specified.

11. Maintenance Management. The system shall be capable of generating maintenance alarms when equipment exceeds adjustable runtime, equipment starts, or performance limits. Configure and enable maintenance alarms as specified in sequences of operations.
12. Sequencing. Application software shall sequence each piece of equipment as required by the specified sequences of operations.
13. PID Control. System shall provide direct- and reverse-acting PID (proportional-integral-derivative) algorithms. Each algorithm shall have anti-windup and selectable controlled variable, setpoint, and PID gains. Each algorithm shall calculate a time-varying analog value that can be used to position an output or to stage a series of outputs. The calculation interval, PID gains, and other tuning parameters shall be adjustable by a user with the correct security level.
14. Staggered Start. System shall stagger controlled equipment restart after power outage. Operator shall be able to adjust equipment restart order and time delay between equipment restarts.
15. Energy Calculations.

    a. The system shall accumulate and convert instantaneous power (kW) or flow rates (gpm) to energy usage data.
    b. The system shall calculate a sliding-window average (rolling average). Operator shall be able to adjust window interval to 15 minutes, 30 minutes, or 60 minutes.

16. Anti-Short Cycling. All binary output objects shall be protected from short cycling by means of adjustable minimum on-time and off-time settings.
17. On and Off Control with Differential. Provide an algorithm that allows a binary output to be cycled based on a controlled variable and a setpoint. The algorithm shall be direct-acting or reverse-acting..
18. Runtime Totalization. Provide software to totalize runtime for each binary input and output. Operator shall be able to enable runtime alarm based on exceeded adjustable runtime limit. Configure and enable runtime totalization and alarms as required by Sequence of Operations.

2.05 **CONTROLLERS**

A. General. Provide an adequate number of Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), Smart Actuators (SA), and Smart Sensors (SS) as required to achieve performance as specified by system performance. Every device in the system which executes control logic and directly controls HVAC equipment must conform to a standard BACnet Device profile as specified in ANSI/ASHRAE 135, BACnet Annex L. Unless otherwise specified, hardwired actuators and sensors may be used in lieu of

communicating actuators, communicating sensors, BACnet Smart Actuators, and BACnet Smart Sensors

B. BACnet.

1. Building Controllers (BCs): Each BC shall conform to BACnet Building Controller (B-BC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L, and shall be listed as a certified B-BC in the BACnet Testing Laboratories (BTL) Product Listing.
2. Advanced Application Controllers (AACs): Each AAC shall conform to BACnet Advanced Application Controller (B-AAC) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-AAC in the BACnet Testing Laboratories (BTL) Product Listing.
3. Smart Actuators (SAs): An actuator which is controlled by a network connection rather than a binary or analog signal (0-10v, 4-20mA, relay, etc.). Each SA shall conform to BACnet Smart Actuator (B-SA) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-SA in the BACnet Testing Laboratories (BTL) Product Listing.
4. Smart Sensors (SSs): A sensor which provides information to the BAS via network connection rather than a binary or analog signal (0-10000 ohm, 4-20mA, dry contact, etc.). Each SS shall conform to BACnet Smart Sensor (B-SS) device profile as specified in ANSI/ASHRAE 135, BACnet Annex L and shall be listed as a certified B-SS in the BACnet Testing Laboratories (BTL) Product Listing.
5. BACnet Communication.

    a. Building Controllers (BC) or combination of Building Controller and BACnet Router/Gateway. Each BC shall connect to a network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol using BACnet/IP or BACnet/SC. BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BCs to networks of AACs and ASCs.
    b. Each AAC shall connect to a network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol using BACnet/IP or BACnet/SC.
    c. Each ASC shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
    d. Each SA shall reside on a BACnet network using the ARCNET or MS/TP Data Link/Physical layer protocol.
    e. Each SS shall reside on a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol with BACnet/IP addressing, or it shall reside on a BACnet network using ARCNET or MS/TP Data Link/Physical layer protocol.

C. Security.

1. Provide BACnet firewall capability, as defined in the BACnet standard.

D. Building Controllers (BC)

1. Communication

    a. Network Connection. Controller shall support a single point ethernet connection.
    b. Ethernet Port. Provide one (1) Gig-E port capable of full duplex communication up to 1000 Mbps
    c. Service Port. Provide one (1) ethernet port for connection to a Portable Operator's Terminal.
    d. Signal Management. BC shall have the ability to manage input and output communication signals to allow distributed controllers to share real and virtual object information and to allow for central monitoring and alarms.

e. Data Sharing. Each BC and AAC shall share data as required with each networked BC and AAC.
f. Stand-Alone Operation. Each piece of equipment shall be controlled by a single controller to provide stand-alone control in the event of communication failure. All I/O points specified for a piece of equipment shall be integral to its controller. Provide stable and reliable stand-alone control using default values or other method for values normally read over the network such as outdoor air conditions, supply air or water temperature coming from source equipment, etc.

2. Environment. Controller hardware shall be suitable for anticipated ambient conditions.

a. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at 29°C to 60°C (20°F to 140°F).
b. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).

3. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to a field-removable modular terminal strip or to a termination card connected by a ribbon cable. Each BC and AAC shall continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond.
4. Real-time Clock. Controller shall have a real-time clock to keep track of time in the event of a power failure for up to three (3) days.
5. Memory

a. Controller memory shall support operating system, database, and programming requirements.
b. Each BC shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. System shall automatically download dynamic control parameters following power loss.

E. Advanced Application Controllers (AAC)

1. Communication

a. Network Connection. Controller shall support a single point ethernet connection or a daisy-chained ethernet connection using the Spanning Tree Protocol (STP).
b. Ethernet Port. Provide two (2) 10/100 Base T ethernet ports with ethernet switching capability.
c. Service Port. Provide one (1) USB port for connection to a Portable Operator's Terminal or a display.
d. Stand-Alone Operation. Each piece of equipment shall be controlled by a single controller to provide stand-alone control in the event of communication failure. All I/O points specified for a piece of equipment shall be integral to its controller. Provide stable and reliable stand-alone control using default values or other method for values normally read over the network such as outdoor air conditions, supply air or water temperature coming from source equipment, etc.

2. Environment. Controller hardware shall be suitable for anticipated ambient conditions.

a. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at 29°C to 60°C (20°F to 140°F).

b. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).

3. Serviceability. Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to a field-removable modular terminal strip or to a termination card connected by a ribbon cable. Each AAC shall continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond.
4. Real-time Clock. Controller shall have a real-time clock to keep track of time in the event of a power failure for up to three (3) days.
5. Memory

a. Controller memory shall support operating system, database, and programming requirements.
b. Each AAC shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. System shall automatically download dynamic control parameters following power loss.

F. BACnet Router (B-RTR): BACnet Router provides BACnet routing between any supported BACnet communication types. B-RTR shall serve as a BACnet Broadcast Management Device (BBMD) and shall be capable of supporting Foreign Device Registration (FDR) and DHCP IP addressing.

1. Communication

a. Network Connection: Controller shall support dual ethernet connections.
b. Ethernet Port: Provide dual (2) ethernet port capable of full duplex communication up to 100 Mbps
c. Service Port: Provide one (1) USB 2.0 port for connection to a Portable Operator's Terminal. This port shall be used for device setup and troubleshooting through a local connection to a computer.
d. Signal Management: B-RTR shall have the ability to provide BACnet routing between any supported BACnet communication types including BACnet/IPv4, BACnet/IPV6 and BACnet/SC. Under normal operation, network traffic not destined for this B-RTR shall be repeated to the other port.
e. Primary Ethernet Port: Primary Ethernet Port shall have built-in fail safe. It shall be capable of supporting direct connection or daisy chain topology natively using BACnet/IP and/or BACnet Ethernet communication.
f. Secondary Ethernet Port:

1) Secondary / Regular Port: When Secondary Ethernet Port as a regular port, it shall have built-in fail safe. It shall be capable of supporting direct connection or daisy chain topology natively using BACnet/IP and/or BACnet Ethernet communication.
2) Secondary / Isolated Port: When using Secondary Ethernet Port as an Isolated port shall not have any IP connectivity to the Primary port and B-RTR shall serve as a BBMD for a BACnet/IP network connected to the Primary Port. DHCP IP addressing capability shall be available on this port. BC, AAC or other control devices connected to this port can be assigned a private network and then can follow an address scheme that is independent of the main (Building) IT network.

2. Environment: Controller hardware shall be suitable for anticipated ambient conditions.

a. Controllers used outdoors or in wet ambient conditions shall be mounted or placed in a UL listed waterproof enclosures and must be suitable for the environmental conditions.
b. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at -40°C to 70°C (-40°F to 158°F).

3. Serviceability: Provide diagnostic LEDs for power, communication, and processor. RTR should continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond. B-RTR shall have built-in network diagnostic capture functionality for troubleshooting. Provide ability to view network statistics numerically or as trend graphs.
4. Real-time Clock. Controller shall have a real-time clock to keep track of time in the event of a power failure for up to three (3) days.
5. Memory

a. Controller memory shall support operating system, database, and programming requirements.
b. Each RTR shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. System shall automatically download dynamic control parameters following power loss.

G. Gateway (GW): Gateway provides BACnet routing between any supported BACnet and other protocol communication types. GW shall serve as a BACnet Broadcast Management Device (BBMD) and shall be capable of supporting Foreign Device Registration (FDR) and DHCP IP addressing.

1. Communication

a. Network Connection: Controller shall support dual ethernet connections.
b. Ethernet Port: Provide dual (2) ethernet port capable of full duplex communication up to 100 Mbps
c. Service Port: Provide one (1) USB 2.0 port for connection to a Portable Operator's Terminal. This port shall be used for device setup and troubleshooting through a local connection to a computer.
d. Signal Management: GW shall have the ability to provide BACnet routing between any supported BACnet communication types including BACnet/IPV6 and BACnet/SC in addition to other protocols like Modbus, N2 Open, SNMP and KNX.
e. Ethernet Ports: GW shall be capable of serving as a BBMD for a BACnet/IP network on each of the BACnet/IP networks. Ports shall support direct connection or daisy chain topology natively using BACnet/IP or BACnet/ethernet communication.

2. Environment. Controller hardware shall be suitable for anticipated ambient conditions.

a. Controllers used outdoors or in wet ambient conditions shall be mounted or placed in a UL listed waterproof enclosures and must be suitable for the environmental conditions.
b. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at -40°C to 70°C (-40°F to 158°F).

3. Serviceability. Provide diagnostic LEDs for power, communication, and processor. RTR shall continually check its processor and memory circuit status and shall generate an alarm on abnormal operation. System shall continuously check controller network and generate alarm for each controller that fails to respond. GW shall have built-in network

diagnostic capture functionality for troubleshooting. Provide ability to view network statistics numerically or as trend graphs.

4. Real-time Clock. Controller shall have a real-time clock to keep track of time in the event of a power failure for up to three (3) days.
5. Memory

    a. Controller memory shall support operating system, database, and programming requirements.
    b. Each GW shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. System shall automatically download dynamic control parameters following power loss.

H. Immunity to Power and Noise. Controllers shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage.

I. Transformer. Power supply shall be fused or current limiting and shall be rated at a minimum of 125% of controller power consumption.

2.06 INPUT AND OUTPUT INTERFACE

A. General. Hard-wire input and output points to BCs, AACs, or ASCs.

B. Protection. All input points and output points shall be protected such that shorting of the point to itself, to another point, or to ground shall cause no damage to the controller. All input and output points shall be protected from voltage up to 24 V of any duration, such that contact with this voltage will cause no controller damage.

C. Binary Inputs. Binary inputs shall allow the monitoring of ON/OFF signals from remote devices. Binary inputs shall sense dry contact closure without application of power external to the controller.

D. Pulse Accumulation Inputs. Pulse accumulation inputs shall conform to binary input requirements and shall also accumulate up to 10 pulses per second.

E. Analog Inputs. Analog inputs shall monitor low-voltage (0–10 Vdc), current (4–20 mA), or resistance (thermistor or RTD) signals. Analog inputs shall be compatible with and field configurable to commonly available sensing devices.

F. Binary Outputs. Binary outputs shall provide for ON/OFF operation or a pulsed low-voltage signal for pulse width modulation control. Binary outputs on Building Controllers have three-position (on-off-auto) override switches and status lights. Outputs shall be selectable for normally open or normally closed operation.

G. Analog Outputs. Analog outputs shall provide a modulating signal for the control of end devices. Outputs shall provide either a 0–10 Vdc or a 4–20 mA signal as required to properly control output devices. Each Building Controller analog output shall have a two-position (auto-manual) switch, a manually adjustable potentiometer, and status lights. Analog outputs shall not drift more than 0.4% of range annually.

H. Tri-State Outputs. Control three-point floating electronic actuators without feedback with tri-state outputs (two coordinated binary outputs). Tri-State outputs may be used to provide analog output control in zone control and terminal unit control applications such as VAV terminal units, duct-mounted heating coils, and zone dampers.

I. Universal Inputs and Outputs. Inputs and outputs that can be designated as either binary or analog in software shall conform to the provisions of this section that are appropriate for their designated use.

2.07 POWER SUPPLIES AND LINE FILTERING

A. Power Supplies. Control transformers shall be UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.

1. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. Regulation shall be 1.0% line and load combined, with 100-microsecond response time for 50% load changes. Unit shall have built-in over-voltage and over-current protection and shall be able to withstand 150% current overload for at least three seconds without trip-out or failure.

    a. Unit shall operate between 0°C and 50°C (32°F and 120°F). EM/RF shall meet FCC Class B and VDE 0871 for Class B and MILSTD 810C for shock and vibration.
    b. Line voltage units shall be UL recognized and CSA listed.

B. Power Line Filtering.

1. Provide internal or external transient voltage and surge suppression for workstations and controllers. Surge protection shall have:

    a. Dielectric strength of 1000 V minimum
    b. Response time of 10 nanoseconds or less
    c. Transverse mode noise attenuation of 65 dB or greater
    d. Common mode noise attenuation of 150 dB or greater at 40–100 Hz

2.08 MISCELLANEOUS MATERIALS

A. Ionization Smoke Detectors: These detectors shall be provided under Division 28. Coordinate all installation work. Verify proper compliance with the requirements of NFPA 90A.

B. Local Control Panels:

1. Type: Provide control panels with suitable brackets for wall mounting. Locate panel adjacent to systems served.
2. Construction: Fabricate panels of 14 gauge, furniture-grade steel, or extruded aluminum alloy, totally enclosed on all four sides, with hinged door and keyed lock all keyed alike, with manufacturer's standard shop-painted finish and color.
3. UL-Listing: Provide UL-listed cabinets for use with line voltage devices.
4. Panel-Mounted Equipment: Include temperature controllers, relays, automatic switches, except low temperature protection thermostats, firestats, and other devices included in the sequence of operation. Mount devices with adjustments accessible through the front of the panel.
5. Door-Mounted Equipment: Flush mount (on the hinged door) the manual switches, including damper "minimum off" positioning switches, manual/automatic switches, dial thermometers, and indicating receiver gauges.
6. Graphics: For those systems so specified, provide color-coded graphic, laminated, plastic displays on the doors to schematically show the system being controlled.

C. Special Tools: Furnish to the Owner not less than two (2) sets of tools necessary to service and maintain tamperproof devices and/or such items requiring special tools.

D. Carbon Monoxide (CO) Meters/Transducers: CO sensors shall be **NDIR**, UL 2075 listed, 0–200 ppm, accuracy ±(3 ppm or 5% of reading), T90 ≤ 30 s, output 2-10 VDC, 4–20 mA or BACnet. Update ≤ 10 s. Provide one calibration kit and one spare transducer to the Owner at project substantial completion.

2.09 AUTOMATIC VALVES/ACTUATORS

A. General: Provide factory-fabricated two-way or three-way valves with two position or modulating control actuators of the type, body material, and pressure class required for each application. Where type or body material is not indicated, provide selection as determined by manufacturer for installation requirements. Valve pressure class and rating shall be selected based on maximum pressure and temperature in the piping system in which it is installed.

B. Performance: All valves shall conform to the following minimum standards and selection requirements.

1. Valves shall be guaranteed to have bubbletight shut off.
2. Maximum pressure drop at design flow shall be 5 psi or as noted on the Drawings.
3. Provide heavy-duty actuators, with proper close-off rating for each individual application.
4. The valve assembly shall be suitable for throttling control and for tight shut-off against pump shut-off head. All valves shall be certified by an authorized officer of the manufacturer to shut-off bubbletight against full system pump shut-off head with a control air pressure 2 psi beyond spring range.
5. All valves which are operated in sequence with damper motors, control switches, or other valves shall sequence properly without overlap. Provide positive positioners, oversized operators, or balanced trim if required for proper sequence control.
6. Valve schedules submitted for review shall clearly show shift in operator span for all valves operated in sequence and shut-off capability for all valves.

C. Valve Types:

1. Two-Way Valves: Provide straight through pattern-type, union globe valves. Valves 1/2" to 2" in size shall have bronze, brass, stainless steel, or approved corrosion resistant bodies and screwed ends. Valves 2-1/2" and larger shall have high-tensile cast iron or cast steel bodies, bronze stainless steel or approved corrosion resistant seats, and internal trim, removable cage-type trim and flanged ends. All valve stems shall be 316 or 416 stainless steel. Valves shall be designed to provide equal percentage flow characteristics at constant pressures with a range ability of 30 to one. Low-pressure valves shall be provided with a renewable composition disc compound which will ensure tight seating.
2. Three-way Valves: Provide three-way mixing type valves. Valves 1/2" to 2" in size shall have bronze, brass, stainless steel, or approved corrosion resistant brass bodies and screwed ends. Valves 2-1/2" and larger shall have high-tensile cast iron or cast steel bodies, bronze, stainless steel or approved corrosion resistant seats and integral trim, removable cage-type trim, and flanged ends. All valve stems shall be 316 or 416 stainless steel. Valves shall provide constant system flow rate at all operating conditions. Provide positive positioners, oversized operators, or balanced trim if required for proper sequence controls.
3. Butterfly Valves: Where indicated on the Drawings or required by the Sequence of Control, utilize full lug butterfly-type control valves rated for the same operating pressure as the piping system in which such valves are installed. Valve construction shall be as specified in Section 23 05 10. Valves shall have bubble tight shut-off against either side

of the valve when the flange is removed from the opposite side. Provide positive positioners or oversized operators if required for proper sequence control.

4. Differential Bypass Valves: Valves for control of differential bypass systems shall be of industrial quality with minimum 50:1 range ability, equal percentage characteristics, cast iron body, 316 stainless steel trim, position indicator, heavy duty operator, stainless steel stem, Teflon spring-loaded packed, and removable or non-removable cage type trim. All working parts (trim) of the valve shall be replaceable without removing the valve body from the line.
5. Small Valves: Small (one inch (1") and smaller) heating hot water and chilled water valves shall be of the three-way or straight-through equal-percentage type with polished stainless-steel stems, spring-loaded Teflon or rubber packing, and back-seating feature to allow the valve to be repacked under pressure without shutting off the system.

D. Modulating Control Operators: Provide all modulating control valves 2-1/2" and larger and all size butterfly valves with a positive positioning power device. Such device shall operate independently of valve spring range or stem friction to ensure the repetition of valve position when related to the same signal increment value of controller output. Positioner sensitivity shall be sufficient to produce a stem travel reversal loss not exceeding 7% of the controller output range as it goes from its full to no-load position within its proportional band operation. Provide positioners whenever required to obtain close-off ratings or proper sequencing of valves with damper operators, relays, or other valves.

E. Fail Position: Chilled water valves shall be normally open and hot water valves shall be normally open or normally closed as specified in the Sequence of Operation.

F. Valve Selection: All valves shall be suitable for the maximum design pressure of the system in which they are installed.

1. Valves shall be selected to provide tight-closing shut-off without chatter against the maximum pressure which can be encountered in the system in which they are installed.
2. Modulating valves shall be sized by the BCAS Manufacturer for fully modulating operation. Where valve size is smaller than line size, coordinate installation of increasers and reducers with the Division 23 Contractor.
3. Two position valves shall be full line size with properly sized internal passages.
4. Water valves shall be sized with a minimum pressure drop equal to the pressure drop of the coil or heat exchanger served and a maximum pressure drop of 5 psi. Relief and bypass valves shall be sized according to the pressure available.

2.10 **AUTOMATIC DAMPERS**

A. General: Provide factory-fabricated opposed blade-type automatic control dampers as shown on the Drawings or required by the Sequence of Operation.

B. Construction: Dampers shall have galvanized bar or channel steel frames which are the full size of the duct or opening in which the damper is installed. Frames on dampers over 4 square feet shall have corner bracing. Damper frames shall be minimum 14 gauge formed galvanized steel with mounting holes for enclosed duct mounting, where applicable. Fabricate of not less than 16-gauge steel with corrosion-resistant galvanized finish. Damper blades shall have a maximum width of 6" and a maximum length of 48". All dampers shall be provided with nylon or oilite bearings, stainless steel or elastomer side seals, and zinc-plated hardware as standard. Axles shall be a minimum of 1/2" diameter and be locked to the blade with rivets or be welded. Blades shall have a minimum of four brakes. All blades on each damper section shall be interconnected to act in unison. Provide neoprene, vinyl polyester, or polyurethane blade edging. Maximum leakage rate through a 48" x 48" closed damper shall not exceed 10.0 cfm per square foot of damper face area at 4" of water pressure differential and a maximum closing torque of 50 inches/pounds. Damper leakage ratings shall be certified in accordance with AMCA Standards.

C. Damper Sizing: Modulating dampers shall be sized according to approach velocities, pressure drops, and similar criteria to obtain linearized characteristics. Maximum approach velocity shall be 1500 feet/minute. Damper free area shall be sized by the BCAS Manufacturer. Provide necessary blank-off plates between damper leaves to obtain the required free area. Damper sizing shall be submitted to the Engineer for approval.

D. Operating Temperature Range: Range shall be from -40°F to 180°F.

E. Operators: Dampers shall be normally closed unless otherwise specified and shall be opened by actuators with sufficient power to open the damper as installed. Operators shall be as specified herein.

F. Operating Linkage: Linkage shall be factory-assembled and shall be capable of withstanding a load equal to twice the maximum operating force of the damper operator without deflection.

2.11 ELECTRONIC CONTROL AND AUTOMATION MATERIALS

A. Electronic Actuators:

1. General: Provide fully proportioning electronic actuators of either the push-pull or rotary type, as required. Actuator motor shall be of the low voltage synchronous type and shall be non-overloading at a continuous stall. Provide each motor with corrosion protection. Actuators for outside air and exhaust applications shall have nonferrous motor housings and stainless-steel shaft and linkage. Actuator control signal shall be 24-volt ac, 0-20 volts dc, 2-wire phase cut or three point floating as required. Provide spring return for normally open/closed positioning.
2. Selection: Size electronic actuators to operate their appropriate dampers and valves with sufficient reserve power to provide smooth modulating or two-position action as specified.
3. HVAC Terminal Unit Actuators: Where required by the Sequence of Operation, electronic actuators shall be suitable for use with the terminal unit controllers and terminal unit control dampers provided on the project. Coordinate provisions for actuator mounting with the HVAC terminal unit manufacturer selected for the project.

B. Temperature Sensors:

1. General: Provide temperature sensors for space, duct, immersion, duct averaging, remote probe, and outside air applications.

   a. DDC temperature sensors shall be of the 500-ohm, 1,000 ohm, or 3,000 ohm platinum type, or 10,000 ohm thermistor type. All sensors of a particular category shall be of the same type manufacturer and shall have an interchangeability of ±0.1% at the reference temperature. Sensors shall provide high accuracy, long term stability, low hysteresis, fast response, and a wide operating range.
   b. Sensor time constant response to temperature change time shall be less than 3 seconds per degree change. Sensors requiring field-calibration shall not be acceptable. All sensors shall be precise and accurate so that they do not require adjustments or calibrations. Linearizing, (ranging and resistance change versus temperature curve interpretations, where required) shall be made by software programming.
   c. Minimum sensor operating ranges shall be as follows:

      1) Chilled Water:.....30°F to 100°F
      2) Condenser Water.....30°F to 150°F
      3) Heating Hot Water .....50°F to 200°F

4) Air Systems ..... 0°F to 150°F
5) Space ..... 30°F to 100°F
6) Outside Air ..... -40°F to 140°F

d. Sensor accuracy shall be ±0.1% at 32°F for platinum sensors and ±0.4°F for thermistor sensors or as required to achieve overall system accuracy (end-to-end) as stated hereinbefore.

2. Space Sensors: Provide sensors designated for wall mounting in occupied areas. Sensors shall be installed in a low-profile metallic enclosure or recessed into a standard receptacle box with stainless steel flat plate sensor cover and shall be mounted to the wall with tamperproof screws. Sensors shall have no logo, occupant adjustment control, or room temperature indication.

a. Fan Powered Terminal Unit Zones: For each zone served by a fan powered terminal unit, furnish, and install a pushbutton on the face of the temperature sensor and wire it to the ASC on its respective terminal unit. Tenants shall be able to activate their air conditioning for after-hours use by depressing this button. The button shall be illuminated when the after-hours program is in operation. The program shall activate enough terminal units on that floor to ensure a stable load on the air handling unit. The program shall be written to energize the air handling unit serving that terminal unit if it is not already. Likewise, a signal shall be sent out to the central plant to activate a chiller and its associated equipment if not already in operation. An alarm message shall print out indicating when a tenant activates his HVAC system for after hours use. Run time shall be accumulated for each tenant and automatically input into the BCAS spreadsheet to be printed out on a monthly basis.

3. Space Sensors (High Profile Areas): Where shown on the Drawings and designated with an "E" in the high-profile areas, provide button type electronic thermistor sensors. Sensors shall be Barber-Coleman Model TS-8131.
4. Duct Sensors: Provide flanged or threaded probe type sensors designed for duct type mounting. Sensor shall be encapsulated in a stainless-steel probe 8" long. Sensors shall include a suitable junction box for terminating sensor wiring and shall include a lagging protrusion where installed in externally insulated ducts.
5. Immersion Sensors: Provide Immersion type sensors with a 1/2" OD threaded fitting for direct installation in a thermowell. The probe shall be encapsulated in a brass jacket and shall be installed in a brass thermowell suitable for installation in a 3/4" NPT threaded fitting. Sensors shall include a suitable junction box for terminating sensor wiring. Thermowells shall have pressure and temperature ratings suitable for their application. Wells for insulated piping shall have a 2-1/2" lagging protrusion. Locate wells so the sensing probe will give a true and correct reading. Install wells so as not to cause undue restriction in small piping. Where wells are located in pipe lines 1-1/2" and smaller, provide a section of pipe of such diameter that the net area of the pipeline will not be reduced by the thermometer well. All wells shall be filled with silicon and complete with caps and chains. Wells shall be installed in a 45-degree angle into the direction of water flow in the monitored piping.
6. Temperature probes and wells shall have the following insertion lengths:

PIPE DIAMETER	INSERTION ORIENTATION	LENGTH
4"	HORIZONTAL	2-1/2"
4", 6"	VERTICAL	4-1/2"
6", 8"	HORIZONTAL	4-1/2"
8", 10"	VERTICAL	6-1/2"

PIPE DIAMETER	INSERTION ORIENTATION	LENGTH
>8"	HORIZONTAL	6-1/2"
>10"	VERTICAL	10"

7. Duct Averaging Sensors: Provide extended flexible probe averaging sensors for coil discharge temperature applications. Sensor probes shall be a minimum of 16' long and shall consist of multiple temperature sensors equally spaced along the probe and wired to provide average temperature sensing. Probe casing shall totally encapsulate and waterproof the sensors and shall be nominal 3/8" OD bendable aluminum. Sensors shall include a suitable junction box for terminating sensor wiring.
8. Remote Probe Sensors: Provide remote probe sensors with sensing elements encapsulated in a nominal 2" stainless steel sheath suitable for return air or strap-on mounting. Sensors shall include a nominal 3' lead section and a suitable junction box for terminating sensor wiring.
9. Outside Air Sensors: Provide shielded, weatherproof outside air sensors with sensing elements encapsulated in a nominal 2" stainless steel sheath suitable for outdoor applications. Sensors shall include a waterproof junction box or conduit body for terminating sensor wiring and a removable sun shield. Provide two sensors each located in separate monitoring locations.

C. Temperature Transducers:

1. General: Provide temperature transducers consisting of a temperature sensor and a solid-state signal conditioner to provide a 4-20 mA or 0-10 volts dc true linear output corresponding to temperature. The signal conditioner shall be factory-calibrated and provided with zero and span trimmers for output adjustment.
2. Accuracy: Sensor accuracy shall be ±0.1% at 32°F for platinum sensors and ±0.4°F for thermistor sensors or as required to achieve overall system accuracy (end-to-end) as stated herein before.
3. Configurations: Temperature transducers shall be provided in configuration as specified hereinabove for Temperature Sensors.

D. Thermostats/Temperature Safeties:

1. Electric Type: Electric space thermostats shall be two position space thermostats with a SPST or SPDT switch activated by a bimetal sensing element, direct or reverse acting as required. The thermostat range shall be adjustable for 50°F to 65°F with a removable external adjustment knob. Each thermostat shall have a blank, impact resistant locking cover.
2. Proportional-acting Room Thermostats: Proportional-acting thermostats shall have precision wound potentiometers that will give a variable voltage output directly proportional to temperature sensed. Thermostats shall have one or two potentiometers as necessary for the required sequence; and when two potentiometer types are required, potentiometers shall act in unison or in sequence as required. Thermostats shall have a range of approximately 55°F to 85°F, a throttling range of 3°F to 8°F, and adjustable stops. Provide locking-type covers without thermometers or external-adjusting device.
3. Remote Bulb Type: Each remote bulb electric thermostat shall consist of a two-position remote bulb thermostat that is bi-metal controlled with sealed mercury switches and a control action as required. Thermostats shall be installed such that adjustment can be made by removing the unit cover and shall be provided with a capillary tube for the remote bulb thermal element.
4. Freeze Protection Switches (Freezestats): Switches shall consist of a manual reset, line voltage, bellows activated switch with a 20' long sensing bulb and 4' capillary. The sensor shall be responsive to the coldest section of the capillary. Switch contact shall open when the air temperature along any point on the capillary falls below 35°F

(adjustable). Provide double pole switches where required by the Sequence of Operation.

5. Safety Temperature High Limit Switches (Firestats): Switches shall consist of a manual reset, line voltage, bimetal activated switches set to operate at 135°F (adjustable from 100°F to 250°F). Switches shall be UL-labeled. Switch contacts shall open when the air temperature exceeds 135°F. Provide double pole switches where required by the Sequence of Operation.

E. Humidity Transducers:

1. General: Provide space, duct, remote probe, and outside air humidity transducers consisting of a solid-state humidity sensor and a solid-state signal conditioner to provide a 4-20 mA or 0-10 volts dc true linear output corresponding to relative humidity (RH). Transducers shall not require periodic maintenance or calibration and shall not be affected by high airflow, dust, moisture saturation or power interruption.
2. Accuracy: Transducers shall provide long-term stability and low hysteresis with an accuracy of ±2% over a 5-95% RH range with ±0.5% RH repeatability and a maximum 30 second response time for a 50% RH change.
3. Space Transducers: Provide transducers designed for wall mounting in occupied areas. Transducer shall be installed in a self-contained nonmetallic enclosure and shall be mounted to the wall with tamperproof screws. Enclosures for space humidity transducers shall be identical in appearance to enclosures for space temperature sensors.
4. Duct Transducers: Provide self-contained flanged or threaded probe type sensors designed for duct mounting. Transducers shall include a suitable junction box for terminating transducer wiring and shall include a lagging protrusion where installed in externally insulated ducts.
5. Remote Probe Transducers: Provide remote probe type transducers with the humidity sensor in a remote probe and connected with a nominal 3' lead section to a junction box containing the signal conditioner and provisions for terminating transducer wiring.
6. Outdoor Air Transducers: Provide weather-sheltered sensors with a weatherproof junction box containing the signal conditioner and provision for terminating transducer wiring. Transducer assembly shall be suitable for outdoor applications.

F. Pressure Transducers:

1. General: Provide pressure transducers for converting duct differential and static pressure, water/steam pressure, water differential pressure and pneumatic supply/branch pressures to analog output signals.
2. Duct Differential and Static Pressure Transducers: Provide transducers to convert static pressure signals from static pressure probes and airflow measurement devices to 4-20- or 0-10-volts dc analog outputs. Pressure shall be sensed by a solid-state pressure sensor which is mounted directly to the transducer enclosure and not physically attached to the transducer circuit board. The transducer shall be designed for operation with unfiltered monitored air and shall not be affected by mounting orientation, vibration, or temperature. Transducer accuracy shall be ±1.0% with linearity of ±0.1%, repeatability of ±0.1% and hysteresis not exceeding ±0.1%. Transducers shall be factory-calibrated and shall have zero and span trimmers for field calibration. Transducers shall be provided with a steel enclosure for panel mounting or a NEMA 1 enclosure for remote mounting, a direct or reverse acting output, as required and a square root output for linearization, where required. Transducer range shall be selected to match the medium being monitored. Transducers shall be Mamac Systems Model PR-272 or an approved equal. Provide flange mounted aluminum duct static pressure sensing probes as required for monitoring duct static pressure. Probes shall be Mamac Systems Model A-520 or an approved equal.

3. Water/Steam Pressure Transducers: Provide transducers to convert water/steam pressure to 4-20 mA or 0-10 volts dc analog outputs. Pressure shall be sensed by a solid-state pressure sensor that is mounted directly to the transducer enclosure and not physically attached to the transducer circuit board. The transducer shall be designed for operation with unfiltered monitored media and shall not be affected by mounting orientation, vibration, or temperature. Transducer accuracy shall be ±1.0% with linearity of ±0.1%, repeatability of ±0.1% and hysteresis not exceeding ±0.1%. Transducers shall be factory-calibrated and shall have zero and span trimmers for field calibration. Transducers shall be provided with a steel enclosure for panel mounting or a NEMA 1 enclosure for remote mounting, a direct or reverse acting output, as required and a square root output for linearization, where required. Transducer range shall be selected to match the medium being monitored. Transducers shall be Mamac Systems Model PR-262 or an approved equal.
4. Water Differential Pressure Transducers: Provide transducers to convert differential pressures to 4-20 mA or 0-10 volts dc analog outputs. Pressure shall be sensed by a solid-state pressure sensor that is mounted directly to the transducer enclosure and not physically attached to the transducer circuit board. The transducer shall be designed for operation with unfiltered monitored media and shall not be affected by mounting orientation, vibration, or temperature. Transducer accuracy shall be ±1.0% with linearity of ±0.1%, repeatability of ±0.1% and hysteresis not exceeding ±0.1%. Transducers shall be factory-calibrated and shall have zero and span trimmers for field calibration. Transducers shall be provided with a steel enclosure for panel mounting or a NEMA 1 enclosure for remote mounting, a direct or reverse acting output, as required and a square root output for linearization, where required. Transducer range shall be selected to match the medium being monitored. Transducers shall be Mamac Systems Model PR-282 or an approved equal.
5. Pneumatic Pressure Transducers (only where shown on the drawings): Provide transducers to convert pneumatic signals up to 30 psi to 4-20 mA or 0-10 volts dc analog outputs. Pressure shall be sensed by a solid-state pressure sensor that is mounted directly to the transducer enclosure and not physically attached to the transducer circuit board. The transducer shall be designed for operation with unfiltered monitored air and shall not be affected by mounting orientation, vibration, or temperature. Transducer accuracy shall be ±1.0% with linearity of ±0.1%, repeatability of ±0.1% and hysteresis not exceeding ±0.1%. Transducers shall be factory-calibrated and shall have zero and span trimmers for field calibration. Transducers shall be provided with a steel enclosure for panel mounting or a NEMA 1 enclosure for remote mounting, a direct or reverse acting output, as required and a square root output for linearization, where required. Transducer range shall be selected to match the medium being monitored. Transducers shall be Mamac Systems Model PR-242 or an approved equal.
6. Sensors installed in all liquid lines shall have an isolation valve and pigtail siphon installed between the sensor and its pressure source.

G. Air Flow Transducers:

1. Flow Cross/Flow Ring: Provide flow cross/ring sensors for all pressure independent HVAC terminal units and as required by the Sequence of Operation.

    a. Each flow cross shall include a minimum of twelve (12) pick-up points of amplified sensing for each 16" of duct diameter. The pick-up points shall be divided evenly in each of the four quadrants of the duct. Ducts larger than 16" in diameter shall be divided into sections that are each averaged to its respective center and then cascaded so that the entire cross-sectional area is traversed.
    b. Averaging sensors shall be center tapped to provide a differential pressure signal that represents actual airflow within an accuracy of ±3%. This accuracy shall be maintained when inlet duct varies from straight to 90-degree entrance approach angle.

c. Provide separate pressure transducers to convert duct flow cross/ring differential pressure output to a 4-20 mA or 0-10 volts dc analog signal. Provide pressure transducers integral to HVAC terminal unit controllers for conversion of differential pressure to a digital signal.

2. Air Monitoring Stations: Provide air monitoring stations where indicated on the Drawings or required by the Sequence of Operation.

a. Each airflow measuring station shall measure airflow by means of a network of static and total pressure sensors factory-positioned and connected in parallel to produce an averaged velocity pressure. The measured velocity pressure converted to airflow (cfm) shall have an accuracy within 2% of the full scale throughout the velocity range from 700 to 4000 fpm when measured under laboratory conditions. The location of air monitoring stations shall meet manufacturer's guidelines so as to approach laboratory conditions.
b. The maximum resistance to air flow shall not exceed 0.6 times the velocity head. The unit shall be suitable to withstand up to a temperature of 250°F.
c. Airflow measuring stations shall be of heavy gauge metal construction and shall be furnished with an air velocity treatment, air straightening section with an open face area of not less than 97%.
d. Provide one portable indicating meter per fan system. Indicating meters shall be provided for direct readout of static pressure and airflow. Airflow meter accuracy shall be 5% for range 0-0.25", 4% for 0-0.36", 3% for 0-0.8", 2% for 0-2.0" range.
e. Provide separate transducers, with integral square root extraction where applicable, to convert air monitoring station differential pressure to a 4-20 mA or 0-10-volt dc analog signal.

H. Water Flow Transducers:

1. Turbine Meters: Provide turbine sensors as specified herein, and where indicated.

a. Sensor shall be of the industrial type. The Sensor shall be accurate to within ±1% of actual flow between a flow velocity of one to 30' per second. Repeatability and linearity shall not exceed ±1% of flow. Sensor is to be of the "Turbine Flow Meter" type. The sensor shall send an analog signal to a local meter panel that provides a 4-20 mA or 0-10-volt dc output for remote sensing. Flow sensor readings shall be displayed at the local panel in gpm.
b. Each flow element shall be complete with 1/4" SAE flare safety shutoff instrument valves, and a permanent metal tag showing design flow rates, meter reading for design flow rates, metered fluid, line size and tag number, station, or location number.
c. Turbine meters shall be provided at locations specified and where shown on the Drawings.

2. Insertion Type Flow Sensors: Provide insertion type flow sensors as specified herein, where indicated on the Drawings, and as required by the Sequence of Operations.

a. Each flow metering system shall consist of a flow sensor installed in a pipe saddle or thread-o-let and an analog flow transmitter to provide a 4-20 mA or 0-10 volts dc flow signal to the BCAS.
b. The flow sensor shall be constructed of stainless steel and nonmetallic wetted parts and shall be designed for hot tap installation in a 1" NPT pipe saddle or thread-o-let. The sensor shall be suitable for use in pipe sizes from 1-1/4" to 40". Sensors installed in pipe size 2-1/2" and larger shall have two turbines. A multi-bladed flow wheel shall provide a flow signal to the flow transmitter. The sensor design shall be such that it is not affected by metallic or rust particles as found in

metal piping systems. The sensor shall be adjustable to provide the manufacturers recommended insertion depth in the pipe being sensed. The sensor shall be suitable for pressures up to 400 psi and temperatures up to 220°F.

c. The analog flow transmitter shall convert the flow sensor output to an analog flow input to the BCAS.

d. The flow sensor shall be installed with a minimum of ten upstream and five downstream pipe diameters of straight pipe for uninterrupted flow and shall have an accuracy of ±3% at flow velocities from one foot (1') to 30' per second with ±0.1% repeatability and ±1% linearity.

e. Insertion flow metering systems shall be Onicon F-1110/F-1210, or an approved equal.

f. Insertion type meters shall be provided at locations specified and where shown on the drawings.

3. Venturi-type Waterflow Metering: Provide Venturi-type sensors where specified herein and where indicated.

a. Provide one piece, brass or cast iron, Venturi flow meters screwed for 3/4" through 2" size and weld neck-type for 2-1/2" and larger. Meters shall be rated for at least 300 psig and water pressure differential at design flow rate as indicated on the Drawings. Pressure loss shall not exceed 10% of indicated flow rate differential pressure. Units shall be complete with valve manifold for connection to flow meter and quick disconnect valves for calibration purposes.

b. Provide a permanent 6" diameter differential pressure gauge with a minimum accuracy of ±1% of full scale for the units as indicated on the Drawings. Differential pressure gauge shall have the dial calibrated in gpm with the scale range as required. Pressure gauge shall be equipped with shutoff valves and shall be suitable for the operating pressure of the systems. Attach a capacity curve chart to each individual venturi flow meter. Provide one portable 6" diameter differential pressure gauge in a carrying case complete with hoses and manifold.

c. Venturi-type meters shall be provided at locations as specified and where shown on the Drawings.

I. Current/Voltage to Pressure Transducers: Provide current/voltage to pneumatic transducers to convert 4-20 mA and 0-10 volts dc analog output signals to 3 to 15 psi pneumatic signals for pneumatic actuation. Transducers shall be a solid-state design with separate supply and exhaust valves to provide non-bleed operation and a solid-state pressure transducer. The transducer shall be designed for operation with unfiltered control air and shall not be affected by mounting orientation, vibration, or temperature. Input and output connections, supply and bleed valves and pressure sensor shall be connected with a common metal manifold with all components field replaceable. The manifold shall be directly mounted to the transducer enclosure and not physically attached to the transducer circuit board. Transducer accuracy shall be ±1% with ±0.1% linearity, ±0.1 psig repeatability and a 0.2 psig resolution at a flow rate of 0.5 scfm. Transducers shall be provided with steel enclosure for panel mounting or a NEMA 1 enclosure for remote mounting, linear or reverse output, as required and a 4-20 mA or 0-10-volt DC direct branch pressure analog output feedback where indicated in the Sequence of Operation. Transducers shall be Mamac System EP-310 Series or an approved equal.

J. Position/Status Indicators:

1. End (Limit) Switches: Limit switches shall be of the sealed or enclosed type as required for the application. Contacts shall be snap-action SPDT rated for the application. Damper end switches shall be industrial quality, shaft-mounted, enclosed switches set to sense open or closed position of damper blades. Switches shall be arranged to prevent

"open-center" operation and for mounting as required. Switch enclosures shall be waterproof with a conduit entry seal where subject to moisture or water.

2. Potentiometers: Potentiometers may be either rotary or linear, depending on application of each position indicator. Position potentiometers shall have a linearity of ±5% and shall indicate position on a percent open basis.
3. Key-Operated Switches: Hand-off automatic (H-O-A), off-automatic, and all similar use switches shall be key-operated with all switches keyed alike where switches are not located in access limited locations. All switches shall be rated for a minimum of 600 Volt ac, 5-A, and shall be mounted in an enclosure as specified or shown.
4. Current Sensitive Relays: Relays shall provide a self-powered, isolated SPDT contact closure to indicate a run condition of monitored equipment. The relay shall have contacts rated at 1 amp at 120 Volt ac, adjustable sensitivity, and an adjustable operating point to match the current draw of the monitored equipment. Current sensitive relays shall be Neilson-Kuljian Model D100AC or an approved equal.
5. Liquid Level Switches: Switches shall consist of a SPDT snap acting switch operated by a sealed float mechanism. Switch body shall be brass with a stainless-steel float and arm and shall be suitable for mounting through a 1-1/2" thread-o-let. Float switches shall be W.E. Anderson Model L4 or an approved equal.
6. Waterflow Switches: Provide industrial quality water flow switches with brass wetted parts, vapor-proof construction with seal at conduit entry, rated for 300 psig, 300°F, and voltage and current ratings as required. Switch shall be of the snap-acting type, SPDT contacts, packless sealed tube with switch in isolated compartment and paddle convertible to suit pipe diameter. Provide externally adjustable flow sensitivity to allow adjustment without removing the assembly from the line. Switches shall be thread-o-let, or tee mounted and shall be W.E. Anderson V4-2-U or V6 Series.
7. Differential Pressure (DP) Water Flow Switches: Switches shall be double bellows type differential pressure switches with brass bellows directly actuating a snap-acting DPDT switch. Switches shall have visible setpoint adjusters. Switches exposed to weather shall be weatherproof. Switch ranges and setpoints shall be appropriate to the manufacturer's recommendations for the pressure at the point of application and the differential pressure being monitored. Differential pressure water flow switches shall be Mercoid Series DP or an approved equal.
8. Pressure Switches: Switches shall be brass button bourdon tube operated with a snap-acting switch directly activated by the bourdon tube. Switches shall have a repetitive accuracy of ±1% of their operating range and shall withstand up to 150% of rated pressure. Switch actuation shall be adjustable over the operating pressure range. Switches shall have snap-action DPDT contacts rated for this application. Switches exposed to weather shall be waterproof. Switch ranges and setpoints shall be appropriate to the manufacturer's recommendations for pressures at the point of application. Pressure switches shall be Mercoid Series DA or an approved equal.
9. Differential Pressure (DP) Air Flow Switches: Switches shall be diaphragm operated to activate a DPDT snap switch. Motion of the diaphragm shall be transmitted to the switch button by means of a direct mechanical linkage. Switches shall be rated for pressures up to 50" WG and shall have 16-gauge steel, zinc-plated, dichromate dipped housing suitable for the environment in which the switch is installed. Switches exposed to unconditioned outside air and weather shall be moisture resistant. Switches exposed to weather shall have weatherproof housing. Switches shall have silicone rubber power and sealing diaphragms with aluminum supports and stainless-steel calibration springs. Switch repetitive accuracy shall be 1% minimum. Switch ranges and setpoints shall be appropriate to the manufacturer's recommendation for the pressure drop access the equipment being monitored. Differential pressure air flow switches shall be Dwyer Series 1620 or an approved equal.
10. Static Pressure Safety Switches: Switches shall be duct or unit mounted and shall consist of a manual reset static pressure sensitive diaphragm operated switch that is adjustable for positive or negative pressure actuation. When the switch pressure setpoint is exceeded, the switch contacts shall open.

K. Output Devices:

1. Control Relays: Control relay contacts shall be rated for the application, with a minimum of two sets of SPDT contacts, enclosed in a dustproof enclosure. Relays shall be rated for a minimum life of one million operations. Operating time shall be 20 milliseconds or less, with release time of 10 milliseconds or less. Relays shall be equipped with coil transient suppression devices to limit transients to 150% of rated coil voltage.
2. Time Delay Relays: Time delay relay contacts shall be rated for the application with a minimum of two sets of SPDT contacts, enclosed in a dustproof enclosure. Relays shall be rated for a minimum life of one million operations. Relays shall be equipped with coil transient suppression devices to limit transients to 150% of rated coil voltage. Delayed contact opening or closing shall be adjustable from one (1) to 60 seconds with a minimum accuracy of ±2% of setting.
3. Latching Relays: Latching relay contacts shall be rated for the application with a minimum of two sets of SPDT contacts, enclosed in a dustproof enclosure. Relays shall be rated for a minimum life of one million operations. Operating time shall be 20 milliseconds or less, with release time of 10 milliseconds or less. Relays shall be equipped with coil transient suppression devices to limit transients to 150% of rated coil voltage.
4. Reed Relays: Reed relays shall be encapsulated in a container housed in a plastic, epoxy, or metal case. Contacts shall be rated for the application. Operating and release times shall be 1 millisecond or less. Relays shall be rated for a minimum life of 10 million operations and shall be equipped with coil transient suppression devices to limit transients to 150% of rated coil voltage.
5. Contactors: Contactors shall be of the single coil, electrically operated, mechanically or electrically held type. Positive locking shall be obtained without the use of hooks, latches, or semi-permanent magnets. Contacts shall be double break silver-to-silver type protected by arcing contacts where necessary. Number of contacts and ratings shall be selected for the application. Operating and release times shall be 100 milliseconds or less. Contactors shall be equipped with coil transient suppression devices to limit transients to 150% of rated coil voltage.
6. Solid State Relays: Input-output isolation shall be greater than 1000 megohms with a breakdown voltage of 1500 Volt root mean square or greater at 60 Hz. Relays shall be rated for a minimum life of 10 million operations. The ambient temperature range shall be at least -20°F to + 140°F. Input impedance shall not be less than 500 ohms. Relays shall be rated for the application in accordance with NEMA ICS 1. Operating and release times shall be one millisecond or less. Transients shall be limited to 150°F of control voltage.

L. Electrical Power Instruments:

1. Potential Transformers: Potential transformers shall be in accordance with ANSI C57.13.
2. Current Transformers: Current transformers shall be in accordance with ANSI C57.13.
3. Watt-hour Meters: Watt-hour meters, with or without demand register shall be in accordance with ANSI C12 and have pulse initiators for remote monitoring of watt-hour consumption. Pulse initiator shall consist of Form C contacts with a current rating not to exceed 2 amperes and voltage not to exceed 500 volts, with combinations of VA not to exceed 100 VA, and a life rating of one billion operations. Meter sockets shall be in accordance with ANSI C12.
4. Watt-hour Meters with Demand Register: Meters shall be in accordance with ANSI C12 and have pulse initiators for remote monitoring of watt-hour consumption and instantaneous demand. Pulse initiators shall consist of Form C contacts with a current rating not to exceed 2 amperes and voltage not to exceed 500 volts, with combinations of VA not to exceed 100VA, and a life rating of 1 billion operations. Meter sockets shall be in accordance with ANSI C12.

5. Current Transducers: Provide current transducers to convert 0 to 5 amperes input signals from standard current transformers to 4-20 mA or 0-10 volts dc analog signals with an accuracy of ±0.5% of CT rating. The transducer shall be factory-calibrated and provided with zero and span adjustments. Transducers shall be installed in dust tight metal enclosures with provisions for terminating current transformer and transducer wiring. Transducer shall be a Mamac Systems Model CU-230 or an approved equal.
6. Voltage Transducers: Provide voltage transducers to monitor three phase voltages on 208- or 480-Volt systems and provide discrete 4-20 mA outputs which are linear for each phase-to-phase voltage. Transducer shall be suitable for mounting in a NEMA 1 enclosure and shall have an accuracy of ±0.25% of full voltage scale. Transducer shall be a Kele & Associates Model PVM-348 or an approved equal.
7. KW and KWH Transducers: Provide kilowatt and kilowatt-hour transducers to convert potential transformer or phase voltage outputs and current transformer current outputs to 4-20 mA outputs proportional to load kW and a pulsed output for kWH consumed. Transducer accuracy shall be ±2.0% at unity power factor and ±2.5% at 0.5 power factor. Transducer shall be provided with a NEMA 1 enclosure, a disconnect switch and current transformer shorting assembly, a phase monitor feature with digital outputs for loss of power, loss of voltage on any phase and undervoltage, and a kWH consumption and demand meter readout kit with LED or LCD readouts. kW and kWH transducers shall be Kele & Associates WHU-238 Series or an approved equal.

2.12 COMPUTERIZED CONTROL AND AUTOMATION MATERIALS

A. General:

1. Building Control and Automation System (BCAS): Provide a system capable of integrating multiple building functions including equipment supervision and control, alarm management, energy management, and historical data collection and archiving.
2. Hardware: The BCAS shall consist of the following, as required:

    a. Standalone DDC panels
    b. Standalone application specific controllers (ASC)
    c. Personal computer / Operator workstations
    d. Communications network interconnection

3. Expansion: The system shall be modular in nature and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, standalone DDC panels, and operator devices.
4. System Architecture: System design shall eliminate dependence upon any single device for alarm reporting and control execution. Each DDC panel shall operate independently by performing its own specified control, alarm management, operator I/O, and historical data collection. The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices.
5. Reliability: Standalone DDC panels shall be able to access any data from or send control commands and alarm reports directly to any other DDC panel or combination of panels on the network without dependence upon a central processing device. Standalone DDC panels shall also be able to send alarm reports to multiple operator workstations without dependence upon a central processing device.
6. Head-End Equipment: A system operator's PC and alarm and report printers shall be located in the Building Engineer's office and one lap top portable shall be provided. The system PC's shall provide the operator interface for monitoring, adjusting, and interface with the BCAS and shall be provided with all software required for graphics interface, operator interface, logging and trending data and other operator functions.
7. Microcomputer based distributed control processors located in DDC panels and application specific controllers shall interface directly with sensors, actuators, and

environmental delivery systems (i.e., HVAC units, boilers, chillers, lighting distribution systems, etc.). Functionality to be implemented at the DDC panel level shall include:

a. Individual input/output point scanning, processing, and control
b. Direct digital control
c. Alarm detection and storage
d. Time, event, and holiday scheduling
e. Bus communications interface and control
f. Local operator terminal interface
g. Central operator terminal interface
h. Trend data acquisition and storage

8. Analog and digital input and output points shall be resident in DDC panels and application specific controllers. All analog outputs shall be true analog current or voltage outputs. Pulse modulation of digital outputs to provide "analog" outputs will be acceptable for HVAC terminal unit control.
9. All control functions related to any given smoke management sequence shall be resident in a single DDC panel or Application Specific Controller or if functions are resident in multiple panels, the smoke management initiation input and verification output shall be hardwired to each panel such that the smoke management functions are maintained with the BCAS communications network out of service.
10. A communication network to allow data exchange between DDC panels, and PC operator terminals at a minimum rate of 19.2 K baud. Direct communications between DDC panels and the operator terminals shall be not be dependent on any other bus connected processor.
11. All system components shall be designed and built to be fault tolerant, including, but not limited to:

a. Satisfactory operation without damage at 110% above and 85% below rated voltage and a ±3 Hz variation in line frequency.
b. Static, transient, and short circuit protection on all inputs and outputs.
c. Communications lines protected against incorrect wiring, static transients, and induced magnetic interference.
d. Bus connected devices to be ac-coupled or equivalent so that any single device failure will not disrupt or halt bus communication.
e. All real time clocks and data file RAM to be battery backed for a minimum of 48 hours.

12. All computer operated system components receiving 120 Volt power from the building power systems shall include integral transient voltage surge suppression (TVSS) devices for protection.
13. All software, real time graphics and accessory hardware required by the following specifications and the performance standards of other sections of this Division.

B. Networking Communications:

1. General: The Building Control and Automation system (BCAS) shall consist of a high-speed, peer-to-peer network of DDC controllers, a control system server, and a web-based operator interface.

a. System software shall be based on a server/thin-client architecture, designed around the open standards of web technology. The control system server shall be accessed using a Web browser over the control system network, the owner’s local area network and (at the owner’s discretion) over the Internet. The server shall also act as a “workstation” when running as a server/client platform. Additional clients shall have concurrent access to the “workstation” in this mode.

b. The intent of the thin-client architecture is to provide operators complete access to the control system via a Web browser. No special software other than a Web browser shall be required to access graphics, point displays, and trends, configure trends, configure points and controllers, or to download programming into the controllers.

c. System shall use BACnet protocol for communication between the control modules and web server. Communication between the web server and the user's browser shall be HTTP or HTTPS protocol utilizing HTML5. Use of Adobe Flash technology must be approved by the Owner in writing and confirmed by the project team.

2. Local Area Network:

a. Workstation/ASC/DDC Panel Support: Operator workstations, ASC, and DDC panels/controllers shall directly reside on a local area network such that communications may be executed directly between controllers, directly between workstations, and between controllers and workstations on a peer-to-peer basis. ASC may reside on communication networks requiring DDC panel interface for communication to the local area network.

b. Dynamic Data Access: All operator devices, either network resident or connected via dial-up modems, shall have the ability to access all point status and application report data, or execute control functions for any and all other devices via the local area network, without an active host processor.

1) Access to data shall be based upon logical identification of building equipment.
2) Access to system data shall not be restricted by the hardware configuration of the facility management system.
3) The hardware configuration of the BCAS network shall be totally transparent to the user when accessing data or developing control programs.

c. General Network Design: Network design shall include the following provisions:

1) High speed data transfer rates for alarm reporting, quick report generation from multiple controllers, and upload/download efficiency between network devices. The minimum communication baud rate shall be 28.8 K baud. To be confirmed between manufacturer of equipment and controls contractor.
2) Support of any combination of controllers and operator workstations directly connected to the local area network. Each local area network shall be capable of supporting a minimum of 64 devices.
3) Devices shall be ac-coupled to the network bus to assure that single or multiple device failures will not cause loss of communications with other network connected devices.
4) Detection and accommodation of single or multiple failures of either workstations, ASC, DDC controllers or the network media. The network shall include provisions for automatically reconfiguring itself to allow all operational equipment to perform their designated functions as effectively as possible in the event of single or multiple failures or be of a collision avoidance configuration.
5) Message and alarm buffering to prevent loss of data information.
6) Error detection, correction, and retransmission to guarantee data integrity.
7) Devices with no messages to transmit must send an "I'm OK" message to each bus cycle. Lack of an "I'm OK" message after successive retries

shall constitute a communications or device failure, be recognized as such, and be recorded as not responding on the system printer.

8) Default device definition to prevent loss of alarms or data, and ensure alarms are reported as quickly as possible in the event an operator device does not respond.
9) Commonly available, multiple sourced, networking components and protocols shall be used to allow the BCAS to coexist with other networking applications such as office automation. ETHERNET and ARCNET are acceptable technologies for the local area network.
10) Synchronization of the real-time clocks in all ASC and DDC panels shall be provided.
11) Full communications shall be sustained as long as there are at least two operational devices on any segment of the bus.
12) Global data (all station messages) is to be available for use by any device on the bus as inputs or outputs to its resident control programs.
13) Each device is to be provided with a communications watchdog to assure that an individual device cannot permanently occupy the bus. If a device is determined to be "babbling", it shall be automatically shutdown and a flag set to annunciate this fact.
14) For data integrity, all data streams are to be encoded to attain a minimum number of bit errors that could cause an undetected error and all messages are to contain a 16-bit check word.
15) Error recovery and communications initialization routines are to be completely distributed, i.e., resident in each bus connected device.
16) Software counters are to be provided as a diagnostic tool for cold starts, warm starts, privilege violation, illegal instructions, address errors, bus errors and zero divide. Error types and counts are to be operator accessible.

C. Standalone DDC Panels:

1. General: Standalone DDC panels shall be microprocessor based, multi-tasking appearance, multi-user, real-time digital control processors. Each standalone DDC panel shall consist of modular hardware with plug-in enclosed processors, communication controllers, power supplies, and input/output modules. A sufficient number of controllers shall be supplied to fully meet the requirements of this specification and the Input/Output attached Point Schedule. Microprocessor and memory shall be socketed for chip replacement.
2. Configuration: Each panel shall include a power supply, A/D and D/A converters, memory and motherboard capacity to accommodate required input/output (I/O) points. If master/slave panels are utilized, (e.g., where data processing, control, and energy management functions are not equally distributed among all panels within the system), a maximum of 64 points may be connected to any one master panel. Input/Output points shall include digital inputs, digital outputs, analog inputs, and analog outputs. Pulse modulation of digital outputs to provide "analog" outputs will be allowed only for HVAC terminal unit control.
3. Memory: Each DDC panel shall have sufficient memory to support its own operating system and databases including:

    a. Control processes.
    b. Real time clock to provide time of day, day of week, date, month, and year with a one-hundred-year calendar and leap year compensation.
    c. Energy management applications.
    d. Alarm management.
    e. Historical/Trend data for all points.
    f. Maintenance support applications

g. Custom Processes
h. Operator I/O.
i. Dial-up communications from at least one panel.
j. Manual override monitoring.
k. Minimum 20% additional memory spare capacity.

4. Point Types: Panels shall accept inputs of the universal type and be capable of handling current, voltage, resistance, or open and closed contacts in any mix. Each DDC panel shall support the following types of point inputs and outputs either directly or through connection to ASC:

   a. Digital inputs for status/alarm contacts.
   b. Digital outputs for on/off equipment control.
   c. Analog inputs for temperature, pressure, humidity, flow, and position measurements.
   d. Analog outputs for valve, damper or other actuator position control and capacity control of primary equipment.
   e. Pulse inputs for pulsed contact monitoring.
   f. Tristate outputs for equipment control.
   g. All analog inputs and outputs shall be 0-10 volts dc or 4-20 mA.

5. Input/Output Signals: Each DDC panel or ASC shall include:

   a. Programmable intermediate ranges and linearization tables are to be provided for sensor types listed under the sensor section of this specification. For all RTD type sensors of 100 ohms or less, contractor shall individually calibrate each input point via precision decade box to compensate for lead length errors.
   b. Proportional current or voltage type analog outputs with a minimum incremental resolution of 0.5% of the full operating range of the valve or damper actuating device (not 0.5% of 0-10-volt output). The proportional range of the output shall be matched to the full operating range of the actuating device. Zero and maximum output voltage or current values; however, shall be used for shutdown and close-off modes. For troubleshooting and load analysis, the value of each analog output shall be available in the data base for trending and display.
   c. Digital outputs shall be capable of handling maintained as well as pulsed outputs for momentary or magnetic latching circuits. It shall be possible to configure outputs for three-mode control (fast-slow-off) and two-mode control.

6. Communication Ports: Each standalone DDC panel and controller shall be provided with USB 3.0 or USB-C connection ports (minimum 2) for simultaneous operation of multiple operator I/O devices such as industry standard, laptop workstations, PC workstations, and panel mounted or portable DDC panel Operator's Terminals. Standalone DDC panels shall allow temporary use of portable devices without interrupting the normal operation of permanently connected network terminals.
7. Override Monitoring: DDC panels/controllers shall monitor the status or position of software overrides and include this information in logs and summaries to inform the operator that automatic control has been inhibited.
8. Integrated On-Line Diagnostics: Each DDC panel/controller shall continuously perform self-diagnostics, communication diagnosis and diagnosis of all subsidiary equipment. The DDC panel/controller shall provide both local and remote annunciation of any detected component failures, or repeated failure to establish communication. Indication of the diagnostic results shall be provided at each DDC panel and shall not require the connection of an operator I/O device. Diagnostics shall include as a minimum:

   a. Transmit
   b. Receive

c. Power up test
d. Power up fail
e. Power up test OK
f. Bus error

9. Power-Fail Restart: In the event of the loss of normal power, there shall be an orderly shutdown of all standalone DDC panels to prevent the loss of database or operating system software.

   a. Memory: Non-volatile memory shall be incorporated for all critical controller configuration data, and battery backup shall be provided to support the real-time clock and all volatile memory for a minimum of 72 hours.
   b. Restart: Upon restoration of normal power, the DDC panel/controller shall automatically resume full operation without manual intervention, returning to it's last mode of operation and set points.
   c. Reload: Should DDC panel memory be lost for any reason, the user shall have the capability of reloading the DDC panel via the local area network or via the local USB port connection.

10. Troubleshooting: Each DDC panel/controller shall be designed for ease of testing and repair.

    a. Panel design shall allow complete installation and check out of field wiring prior to the installation of electronic boards and controllers. All board terminations are to be made via plug-in connectors and to facilitate troubleshooting, repair, and replacement. The complete DDC panel including accessory devices such as relays, transducers, power supplies, etc., shall be factory-mounted, wired and housed in a steel enclosure with wire management system.
    b. DDC panel boards shall be provided with a pre-wired connector for connection of a portable terminal. Attachment shall not interrupt or disable normal panel operation or bus communications.

D. Application Specific Controllers - (ASC):

1. Each Standalone DDC Controller shall be able to extend its performance and capacity through the use of remote Application Specific Controllers (ASC).
2. Each ASC shall operate as a standalone controller capable of performing its specified control responsibilities independently of other controllers in the network. Each ASC shall be a microprocessor based, multi-tasking, real-time digital control processor.
3. Each ASC shall have sufficient memory to support its own operating system and data bases including:

   a. Control Processes
   b. Energy Management Applications

4. The operator interface to any ASC point data or programs shall be through any network-resident PC workstation, or any PC or portable operator's terminal connected to any DDC panel in the network.
5. All system set points, proportional bands, control algorithms, and any other programmable parameters shall be stored such that a power failure of any duration does not necessitate reprogramming the controller.

6. Application Descriptions:

a. Variable Air Volume (VAV) Terminal Unit Controllers:

1) VAV Terminal Unit Controllers shall support, but not be limited to, the control of the following configurations of VAV boxes to address current requirements as described in the Sequence of Operation section of this specification, and for future expansion:

a) Single duct only (cooling only or cooling with reheat)
b) Fan powered (parallel/side pocket, series/on-off logic, constant fan)
c) Dual duct (constant volume, variable volume)
d) Supply/Exhaust

2) The modes of operation supported by the VAV Terminal Unit Controllers shall minimally include, but not be limited to, the following:

a) Day/Weekly schedules (may be via DDC panels)
b) Comfort/Occupancy mode
c) Economy mode (standby mode, unoccupied, etc.)
d) Temporary override mode

3) Occupancy-based Standby/Comfort Mode Control: Each VAV Terminal Unit Controller shall have a provision for occupancy sensing overrides. Based upon the contact status of either a manual wall switch or an occupancy sensing device, the VAV Terminal Unit Controller shall automatically select either Standby or Comfort mode to minimize the heating and cooling requirements while satisfying comfort conditions.

b. Unitary Controllers:

1) Unitary Controllers shall support, but not be limited to, the following types of systems to address specific applications described in the Sequence of Operation section of this specification, and for future expansion:

a) Unit vents (ASHRAE Cycle I, II, III or IV)
b) Heat pumps
c) Packaged rooftops
d) Fan coils (two-pipe, four-pipe)

2) Unitary controllers shall support the following types of point inputs and outputs:

a) Economizer Switchover Inputs:

(1) Dry bulb
(2) Outdoor air enthalpy
(3) Differential temperature
(4) Binary input from a separate controller

b) Economizer Output:

(1) Integrated analog with minimum position
(2) Binary output to enable self-contained economizer actuator

c) Heating and Cooling Outputs:

(1) One to three stages
(2) Analog output with two-pipe logic
(3) Reversing valve logic for heat pumps

d) Fan Output:

(1) On/Off logic control

3) Unitary Controllers shall support the following library of control strategies to address the requirements of the sequences described in the Sequence of Operation section of this specification, and for future expansion:

a) Daily/Weekly schedules (may be via DDC panels)
b) Comfort/Occupancy mode
c) Economy mode

(1) Standby mode/economizer available
(2) Unoccupied/Economizer not available
(3) Shutdown

d) Temporary Override Mode:

(1) Temporary comfort mode (occupancy-based control)
(2) Boost (occupant warmer/cooler control)

4) Occupancy-based Standby/Comfort Mode Control: Each Unitary Controller shall have a provision for occupancy sensing overrides. Based upon the contact status of either a manual wall switch or an occupancy sensing device, the Unitary Controller shall automatically select either standby or comfort mode to minimize the heating and cooling requirements while satisfying comfort conditions.

c. Air Handling Unit Controllers:

1) Air handling unit controllers shall support, but not be limited to, the following configurations of systems to address current requirements as described in the Sequence of Operation section of this specification, and for future expansion:

a) Large Air Handling Units:

(1) Mixed air-single path
(2) Mixed air-dual path
(3) 100% single path
(4) 100% dual path

2) Air handling unit controllers shall support all the necessary point inputs and outputs to perform the specified control sequences in a totally standalone fashion.
3) Air handling unit controllers shall have a library of control routines and program logic to perform the Sequence of Operation specified.

4) Occupancy-based Standby/Comfort Mode Control: Each air handling unit shall have a provision for occupancy sensing overrides. Based upon the contact status of either a manual wall switch or an occupancy sensing device, the air handling unit controller shall automatically select either standby or comfort mode to minimize the heating and cooling requirements while satisfying comfort conditions.

E. Central Hardware:

1. Personal Computer Operator Workstation Description: Personal computer operator workstations shall be provided for command entry, information management, network alarm management, and database management functions. All real-time control functions shall be resident in the standalone DDC panels to facilitate greater fault tolerance and reliability.

a. Computer: Workstations shall be general purpose, commercially available, personal computers with sufficient memory and processor capacity to perform all functions described in this Specification, including mouse and keyboard. Computer shall be a Windows 11 Compatible PC.
b. Monitor: Minimum 27" LED 4K monitor, 60 Hz. The screen shall be non-reflective.
c. Location: Provide one operator workstation located at the central location in the engineer's office. Coordinate with Owner for location of PC.

F. BCAS Wiring Materials:

1. Wiring shall be jacketed cables installed with or without conduit as specified hereinbelow or single conductors installed in conduit. Control wiring shall have minimum 300-volt insulation for low voltage wiring 600-volt insulation for the line voltage wiring.
2. Minimum requirements for control wiring shall be as follows:

a. Digital Functions: Control wiring for digital functions shall be No. 18 AWG copper minimum, with 300-Volt insulation. Multi-conductor wire shall have an outer jacket of polyvinyl chloride (PVC) where installed in conduit or UL-listed plenum rated jacket where installed without conduit.
b. Analog Functions: Control wiring for analog functions shall be No. 18 AWG copper minimum, with 300-volt insulation, twisted and shielded, 2-, 3-, or 4-wire to match analog function hardware. Multi-conductor wire shall have an outer jacket of PVC where installed in conduit or UL-listed plenum jacket where installed without conduit.
c. Sensor Wiring: Sensor wiring shall be No. 20 AWG copper minimum, twisted and shielded, 2-, 3-, or 4-wire to match analog function hardware. Multi-conductor wire shall have an outer jacket of PVC where installed in conduit or UL-listed plenum rated jacket where installed without conduit.
d. Low Energy Conductors: Class 2 low energy conductor sizes specified for digital and analog functions shall take precedence over any requirements for Class 2 low energy remote control and signal circuit conductors specified elsewhere, unless the NEC requires a larger conductor size.

3. BACnet IP, Arcnet or MS/TP communications wiring shall be installed in accordance with ASHRAE/ANSI Standard 135. This includes but is not limited to:

a. IP

1) The network shall use Cat6 or greater cabling for connections.

2) Custom made patch cables must use either the T568A or T568 wiring standard and must use the same standard on both ends of the cable.

b. Arcnet

1) The network shall use shielded, twisted-pair cable with characteristic impedance between 100 nominal. Distributed capacitance between conductors shall be less than 12.5 pF per foot (41 pF per meter.)
2) The maximum length of an Arcnet segment is 610 meters (2000 ft) with AWG 22 cable.
3) The maximum number of nodes per segment shall be 32, as specified in the EIA 485 standard. Additional nodes may be accommodated by the use of repeaters.
4) An Arcnet network shall have no T connections.

c. MS/TP

1) The network shall use shielded, twisted-pair cable with characteristic impedance between 100 and 120 ohms. Distributed capacitance between conductors shall be less than 100 pF per meter (30 pF per foot.)
2) The maximum length of an MS/TP segment is 1200 meters (4000 ft) with AWG 18 cable. The use of greater distances and/or different wire gauges shall comply with the electrical specifications of EIA-485
3) The maximum number of nodes per segment shall be 32, as specified in the EIA 485 standard. Additional nodes may be accommodated by the use of repeaters.
4) An MS/TP EIA-485 network shall have no T connections.

G. DDC Panel Software:

1. General:

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

2. Control Software Description:

a. Pre-Tested Control Algorithms: The DDC panels shall have the ability to perform the following control algorithms:

1) Two Position Control
2) Proportional Control
3) Proportional plus Integral Control
4) Proportional, Integral, plus Derivative Control
5) Automatic Control Loop Tuning is desirable but must be easily disengaged.

b. Equipment Cycling Protection: Control software shall include a passive provision for limiting the number of times each piece of equipment may be cycled within any one (1) hour period.
c. 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.

d. 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.

3. Energy Management Applications:

a. Programs: DDC panels shall have the ability to perform any or all of the following energy management routines:

b. Time and Calendar Programs:

1) An independent start and stop program calendar and time shall be provided for each system identified in the Input/Output summary.
2) It shall be possible to assign two independent start and stop times/day to any equipment connected to a controller. Outputs from this program are start/stop command signals to air handling, heating or cooling systems, etc.

c. Exception Day Scheduling:

1) An Exception Day program is to be provided to accommodate holidays and other planned exceptions to the normal time programs. Exception schedules shall be DDC panel resident and operator programmable up to one (1) year in advance.
2) The program shall allow definition of up to 32 exception time spans. Each span to be defined as to calendar start day and calendar stop day.
3) The exception day program shall also apply to all time schedule energy management programs like Optimum Start and Stop and Duty Cycle.

d. Resident Temporary Scheduler: A resident temporary scheduler shall be provided to allow the operator to modify present time program control of the equipment. The minimum features required include:

1) Ability to alter time schedule changes as much as twenty-one days in advance.
2) Ability to alter either start time, stop time or both for each day.
3) Temporary schedules to be in effect for all days specified.
4) Automatically delete the temporary schedule and restore program to normal schedule after execution.
5) Ability to alter the stop time for the current day.
6) Ability to assign schedule changes as permanent or temporary.

e. Distributed Power Demand: Distributed power demand program shall be based on a sliding window instantaneous demand algorithm. The DDC panel interface to the demand meter shall calculate the demand, forecast the demand trend, compare it to established demand limits and initiate load shedding action or reestablishment of loads as required. Shedding shall be on a sequential basis with least important loads shed first and restored last. Restoration cycle shall add the most important loads first. DDC panels on the bus shall each have a four-tier shed table for assignment of shedable loads. When a request is issued to the bus to shed a specific number of kilowatts each controller will shed Tier 2 loads, etc. until the shed requirement is met. The power demand control software shall be furnished but shall not be implemented.

f. Optimum Start: Optimum Start and Unoccupied Period Cycling are to be integrated into a single coordinated software package addressing the unique requirement of the building's unoccupied periods. Each air handling unit or

control area is to be assigned an independent unoccupied period program which may include one or more of the following:

1) Optimum Start Program shall delay equipment start-up based on outdoor temperature, space temperature and system response to assure that comfort conditions are reached exactly at scheduled occupancy time. The program is to operate in both heating and cooling cycles. An adaptive algorithm is to be employed which automatically adjusts according to the previous day's actual start time and whether comfort conditions were reached prior to or after scheduled occupancy time. The program shall automatically assign longer lead times for weekend and holiday shutdowns. Space temperature input is to be the highest value of zones served. If shall be possible to assign occupancy start time on a per air handling unit basis.
2) Unoccupied Period Cycle program shall apply to the heating and cooling cycles. For the cycle, the lowest or highest temperature (as applicable) of the zones served shall be used to determine the "fan on" or "zone activated/reset" command. A low and high temperature limit shall be assigned as the minimum unoccupied period temperatures.

g. Optimum Stop: An Optimum Stop program shall be provided for utilizing stored energy (flywheel effect) to carry the heating or cooling load on a short-term basis. Program shall be applicable to any primary or secondary system that supplies heating or cooling medium to the space. An adaptive algorithm shall be employed to automatically accelerate the stop time as much as one (1) hour based on external load conditions and the rate of temperature change of the occupied space with the energy source off (Drift Rate). Independent Drift Rate - calculations are required for heating and cooling. Drift rate for heating shall be calculated on the bases of the zone having the greatest cooling load. For multi-zone applications a subroutine shall be provided that compares several zone temperatures, then selected the lowest or highest for the Drift Rate calculation depending on whether heating or cooling energy is being supplied. Historical Drift Rates for both heating and cooling are to be stored and adjusted daily for the current heating and cooling load. The lead time for stopping equipment shall not cause space conditions to exceed either the heating or cooling comfort limits.

h. Enthalpy Program: Provide an enthalpy program which will automatically select the air source, outdoor air or return air, or mix of both; that presents the least total heat load to the cooling coil. The control algorithm shall base its decision on measurement of outside air-dry bulb, outside air dew point or RH and return air dry bulb, return air dew point or RH. Calculation of total heat content for each source is to be made and compared to determine if minimum outdoor air is to be used or a mix of outdoor and return air.

i. Load Reset Program: A load-reset program shall be provided to assure that only the minimum amount of heating and cooling energy is supplied to satisfy zone temperature requirements. The program shall be applicable to air handling units and the chilled water and heating hot water supply to individual air handlers of all types. Individual programs are to be provided, each sensing the worst-case zone requirements and providing only the minimum temperature source media to satisfy the need. Control shall include the following, as a minimum:

1) Fan speed/cfm control
2) Heating/Cooling interlock
3) Cold deck reset
4) Hot deck reset
5) Hot water reset
6) Chilled water reset

7) Condenser water reset
8) Chiller sequencing

j. Chiller Optimization (if applicable):

1) The optimization program shall include:

a) Optimum chiller selection based on capacities, efficiencies, measured energy usage, and tonnage required.
b) Chilled water temperature optimization based on average load.
c) Condenser water temperature optimization from outdoor air wet bulb.

2) The optimizing algorithm shall be such that all parameters of chiller selection, condenser water supply and return and chilled water supply and return are considered to truly optimize the total chiller plant. It is designed to select the most favorable chiller combination and adjust both condenser water and chilled water discharge temperature for optimum efficiency and minimal total energy usage. In addition, it optimizes cooling tower fan operation.
3) Chiller Selection: Chiller selection is to be based on chiller plant load requirements. Changeover shall be based on a calculated load schedule. Calculated changeover shall be based on individual machine limits, chiller load, measured kW per ton for individual chillers, and calculated break-even-efficiency between one, two or more chillers for different refrigerant heads.
4) Condenser Water Optimization: The condenser water optimization portion of the chiller optimizing algorithm is based on optimizing evaporation by the cooling tower. The program evaluates dew point and dry bulb temperature and determines the optimum condenser water temperature. The program then automatically resets the condenser water set point temperature based on the evaporation rate calculation.
5) Cooling Tower: The cooling tower fan operation is optimized by use of the condenser water optimization portion of the chiller plant control algorithm. The condenser water loop is optimized for savings of chiller load by lowering the condenser water temperature when outside conditions make it economically feasible to implement. If outside conditions of high wet bulb prevent reducing condenser water temperature, the cooling tower fan energy is reduced by reducing fan speeds and turning fans off.
6) Chilled Water (CHW) Optimization: The chilled water (CHW) optimization portion of the chiller optimizing algorithm resets the CHW discharge to the highest acceptable limit to reduce the chilled water pump head to minimize energy consumption. The program automatically resets the discharge controller based on the average system load.
7) To benefit from increased chiller efficiency with increased leaving chilled water temperature and minimum head pressure, the chilled water supply temperature is raised one increment at a time on 15-minute (adjustable) intervals until the chilled water return temperature begins to rise, at which time the chilled water supply temperature is reset one increment lower. The operator can then set a fixed temperature overriding the reset program. Also provide a high temperature limit control (adjustable) for chilled water supply.
8) The plant engineer shall be supplied with chiller plant optimization programming completely implemented. These reports provide chiller plant profile information on a timed or demand basis. It shall be possible

for the system operator to completely change system report program and times of reports. The system is to be installed with the following performance reports. Refer to Sequence of Operation and Input/Output Point Schedules for degree of implementation.

a) Flow rate of chilled water for total plant.
b) Chilled water supply and return temperature (common).
c) Condenser water supply and return temperature (common).
d) Outdoor air-dry bulb temperature.
e) Outdoor air dew point.
f) Ton hours of chilled water per day.
g) KW each chiller.
h) KW/ton each chiller and plant.
i) KWH each chiller per day.
j) KWH all chillers per day.
k) Tons each chiller.
l) Ton hours each chiller per day.
m) Flow rate of each chiller.
n) Chilled water supply temperature (each chiller).

9) Changes in chiller on/off are made by the system operator, not automatically. If the chiller optimizing programming determines a chiller should be turned on or off, the system prints out a message for the Operator and instructs him as to which machine should be added or deleted to maintain comfort levels and efficient operation.

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

4. Custom Process Programming Capability: DDC controllers shall be able to execute custom, job-specific processes defined by the user, to automatically perform calculations and special control routines.

a. Process Inputs and Variables: It shall be possible to use any of the following in a custom process:

1) Any system-measured point data or status
2) Any calculated data
3) Any results from other processes
4) User-Defined Constants
5) Arithmetic functions (+, -, *, square root, exp., etc.)
6) Boolean logic operators (and, or, exclusive or, if, etc.)
7) On-delay/Off-delay/One-shot timers

b. Process Triggers: Custom and built in processes or commands may be triggered based on any combination of the following:

1) Time interval
2) Time of day
3) Date
4) Other processes
5) Time programming
6) Events (e.g., point alarms)

c. Dynamic Data Access: A single process shall be able to incorporate measured or calculated data from any and all other DDC panels 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.

d. 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 or pager.

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

f. Custom DDC Programs: Custom DDC programs are to be provided to meet the control strategies as called for in the sequence of operation sections of these specifications. Each DDC controller shall have resident in its memory and available to the programs a full library of DDC algorithms, intrinsic control operators, arithmetic, logic and relational operators for implementation of control sequences.

1) All DDC set points, gains and time constants associated with DDC programs shall be available to the operator for display and modification via the central operator interface and portable operator's terminals.
2) The execution interval of each DDC loop shall be adjustable from 2 to 120 seconds in one (1) second increments.
3) DDC control programs shall include assignment of initialization values to all outputs to assure that controlled devices assume a fail-safe position on initial system start-up.

g. Time and Event Programming: Provide a time and event programming (TEP) capability which will initiate a controlled sequence of events for execution at a specific time or upon the occurrence of an event. Program features required as a minimum are:

1) Analog points to be commandable to a specific value.
2) Digital points commandable to a specific state; i.e., on or off; fast, slow, or off.
3) Initiator to be a specific date and time or a specific event; i.e., either analog or digital alarm occurrence.
4) Manual initiation via operator's command.
5) Commands must honor command delays to prevent current surges and assigned minimum On and Off times.
6) Commands must honor command and residual priority structures allowing high priority commands (like smoke management) to override lower priority commands (like duty cycle) and residual priority.
7) Ability to chain TEP's.
8) Ability to enable and disable TEP's individually.
9) Ability to enable/disable TEP initiators.

5. Historical Data and Trend Analysis: A variety of historical data collection and data base management utilities shall be provided to automatically sample, store, and display system data in all of the following ways:

a. Continuous Point Histories: Standalone DDC panels 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. Samples for all points shall be stored for the past day (minimum) 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 changes or commands for each point.

b. Control Loop Performance Trends: Standalone DDC panels shall also provide high-resolution sampling capability with an operator-adjustable resolution of 10-300 seconds in one (1) second increments for verification of control loop performance.

c. 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 one (1) minute to 2 hours, in one (1) minute intervals, shall be provided. Each standalone DDC panel shall have a dedicated buffer for trend data and shall be capable of storing up to 30 days of trended data for any piece of equipment at any time.

d. Data Storage and Archiving: Trend data capability for all input and output points shall be stored however required to ensure it is easily accessible by users and backed up at the server level. Data shall be stored in ASCII format, in addition to any other common formats provided.

6. Runtime Totalization: Standalone DDC panels/controllers shall automatically accumulate and store runtime hours for binary input and output points as specified in the Execution portion of this specification.

   a. The Totalization routine shall have a sampling resolution of one (1) minute or less.
   b. 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.

7. Analog/Pulse Totalization: Standalone DDC panels shall have the capability to automatically sample, calculate, and store consumption totals on an hourly, daily, weekly, or monthly basis for user-selected analog and binary pulse input-type points. Totalization shall provide calculation and storage of accumulations of up to 99,999.9 units (e.g., kWh, gallons, kBtu, tons, etc.).
8. 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.
9. Input/Output Point Processing Software: Software shall include:

   a. Continuous update of input and output values and conditions. All connected points are to be updated at a minimum of one (1) second intervals.
   b. Analog to digital conversion, scaling and offset, correction of sensor, nonlinearity, sensing no response or failed sensors. Both the maximum and minimum values sensed for each analog input are to be retained in memory. It shall be possible to input subsets of standard sensor ranges to the A/D converter and assign gains to achieve high accuracy readout.
   c. A reasonability check on all analog inputs against the previously read value, discarding those values failing outside preprogrammed reasonability limits.
   d. Assignment of proper engineering units and status condition identifiers to all analog and digital input and output.
   e. Analog input alarm comparison with the ability to assign two individual sets of high and low limits (warning and actual alarm) to an input or to assign a set of floating limits (alarm follows a reset schedule or DDC control point) to the input. Each alarm shall be assigned to unique differential to prevent a point from oscillating into and out of alarm. Alarm comparisons are to be made during each scan cycle.

f. Debounce of digital input to prevent nuisance alarms. Debounce timing shall be adjustable from two seconds to two minutes in one (1) second increments.

10. Command Control Software: Software shall manage the receipt of commands from the central operator's console, portable operator's terminal and from control programs.

a. Command delay shall be provided to prevent simultaneous energizing of loads. Delay shall be programmable from 0 to 30 seconds.
b. Each command shall be assigned a command and residual priority to manage contentions created by multiple programs having access to the same command point. Only outputs with a higher command priority shall be permitted to execute. Whenever a command is allowed to execute, its assigned residual priority shall replace the existing residual priority.
c. A "fixed mode" option shall be supported to allow inputs to and outputs from DDC control programs to set to a fixed state or value. When in the "fixed mode", inputs and outputs are to be assigned a high residual command priority to prevent override by application programs.
d. A last user record is to be maintained to positively identify which program or manual command is in control of a given point. The last user information shall be displayed among with other point data on the CRT display of logical groups.

H. Operator Station Software:

1. General: Operator Station software shall include as a minimum the Operating System (OS), Data Base Manager, Communications Control, Operator Interface (OI), Trend and History Files, Report Generator, Support Utilities, Scheduler and Time and Event Programs.

a. Real time operating system shall provide true multitasking providing concurrent execution of multiple real time programs and custom program development. "Switching" from foreground applications to background applications where the background applications are suspended is not acceptable.
b. Data Base manager is to manage all data on an integrated and non-redundant basis. It shall allow additions and deletions to the database without any detriment to the existing data. Cross linkages are to be provided such that no data required by a software program may be deleted by the operator until that data has been deleted from its respective program.
c. Communications control, scheduler, trend files, reports, operator interface, and utilities shall be as specified hereinafter.

2. Operator Interface Software:

a. Operator Interface. The web server shall reside on a high-speed network with the building controllers. Web pages generated by this server shall be compatible with the latest versions of Microsoft Internet Explorer or Edge, Google Chrome, Mozilla Firefox, and Apple Safari browsers. Any of these supported browsers connected to the server shall be able to access all system information. Mobile devices shall be recognized by the web server and shall supply the appropriate system content as needed. The Operator Interface (web server with client devices) shall conform to the BACnet Operator Workstation (B-OWS) or BACnet Advanced Workstation (B-AWS) device profile as specified in ASHRAE/ANSI 135 BACnet Annex L. This includes the ability to configure and/or reconfigure the system from the client device (change programs, graphics, labels, etc.).
b. Communication. Web server and controllers shall communicate using the BACnet protocol. Web server and control network backbone shall communicate using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP

addressing as specified in ANSI/ASHRAE 135, BACnet Annex J. Communication between the web server and client (workstation) shall be HTTP or HTTPS protocol utilizing HTML5 language. Use of Adobe Flash in any part of the communication infrastructure is not acceptable.

c. Hardware.

1) Web server and/or workstation. Industry-standard hardware shall meet or exceed DDC system manufacturer's recommended specifications and shall meet response times specified elsewhere in this document. The web server may also be configured in client/server fashion to accommodate a "workstation" definition. In "workstation" configuration, the workstation will also perform as a server supplying additional clients as needed. The following hardware requirements apply:

2) System storage shall have sufficient memory to accommodate:

a) All required system software.
b) A DDC database to accommodate, as a minimum, twice the size of the delivered system database.
c) Two years of archival trend data based on the points specified to be trended at their specified trend intervals.
d) Provide additional hardware (communication ports, video drivers, network interface cards, cabling, etc.) to facilitate all control functions and software requirements specified for the DDC system.
e) Minimum hardware configuration shall include the following:
f) Quad Core Processor
g) 8-24 GB RAM (size dependent on size of system)
h) 1 TB (minimum) hard disk providing data at 3.0 Gb/sec (size dependent on historical data storage requirements)
i) 16x DVD+/-RW drive
j) Qwerty Keyboard
k) Optical Mouse
l) 27-inch 4K LED Color monitor with 75Hz refresh rate and resolution to provide a minimum screen resolution of 1920 x 1080 pixels.
m) Serial (USB) and network communication ports, with cables as required for proper DDC system operation
n) System Software.

d. Operating System. Web server shall have an industry-standard professional-grade operating system. Operating system shall meet or exceed the BMS manufacturer's minimum requirements to support their software. Acceptable systems include the most recent version of a Microsoft Windows Server, Red Hat Enterprise Linux, or Ubuntu Desktop, or Owner's preferred/selected system. Shall be manufacturer's latest web-based software.

e. Security. The web server application shall support Transport Layer Security (TLS) 1.3 capable of encryption of up to 256 bit elliptical curve for transmitting private information over the Internet using HTTPS. Additionally, the web server shall have SHA-2 certificate support capability.

f. Database. System shall support any JDBC (Java DataBase Connectivity) compliant engine. This includes: MS SQL, My SQL, Apache Derby, PostgreSQL and Oracle.

g. The BMS system shall allow an unlimited number of concurrent users.

h. The BMS manufacturer shall provide all software and tools necessary to provide the following capabilities:

1) Create and/or edit any programming used in controllers
2) Create and/or edit any graphics used in the system
3) Software shall not be subscription based and be given to owner at time of turnover. If software is subscription based, manufacturer shall include 10 years of subscription service.
4) The owner shall have the ability to install software on a minimum of five (5) additional owner furnished computers without additional licenses or fees.

3. Provide a hierarchical linked dynamic graphic operator interface for accessing and displaying system data and commanding and modifying equipment operation. The interface shall utilize the mouse to provide "heads up operation" with pull-down menus, dialog boxes, zoom, coloration and animation to facilitate operator understanding of the system. A minimum of twenty (20) levels of graphic penetration shall be provided with the hierarchy operator assignable (for example: area, building, wing, floor, air handler, sequence of operation pages, dynamic program display, and point group). Dynamic system data points shall be assignable to each penetration level. Descriptors for graphics, points, alarms, etc. shall be modified through the operator's station under password control.

a. Operator access to the system is to be under personal ID and password control for up to 12 unique operators. Up to 12 alphanumeric characters for personal ID and up to 12 alphanumeric characters for password shall be assignable to each operator via the operator station. The operator shall be able to access the system from any operator station in the system by entry of the proper ID and password. The operators shall be permitted to change their own password without permitting access to any other password. Sign-off from a station shall be a manual operation via pull-down menu. All sign-on/sign-off activity shall be automatically archived on the operator station disk for subsequent display or printout as desired.
b. Operator access to system points shall be controlled by individual operator-assigned graphic hierarchy and by privileges. The hierarchy shall permit access to an operator-assigned initial graphic and to all graphics linked to and below the initial graphic. The operator shall not have access to graphics in another hierarchical graphic "tree". For example, an operator may have access to one building, but not to another building, or to lighting points, but not fire alarm points. Each operator shall have any combination of user assigned keyboard privileges of alarm acknowledgment, point commanding, data modification, DOS access, schedule changes, and system configuration changes.
c. Data to be displayed within a unique graphic shall be assignable regardless of physical hardware address, communication channel or point type (temperature, humidity, fire alarm, etc.). Graphics are to be on-line programmable and under ID and password control. Points may be assignable to multiple graphics where necessary to facilitate operator understanding of system operation and where specified. Graphics shall also contain calculated or pseudo points. Each physical point and each point assigned to a graphic shall be assigned an English descriptor for use in reports.
d. Data segregation shall be provided for control of specific data routed to an operator station, or to a given output device such as a printer. Point classes shall be randomly selectable such as all fire points, fire points second floor, all space temperature points, HVAC points, command points, etc. Display and/or output of data to printer or color monitor shall occur where there is a match of peripheral segregation class assignment and the point segregations. Operators and peripherals shall be assignable, and all assignments are to be on-line programmable and under password control.

e. Penetration within a graphic hierarchy shall display each graphic name as graphics are selected to facilitate operator understanding. The "backtrace" shall permit the operator to move upward in the hierarchy by mouse click on the backtrace. The backtrace shall show at least the previous four penetration levels. The operator shall be provided the option of showing each graphic full screen size with the backtrace as the horizontal header or by showing a "stack" of graphics, each with a backtrace.

f. All Operator accessed data shall be displayed on the color monitor. The operator shall select further penetration via mouse click on an area, building, floor, fan, etc. The defined linked graphic below that selection shall then be displayed. Dynamic data shall be assignable to any and all graphics.

g. The Operator shall be provided with a means to directly access any graphic or any point without going through the penetration path.

    1) Direct access to graphics shall be menu selectable wherein the operator may optionally enter the name of the graphic system desired or select the desired graphic via cursor positioning on a scroll bar listing of all graphics or may be selected via keyboard entry.
    2) Operators may assign simple key names or group names for points to allow direct display or commanding of points. Key name assignments shall be fully operator assignable and as simple as one, two, or three characters, or as lengthy as 20 characters, such that frequently selected points may be accessed independent of complex penetration schemes. For example, a fan serving the south quadrant lobby of the headquarters building may be assigned a key name as simple as "HF1". The key name processor shall also allow the selection of graphics associated to points by entering the key name and a graphic appendage, such as "HF1 G"; and shall allow the direct execution of a command by entering the key name and a command appendage, such as "HF1 ON".

h. Points (physical and pseudo) shall be displayed with dynamic data provided by the system with appropriate text descriptors, status or value, and engineering unit. Coloration shall be used to denote status and alarm states. Coloration conventions shall be variable for each class of points, as chosen by the owner. In addition, animation shall be used to confirm latest status (e.g., fan rotation, damper position, fluid flow, etc.) where specified. All points shall be dynamic with update rates user adjustable on a per point basis from 20 seconds to 120 seconds, depending upon the process dynamics.

i. For Operators with the appropriate privilege(s), points shall be commanded directly from the color monitor via mouse selection. For a digital command point such as a changeover valve position, the valve would show its current state (e.g., CLOSED) and the operator could select OPEN via mouse click. For most operations, a keyboard equivalent shall be available for those operators with that preference.

j. Upon selection of analog commandable points (such as discharge air static pressure), a dialog box shall appear containing the following:

    1) The decimal value of the setpoint with adjacent up-down arrows.
    2) The operator shall be afforded three methods of analog commanding from which to choose as follows:
    3) Click the cursor on the decimal setpoint value and enter a new setpoint value via the keyboard decimal keypad.
    4) Drive the decimal value up or down via the up-down arrows.
    5) "Drag" the set point arrow up or down by moving the cursor to the desired position and clicking.

6) The bar chart shall also have an associated colored scale showing the current position (scaled value) of the alarm limits.

k. An Operator shall be permitted to split or resize the viewing screen to show one graphic on the left half of the screen and another graphic, spreadsheet, bar chart, word processing, curve plot, etc., on the right half screen. This will allow real time monitoring of one part of the system while displaying other parts of the system or data from the system to facilitate system operation.

l. An on-line context-sensitive "help" utility shall be provided to facilitate operator training and understanding. The help feature shall be a hypertext document with the ability to bridge to further explanation of selected keywords. The document shall contain text and graphics to clarify system operation. At a minimum, help shall be available for every menu item and dialog box. If the help utility does not have this ability to bridge on keywords for more information, four complete sets of user manuals shall be provided with quarterly updates and additional training as hereinafter described.

m. Electronic messaging facility shall be provided on the Operator station for any operator to enter a message to another operator by selecting the MAIL menu item, selecting the receiving operator's ID and entering the message (such as CLEAN PRE-HEAT STRAINER ON AHU-16). When an operator with a queued message signs onto the operator station, the "Mail Message" area of the dialog box shall indicate that a message is waiting. Upon selecting a mail display, the Operator shall be presented an index of the title or subject of each from which he may select the order of display. Upon displaying a mail message, the display shall prompt the operator with three message options to execute; delete, print, or save. Messages shall also include the time and date the message was sent, the sender's personal ID, and is 300 characters minimum length, plus a brief title or subject description.

4. Site Specific Customizing Software

a. Provide software, which will allow the user to modify and tailor the BCAS to the specific and unique requirements of the equipment installed, the programs implemented, and to staffing and operational practices. Online modification of system configuration, program parameters, and database shall be provided via menu selection and keyboard entry of data into preformatted self-prompting templates. As a minimum, the following modification capability shall be provided.

1) Operator assignment capability shall include designation of operator passwords, privilege(s), starting graphic and auto sign off duration.
2) Peripheral assignment capability shall include assignment of segregation groups to consoles and printers, and designation of backup printers.
3) System configuration/diagnostic capability shall include communications and peripheral port assignments, DDC panel assignments to the communications network, DDC panel enable/disable, assignment of command trace to points, and initiation of diagnostics.
4) System text add/change capability shall include English descriptors for graphic points, action messages for alarms and runtime, and trouble condition messages.
5) Time/Schedule change capability shall include time/date set, time/occupancy schedules, holiday schedules; daylight savings time schedules and activity defined schedules. All time and calendar scheduling and schedule modification shall be accomplished graphically via color bars and calendars in a hardware independent manner.
6) Points shall be uniquely definable as to coloration, animation, audible rate and duration, point descriptors (60 characters minimum), Operator

messages (480 characters minimum), printer options, alarm archival option, alarm and warning limits, and engineering units. All messages specified and all physical and pseudo point descriptors shall be entered by the vendor.

7) Point related change capability shall include system/point enable/disable; run time enable/disable; assignment of points to point classes, analog value offset, lockout, run time limits, and setting a fixed input value or output status.

8) Application program change capability shall include enable/disable of EMS programs, EMS program parameter changes, assignment of comfort limits, global points, time and event initiators, time and event schedules and enable/disable time and event programs.

9) Graphic construction is specified under Graphic Creation.

b. Provide software which will allow the user to add points, or groups of points, to the system and to link them to control programs. All additions and modifications are to be online programmable via operator station, downline loaded to DDC panels, and entered into their databases. After verification of point additions and associated program operation, the database shall be upline loaded and recorded on hard disk for subsequent re-initialization download.

c. Provide a Pascal, Block, or other high-level non-proprietary language programming capability for implementation of custom DDC programs. Software shall include a compiler, a linker and upline/downline load capability. In addition, a library of DDC algorithms, intrinsic control operators, logic operators, and relational operators for implementation of control sequences shall be provided and shall include as a minimum:

1) Proportional Control, Proportional plus Integral (PI), Proportional plus Integral plus Derivative (PID), and Adaptive Control (self-learning). The Adaptive Control algorithm shall be used on control loops, as indicated in the Data and Control summary, where the controlled medium flow rate is variable (such as VAV units and variable flow pumping loops). The adaptive control algorithm shall monitor the loop response to output corrections and adjust the loop response characteristics in accordance with the time constant changes imposed by variable flow rates. The algorithm shall operate in a continuous self-learning manner and shall retain in memory a stored record of the system dynamics so that on system shutdown and restart, the learning process starts where it left off. Standard PI or PID algorithms are not acceptable substitutes for variable flow applications since they will provide optimal control at only one flow rate and will require continued manual fine tuning.

2) Fully implemented intrinsic control operators including sequence, reversing, ratio, time delay, time of day, highest select, lowest select, analog controlled digital output, analog control analog output, and digitally controlled analog output.

3) Logical, mathematical, and relational operators (AND, OR, NOT; EQUAL TO, NOT EQUAL TO, LESS THAN; etc.), which are a standard set available with Pascal or other similar high-level language.

5. Alarm handler software shall be provided to respond to alarm conditions sensed and transmitted from DDC panels and application specific controllers. First in, first out handling of alarms in accordance with alarm priority ranking (fire alarm first, security second, etc.) is required with buffer storage for a minimum of twenty (20) alarms in case of simultaneous multiple alarms. Alarm handler shall be active in both the Signed On and Signed Off modes to assure that alarms will be processed even though an operator is not currently signed on.

a. Alarms shall be displayed in a dialog box of the color monitor. Display shall include as a minimum:

1) Indication of alarm condition; i.e., ABNORMAL OFF, HI ALARM/LO ALARM, analog value or status, and English group and point identification such as SPACE TEMPERATURE TECH CENTER SECOND FLOOR ROOM 202.
2) A discrete per point alarm action-taking message; i.e., "The fan has shutdown due to an excessively high discharge duct pressure. There is a strong indication of a system malfunction such as an inlet vane drive failure, or major fire damper closure. The switch should not be manually reset until a thorough investigation of the cause is conducted" of up to 480 characters.

b. Alarms are to be directed to appropriate operators, operator stations, and printers for segregation assignments as specified in previous sections of this specification.
c. Alarm silencing shall be by selecting the "silence" button or by authorized operator's acknowledgment. In all cases, alarm acknowledgment shall only be allowed by operators authorized to acknowledge a point in alarm.
d. Each point shall be assigned to an alarm class, with no limit to the quantity of alarm classes. Each alarm class shall be uniquely assignable to any combination of the following alarm processing attributes:

1) Audible beep duration (none, 10 seconds, 20 seconds, continuous)
2) Audible beep rate (slow-medium-fast)
3) Alarm historically archived (yes or no)
4) Alarm printed, with printer ID
5) Associated coloration with any of 256 colors, with separate brightness control, assignable to each alarm state (high alarm, high warning, normal, low warning, low alarm). Digital points shall similarly be distinguished with different colors for each possible state.

e. Alarms shall be displayed and/or printed at each peripheral to which its segregation allows, but only those operators having proper privilege level will be allowed to acknowledge alarms.
f. An unacknowledged alarm indicator shall be provided on the color monitor display to alert the operator that there are unacknowledged alarms in the system.
g. Symbols for points in a graphic display that are in an unacknowledged alarm state shall flash red; when in an acknowledged state, the symbol shall be non-flashing-red.
h. Run time limit messages shall be presented and processed as alarm messages except the action message shall be of a maintenance directive nature.

6. Standard reports shall be provided which shall be operator selectable to appear on the operator station, any selected printer or both. A "terminate report" command shall be available to allow the operator to stop any report in the process of being printed. The following standard pre-formatted reports to be provided shall include:

a. Point summary reports may be requested at any penetration level (facility, building, area, system) and shall include only points at and below that level. Point summary reports shall include the current value/status and condition, English system and point descriptors for all points. Point summary reports shall be selectable for all points, only those points in alarm, fixed points, disabled points locked out points, locked out and in alarm points, analog input or output

points, digital input or output points. All reports shall be capable of being scheduled to run at a specific time and/or interval via an operator function supported by necessary data entry templates and interactive prompts.

b. Trend reports shall allow the operator to randomly select logical arrays of points to be recorded at selectable time intervals. It shall be possible to assign up to ten variables to each trend report. The format, headers, footers and calculations shall be selectable by the Operator. The trend report shall be stored to disk and shall be subsequently capable of being displayed, and/or printed by the Operator.

c. Dynamic trends shall provide up to six points and show real time activity of the associated points. This information shall be printed and/or displayed in numeric, bar chart, curve plot, pie chart, etc., as selected by the operator. Graphic plots shall allow a unique color for each point. As new point values are sampled, they shall be processed, scaled, and dynamically appended to any plot being displayed. Sample interval of points selected for dynamic trend shall be user selectable from five seconds to sixty minutes.

d. Alarm and run time reports shall be automatically issued to assigned printers immediately upon occurrence, and shall consist of the point descriptor, the status or value of the point with engineering unit, the time and date, and an action taking alarm message.

e. The user shall be provided with a command trace feature selectable on a per point basis allowing the archiving of all commands issued to each point. The archived trace shall include the command, the command source, the point ID, and the time and date. Command trace reports shall be output upon Operator demand.

f. A custom report capability shall be provided to allow the user to format reports of any mix of text, points with status/value and descriptors, and points with status/value only. Custom reports may be scheduled or requested manually. A spreadsheet program similar to Microsoft Excel shall be provided fully integrated with the BCAS data base, and available to the user. Spreadsheet packages, which require offline execution, or manual translation of data files from one program format to another, are not acceptable.

g. In the event of failure of any printer, subsequent reports directed to that printer shall be automatically redirected to an Operator pre-assigned backup printer located at the operator station.

7. Graphic Creation: An on-line graphic development facility shall be provided to allow the user to develop or modify graphic displays and assign and position any array of points within each graphic.

a. All graphic displays shall be created via operator station graphics package. Graphics shall be created via mouse and keyboard selection of graphic library stored symbols and system profiles. Provide, in addition, the capability to create custom symbols, system profiles, floor plans, buildings, etc., and to store them in the graphic library.

b. The number and type of graphics to be provided is as noted in the Data Control and Graphics summary.

c. The system shall provide expansion to a minimum of 1,000 graphics.

8. Digital System Management: The Operation Station shall provide complete utilities necessary for management of the network of digital controllers and devices.

a. Provide a multi-page set of dynamic graphic architectural displays showing each digital module including each remote panel, PC, peripheral, and communication links. Clicking on any device shall start an interactive dialog allowing the user to observe the device status and to select device management options. Each device shall also be provided with an English descriptor of up to 60 characters.

Digital devices in a failed or non-responsive mode shall show up distinctly red in digital system graphics.

b. Any RAM based digital device may be up-line or down-line loaded to or from the Operator Station disk for backup archival.

c. Provide software to execute and observe diagnostics of any remote device connected to the peer bus and the ability to deactivate and restart the device.

d. The Operator shall be provided with the ability to override the use of a portable operator's terminal on any remote NCP.

9. Operator Station Utilities: The Operator Station personal computer shall be provided with the following menu selected graphic system utilities or desktop application packages:

a. Clock - Real Time Clock
b. Calculator - Basic arithmetic calculation functions (add, subtract, multiply, divide, percent, square root)
c. Clipboard - Data transfer facility between dissimilar programs
d. Calendar - Electronic Appointment Calendar, with Auto Alarm
e. Card File - Electronic index card file
f. Control Panel-Basic PC operating characteristic control: Cursor blink rate, mouse sensitivity, screen color control, etc.
g. Note Pad - Archive for miscellaneous notes
h. Write - Word processing program

10. Compatible Software: The system provided must be capable of running standard off-the-shelf MS Windows 11 compatible software packages concurrently with the real time system. Fully tested and qualified integrated third-party software packages including spreadsheet, data base manager, and word processing shall be provided capable of running under MS DOS is to be identified as system compatible and listed in the submittal.

a. The base system software shall include a CRT "windowing" feature to allow the operator to monitor the real time system and use third party software simultaneously.
b. All third-party software packages identified shall have access to the system historical database previously specified.

PART 3 - EXECUTION

3.01 INSTALLATION

A. General: Install system and materials in accordance with manufacturer's instructions, roughing-in drawings and details on the Drawings. All components and appurtenances shall be installed in accordance with the manufacturer's instructions, as shown, and as specified. All necessary interconnections, services, and adjustments required to prepare the building for interface to the BCAS shall be furnished. All electrical work shall be in accordance with Division 26. Instrumentation grounding as necessary to preclude ground loops and noise from adversely affecting equipment operations shall be installed. Final adjustment shall be performed by specially trained personnel in the direct employ of the manufacturer of the BCAS.

B. Electrical Wiring: Refer to the applicable Sections of Division 26 for electrical wiring and raceway installation requirements.

C. Mechanical Work: Refer to the applicable Sections of Division 23 for the installation of wells, valve bodies, and dampers in mechanical systems.

D. I/O Summary Tables shall be used in conjunction with the Drawings to identify the hardware required for each building control and automation system.

E. All temperature control and automation materials shall be applied and installed per the manufacturers' recommendations.

F. Remote bulbs shall be flange mounted in ductwork and casings and mounted with separable sockets in pipes and tanks. Where installed through insulation, flanges and sockets shall have extension necks to finish flush with the insulation surface.

G. All sensing elements for supply air temperature in ductwork or casings shall be averaging type with sensing length of number of elements to measure air temperature through the entire cross section of the duct or casing.

H. The project plans shall be thoroughly examined for control device and equipment locations. Any discrepancies, conflicts, or omissions shall be reported to the architect/engineer for resolution before rough-in work is started.

I. The contractor shall inspect the site to verify that equipment may be installed as shown. Any discrepancies, conflicts, or omissions shall be reported to the engineer for resolution before rough-in work is started.

J. The contractor shall examine the drawings and specifications for other parts of the work. If head room or space conditions appear inadequate—or if any discrepancies occur between the plans and the contractor’s work and the plans and the work of others—the contractor shall report these discrepancies to the engineer and shall obtain written instructions for any changes necessary to accommodate the contractor’s work with the work of others. Any changes in the work covered by this specification made necessary by the failure or neglect of the contractor to report such discrepancies shall be made by—and at the expense of—this contractor

3.02 **PROTECTION**

A. The contractor shall protect all work and material from damage by his/her work or employees and shall be liable for all damage thus caused.

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

3.03 **COORDINATION**

A. Site.

1. Where the mechanical work will be installed in close proximity to, or will interfere with, work of other trades, the contractor shall assist in working out space conditions to make a satisfactory adjustment. If the contractor installs his/her work before coordinating with other trades, so as to cause any interference with work of other trades, the contractor shall make the necessary changes in his/her work to correct the condition without extra charge.
2. Coordinate and schedule work with other work in the same area and with work dependent upon other work to facilitate mutual progress.

B. Test and Balance.

1. The contractor shall furnish a single set of all tools necessary to interface to the control system for test and balance purposes.
2. The contractor shall provide training in the use of these tools. This training will be planned for a minimum of 4 hours.
3. In addition, the contractor shall provide a qualified technician to assist in the test and balance process, until the first 20 terminal units are balanced.
4. The tools used during the test and balance process will be returned at the completion of the testing and balancing.

C. Life Safety.

1. Duct smoke detectors required for air handler shutdown are provided under Division 28. Interlock smoke detectors to air handlers for shutdown as specified in Section 23 09 93 (Sequences of Operation).
2. Smoke dampers and actuators required for duct smoke isolation are provided under Division 15. Interlock smoke dampers to air handlers as specified in Section 23 09 93 (Sequences of Operation).
3. Fire and smoke dampers and actuators required for fire-rated walls are provided under Division 23. Fire and smoke damper control is provided under Division 28.

D. Coordination with controls specified in other sections or divisions. Other sections and/or divisions of this specification include controls and control devices that are to be part of or interfaced to the control system specified in this section. These controls shall be integrated into the system and coordinated by the contractor as follows:.

1. All communication media and equipment shall be provided as specified in Section 23 09 23 Article 2.2 (Communication).
2. Each supplier of a controls product is responsible for the configuration, programming, start up, and testing of that product to meet the sequences of operation described in Section 23 09 93
3. The contractor shall coordinate and resolve any incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.
4. The contractor is responsible for providing all controls described in the contract documents regardless of where within the contract documents these controls are described
5. The contractor is responsible for the interface of control products provided by multiple suppliers regardless of where this interface is described within the contract documents.

3.04 **GENERAL WORKMANSHIP**

A. Install equipment, piping, and wiring/raceway parallel to building lines (i.e. horizontal, vertical, and parallel to walls) wherever possible.

B. Provide sufficient slack and flexible connections to allow for vibration of piping and equipment.

C. Install equipment in readily accessible locations as defined by Chapter 1 Article 100 Part A of the National Electrical Code (NEC).

D. Verify integrity of all wiring to ensure continuity and freedom from shorts and grounds.

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

3.05 FIELD QUALITY CONTROL

A. All work, materials, and equipment shall comply with rules and regulations of applicable local, state, and federal codes and ordinances as identified in Section 23 09 23 Article 1.8 (Codes and Standards).

B. Contractor shall continually monitor the field installation for code compliance and quality of workmanship.

C. Contractor shall have work inspection by local and/or state authorities having jurisdiction over the work.

3.06 PANEL LOCATIONS

A. General: Direct Digital Control (DDC) Panels, status/monitoring panels and other control panels shall be located where shown on the Drawings or as close to the controlled equipment as is feasible.

B. Location: Panels shall be located so as to provide adequate clearance for maintenance and shall not interfere with maintenance or code clearances for other equipment. Floor plan drawings showing the proposed locations of all control panels shall be submitted for approval.

C. Mounting: Wall mounted panels shall be adequately supported from the wall to which they are attached. Floor mounted panels shall be mounted on housekeeping pads.

D. Coordination: Panel location shall be coordinated with the Division 26 Contractor so that there is adequate lighting and convenience outlets at the panel location for panel use and maintenance.

3.07 CONTROL POWER CIRCUIT SOURCES

A. General: Control power circuit sources are provided by Division 26 where shown to BCAS panel locations and at other locations shown on the Electrical Drawings. Control power transformers creating control power circuits are typically provided in motor starters on the project. All other control power circuit sources required by Division 23 shall be provided by Division 26 at the expense of Division 23.

B. Coordination: Control power circuit requirements and source locations shall be coordinated with the Division 26 contractor. This Contractor shall be responsible for any additional costs incurred to provide the required control power circuit sources. Input to the Division 26 Contractor shall include, but not be limited to:

1. Locations requiring control power.
2. Voltage, phase and ampacity.
3. Power type, normal or emergency
4. Type of connection.

3.08 BCAS WIRING INSTALLATION

A. General: All wiring required for a complete and operational building control and automation system shall be provided by this Division.

B. All line voltage control wiring, and all low voltage control wiring and the main data communications loop shall be installed in conduit. At the Contractor's option, low voltage wiring to HVAC terminal unit controllers and HVAC terminal unit temperature sensors may be installed in concealed accessible locations using UL-listed plenum rated cable installed without a raceway.

Cable shall not be installed without a raceway when exposed or in inaccessible locations (except individual sensor drops in drywall partitions).

C. All low voltage control wiring which is routed through concealed accessible locations shall be UL-approved low smoke producing jacketed plenum cable. Wiring run without conduit shall be properly supported from the building structure on maximum 5' centers and shall not depend upon the ceiling grid for support.

D. Line and low voltage control wiring shall not be installed in the same conduit and control wiring shall not be installed in the same conduit with power wiring.

E. All conduit in exposed locations shall be run in a neat manner and shall be perpendicular and parallel to building lines. Coordinate conduit routing with field conditions so as not to interfere with code clearances for other equipment, maintenance access and walkways.

F. All conduit and control wiring in concealed locations shall be installed in an orderly manner, generally perpendicular and parallel to building lines.

G. Permanently mark terminal blocks for identification. Protect all circuits to avoid interruption of service due to short-circuiting or other conditions. Line-protect from lightning and static electricity all wiring that comes from external sources to the site.

H. Label or code each field wire at each end. Permanently label or code each point of all field terminal strips to show the instrument or item served. Color-coded cable with cable diagrams may be used to accomplish cable identification.

I. Signal Transmission System wiring shall be installed as follows:

1. Splices in shielded and coaxial cables shall consist of terminations and the use of shielded cable couplers. Termination shall be in accessible locations. Cables shall be harnessed with cable ties.
2. Fit all equipment contained in cabinets or panels with service loops, each loop being at least 12" long. Equipment for fiber optics system shall be rack-mounted, as applicable, in ventilated, self-supporting, code gauge steel enclosure. Cables shall be supported for minimum sag.
3. Keep cable runs as short as possible. Allow extra length for connecting to the terminal board.
4. Do not bend flexible coaxial cables in a radius less than ten times the cable outside diameter.
5. Use vinyl tape, sleeves, or grommets to protect cables from vibration at points where they pass around sharp corners, through walls, panel cabinets, etc.
6. Grounding shall be in accordance with NFPA 70. All ground wire shall be insulated conductors.
7. Ground wire shall be run to service entrance ground.
8. To prevent ground loops, conduit grounds shall be isolated from EMC panels by non-metallic couplings approved for installation in air plenums.

J. Refer to applicable Division 26 Sections for additional requirements for conduit and wiring materials and installation. All conduit and wiring shall be installed in accordance with all applicable requirements of the National Electrical Code and the city authorities having jurisdiction.

K. All control and interlock wiring shall comply with national and local electrical codes, and Division 26 of this specification. Where the requirements of this section differ from Division 26, the requirements of this section shall take precedence.

L. All NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway according to NEC and Division 26 requirements.

M. All low-voltage wiring shall meet NEC Class 2 requirements. Low-voltage power circuits shall be subfused when required to meet Class 2 current limit.

N. Where NEC Class 2 (current-limited) wires are in concealed and accessible locations, including ceiling return air plenums, approved cables not in raceway may be used provided that cables are UL listed for the intended application.

O. All wiring in mechanical, electrical, or service rooms – or where subject to mechanical damage – shall be installed in raceway at levels below 3 m (10ft).

P. Do not install Class 2 wiring in raceways containing Class 1 wiring. Boxes and panels containing high-voltage wiring and equipment may not be used for low-voltage wiring except for the purpose of interfacing the two (e.g. relays and transformers).

Q. Do not install wiring in raceway containing tubing.

R. Where Class 2 wiring is run exposed, wiring is to be run parallel along a surface or perpendicular to it and neatly tied at 3 m (10 ft) intervals.

S. Where plenum cables are used without raceway, they shall be supported from or anchored to structural members. Cables shall not be supported by or anchored to ductwork, electrical raceways, piping, or ceiling suspension systems.

T. All wire-to-device connections shall be made at a terminal block or terminal strip. All wire-to-wire connections shall be at a terminal block.

U. All wiring within enclosures shall be neatly bundled and anchored to permit access and prevent restriction to devices and terminals.

V. Maximum allowable voltage for control wiring shall be 120 V. If only higher voltages are available, the contractor shall provide step-down transformers.

W. All wiring shall be installed as continuous lengths, with no splices permitted between termination points.

X. Install plenum wiring in sleeves where it passes through walls and floors. Maintain fire rating at all penetrations.

Y. Size of raceway and size and type of wire shall be the responsibility of the contractor in keeping with the manufacturer's recommendations and NEC requirements, except as noted elsewhere.

Z. Include one pull string in each raceway 2.5 cm (1 in.) or larger.

AA. Use color-coded conductors throughout with conductors of different colors.

BB. Control and status relays are to be located in designated enclosures only. These enclosures include packaged equipment control panel enclosures unless they also contain Class 1 starters.

CC. Conceal all raceways except within mechanical, electrical, or service rooms. Install raceway to maintain a minimum clearance of 15 cm (6 in.) from high-temperature equipment (e.g. steam pipes or flues).

DD. Secure raceways with raceway clamps fastened to the structure and spaced according to code requirements. Raceways and pull boxes may not be hung on flexible duct strap or tie rods. Raceways may not be run on or attached to ductwork.

EE. Adhere to this specification's Division 26 requirements where raceway crosses building expansion joints.

FF. Install insulated bushings on all raceway ends and openings to enclosures. Seal top end of vertical raceways.

GG. The contractor shall terminate all control and/or interlock wiring and shall maintain updated (as-built) wiring diagrams with terminations identified at the job site.

HH. Flexible metal raceways and liquid-tight flexible metal raceways shall not exceed 1 m (3 ft) in length and shall be supported at each end. Flexible metal raceway less than ½ in. electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal raceways shall be used.

II. Raceway must be rigidly installed, adequately supported, properly reamed at both ends, and left clean and free of obstructions. Raceway sections shall be joined with couplings (according to code). Terminations must be made with fittings at boxes, and ends not terminating in boxes shall have bushings installed.

3.09 COMMUNICATION WIRING

A. The contractor shall adhere to the items listed in the Wiring" article in Part 3 of the specification.

B. All cabling shall be installed in a neat and workmanlike manner. Follow manufacturer's installation recommendations for all communication cabling.

C. Do not install communication wiring in raceways and enclosures containing Class 1 or other Class 2 wiring.

D. Maximum pulling, tension, and bend radius for the cable installation, as specified by the cable manufacturer, shall not be exceeded during installation.

E. Contractor shall verify the integrity of the entire network following cable installation. Use appropriate test measures for each particular cable.

F. When a cable enters or exits a building, a lightning arrestor must be installed between the lines and ground. The lighting arrestor shall be installed according to manufacturer's instructions.

G. All runs of communication wiring shall be unspliced length when that length is commercially available.

H. All communication wiring shall be labeled to indicate origination and destination data.

I. Grounding of coaxial cable shall be in accordance with NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

J. BACnet IP, Arcnet or MS/TP communications wiring shall be installed in accordance with ASHRAE/ANSI Standard 135. This includes but is not limited to:

1. IP

a. The network shall use Cat5e or greater cabling for connections.

b. Custom made patch cables must use either the T568A or T568 wiring standard and must use the same standard on both ends of the cable.

2. Arcnet

a. The network shall use shielded, twisted-pair cable with characteristic impedance between 100 nominal. Distributed capacitance between conductors shall be less than 12.5 pF per foot (41 pF per meter.)
b. The maximum length of an Arcnet segment is 610 meters (2000 ft) with AWG 22 cable.
c. The maximum number of nodes per segment shall be 32, as specified in the EIA 485 standard. Additional nodes may be accommodated by the use of repeaters.
d. An Arcnet network shall have no T connections.

3. MS/TP

a. The network shall use shielded, twisted-pair cable with characteristic impedance between 100 and 120 ohms. Distributed capacitance between conductors shall be less than 100 pF per meter (30 pF per foot.)
b. The maximum length of an MS/TP segment is 1200 meters (4000 ft) with AWG 18 cable. The use of greater distances and/or different wire gauges shall comply with the electrical specifications of EIA-485
c. The maximum number of nodes per segment shall be 32, as specified in the EIA 485 standard. Additional nodes may be accommodated by the use of repeaters.
d. An MS/TP EIA-485 network shall have no T connections.

3.10 FIBER OPTIC CABLE

A. Maximum pulling tensions as specified by the cable manufacturer shall not be exceeded during installation. Post-installation residual cable tension shall be within cable manufacturer's specifications.

B. All cabling and associated components shall be installed in accordance with manufacturers' instructions. Minimum cable and unjacketed fiber bend radii, as specified by cable manufacturer, shall be maintained.

3.11 EQUIPMENT INSTALLATION

A. Temperature Instruments:

1. Temperature Instruments: When a temperature sensor/transducer is installed in pipes or is susceptible to corrosion and vibration, the sensor shall be installed in a thermowell. Temperature sensors/transducers used for space temperature sensing shall include a housing suitable for wall mounting. Temperature sensor/transducers used for outside air sensing shall have an instrument shelter to minimize solar effects and shall be mounted to minimize building effects. Assemblies shall be readily accessible and installed in a manner as to allow easy replacement without special tools. Mount duct sensors/transducers in locations to sense the correct temperature of the air only, within the vibration and velocity limits of the sensing element. Mount extended surface element, when used, securely within the duct and position to measure the average temperature. Thermally isolate elements from bracket and supports to respond to air temperature only. Securely seal duct penetrations.
2. Sensor locations: Sensors shall be wall mounted in office areas, approximate locations are shown on the Drawings. Locate sensors to sense average return air temperature in the space monitored. Submit Drawings showing proposed locations of space and return air temperature sensors to the Engineer for review.

3. Temperature Switches: Temperature switches shall be installed as specified for temperature sensors. Temperature switches shall be adjusted to the proper setpoint and shall be verified by calibration. Switch contact ratings and duty shall be selected in accordance with NEMA ICS 1.
4. Relative Humidity Sensors/Transducers: Relative humidity sensors/transducers shall have air guards when installed in air flows of more than 50 fpm across the sensor element.

B. Pressure Instruments:

1. Pressure sensors/Transducers: Pressure sensors/transducers (all types) installed on liquid lines shall have isolation and drain valves. Pressure sensors/transducers installed on steam lines shall have isolation and drain valves and siphons. All pressure sensors shall have valves for isolation, venting, and taps for calibration. Pressure sensors/transducers shall have nulling valves.
2. Pressure Switches: Pressure switches (all types) installed on liquid lines shall have drains. Pressure switches installed on steam lines shall have drains and siphons. All pressure switches shall have valves for isolation, venting, and taps for calibration. Pressure switches shall be adjusted to the proper setpoint and shall be verified by calibration. Pressure switches shall be mounted higher than the process connection. Differential pressure switches shall have nulling valves. Switch contact ratings and duty shall be selected in accordance with NEMA ICS 1.

C. Flow Instruments:

1. Flowmeters: Flowmeters shall be installed in accordance with ASME Fluid Meters, Their Theory and Application and the manufacturer's recommendations for flow accuracy.
2. Venturi Tubes: Venturi tubes shall be installed in horizontal pipe runs. Venturi tubes shall be installed for ease of accessibility for periodic maintenance and as recommended by the manufacturers for flow accuracy.
3. Turbine Meters: Turbine meters shall be installed so that the sensor is located in the center of the fluid flow pipe on the main axis and as recommended by the manufacturers for flow accuracy.
4. Flow Switches: Flow switches shall be installed in such a manner as to minimize any disturbance in the flow of fluid while maintaining reliable operation of the switch.

D. Electric Power Devices:

1. Potential transformers and current transformers shall be installed in cabinets as shown or required.
2. Watt-hour meters, watt-hour demand meters, and current, voltage, and watt-hour transducers shall be installed in cabinets as shown or required.

E. Output Devices:

1. Relays and Contactors: Install relays and contactors in control cabinets or as required.
2. Controllers: Install controller in control cabinets or as required.
3.

F. Position Sensors:

1. End (Limit) Switch: Limit switch type and mounting shall be properly suited for the application to provide reliable switch operation.
2. Potentiometers: Potentiometer type and mounting shall be properly suited for the application to provide reliable operation.

3. Instrument shelters shall be installed with bottom 4' above the supporting surface using legs and secured rigidly to minimize vibrations from winds. Instrument shelters shall be oriented facing north.

G. Carbon Monoxide (CO) Sensors: Install the CO sensors in accordance with the manufacturers written installation instructions and project design drawings. System checkout, start-up, calibration, and testing shall be performed by a field-service engineer in the direct employ of the BCAS manufacturer.

3.12 WARNING LABELS

A. Permanent warning labels shall be affixed to all equipment that can be automatically started by the control system.

1. Labels shall use white lettering (12-point type or larger) on a red background.
2. Warning labels shall read as follows.

a. C A U T I O N: This equipment is operating under automatic control and may start or stop at any time without warning. Switch disconnect to “Off” position before servicing.

B. Permanent warning labels shall be affixed to all motor starters and control panels that are connected to multiple power sources utilizing separate disconnects.

1. Labels shall use white lettering (12-point type or larger) on a red background.
2. Warning labels shall read as follows.

a. C A U T I O N: This equipment is fed from more than one power source with separate disconnects. Disconnect all power sources before servicing.

3.13 IDENTIFICATION OF HARDWARE AND WIRING

A. All wiring and cabling, including that within factory-fabricated panels, shall be labeled at each end within 5 cm (2 in.) of termination with control system address or termination number.

B. All pneumatic tubing shall be labeled at each end within 5 cm (2 in.) of termination with a descriptive identifier.

C. Permanently label or code each point of field terminal strips to show the instrument or item served.

D. Identify control panels with minimum 1 cm (½ in.) letters on laminated plastic nameplates.

E. Identify all other control components with permanent labels. All plug-in components shall be labeled such that removal of the component does not remove the label.

F. Identify room sensors related to terminal boxes or valves with nameplates.

G. Manufacturers’ nameplates and UL or CSA labels shall be visible and legible after equipment is installed.

H. Identifiers shall match record documents.

3.14 CONTROLLERS

A. Provide a separate controller for each AHU or other HVAC system. A DDC controller may control more than one system provided that all points associated with the system are assigned to the same DDC controller. Points used for control loop reset, such as outside air or space temperature, are exempt from this requirement.

B. Building Controllers and Custom Application Controllers shall be selected to provide the required I/O point capacity required to monitor all of the hardware points listed in Section 15900 Appendix A (Sequences of Operation).

3.15 COMPUTER PROGRAMMING

A. Provide sufficient internal memory for the specified sequences of operation and trend logging.

B. Point Naming. Name points as shown on the equipment points list provided with each sequence of operation. See Section 23 09 93 (Sequences of Operation). If character limitations or space restrictions make it advisable to shorten the name, the abbreviations given in Appendix B to Section 23 09 93 may be used. Where multiple points with the same name reside in the same controller, each point name may be customized with its associated Program Object number. For example, “Zone Temp 1” for Zone 1, “Zone Temp 2” for Zone 2.

C. Software Programming.

1. Provide programming for the system and adhere to the sequences of operation provided. All other system programming necessary for the operation of the system, but not specified in this document, also shall be provided by the contractor. Imbed into the control program sufficient comment statements to clearly describe each section of the program. The comment statements shall reflect the language used in the sequences of operation. Use the appropriate technique based on the following programming types:

a. Text-based:

1) Must provide actions for all possible situations
2) Must be modular and structured
3) Must be commented

b. Graphic-based:

1) Must provide actions for all possible situations
2) Must be documented

c. Parameter-based:

1) Must provide actions for all possible situations
2) Must be documented.

D. Operator Interface

1. Standard Graphics. Provide graphics for all mechanical systems and floor plans of the building. This includes each chilled water system, hot water system, chiller, boiler, air handler, and all terminal equipment. Point information on the graphic displays shall dynamically update. Show on each graphic all input and output points for the system. Also show relevant calculated points such as setpoints. As a minimum, show on each equipment graphic the input and output points and relevant calculated points as indicated on the applicable Points List in Section 23 Appendix A.

2. The contractor shall provide all the labor necessary to install, initialize, start up, and troubleshoot all operator interface software and its functions as described in this section. This includes any operating system software, the operator interface database, and any third-party software installation and integration required for successful operation of the operator interface.

3.16 CONTROL SYSTEM CHECKOUT AND TESTING

A. Startup Testing. All testing listed in this article shall be performed by the contractor and shall make up part of the necessary verification of an operating control system. This testing shall be completed before the owner's representative is notified of the system demonstration.

1. The contractor shall furnish all labor and test apparatus required to calibrate and prepare for service of all instruments, controls, and accessory equipment furnished under this specification.
2. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
3. Enable the control systems and verify calibration of all input devices individually. Perform calibration procedures according to manufacturers' recommendations.
4. Verify that all binary output devices (relays, solenoid valves, two-position actuators and control valves, magnetic starters, etc.) operate properly and that the normal positions are correct.
5. Verify that all analog output devices (I/Ps, actuators, etc.) are functional, that start and span are correct, and that direction and normal positions are correct. The contractor shall check all control valves and automatic dampers to ensure proper action and closure. The contractor shall make any necessary adjustments to valve stem and damper blade travel.
6. Verify that the system operation adheres to the sequences of operation. Simulate and observe all modes of operation by overriding and varying inputs and schedules. Tune all DDC loops.
7. Alarms and Interlocks:

    a. Check each alarm separately by including an appropriate signal at a value that will trip the alarm.
    b. Interlocks shall be tripped using field contacts to check the logic, as well as to ensure that the fail-safe condition for all actuators is in the proper direction.
    c. Interlock actions shall be tested by simulating alarm conditions to check the initiating value of the variable and interlock action.

3.17 CONTROL SYSTEM DEMONSTRATION AND ACCEPTANCE

A. Demonstration.

1. Prior to acceptance, the control system shall undergo a series of performance tests to verify operation and compliance with this specification. These tests shall occur after the Contractor has completed the installation, started up the system, and performed his/her own tests.
2. The tests described in this section are to be performed in addition to the tests that the contractor performs as a necessary part of the installation, start-up, and debugging process and as specified in the "Control System Checkout and Testing" article in Part 3 of this specification. The engineer will be present to observe and review these tests. The engineer shall be notified at least 10 days in advance of the start of the testing procedures.
3. The demonstration process shall follow that approved in Part 1, "Submittals." The approved checklists and forms shall be completed for all systems as part of the demonstration.

4. The contractor shall provide at least two persons equipped with two-way communication and shall demonstrate actual field operation of each control and sensing point for all modes of operation including day, night, occupied, unoccupied, fire/smoke alarm, seasonal changeover, and power failure modes. The purpose is to demonstrate the calibration, response, and action of every point and system. Any test equipment required to prove the proper operation shall be provided by and operated by the contractor.
5. As each control input and output is checked, a log shall be completed showing the date, technician's initials, and any corrective action taken or needed.
6. Demonstrate compliance with Part 1, "System Performance."
7. Demonstrate compliance with sequences of operation through all modes of operation.
8. Demonstrate complete operation of operator interface.
9. Additionally, the following items shall be demonstrated:

    a. DDC loop response. The contractor shall supply trend data output in a graphical form showing the step response of each DDC loop. The test shall show the loop's response to a change in set point, which represents a change of actuator position of at least 25% of its full range. The sampling rate of the trend shall be from 10 seconds to 3 minutes, depending on the speed of the loop. The trend data shall show for each sample the set point, actuator position, and controlled variable values. Any loop that yields unreasonably under-damped or over-damped control shall require further tuning by the Contractor.
    b. Demand limiting. The contractor shall supply a trend data output showing the action of the demand limiting algorithm. The data shall document the action on a minute-by-minute basis over at least a 30-minute period. Included in the trend shall be building kW, demand limiting set point, and the status of sheddable equipment outputs.
    c. Optimum start/stop. The contractor shall supply a trend data output showing the capability of the algorithm. The change-of-value or change-of-state trends shall include the output status of all optimally started and stopped equipment, as well as temperature sensor inputs of affected areas.
    d. Interface to the building fire alarm system.
    e. Operational logs for each system that indicate all set points, operating points, valve positions, mode, and equipment status shall be submitted to the architect/engineer. These logs shall cover three 48-hour periods and have a sample frequency of not more than 10 minutes. The logs shall be provided in both printed and disk formats.

10. Any tests that fail to demonstrate the operation of the system shall be repeated at a later date. The contractor shall be responsible for any necessary repairs or revisions to the hardware or software to successfully complete all tests

B. Acceptance.

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

3.18 **CLEANING**

A. The contractor shall clean up all debris resulting from his/her activities daily. The contractor shall remove all cartons, containers, crates, etc., under his/her control as soon as their contents have been removed. Waste shall be collected and placed in a designated location.

B. At the completion of work in any area, the contractor shall clean all work, equipment, etc., keeping it free from dust, dirt, and debris, etc.

C. At the completion of work, all equipment furnished under this section shall be checked for paint damage, and any factory-finished paint that has been damaged shall be repaired to match the adjacent areas. Any cabinet or enclosure that has been deformed shall be replaced with new material and repainted to match the adjacent areas.

3.19 **FINAL ADJUSTMENT OF EQUIPMENT**

A. General: After completion of the installation, adjust thermostats, control valves, motors, and similar equipment provided as work of this Section. Final adjustments shall be performed by specially trained personnel in the direct employ of the manufacturer of the primary temperature control system.

B. Start up, check out, and test all hardware and software and verify communication between all components.

1. Verify that all control wiring is properly connected and free of all shorts and ground faults. Verify that terminations are tight.
2. Verify that all analog and binary input/output points read properly.
3. Verify alarms and interlocks.
4. Verify operation of the integrated system.

END OF SECTION

SECTION 23 21 13 - HVAC WATER PIPING

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Scope of Work - Section 23 05 01
5. Start-up, Testing, Adjusting, and Balancing - Section 23 05 93

1.02 SCOPE

A. Furnish and install a complete HVAC piping system as specified herein and as shown on the Drawings.

B. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. Pipe Heat Tracing - Section 20 05 33
2. Noise and Vibration Isolation - Section 20 05 48
3. Thermal Insulation - Section 20 07 00
4. HVAC Water Piping Accessories - Section 23 05 10

1.03 QUALITY ASSURANCE

A. Codes and Standards: All piping shall be manufactured in the United States of America by one of the manufacturers listed in the latest edition of the American Petroleum Institute (API) approved manufacturers listing.

B. All grooved components including couplings, fittings, valves, gaskets, and specialties shall be of one manufacturer. All castings shall be dated stamped for quality assurance and traceability.

1.04 PIPE HEAT TRACING (FREEZE PROTECTION)

A. The mechanical contractor shall furnish and install heat-tracing cable as specified in Section 20 05 33, where shown on the Drawings, and where piping is exposed to freezing conditions. The entire length of the exposed pipe including all valves, fittings, and accessories shall be traced and insulated. Refer to Section 20 07 00 for insulation requirements.

PART 2 - PRODUCTS

2.01 CHILLED WATER PIPING (ABOVE GROUND)

A. General: All chilled, condenser, and heating hot water piping above ground on the project shall be designed for 150 psig and shall be Schedule 40 in accordance with ANSI B36.10. Piping 4" and smaller shall be ASTM-A53 black steel. Piping 5" and larger shall be black steel ASTM A-53 seamless or electric resistance welded (fully normalized after welding).

B. 2" and Smaller: Screwed fittings and flanges shall be used on pipe sizes up through 2" IPS. All screwed connections or fittings shall be accessible for repair and shall not be permitted in inaccessible locations. All taps shall be made using factory manufactured screwed fittings. Screwed fittings, where permitted shall be Class 150 ANSI B16.3 screwed malleable iron.

C. 2-1/2" and Larger: All piping, 2-1/2" and larger, shall be butt-welded system in accordance with ANSI B31.1.0 except with flanges where required for service or equipment connections. All flanged or screwed connections shall be accessible for repair and shall not be permitted in inaccessible locations.

D. Welded fittings shall be factory made wrought steel in accordance with ANSI B16.9 with wall thickness and material identical to pipe being fitted. Flanges shall be Class 150 ANSI B16.5 forged steel with beveled edge weld type neck. Branch piping taps more than one size smaller than the main shall be made with weldolets and/or threadolets manufactured in accordance with ANSI B16.9. All butt weld fittings shall have wall thickness as specified by ANSI B31.1.0 and ANSI B36.10 standards and they shall be suitable for the working pressure and temperature of the piping that they are installed in. No branch piping tap to the main shall be made by burning a hole in the main, inserting the end of the branch piping and then welding the branch piping to the main.

E. Piping shall be installed in such a manner as to not obstruct the removal of filters, lubrication access to areas or general servicing of connected equipment. The routing of piping shall be placed so as to conserve as much space as possible in equipment rooms. Grade all piping, (1/16" per foot), to air vent locations. Bull-head tee connections and other piping connections which cause excessive pressure drop are not permitted. Reductions in line size for control valves shall not be made more than two pipe diameters away from the connections to the valve.

F. Grooved Piping: At the Contractor's option, a UL listed grooved piping connection system with "cut-grooves" or "roll-grooves" may be used for piping 2-1/2" and larger above ground. Fittings for elbows, tees reducers, etc., shall be full flow fittings.

1. QuickVic™ couplings for pipe prepared with the Victaulic Original Grooved System (OGS) groove profile, sizes 2” through 12” (DN50 through DN300), consisting of two ductile iron housing segments conforming to ASTM A536 Grade 65-45-12, orange coated or hot dipped galvanized as per ASTM A123, center-leg gasket, and ASTM A449 and A563 compliant zinc-electroplated carbon steel or ASTM F593 and F594 compliant stainless steel (with galling reducing coating) bolts and nuts. Installation-Ready™, for direct stab installation without field disassembly.

a. Rigid Type: Housings cast with torque-absorber and shift-limiting slant bolt pad design to provide piping system rigidity and support and hanging in accordance with ANSI B31.1 and B31.9, and to prevent mis-assembly due to over shift. Basis of Design: Victaulic Installation-Ready™ Style 107V.

1) Housings cast with alignment indicator notch for visual proper alignment to adjoining fitting.
2) Gaskets: Gaskets shall be verified as suitable for the intended service.

a) Grade EHP (EPDM) for water services, temperature range –30°F to +250°F/–34°C to +121°C.

b. Flexible Type: Use in locations where vibration attenuation and stress relief are required. Flexible couplings may be used in lieu of flexible connectors at equipment connections. Three couplings, for each connector, shall be placed in close proximity to the vibration source.

1) 2” (DN50) through 8” (DN200): Victaulic Style 177 (Quick-Vic™). Installation ready flexible coupling for direct stab installation without field disassembly. Gasket shall be Grade “EHP” EPDM compound with red color code designed for operating temperatures from -30 deg F (-34 deg C) to +250 deg F (+120 deg C).
2) 10” (DN250) through 12” (DN300): Victaulic Style 75 or 77 standard flexible couplings. Gasket shall be Grade “E” EPDM compound with green color code designed for operating temperatures from -30 deg F (-34 deg C) to +230 deg F (+110 deg C).

c. Pipe sizes 14” and larger: Use Victaulic AGS series with lead-in chamfer on housing key and wide width FlushSeal® gasket. Couplings shall be Victaulic Style W07 AGS Rigid Couplings with grade “EHP” gaskets in areas where piping system rigidity is required. Victaulic Style W77 AGS Flexible Couplings with grade “EHP” gaskets may be used in certain situations where vibration attenuation, stress relief, or accommodation of thermal expansion and contraction are required.
d. Taps to mains shall be made using Victaulic Style 72 outlet coupling or Style 920/920N mechanical tees or Victaulic Style 923/924 strapless outlets. Mechanical T couplings with U-bolts (i.e., Victaulic Style 921) shall not be permitted. Flange connections shall be made using Victaulic Style 741/743 flanges with grade "E" gaskets. Fittings for elbows, tees, reducers, etc., shall be Victaulic full flow fittings.

2. All proposed grooved or rolled piping connections materials shall be suitable for use at the temperatures and pressures encountered at the point of application. Painted couplings may be utilized in lieu of galvanized couplings.
3. Manufacturers: If they comply with these Specifications, only grooved piping products manufactured by Victaulic shall be allowed. No substitutions are acceptable.
4. Installation: The grooved coupling manufacturer’s factory trained representative shall provide on-site training for contractor’s field personnel in the use of grooving tools and installation of grooved joint products. The representative shall periodically visit the jobsite and review contractor is following best recommended practices in grooved product installation. (A distributor’s representative is not considered qualified to conduct the training or jobsite visit(s).)

2.02 **COPPER PIPING**

A. Copper pipe 2-1/2" and smaller may be used for chilled water and heating hot water Class 150 psig working pressure piping. Contractor shall coordinate valves and accessories where copper pipe is used, for proper connections. Steel pipe sizes are shown on the Drawings and shall be adjusted by the Contractor using the following pipe sizing conversion chart or as required to limit friction loss at scheduled GPM's to 5 ft./100 ft. Velocities shall not exceed 5 ft. per second in copper pipe.

GALVANIZED PIPE SIZE (IN)	COPPER PIPE SIZE (IN)
1/2	1/2
3/4	1
1	1-1/4
1-1/4	1-1/2
1-1/2	2
2	2-1/2

B. Connections between steel and copper pipe shall be made with insulating unions or approved insulating couplings.

C. Copper pipe shall be Cerro, Mueller, or approved equal Type L copper hard drawn ASTM B88-55, 1423.1.

D. Fittings for copper pipe shall be domestically manufactured by Mueller, Nibco, or Elkhart for wrought copper joint fittings conforming to ASME B16.22 or ASME B16.18.

E. All fittings shall either be soldered with Bridgit solder, using Bridgit burn resistant soldering flux (no exceptions), or press fittings (ProPress system) by Ridgid/Viega. Press fittings shall employ an EPDM o-ring seal and shall be pressed using the tool approved by the system manufacturer.

F. Hangers shall be Fee & Mason, Figure 364 with Figure 227 adjustable, or approved equal.

G. Refer to Section 23 05 10 for valves to be used in copper piping.

H. Copper Option: Copper pipe type “L” hard drawn in sizes 2-1/2”, 3", 4" and 6" for 150 psig systems may be used and assembled with Victaulic style 607 couplings. All fittings shall be Victaulic style 600 series copper "no sweat" full flow with grooved ends manufactured to copper-tube dimensions. (Flaring of tube or fitting ends to accommodate alternate size couplings is not permitted.) Piping shall be roll grooved utilizing the grooving system manufacturer's roll-grooving machine. Couplings and fittings shall be of one manufacturer. Valves shall be as specified in Section 23 05 10. Flange adapters with lug-style butterfly valves will not be allowed.

I. Plain End Carbon Steel Option: If the capability of the Subcontractor is demonstrated to the Engineer, at the Subcontractor’s option, plain-end carbon steel piping 2" and smaller for 150 and 300 psig working pressures may be joined by the Victaulic® QuickVic™ SD Installation-Ready™ System. Pipe to be as specified above for Carbon Steel Pipe herein.

1. For Fittings and Couplings: Ductile iron conforming to ASTM A536, Grade 65-45-12. Gasket shall be Victaulic Grade "EHP" EPDM suitable for water service temperature range -30°F to +250°F.
2. Tool: PC3110 Cut & Mark Tool designed to cut and mark (knurled marks to clearly display the insertion depth on the outside of the pipe for proper coupling/fitting installation) the pipe simultaneously. Tool to be supplied by Victaulic. If a PC3110 Cut & Mark tool is not used, insertion depth witness marks shall be applied and visible on every joint to ensure correct insertion depth installation.

PART 3 - EXECUTION

3.01 SUBMITTAL

A. Shop drawing submittal shall include, but not be limited to, the following:

1. Cut sheets marked to clearly indicate all HVAC piping system materials to be used.
2. Piping fabrication drawings shall be submitted for all piping in the Central Plant, Mechanical Rooms, and for Equipment connections in all other areas. Pipe fabrication drawings shall be double line drawings to scale on 1/4" scale building floor plans and shall indicate pipe size, fittings, valves, accessories, connections, system type, insulation, support requirements, isolator locations and types, pipe elevations and other information required for coordination with other trades and fabrication of piping.
3. Pipe fabrication drawings for all underground piping showing location and sizes of all expansion/contraction loops, thrust block location, anchors and guides.
4. Manufacturer's installation recommendations and instructions.

B. Grooved products shall be shown on drawings and product submittals and shall be specifically identified with the applicable style or series number.

END OF SECTION

SECTION 23 21 23 - HVAC PUMPS

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Scope of Work - Section 23 05 01
5. Start-up, Testing, Adjusting, and Balancing - Section 23 05 93

1.02 SCOPE

A. Furnish and install HVAC pumps as shown, scheduled, and specified including, but not limited to:

1. Horizontal split case centrifugal pumps.
2. Horizontal end suction centrifugal pumps.

B. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. Motors and Controllers - Section 20 05 13
2. Electronic Variable Speed Drives - Section 20 05 14
3. Noise and Vibration Isolation - Section 20 05 48
4. Thermal Insulation - Section 20 07 00

1.03 QUALITY ASSURANCE

A. Manufacturers: If they comply with these specifications and requirements, products of the following manufacturers will be acceptable:

1. Pumps:

a. Bell and Gossett
b. Aurora Pump Company
c. Taco

B. General Construction: The entire pump assembly including suction flange shall be suitable for operation with the maximum working pressures and temperatures scheduled on the Drawings.

PART 2 - PRODUCTS

2.01 CENTRIFUGAL PUMPS

A. General: Furnish and install horizontal base mounted, flexible coupled, bronze fitted centrifugal type, mechanical seal pumps of the size, capacity, and head scheduled on the Drawings. The selected pump operation point shall have a minimum efficiency as scheduled and impeller diameter shall not exceed 85% of the cutwater diameter for the selected pump casing size. All

pumps shall have dynamically balanced impellers. Shutoff head shall be at least 110% of design head but shall not exceed 140% of design head, unless scheduled otherwise.

B. Pumps: Pumps, casings, flanges and seals shall be suitable for operation at 150 psig minimum and shall be suitable for use within the normal temperature operating ranges of the system in which they are installed. Pumps shall have carbon steel shafts, stainless steel sleeves, cast-iron or bronze casing wear rings, bronze impeller wear rings, external seal water piping, cast-iron deflectors, stainless steel impeller keys, coated fiber packing gaskets and steel casing studs and bolts.

C. Couplings and Alignment: Pump couplings shall be Woods Type SC Sure-Flex flexible couplings, or an approved equal. Coupling alignment shall be field calibrated to a maximum of 2 mils vibration. Provide factory manufactured coupling guard meeting OSHA standards with each pump.

D. Impellers:

1. All pumps shall have dynamically balanced impellers and those with motors 10 HP or greater shall be factory capacity tested after final assembly. Certified factory pump performance test curves shall be submitted indicating capacity, head, horsepower and efficiency from shutoff to 125% of design flow.
2. The impeller selected shall not exceed 85% of the cutwater diameter for the pump casing size. This shall be clearly certified on the pump submittal.

E. Seals: All pumps shall be equipped with mechanical seals manufactured by John Crane Company or approved equal and suitable for the service intended.

1. For working pressures less than or equal to 150 psig, Type 1 or 2 seals shall be furnished.
2. For working pressures greater than 150 psig, Type 1B or 2B pressure balanced seals shall be furnished.
3. Seal material for pumps handling treated fluids up to 180ºF shall be Type BP (66)1D1.
4. Seal material for pumps handling treated fluids greater than 180ºF shall be Type XP (66)1D1.

F. Seal Protection: The mechanical seals on all condenser water pumps shall be provided with a Dorr-Oliver Type P "Doxie" impurity eliminator constructed throughout with Nylon. Piping shall be copper or Schedule 40 galvanized steel and shall be provided with isolation gate valves and valved bypass piping as recommended by the impurity eliminator manufacturer or as shown on the Drawings.

G. Bearings: All pumps shall have grease-lubricated ball bearings with grease fittings and relief plugs. Bearings shall have 400,000 hours minimum life for suction pressures below 200 psi and 200,000 hours minimum life for suction pressures 200 psi and above. Bearings shall limit impeller and mechanical seal face deflection to a maximum of 0.002 inches.

H. Base: Each pump shall have a drip lip type (except outdoor units) cast iron or steel base. The base shall have provisions for grouting, anchor bolts, and collection of all seal leakage. The base shall have machined surfaces for the mounting of pump casing and motor. Motor mounting shall permit horizontal movement. A 3/4" threaded outlet shall be provided in the base at the pump end for field piping of drainage to the nearest floor drain. The base shall be sufficient strength to prevent vibration, warping or misalignment of the pump and motor when installed without grouting. The base shall be rigidly bolted to the vibration isolation base. After final alignment, all pumps with 25 HP or larger motors shall have the pump and motor doweled to the base.

I. Motors: Pump motors shall be Energy Efficient 1750 RPM open drip-proof type (indoors) or TEFC (outdoors) and shall be selected to drive the pump through its characteristic curve from zero flow to 125% of design flow without exceeding rated full load nameplate horsepower. Refer to Section 20 05 13 for additional motor requirements and minimum efficiencies.

J. Miscellaneous:

1. Pumps shall be free of flashing and cavitation at all flow rates from 25% to 125% of design flow under the suction conditions of the pump installation.
2. Critical speed of each pump shall be at least 115% of the running speed scheduled.
3. Each motor shall have a maximum speed of 1750 RPM and shall be selected to drive the pump through its characteristic curve, from zero flow to 125% of design flow without exceeding rated nameplate horsepower.

K. Factory Tests: Pumps with drive motors 20 horsepower and larger shall be individually factory capacity tested after final assembly. Provide certified copies of test results showing capacity, head, horsepower, and efficiency at flow rates from shut off to 125% of design flow. The certification shall also indicate results of factory dynamic balance and pressure testing. Provide certified performance curves for pumps less than 20 horsepower.

PART 3 - EXECUTION

3.01 SUBMITTALS

A. Shop drawing submittals shall include the following:

1. Pump cut sheets with all pump capacities, characteristics, features, accessories and options clearly indicated.
2. Pump pressure/flow curves with selection point clearly indicated.
3. Motor data as required in Section 20 05 13.

3.02 INSTALLATION

A. Pipe, install and insulate HVAC pumps as shown on the Drawings. All base mounted pumps shall be mounted on a housekeeping pad as specified in Section 20 05 05 with vibration isolation as specified in Section 20 05 48. After pump installation is complete, field check alignment and dowel all pumps and motors on pumps 25 horsepower and larger to the base. Grout all pump bases in place.

B. After pumps have been in operation for 90 days, the contractor shall check all seals and replace any which are defective.

END OF SECTION

SECTION 23 64 33- WATER CHILLING UNITS - AIR COOLED

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Scope of Work - Section 23 05 01
2. Basic Division 20-28 Requirements - Section 20 05 03
3. Schedule of Submittal Data - 20 05 04
4. General Division 20-28 Materials and Methods - Section 20 05 05
5. Start-up, Testing, Adjusting, and Balancing - Section 23 05 93

1.02 SCOPE

A. Furnish and install complete factory assembled air-cooled reciprocating rotary, or scroll liquid chiller units of the type, size, and capacity shown, scheduled, and specified.

B. Air Cooled reciprocating, rotary, or scroll liquid chillers shall consist of a compressor or multiples thereof, direct expansion cooler, air cooled condenser for each refrigerant circuit and control panel completely factory wired, piped and charged with refrigerant.

1.03 QUALITY ASSURANCE

A. Manufacturers: Equipment schedules and specifications are based on Carrier Model 30GB, 30GT, and 30GX Air Cooled chillers. If they comply with these specifications and requirements, products of the following manufacturers will be acceptable:

1. Trane (Basis of Design)
2. JCI/York
3. Carrier

B. If equipment manufactured by a manufacturer other than that scheduled is utilized, then the Mechanical Contractor shall be responsible for coordinating with the General Contractor and all affected Subcontractors to ensure proper provisions for installation of the furnished unit. This coordination shall include, but not limited to, the following:

1. Structural supports for units
2. Piping size and connection/header location.
3. Electrical power requirements and wire, conduit, and overcurrent protection sizes.
4. The Mechanical Contractor shall be responsible for all costs incurred by the General Contractor, Subcontractors and Consultants to modify the building provisions to accept the furnished units.

C. Codes and Standards: Products shall be designed, tested, rated, and installed in compliance with the following standards, as applicable:

1. ANSI/ASHRAE STANDARD 15 (Current Edition)/Safety Codes for Mechanical Refrigeration.
2. ANSI/ASHRAE 90A/Energy Conservation in New Building Design.
3. ANSI/ASME SEC VIII/Boiler and Pressure Vessel Code.

4. ANSI/ASME B31.S (Current Edition)/ASME Code for Pressure Piping and Refrigeration Piping.
5. ANSI/UL 465/Central Cooling Air Conditioners.
6. AHRI Standard 590.
7. AFBMA 9/Load Ratings and Fatigue Life for Ball Bearings. Bearings must have life of not less than 200,000 hours.

D. Ratings and Certifications: Products shall be rated and certified in accordance with the following:

1. Conform to AHRI Standard 590 code for rating and testing of reciprocating chillers.
2. Conform to ANSI/ASME Boiler and Pressure Vessel Code for construction and testing.
3. Conform to ANSI/ASHRAE Standard 15 code for construction and operation of chillers.
4. Units shall be UL listed and CSA certified.
5. Construction shall comply with ANSI B9.1 safety code.

E. Warranty: Provide ten (10) year full warranty for chillers including coverage for complete chiller package as manufactured and delivered to site including materials and labor. Warranty shall also include all miscellaneous materials, travel time, expenses, shipping, refrigerant, oils, lubricants, belts, filters, insulation and any expenses related to service calls required to diagnose and correct warranty issues with equipment. All warranty work shall be performed by factory direct service technician, not the project mechanical contractor. During warranty phase, provide quarterly inspections (4 per year) by factory direct technician. Provide at least one week notice to owner to schedule service. All warranties shall begin upon project substantial completion, no exceptions. All components replaced through the warranty process shall be new and not rebuilt.

F. Maintenance Service: Offer service and maintenance of chillers for period subsequent to Date of Substantial Completion. Manufacturer shall have local stock of parts for centrifugal chiller proposed. Manufacturer shall have local service organization which shall have been established for at least five (5) years.

1.04 SUBMITTALS

A. Shop drawing submittals shall include, but not be limited to, the following:

1. Compliance to the Specifications: Submittal shall include an item-by-item description including a written description of equipment functions and normal operating characteristics.
2. Physical Data: Drawings indicating components, assembly, dimensions, weights, and loadings, required clearances, and location and size of field connections. Indicate equipment, piping and connections, valves, strainers, and thermostatic valves required for complete system.
3. Performance Data: Submittal shall include chiller manufacturer’s computer-generated performance ratings. These computer ratings shall be certified in accordance with AHRI 550-90. Computer ratings shall also contain AHRI certified part load values for operation at 100%, 75%, 50%, and 25% of full load with 2.5 F reduction in entering condenser water temperature per every 10% reduction in load. The chiller manufacturer shall guarantee that the chiller will maintain stable operation at the entering condenser water temperatures for these four (4) load points.
4. Start-Up Instructions: Written operating instructions including check-out, adjustment, start-up, routine and normal operations, regulations and controls, and shutdown for emergency.
5. Assembly Instructions: Written instructions for installation and assembly, where required, including assembly drawings showing match-marking of field-assembled components.
6. Starter: Motor starter cut sheets with components, features, and wiring clearly indicated.
7. Motor: Motor data as specified in Section 20 05 13, Motors and Controllers.

8. Power and Control Wiring: Wiring diagrams, showing power and control wiring for chiller components, safety devices, and controls, clearly indicating both factory and field wiring.
9. Minimum Circuit Ampacity (MCA)
10. Maximum Overcurrent Protection (MOCP)
11. Control panel interrupting rating (AIC)
12. Insulation: Insulation details for units.
13. Limitations: Written listing of limiting conditions of chiller including permissible temperatures, minimum voltages, maximum and minimum permitted ambient conditions, maximum permitted chilled water entering temperature, recommended thermal shock, and change-over temperatures.
14. Certifications: Performance certifications and certified reports.
15. Warranties and guarantees.
16. O & M Manual: Installation, operation, maintenance, and replacement parts manual. Manufacturer shall furnish three (3) copies of installation, operation, and replacements parts manuals for the water chilling units furnished, and shall include in these manuals a copy of the above approved submittals, noted for construction. Manuals shall include the following information:

    a. Instructions on where and how to contact local service and parts centers.
    b. Warranty details.
    c. Approved for construction submittals.
    d. Description and setpoint of controls.
    e. Start-up completion records.
    f. Manufacturer shall furnish a start-up completion record, signed by the manufacturer's representative and the successful Contractor and shall include:

        1) Dates of start-up and personnel in attendance.
        2) Dates of Owner instruction and personnel in attendance.
        3) Design performance data.
        4) Actual performance data.

17. Additional information as specified in Section 20 05 03.

PART 2 - PRODUCTS

2.01 COMPRESSORS

A. Each compressor shall be of the serviceable hermetic rotary type, or scroll and shall be equipped with an automatically reversible oil pump, operating oil charge, suction, and discharge shutoff valves, and shall be factory mounted on spring vibration isolators. Compressors must be field re-buildable.

B. Compressor motor shall be cooled by suction gas passing around the motor windings and shall be thermally protected.

C. Each compressor shall be equipped with an insert-type crankcase heater factory sized to control oil dilution during shutdown.

D. Each compressor shall be mounted on spring vibration isolators with an isolation efficiency of no less than 95%.

E. Compressor speed shall not exceed 1750 RPM at 60 hertz.

F. Cycles per hour per compressor shall not exceed six.

2.02 **COOLER**

A. Cooler shall be shell-and-tube type, with removable heads. Seamless copper tubes shall be rolled into tube sheets. Provide single water pass with multiple internal polypropylene baffles.

B. Cooler shall be tested and stamped in accordance with ASME code for refrigerant side working pressure of 235 psig and a minimum waterside working pressure of 150 psig.

C. Shell shall be insulated with 3/4" closed cell polyvinyl chloride foam insulation.

D. Cooler shall have two independent direct expansion refrigerant circuits on multiple compressor units and one refrigerant circuit on single compressor units.

E. Equip with electric heaters along shell under insulation to protect against freeze-up.

2.03 **CONDENSER**

A. Air-cooled condenser shall be constructed of mechanically bonded aluminum fins to seamless copper tubes. Aluminum fin shall have applied a corrosion resistant coating (anti-corrosive protectant).

B. Condensers shall be tested and stamped in accordance with ASME code for refrigerant side working pressure of no less than 450 psig.

C. Construction shall be as such to provide positive sub-cooling of the liquid refrigerant.

2.04 **REFRIGERANT COMPONENTS**

A. Each chiller refrigerant circuit shall include hot gas muffler, combination sight glass and moisture indicator, refrigerant filter-drier (replaceable), and charging valve. Maximum operating pressure thermal expansion valve only shall be provided to prevent compressor overload by limiting inlet suction pressure. All suction lines shall be insulated with close-fitting cellular foam insulation.

2.05 **CHILLER CONTROLS**

A. Unit shall have a control box which contains high- and low-pressure cut-out switched for each refrigerant circuit, manual reset low water temperature cut-out switch, multiple step chilled return water temperature controller to provide steps of capacity control, power terminal blocks, circuit breakers for compressor motor overload protection and contactors. Circuit breakers shall be manual reset and ambient insensitive.

B. Control panel shall have individual compressor indicator lights, a start-stop button, control power fuse or circuit breaker, and demand limit switch mounted on it. On multiple compressor units, a manual switch shall be factory provided to alternate the starting sequence of the compressors from one refrigerant circuit to the other (lead-lag).

C. Capacity control: Chillers shall have no less than four (4) steps of control and shall not utilize hot gas bypass.

2.06 **ELECTRICAL**

A. Unit shall be capable of operating on 480 volt, three-phase, 60-cycle supply.

B. Provide NEMA 3R enclosure housing all motor starters, interlocks, disconnects and accessories.

C. Input main fused disconnect or main circuit breaker.

D. Single point power input for controls, motors, and all accessories.

E. 35,000 amp withstand rating for units with MCA <= 150 amp unless otherwise noted on drawings.

F. 65,000 amp withstand rating for units with MCA > 150 amp unless otherwise noted on drawings.

G. Conduit: All conduit exposed to the outdoors shall be liquid-tight flexible metal conduit or rigid steel conduit. EMT conduit is not acceptable. See Section 26 05 33.

2.07 **ACCESSORY ITEMS**

A. Accessories shall include:

1. Compressor oil safety switch.
2. Suction/discharge pressure gauges and shutoff valves.
3. Remote control panel package.
4. Sound reduction kit with specially designed fans and orifices.

PART 3 - EXECUTION

3.01 **INSTALLATION**

A. General: Install chillers, including components and controls required for chiller operation, in accordance with chiller manufacturer's written instructions and recommendations. Chillers shall be installed on an equipment (housekeeping) pad with vibration isolators as specified in Section 20 05 48.

B. Location: Locate chiller in general position indicated in relation to other work. Position chiller with sufficient clearance for normal service and maintenance, including clearance for cleaning and replacement of tubes and motor.

C. Components: Install auxiliary piping, solenoid valves, shut-off valves, water strainers and controls for accessory systems including, but not limited to, oil cooler, compressor motor cooler, and transfer systems. Comply with manufacturer's instructions.

D. Interlock: Interlock flow switches with chiller controls in accordance with the manufacturer's instructions, except as otherwise indicated.

E. Refrigerant Relief: Pipe and install refrigerant relief line as required by codes or as indicated on Drawings; size shall be as recommended by the manufacturer in accordance with ASHRAE/ANSI 15-1992 Safety Code.

F. Electrical Feeder: Coordinate electrical power connection for main feeder and any separate power feeds with Division 26.

G. Supervision: The unit manufacturer shall supervise the installation and final check-out of the electrical interlock control wiring and review the location of the flow switches so that they perform the safety function without faulty operation or excessive vibration of the sensor.

H. Insulation: Field insulate all cold surfaces not factory insulated to prevent condensation

I. Finish: Paint damaged and abraded factory finish with touch-up paint matching factory finish.

3.02 **START-UP SERVICES**

A. Manufacturer's Supervision: A factory trained technical service representative of the manufacturer shall supervise the field assembly (if any), installation, pressure testing, checkout, and start-up of each chiller, for a minimum of five working days, plus one additional day for each chiller unit in excess of one unit. Prepare manufacturer's written report/log of the installation and start-up, signed by the service representative and the Owner.

B. Representative shall supervise leak testing, evacuation, dehydration, vacuum pumping, charging, lubrication, including the filling of reservoirs and confirm that lubricant is of the quantity and type as instructed by the manufacturer. If any chiller is found to have lost its shipping pressure prior to the time of installation and assembly, then the machine shall be leak tested, repaired, and shall be evacuated a minimum of 24-hours. Other special provisions for unit testing and setup as recommended by the equipment manufacturer shall also be followed.

C. Representative shall instruct the Owner's operating personnel in the operation and service of the units for a period of one week, based on a 40-hour week, excluding nights, weekends, and travel time to and from the project.

D. Sustained Operation: Do not place the chiller in sustained operation prior to the initial balancing of the mechanical systems affected by chiller operation. Refer to requirements of Section 23 05 93, Start-Up, Testing, Balancing and Adjusting. Notify Architect/Engineer prior to chiller start-up.

E. Cooperation: Cooperate with other trades and installers of other work during the testing, adjusting, balancing and start-up of mechanical systems.

END OF SECTION

DIVISION 25 - INTEGRATED AUTOMATION INDEX

SECTION	DESCRIPTION
25 00 00	INTEGRATED AUTOMATION INDEX
25 05 01	SCOPE OF WORK
25 06 01	STRUCTURED CABLING INFRASTRUCTURE
25 07 01	NETWORK AND CENTRAL HARDWARE
25 09 01	INSTALLATION, TESTING, AND TRAINING
25 09 02	PANELS AND CONTROLLERS
25 09 03	DAMPERS, VALVES AND ELECTRONIC CONTROL AND AUTOMATION HARDWARE
25 09 16	BUILDING CONTROL AND AUTOMATION SYSTEM (BCAS) SOFTWARE
25 09 93	SEQUENCE OF OPERATION

END OF INDEX

SECTION 25 05 01 - SCOPE OF WORK

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Refer to Specification Section 20 05 00 for related required Codes and Standards.

C. Refer to Specification Section 20 05 04 for related required Schedule of Submittal Data.

D. Requirements of Division 20 apply to all Work of Divisions 20-28.

1.02 SCOPE

A. General: Where renovation work requires addition or adjustment to the building automation system, the contractor is responsible to provide a fully integrated Building Control and Automation System (BCAS) incorporating Direct Digital Control (DDC), energy management hardware and software, equipment monitoring and control, and common Ethernet TCP/IP LAN for the additional controls items per the contract document. This Division requires the furnishing and installing of all items Specified herein, and as indicated on the Drawings, or reasonably inferred as necessary for safe and proper operation; Including every article, device or accessory (whether or not specifically called for by item) necessary to facilitate each system's functioning as indicated by the design, the equipment specified, the sequence of operation specified, and input/output tables and points list. Elements of the work include, but are not limited to, materials, labor, engineering, supervision, supplies, equipment, transportation, storage, utilities, services, programming, testing, and all required permits and licenses.

1. If necessary, the Owner will provide all communication media, connectors, repeaters, network switches, and routers necessary for the high-speed Ethernet network. An active Ethernet port will be provided adjacent to each System Controller and operator interface (PC) for connection to this high-speed Ethernet network.

B. Drawings: Refer to the Mechanical, Electrical, and Plumbing Drawings for graphic representations, equipment schedules, and notations showing elements of building control and automation work.

C. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. Commissioning - Division 01 and Section 20 08 00
2. Variable Speed Drivers - Section 20 05 14
3. Water Chilling Units - Section 23 64 16
4. Conductors - Section 26 05 19
5. Conduit - Section 26 05 33
6. Power Distribution Equipment - Section 26 27 10
7. Building Security System - Division 28

D. Work included: The work includes, but is not limited to, the following systems, equipment, and services:

1. Provide a complete new Building Control and Automation System. The BCAS shall be comprised of a Network Server, Network Area Controller or Controllers (NAC) within the

facility. The NAC shall connect over a management level Local Area Network (LAN) using high-speed BACnet MS/TP, BACnet Zigbee, or BACnet Ethernet TCP/IP. Access to the system, either locally in the building, or remotely from a central site or sites, shall be accomplished through standard Web browsers, via the Internet and/or LAN.

2. Each NAC shall communicate to field level DDC controllers provided under this section of the contract documents using BACnet MS/TP or BACnet Zigbee (802.15.4) as defined by the Zigbee Standard.

    a. Each System Controller shall function as a BACnet Router to each unit controller providing a unique BACnet Device ID for all controllers within the system.
    b. Wireless equipment controllers and auxiliary control devices shall conform to:

        1) IEEE 802.15.4 radios to minimize risk of interference and maximize battery life, reliability, and range.
        2) Communication between equipment controllers shall conform to ANSI/ASHRAE Standard 135-2016 (BACnet®/ZigBee®) standard as BACnet tunneling devices to accommodate future integration.
        3) Operating range shall be a minimum of 200 feet (60 m); open range shall be 2,500 ft. (762 m) with less than 2% packet error rate.
        4) To maintain robust communication, self-healing, redundant mesh networking and two-way communications shall be used to optimize the wireless network health.
        5) Wireless communication shall be capable of many-to-one sensors per controller to support averaging, monitoring, and multiple zone applications.
        6) Space/wall sensors shall be available with batteries with a typical life of 15 or more years to minimize maintenance costs or with power harvesting capabilities to minimize the need for batteries.
        7) The controls wireless network shall be secured using Advanced Encryption Standard AES-128 (FIPS Pub 197) and HMAC (FIPS Pub 198). A Trust Center will create a randomly generated 128-bit network security key for each ZigBee network.
        8) Certifications shall include FCC CFR47 - RADIO FREQUENCY DEVICES Section 15.247 & Subpart E.

3. Provide all necessary hardware shall be BACnet BTL (BACnet Testing Laboratories) with appropriate classifications:

    a. System controller shall be BTL listed BACnet Building Controller (B-BC).
    b. Equipment Controllers shall be BTL listed BACnet Application Specific Controller (B-ASC) or BACnet Advanced Application Controller (B-AAC), as appropriate for the purpose of the controller.

4. Prepare individual hardware layouts, interconnection drawings, and software configuration from project design data.
5. Implement the detailed design for all analog and binary objects, system databases, graphic displays, logs, and management reports based on control descriptions, logic drawings, configuration data, and bid documents.
6. Design, provide, and install all equipment cabinets, panels, data communication network cables needed, and all associated hardware.
7. Provide and install all interconnecting cables between supplied cabinets, application controllers, and input/output devices.
8. Provide and install all interconnecting cables between all operator’s terminals and peripheral devices (such as printers, etc.) supplied under this section.
9. Provide complete manufacturer’s specifications for all items that are supplied. Include vendor name of every item supplied.

10. Provide supervisory specialists and technicians at the job site to assist in all phases of system installation, startup, and commissioning.
11. Provide a comprehensive operator and technician training program as described herein.
12. Provide as-built documentation, operator's terminal software, diagrams, and all other associated project operational documentation (such as technical manuals) on approved media, the sum total of which accurately represents the final system.
13. Provide computer software and hardware, operator input/output devices, control units, local area network (LAN), sensors, control devices, actuators, control valves, dampers and operators, indicating devices, interface equipment and other apparatus and accessories to operate mechanical systems, and to perform integration functions specified.
14. All necessary controls, wiring and installation shall be provided and installed. Provide a complete system of devices to perform the sequences and programs outlined in Sections 25 09 93 and 25 09 33 including, but not limited to:

    a. Electric, electronic and computer control for all items shown on the Drawings, to provide the specified Sequence of controls as specified hereinafter including thermostats, sensors, relays, and motors.
    b. Electric damper operators and control valves furnished to the appropriate trade as specified under the Work of other Sections.
    c. Control panels as specified hereinafter and as shown on the Drawings.

15. Participate in Owner's Commissioning Plan, and support Owner's Building Commissioning Agent as necessary per Owner's Project Requirements and Divisions 1 and 20 Specifications.
16. Integrate building's water chilling units, variable frequency drives, and other pre-packaged controlled units through BACnet MS/TP or IP with full access to all attributes including control and reporting of these attributes. Coordinate with Division 23 Contractor.
17. Other miscellaneous control system components as shown on the Drawings, specified herein, and/or required.

E. Work of Other Sections:

1. Control valves, flow meters, air flow stations, automatic dampers, temperature sensors, flow switches, pressure switches, and other duct and piping system sensors and control devices shall be furnished under this Section for installation by the Division 23 Contractor.
2. The Division 23 Contractor shall:

    a. Install immersion wells, pressure taps and any associated shut-off cocks.
    b. Install flow switches and water flow sensors.
    c. Install automatic control valves.
    d. Install level switches.
    e. Furnish and install Venturi flanges.
    f. Install Venturi and flow sensors.
    g. Furnish and install automatic valve flanges, flange gaskets, increasers, reducers, nuts, and bolts as required.
    h. Furnish and install flare nuts for unitary valves.
    i. Furnish and install union fittings where required in unitary equipment for service of automatic valves, including necessary transitions.
    j. Install automatic control dampers.
    k. Provide and install necessary transitions and blank-off plates required to install automatic control dampers that are different than duct size.

l. Assemble multiple section dampers with required interconnecting linkages and extend required number of shafts through duct for external mounting of damper motors.
m. Provide and install necessary sheet metal baffle plates to eliminate stratification and provide air volumes specified. Locate baffles by experimentation and affix and seal permanently in place only after stratification problem has been eliminated.
n. Provide, install, and label access door or other approved means of access through ducts for service to control equipment.
o. Provide and install necessary duct transitions to provide velocities as recommended by airflow station manufacturers.
p. Install airflow measurement stations as indicated on the Drawings, specified, or required.
q. The chillers furnished under Division 23 shall include all factory-furnished control devices, transformers, relays and other appurtenances as required per the chiller manufacturers wiring diagram. All wiring on the chiller shall be the responsibility of the chiller manufacturer. The control interface module for each chiller shall be furnished and factory installed by the chiller manufacturer.
r. HVAC terminal units provided by Division 23 shall have factory mounted and wired velocity transducer, controllers and damper actuators provided by the BCAS subcontractor for installation by the terminal unit manufacturer.

3. The Division 26 Contractor shall:

a. Provide control power source circuits to all BCAS control panels. All other BCAS control wiring and control power source circuits required but not shown on the Electrical Drawings shall be included in the work of this Section.
b. Fire alarm interface relays and addressable input devices shall be provided by Fire Alarm Contractor. Interface relays shall be mounted adjacent to motor starters. Control wiring to these relays from the fire alarm system shall be by Fire Alarm Contractor and wiring of HVAC control circuits shall be by this Contractor. Fire Alarm work shall be contracted under Division 26.

F. System Capacity: The addition to the BCAS system shall have adequate front end capacity to accommodate a 30% increase in connected points, in excess of those specified, without the addition of any new hardware or software to the front end. Each stand-alone DDC Controller as defined herein shall have minimum of 20% spare points, in excess of those specified.

1.03 COORDINATION WITH OTHER TRADES

A. The BCAS Contractor shall be responsible for coordinating the Work of this section with the Work of other sections and Divisions 20-28 and providing all materials and labor required for installation of the Building Control and Automation System, which is not specified to be provided under another Division.

B. During the course of construction, the BCAS Contractor shall be responsible for coordinating BCAS provisions by other Divisions and shall be responsible for the proper installation of all provisions. Where provisions are not properly coordinated, it shall be the responsibility of this Division to correct the provisions at the expense of the BCAS Contractor.

C. The BCAS Contractor shall be responsible for reviewing the Division 20-28 Drawings and Specifications to determine the BCAS provisions and interface points provided under those Divisions and coordinating the work of this Section as required to properly interface.

D. The BCAS Subcontractor shall participate in and assist in the operation of the fire safety ventilation equipment as required during the performance testing and startup of the Division 28

Fire Detection, Alarm and Communication Systems. Refer to Division 28 Section 28 31 00 titled "Fire Alarm and Communication Systems" for additional requirements.

E. The BCAS Contractor shall participate in the development of coordinated drawings with the Division 20-28 Subcontractors. The Division 21, 22, and 23 Subcontractors shall indicate all mechanical, plumbing and fire protection work on the drawings. The Division 26 Subcontractor shall then add the electrical and fire detection, alarm and communication system work to the drawings. The BCAS Subcontractor shall indicate the required Division 25 work on the drawings. Assist and cooperate with the other trades to ensure a complete and coordinated set of drawings has been generated.

F. The Division 25 Contractor shall coordinate installation, testing and commissioning of Owner's Vertical Backbone Riser (OVBR) with other Trades (i.e., Security Contractor) who are reliant on functionality of OVBR to complete their work. The General Contractor shall provide schedule requirements to Division 25 Contractor.

1.04 **PRE-QUALIFIED CONTRACTORS**

A. Installation by the following contractors is acceptable contingent upon compliance with all aspects of the Specifications.

1. Automated Logic Corp. (Factory Branch)
2. Unify Energy Solutions

1.05 **QUALITY ASSURANCE**

A. General: All of the following Quality Assurance requirements shall be met:

1. All BCAS work shall be furnished and installed by the Division 25 Contractor. The work shall be performed by skilled technicians under the direction of experienced engineers, all of whom shall be properly trained and qualified for this work.
2. All materials and equipment used shall be standard catalogued components, regularly manufactured for use in HVAC control systems, and not custom designed for this project. All systems and components shall be manufacturer's latest standard design and have been thoroughly tested and proven in actual use.
3. Single source responsibility of the BCAS Contractor shall be the complete installation and proper operation of the BCAS, and shall include debugging and proper calibration of each component in the entire system.
4. The BCAS Contractor shall have an established support facility within 100 miles of the project site with factory trained technical staff, spare parts inventory, and all necessary test and diagnostic equipment. The BCAS Contractor must provide 24 hours/day, 7 days/week response in the event of a customer warranty or service call.
5. Maintenance service contract by supplier using an established program shall be available to the Owner following the warranty period.
6. The specification covers minimum requirements and is not intended to preclude provisions of equipment or methods that exceed the requirements.
7. All electronic equipment shall conform to the requirements of FCC regulation Part 15, Section 15 governing radio frequency electromagnetic interference and be so labeled.
8. Electrical work and safety requirements shall comply with NFPA 70 and all applicable local and state codes.
9. The system shall use BACnet MS/TP, as the communications protocol from node to node and from nodes to the network area controllers. System level integration shall be via BACnet MS/TP, TCP/IP over a BACnet Ethernet LAN or Modbus.
10. Control system components shall be new and in conformance with the following applicable standards for products specified:

a. American Society for testing materials, ASTM
b. Institute of Electrical and Electronic Engineers, IEEE
c. National Electrical Manufacturers Association, NEMA
d. Underwriters Laboratory, UL (UL 916)
e. FCC Regulation, Part 15, Section 156
f. National Fire Protection Association, NFPA
g. Local building codes
h. BACnet Testing Lab (BTL)

11. The Manufacturer of the network and unit controllers shall provide documentation supporting compliance with ISO-9001 (Model for Quality Assurance in Design/Development, Production, Installation and Servicing). Product literature provided by the network and unit controller manufacturer shall contain the ISO-9001 Certification Mark from the applicable registrar.
12. Use new products that the manufacturer is currently manufacturing and that have been installed in a minimum of 25 installations. Do not use this installation as a product test site unless explicitly approved in writing by the owner or the owner's representative. Spare parts shall be available for at least five years after completion of this contract.
13. Environmental Conditions of Operation:

    a. DDC controller and I/O equipment shall be designed to operate in ambient temperatures from 32oF to 122oF and relative humidity from 10% to 95% non-condensing.
    b. Sensors and Operating Devices: The environment that they are sensing or controlling but not less severe than for controller and I/O devices.

14. Ratings: All equipment shall be rated for continuous operation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified or normally encountered at the installed location.

1.06 SUBMITTAL REQUIREMENTS

A. BAS manufacturer shall provide shop drawings and manufacturers' standard specification data sheets on all hardware and software being provided for this project. No work may begin on any segment of this project until the Engineer and Owner have reviewed submittals for conformity with the plan and specifications. Five (5) copies are required. All shop drawings shall be provided to the Owner electronically as .dwg or .dxf file formats once they have been approved and as-built drawings have been completed.

B. Quantities of items submitted shall be reviewed by the Engineer and Owner. Such review shall not relieve the BAS manufacturer of furnishing quantities required based upon contract documents.
C. Provide the Engineer and Owner, any additional information or data which is deemed necessary to determine compliance with the specifications or which is deemed valuable in documenting and understanding the system to be installed.

D. Submit the following within 90 days of contract award:

1. A complete bill of materials of equipment to be used indicating quantities, manufacturers and model numbers.
2. A schedule of all control valves including the valve size, pressure drop, model number (including pattern and connections), flow, CV, body pressure rating, and location.
3. A schedule of all control dampers including damper size, pressure drop, manufacturer, and model number.
4. Provide all manufacturers' technical cut sheets for major system components. When technical cut sheets apply to a product series rather than a specific product, the data

specifically applicable to the project shall be highlighted or clearly indicated by other means. Include:

a. Building Controllers
b. Custom Application Controllers
c. Application Specific Controllers
d. Operator Workstations
e. Portable Operator Terminals
f. Auxiliary Control Devices

5. Provide proposed Building Automation System architectural diagram depicting various controller types, workstations, device locations, addresses, and communication cable requirements.
6. Provide detailed termination drawings showing all required field and factory terminations, as well as terminal tie-ins to DDC controls provided by mechanical equipment manufacturers. Terminal numbers shall be clearly labeled.
7. Provide points list showing all system objects and the proposed English language object names.
8. Provide a sequence of operation for each controlled mechanical system and terminal end devices.
9. Provide a BACnet Protocol Implementation Conformance Statement (PICS) for each BACnet system level device (i.e. Building Controller & Operator Workstations) type. This defines the points list for proper coordination of interoperability with other building systems if applicable for this project.
10. Provide BacNET Certification and functional profile SNVT's for unitary-level controllers (i.e. chillers, RTU's, AHU's, Terminal VAV boxes, FCU's, UV's, etc.) for interoperability with other building systems if applicable for this project.

11. Project Record Documents: Upon completion of installation, submit three (3) copies of record (as-built) documents. The documents shall be submitted for approval prior to final completion and include:

a. Project Record Drawings - These shall be as-built versions of the submittal shop drawings. One set of electronic media including CAD .dwg and .pdf drawing files shall be provided.
b. Testing and Commissioning Reports and Checklists signed off by trained factory (equipment manufacturers) and field (BAS) commissioning personnel.
c. Operating and Maintenance (O & M) Manuals - These shall be as-built versions of the submittal product data. In addition to the information required for the submittals, Operating & Maintenance manual shall include:

1) Names, address and 24-hour/7-day per week telephone numbers of Contractor personnel managing and installing equipment, along with service personnel responsible for supporting the ongoing warranty and services of the control system.
2) Procedures for operating the BAS including logging on/off, alarm management, generation of reports, trends, overrides of computer control, modification of setpoints, and other interactive system requirements.
3) Description of the programming language including syntax, statement descriptions, algorithms, calculations, point database creation and modification, program creation and modification, and operator use of the editor.
4) Explanation of how to design and install new points, new DDC controllers, and other BAS hardware.

5) Preventative Maintenance and calibration procedures; hardware troubleshooting; and hardware repair and/or replacement procedures.
6) Documentation of all software program logic created for Custom Programmable Controllers including the overall point database. Provide one set of magnetic media containing files of the software and point database.
7) One set of electronic media containing files of all operator color graphic screens for the project.
8) A list of recommended spare parts including pricing, manufacturer, supplier, and part numbers.
9) Documentation, installation, and maintenance information for all third party hardware/software products provided including personal computers, printers, hubs, sensors, valves, etc.
10) Original issue media for all software provided, including operating systems, programming language, operator workstation software, and graphics software.
11) Licenses, Guarantee, and Warranty documents for all equipment and systems.
12) Recommended preventive maintenance procedures for all system components including a schedule of tasks (inspection, cleaning, calibration, etc.) and task descriptions.

12. Training Manuals: The BAS manufacturer shall provide a course outline and copies of training manuals at least two weeks prior to the start of any corporate training class to be attended by the Owner.

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION (NOT APPLICABLE)

END OF SECTION

SECTION 25 06 01 - STRUCTURED CABLING INFRASTRUCTURE

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Design Criteria - Section 20 05 02
2. Basic Division 20-28 Requirements - Section 20 05 03
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Schedule of Submittal Data - Section 20 05 04
5. Start-up, Testing, Adjusting, and Balancing - Section 23 05 93
6. Scope of Work - Sections 25 05 01 and 26 05 01
7. Lighting Control System - Section 26 09 33
8. Electronic Security System - Division 28

1.02 SCOPE

A. Provide a complete Base Building Local Area Network (LAN) for communication of all IP based systems as outlined in these specifications.

B. LAN shall provide a common TLP/IP based network for communications usage by the various intelligent systems installed in the building.

C. The building LAN includes fiber trunk, conduit, patch panels, CAT 5 cabling, network drops, POE switches, and other network devices necessary for a complete and operable system.

D. All cabling connections from the network drops provide by this Division for use by the various systems sharing the common backbone will be by the corresponding Contractor providing those systems. The Building LAN shall provide a common backbone for the following systems:

1. Building Control and Automation System (BCAS)
2. Utility Metering System
3. Lighting Control System
4. Electronic Security System (ESS)
5. Elevator Control System
6. Parking Control System

E. This Section also includes the following:

1. Warranty on all provided equipment for one (1) year from substantial completion.
2. Comprehensive testing and commissioning per Industry Standards.
3. Owner training at substantial completion and again part occupancy (eight (8) hours each, minimum).
4. Coordination with other Contractors and Vendors sharing LAN for their system functionality.
5. Maintenance of equipment during warranty period.

F. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. Conduit - Section 26 05 33

1.03 **QUALITY ASSURANCE**

A. Manufacturers: If they comply with these specifications and requirements, products of the following manufacturers will be acceptable. Substitute products shall follow procedures as outlined in Division 20.

1. Siemens
2. Cisco
3. Belden
4. Juniper
5. Corning
6. Panduit

1.04 **SUBMITTALS**

A. Submittals shall include, but not be limited to, the following:

1. Data showing compliance with Quality Assurance Requirements.
2. Riser Diagram showing all proposed network equipment and cabling.
3. Product Data of all equipment and cabling.
4. Certifications of all installers.
5. Wiring Diagrams of all network equipment.
6. Proposed Commissioning procedure.
7. Additional information as required by Section 20 05 03, Basic Division 20-28 Requirements.

PART 2 - PRODUCTS NOT APPLICABLE

PART 3 - EXECUTION

3.01 **SUBMITTALS**

A. Project Initiation: Within thirty (30) days of Notice to Proceed, the data network system installer shall furnish the following in a single consolidated submittal:

1. Permits: The Contractor shall obtain all required permits and provide copies to the Owner/Architect/Engineer.
2. Product Literature: Complete manufacturer's product literature for all cable, patch panels, cable supports, cable labels, outlet devices, and other products to be used in the installation. In addition, whenever substitutions for recommended products are made, the manufacturer's supporting documentation demonstrating compatibility with other related products shall be included. The submittal shall have some type of distinguishing marker or pointer to indicate what specific product is to be provided.
3. Construction Schedule: A time-scaled Construction Schedule, using PERT/CPM, indicating general project deadlines and specific dates relating to the installation of the local area network system.
4. Testing: Proposed Contractor Category 6 UTP cable test result forms, fiber optic cable test result forms and a list of instrumentation to be used for systems testing.

B. Project Completion: As a condition for project acceptance, the Contractor shall submit the following for review and approval:

1. Inspection and Test Reports: During the course of the project, the Contractor shall maintain an adequate inspection system to ensure that the materials supplied, and the

work performed conform to Contract requirements. The contractor shall provide written documentation that indicates that materials acceptance testing was conducted as specified.

a. The Contractor shall also provide documentation, which indicates that all cable termination testing was completed and that all irregularities were corrected prior to job completion.
b. Operating and Maintenance Instructions: Operating and maintenance instructions for all devices within the system. These instructions shall reflect any changes made during the course of construction, and shall be provided to the Owner for their use in a three-ring binder labeled with the project name and description (four (4) copies).
c. One (1) 30” x 42” laminated floor plan sheets illustrating technology drops and cable designation for each Floor. Two (2) 30” x 42” laminated floor plan sheets illustrating technology drops and cable designation for each telecommunications room (MDF or IDF) mounted on wall. Coordinate mounting locations with owner prior to installation.

3.02 **INSTALLATION**

A. Installation: The cabling shall be installed per requirements of the manufacturer and the Project Documents utilizing materials meeting all applicable TIA/EIA standards. The Contractor is responsible for providing all incidental and/or miscellaneous hardware not explicitly specified below as required for a complete and operational system.

B. Materials: Materials shall be as listed or shall be approved equivalent products of other manufacturers meeting the intent and quality level of the TIA/EIA specifications. All approved equivalent products will be published by addendum ten days prior to proposal for Architect/Engineer to review.

C. UTP Testing:

1. Notification: The Owner and Engineer shall be notified one week prior to any testing so that the testing may be witnessed.
2. Inspection: Before requesting a final inspection, the Contractor shall perform a series of end-to-end installation performance tests. The Contractor shall submit for approval a proposal describing the test procedures, test result forms and timetable for all copper and fiber optic cabling.
3. Procedures: Trained personnel shall perform all testing. Acceptance of the test procedures discussed below is predicated on the Contractor’s use of the recommended products and adherence to the inspection requirements and practices set forth. Acceptance of the completed installation will be evaluated in the context of each of these factors.
4. Errors: When errors are found, the source of each shall be determined, corrected and the cable retested. All defective components shall be replaced and retested. Re-test results must be provided on Owner approved forms and witnessed by Owner.
5. Twisted Pair Cable Testing:

a. At a minimum, the Contractor shall test all station drop cable pairs from Data Closet termination patch panels to outlet device RJ45 jacks. Category 6 products shall be tested for compliance to ANSI/TIA/EIA 568A and ISO/IES 11801 for a Category 6 rated installation. Test equipment used shall meet TIA/EIA TSB-67, Level II accuracy. Further, the contractor shall have a copy of TSB-67 in their possession and be familiar with its contents.
b. Each wire/pair shall be tested at both ends for the following:

1) Wire map (pin to pin connectivity)
2) Length (in feet)
3) Attenuation
4) Near end cross talk (NEXT)
5) Power Sum

c. Test equipment shall provide an electronic and printed record of these tests. Test results will be required for warranty. Any un-witnessed testing is at risk of not receiving a manufactures warranty.

6. Fiber Optic Testing:

a. Testing device for fiber optic cables shall be a high quality OTDR (Optical Time-Domain Reflectometer) equipped with a printer. The printed data shall show, in addition to any summary information, the complete test trace and all relevant scale settings. The OTDR must have the capability to take measurements from bare fiber strands as well as SC connector terminations.
b. All fiber optic cable shall be tested on the reel before installation to ensure that it meets the specifications outlined herein.
c. After installation, the Contractor shall test each fiber strand in accordance the EIA 455-171 Method D procedures (bi-directional testing) at both 850nm and 1300nm for multimode. A form shall be completed for each cable showing data recorded for each strand including length, total segment (end-to-end) loss (dB) and connector losses (dB) at each end. In addition, the printed data strip for each strand shall be attached to the form. Patch cables shall also be tested.
d. Acceptable fiber optic connector loss shall not exceed .75dB per mated pair. The Contractor is responsible for obtaining minimum loss in fiber connections and polishing per manufacturer specifications.
e. Multimode: 50um micron multimode fibers shall have a maximum attenuation of 3.5 dB/km at 850 nm and 1.5 dB/km at 1300 nm. Minimum bandwidth shall be 2000 MHz/km at 850 nm and 500 MHz/km at 1300 nm.
f. OTDR shots shall be provided for each strand of fiber optics completely installed and terminated.

D. Ratings: All products shall be new and brought to the job site in the original manufacturer's packaging. Electrical components (including innerduct) shall bear the Underwriter's Laboratories label. All communications cable shall bear flammability testing ratings as follows:

1. CM Communications Cable
2. CMP Plenum Rated Communications Cable
3. CMR Riser-Rated Communications Cable

E. Initial Cable Inspection: The Contractor shall inspect all cable prior to installation to verify that it is identified properly on the reel identification label, that it is of the proper gauge, containing the correct number of pairs, etc. Note any buckling of the jacket that would indicate possible problems. Damaged cable or any other components failing to meet specifications shall not be used in the installation.

F. Cable Lubricants: Lubricants specifically designed for installing communications cable may be used to reduce pulling tension as necessary when pulling cable into conduit. After installation, exposed cable and other surfaces must be cleaned free of lubricant residue.

1. Approved Products:

a. Twisted-Pair Cable:

1) Dyna-Blue
2) American Polywater

G. Fire Wall Sealant: Any penetration through firewalls (including those in sleeves) will be resealed with an Underwriter Laboratories (UL) approved sealant.

1. Approved Products:

a. 3M
b. Pre-Approved Equal

H. Fire Wall Penetrations: The contractor shall avoid penetration of fire-rated walls and floors wherever possible. Where penetrations are necessary, they shall be sleeved with metallic conduit and resealed with an Underwriter Laboratories (UL) approved sealant. Contractor shall also seal all floor, ceiling and wall penetrations in fire or smoke barriers and in the wiring closet.

I. Allowable Cable Bend Radius and Pull Tension: In general, communications cable cannot tolerate sharp bends or excessive pull tension during installation. Refer to the cable manufacturers allowable bend radius and pull tension data for the maximum allowable limits.

J. Pull Strings: Provide pull strings in all new conduits, including all conduits with cable installed as part of this contract. Pull test is not to exceed 200 pounds.

K. Conduit Fill: Conduit fill shall not exceed 40%.

L. Damage:

1. The Contractor shall replace or rework cables showing evidence of improper handling including stretches, kinks, short radius bends, over-tightened bindings, loosely twisted and over-twisted pairs at terminals and cable sheath removed too far (over 1-1/2 inches).
2. The Contractor shall replace any damaged ceiling tiles that are broken during cable installation.

3.03 CABLE TESTING REQUIREMENTS

A. Notification: The Owner and Engineer shall be notified one week prior to any testing so that the testing may be witnessed.

B. Inspection: Conformance to the installation practices covered above are to be verified when completed. In some cases, the Owner/Designer may inspect before acceptance.

1. Written Test Report:

a. Complete test results, including actual values associated with tests.
b. Show all certifications for telecommunications wiring systems.
c. Include cable maps showing each cable route and keyed to cable labels. Provide owner with complete floor plans identifying outlet location and cable routing drawing in AutoCAD format. Provide electronic copy of drawings to owner in AutoCAD version 2004 or newer.
d. Documentation of outlet, cable, and rack labeling system.

2. After performing all tests, tabulate results and bind together in format acceptable to Owner. Installer shall provide written certification in the test report that telecommunications cable is properly installed, and test results certify system to all specified standards.

C. Procedures: Trained personnel shall perform all testing. Acceptance of the test procedures discussed below is predicated on the Contractor's use of the recommended products and adherence to the inspection requirements and practices set forth. Acceptance of the completed installation will be evaluated in the context of each of these factors.

D. Errors: When errors are found, the source of each shall be determined, corrected and the cable retested. All defective components shall be replaced and retested. Re-test results must be provided on Owner approved forms and witnessed by Owner.

E. Twisted Pair Cable Testing:

1. At a minimum, the Contractor shall test all station drop cable pairs from Data Closet termination patch panels to outlet device RJ45 jacks. Category 6 products shall be tested for compliance to ANSI/TIA/EIA 568A and ISO/IES 11801 for a Category 6 rated installation.
2. Test equipment used shall meet TIA/EIA TSB-67, Level II accuracy. Further, the contractor shall have a copy of TSB-67 in their possession and be familiar with its contents.
3. Each wire/pair shall be tested at both ends for the following:

    a. Wire map (pin to pin connectivity)
    b. Length (in feet)
    c. Attenuation
    d. Near end cross talk (NEXT)
    e. Power Sum
    f. ACR

4. Test equipment shall provide an electronic and printed record of these tests.
5. Test results for each Enhanced Category 6 four-pair UTP cable must be submitted with identification to match labels on all patch panel ports and user outlets and must match as-builts associated with that cable.

F. Testing: Once installed the cabling will be tested for continuity, shorts, and grounds.

1. Cabling:

    a. Continuity - 100% continuity testing is required and will be tested from the MDF/IDF location to each classroom drop. A checklist of each cable and test performed on that cable will be submitted once the testing has been completed.
    b. Shorts - No cable shorts will be permitted on the system. If a short is detected, the connector or cable will be repaired or replaced.
    c. Grounds - No direct ground on the center conductor of the AVDN cables are permitted.

2. System:

    a. Continuity - As tested in the above testing requirements.
    b. Power Readings - A power reading will be required at each drop of each of the cabling systems. A +3 dB to a +7 dB is required at each drop with a common feed signal of + 15 dB into the head end amplifier. These measurements to be taken with an approved field strength meter of know calibration. Test measurements to be performed at low channel, mid-band channel, and high channel to determine cable slope.
    c. Signal Quality - A standard receiver, typical of those used in the system, shall randomly be connected to 10% of the outlets across the system and tuned to a

reference channel of known quality. No visible indication of co-channel interference, noise, ghosting, or beat interference may be observed.

d. Carrier to Noise - Carrier to Noise shall be measured at random outlets representing an average cross section of the drops with an approved field strength meter by the following process. With normal operating levels the field set shall be tuned to each channels visual carrier and the level recorded. The input signal to the head end amplifier shall be removed and the input of the amplifier terminated with a short. Each channel shall be re-measured, and the noise levels recorded. The Carrier to Noise measurement is the difference of the two figures.

e. Documentation of Results: All recorded measurements are to be tabulated and included in the systems documentation manual for reference during maintenance of the system.

3.04 **INSPECTION**

A. General: Conformance to the installation practices covered above are to be verified when completed. In some cases, the Owner/Designer may inspect before acceptance.

END OF SECTION

SECTION 25 07 01 - NETWORK AND CENTRAL HARDWARE

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Design Criteria - Section 20 05 02
2. Basic Division 20-28 Requirements - Section 20 05 03
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Schedule of Submittal Data - Section 20 05 04
5. Scope of Work - Sections 25 05 01 and 26 05 01
6. Start-up, Testing, Adjusting, and Balancing - Section 23 05 93
7. Lighting Control System - Section 26 09 33

1.02 SCOPE

A. Provide and install workstations and associated network interconnections as specified here and as indicated on the Drawings.

1.03 RELATED SECTIONS

A. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. All Division 25 Sections

PART 2 - PRODUCTS

2.01 GENERAL

A. Hardware: The BCAS shall consist of the following, as required:

1. Communications Network Interconnection
2. Network Data Server
3. Operator Workstation PC
4. Laptop PC
5. Portable Device

B. Head-End Equipment: A Network Data Server (NDS) shall be provided with all software required for graphics interface, operator interface, logging and trending data and other operator functions, and shall be located in location to be determined by Owner, and connected to BCAS through the LAN. One (1) PC Operator Workstation shall be provided in Building Engineer's Office and shall be connected through LAN to NDS and BCAS devices. An optional Laptop PC may be provided at Owner's direction. Provide alternate price for Laptop PC.

2.02 NETWORKING COMMUNICATIONS

A. General: The design of the BCAS shall network operator workstations, ASC, and DDC controllers. The system design shall readily allow and accommodate expansion or modification of the network either via the local area network, or access through the Internet.

B. The Virtual Local Area Network (VLAN) shall be a 100 Megabits/sec Ethernet network supporting BACnet, Java, XML, HTTP, and SOAP for maximum flexibility for integration of building data with enterprise information systems and providing support for multiple Java Application Control Engines (JACEs), user workstations and, if specified, a local server. The VLAN will be managed by the Facilities Information Management department. The Facilities Information Management department will control the access to the BCAS residing at each facility.

C. Local area network minimum physical and media access requirements:

1. Ethernet; IEEE standard 802.3
2. Cable; 100 Base-T, UTP-8 wire, category 5
3. Minimum throughput; 100 Mbps.

D. Local Area Network:

1. Workstation/ASC/DDC Controller Support: Operator workstations, ASC, and DDC controllers shall directly reside on a local area network such that communications may be executed directly between controllers, directly between workstations, and between controllers and workstations on a peer-to-peer basis. ASC may reside on communication networks requiring DDC controller interface for communication to the local area network.
2. Dynamic Data Access: All operator devices, either network resident or connected via Internet, shall have the ability to access all point status and application report data, or execute control functions for any and all other devices via the local area network, without an active host processor.

    a. Access to data shall be based upon logical identification of building equipment.
    b. Access to system data shall not be restricted by the hardware configuration of the facility management system.
    c. The hardware configuration of the BCAS network shall be totally transparent to the user when accessing data or developing control programs.

3. General Network Design: Network design shall include the following provisions:

    a. High-speed data transfer rates for alarm reporting, quick report generation from multiple controllers, and upload/download efficiency between network devices.
    b. Support of any combination of controllers and operator workstations directly connected to the local area network. Each local area network shall be capable of supporting a minimum of 32 devices.
    c. Devices shall be ac-coupled to the network bus to assure that single or multiple device failures will not cause loss of communications with other network-connected devices.
    d. Detection and accommodation of single or multiple failures of either workstations, ASC, DDC controllers or the network media. The network shall include provisions for automatically reconfiguring itself to allow all operational equipment to perform their designated functions as effectively as possible in the event of single or multiple failures, or be of a collision avoidance configuration.
    e. Message and alarm buffering to prevent loss of data information.
    f. Error detection, correction, and retransmission to guarantee data integrity.
    g. Devices with no messages to transmit must send an "I'm OK" message to each bus cycle. Lack of an "I'm OK" message after successive retries shall constitute a communications or device failure, be recognized as such and be recorded as not responding on the system printer.
    h. Default device definition to prevent loss of alarms or data, and ensure alarms are reported as quickly as possible in the event an operator device does not respond.

i. Commonly available, multiple sourced, networking components and protocols shall be used to allow the BCAS to coexist with other networking applications such as office automation.
j. Synchronization of the real-time clocks in all ASC and DDC controllers shall be provided.
k. Full communications shall be sustained as long as there are at least two operational devices on any segment of the bus.
l. Global data (all station messages) is to be available for use by any device on the bus as inputs or outputs to its resident control programs.
m. Each device is to be provided with a communications watchdog to assure that an individual device cannot permanently occupy the bus. If a device is determined to be "babbling", it shall be automatically shutdown and a flag set to annunciate this fact.
n. Error recovery and communications initialization routines are to be completely distributed, i.e., resident in each bus connected device.
o. Software counters are to be provided as a diagnostic tool for cold starts, warm starts, privilege violation, illegal instructions, address errors, bus errors and zero divide. Error types and counts are to be operator accessible.

2.03 **CENTRAL HARDWARE**

A. Virtual Network Data Server

1. The Enterprise system shall reside on a control company provided server (with a 3 year service contract) or on a control company hosted remote server farm (with a 3 year contract). The control company shall provide and add price to extend this service contract from 3 to 5 years. BEMS Software shall store and provide data access via cloud-based server:

a. Data is stored in a Class 5 secure hosting location protected by ISO 5001-complaint firewall and intrusion detection systems with support for major network security protocols such as HTTPS and SFTP to securely access and store data.
b. BEMS data shall use “push” technology to communicate with and send data to the central server, requiring limited outbound ports.

OR

B. Network Data Server - (NDS)

1. The Division 25 Contractor shall supply one Network Data Server at location to be determined by Owner.
2. The Network Data Server shall utilize the Internet and provide efficient integration of standard open protocols, such as BACnet and LonWorks. The Network Server shall create a powerful network environment with comprehensive database management, alarm management and messaging services. In addition, the NDS shall provide an engineering environment and graphical user interface. The NDS shall be capable of providing the following:

a. Powerful Java enabled graphical user interface
b. Support an unlimited number of users over the Internet/intranet with a standard Web browser
c. Enterprise level information exchange using an SQL database and HTTP/HTML/XML text formats
d. Audit trail of database changes indicating user, time stamp, and audit action
e. Synchronize controller databases, database storage scheduling, control and energy management routines

f. Sophisticated alarm processing and routing which includes email and paging
g. Access to alarms, logs, graphics, schedules and configuration data with a standard Web browser
h. Password protection and security using standard Java authentication and encryption techniques
i. HTML based help system that includes comprehensive online system documentation
j. Support of multiple Network Area Controller (NAC) controllers connected to a local Ethernet or the Internet

3. Server Functions and Hardware

a. Local connections shall be via an Ethernet LAN. Remote connections can be via ISDN, ADSL, T1 or dial-up connection.
b. Without a license, software key, or Client Software Package, it shall be possible to provide access to all Network Area Controllers via a single connection to the server. In this configuration, each Network Area Controller can be accessed from a remote Graphical User Interface (GUI) or from a standard Web browser (WBI) by connecting to the server.
c. The server shall provide the following functions, at a minimum:

1) Global Data Access: The server shall provide complete access to distributed data defined anywhere in the system.
2) Distributed Control: The server shall provide the ability to execute global control strategies based on control and data objects in any NAC in the network, local or remote.
3) The server shall include a master clock service for its subsystems and provide time synchronization for all Network Area Controllers (NAC).
4) The server shall accept time synchronization messages from trusted precision Atomic Clock Internet sites and update its master clock based on this data.
5) The server shall provide scheduling for all Network Area Controllers and their underlying field control devices.
6) The server shall provide demand limiting that operates across all Network Area Controllers. The server must be capable of multiple demand programs for sites with multiple meters and or multiple sources of energy. Each demand program shall be capable of supporting separate demand shed lists for effective demand control.
7) The server shall implement the BACnet Command Prioritization scheme (16 levels) for safe and effective contention resolution of all commands issued to Network Area Controllers.
8) Each Network Area Controller supported by the server shall have the ability to archive its log data, alarm data and database to the server, automatically. Archiving options shall be user-defined including archive time and archive frequency.
9) The server shall provide central alarm management for all Network Area Controllers supported by the server. Alarm management shall include:

a) Routing of alarms to display, printer, email and pagers
b) View and acknowledge alarms
c) Query alarm logs based on user-defined parameters

10) The server shall provide central management of log data for all Network Area Controllers supported by the server. Log data shall include process logs, runtime and event counter logs, audit logs and error logs. Log data management shall include:

a) Viewing and printing log data
b) Exporting log data to other software applications
c) Query log data based on user-defined parameters

4. The Network Server shall be capable of supporting the following open system drivers:

a. oBIX Driver for connecting to any devices
b. BACnet IP Driver
c. OPC Driver
d. Modbus TCP Driver
e. SNMP Drive

5. Network Server Platform Requirements

a. Server Hardware

1) Processor: Two (2) Intel Quad Core, 3 GHz or higher.
2) Memory: 16 GB, DDR 266 SDRAM memory.
3) Hard Drive: 3 TB free hard drive space.
4) RAID-5
5) Microsoft Windows Server 2012/2014+
6) Microsoft SQL Server 2008/2012+
7) .NET Framework V 3.5, 4.0+
8) TCP/IP Interface
9) Configuration: Rack mounted.
10) Display: Video card and minimum 17" monitor capable of displaying 1280 x 1024 pixel resolution or greater.
11) Network Support: Ethernet adapter (10/100 Mb with RJ-45 connector).
12) Provide one NDS at location to be determined by Owner.

b. Operating System Software: Latest version of Microsoft Windows.

C. Personal Computer Operator Workstation

1. The PC Operator Workstation shall be provided for permanent interface with the BCAS through the building's LAN. The monitoring and control function of the BCAS shall be completely independent of the Operator's Workstation such that if the PC is not operational, there shall be no impact on the BCAS.

a. Provide one (1) PC Operator Workstation at the Building Engineer's Office.
b. PC Operator Workstation Platform Requirements:

1) PC Hardware:

a) Processor: Intel Quad Core, 3.6 GHZ, or higher
b) Memory: 8 GB RAM
c) Hard Drive: 160 GB
d) Display: 21" LCD with 1280 x 1024 pixel display
e) Network: 10/100 MB NIC

2) Operating System: Windows (latest version)
3) Printer: HP 5650 Inkjet, or equal

D. Laptop PC Workstation

1. Laptop Personal Computer Workstations shall be provided for command entry, alarm management, information management, and data base management functions. Laptop PC's may be directly interfaced to Standalone DDC panels on a temporary basis. All real-time control functions shall be resident in the Standalone DDC panels to facilitate greater fault tolerance and reliability. Provide an Alternate price for this Scope of Work; refer to Division 20, Alternates.

    a. Laptop PC Operator Workstations shall be general purpose, commercially available, personal computers with sufficient memory and processor capability to perform all functions described in this specification. A minimum of a Pentium Core 2 DUO or better with 4 GB of RAM, and minimum 100 GB hard disk storage shall be provided.
    b. The Laptop display shall have a diagonal screen measurement of no less than 15", and a minimum display resolution of no less than 1024 x 768 pixels. The screen shall be non-reflective.
    c. DDC Panel Interface: When temporarily directly connected to a DDC controller, the combination of DDC controller and Laptop PC shall also be capable of supporting an output printer. The printer may be connected to the DDC controller or the Laptop PC.

E. Operator Interface / Mobile App Operator Interface:

1. The operator interface shall be accessible via a web browser.
2. The operator interface shall support the following Internet web browsers:

    a. Microsoft Edge
    b. Mozilla Firefox
    c. Google Chrome

3. The operator interface shall support the following mobile web browsers:

    a. IOS (iPad/iPhone)
    b. Android (Tablet)
    c. Android (Phone)

4. Mobile App Operator Interface shall support the following Operating systems:

    a. Apple iOS
    b. Android

5. Regular and Mobile App Operator interface shall support system access on a mobile device via a mobile app to:

    a. Alarm log
    b. System status
    c. Equipment status
    d. Space status
    e. Standard equipment graphics

6. Regular and Mobile App Operator interface shall support actions on a mobile device via a mobile app to:

    a. Override set points
    b. Override occupancy
    c. Acknowledge Alarms
    d. Comment on Alarms

PART 3 - EXECUTION (NOT APPLICABLE)

END OF SECTION

SECTION 25 09 01 - INSTALLATION, TESTING, AND TRAINING

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Scope of Work - Section 25 05 01

1.02 SCOPE

A. Installation requirements, testing and training specifications for the Building Control and Automation System (BCAS).

1.03 RELATED SECTIONS

A. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. Commissioning - Section 20 08 00 and Division 1
2. All Division 25 Sections
3. Conductors - Section 26 05 19
4. Conduit - Section 26 05 33
5. Lighting Control System - Section 26 09 33

1.04 QUALITY CONTROL

A. All components shall be tested by the BCAS subcontractor to ensure compliance with the specifications before they leave the BCAS subcontractor's premises and shall be tested again on-site by the BCAS subcontractor before the commencement of acceptance testing. The BCAS subcontractor shall not ship components to the project site until they have been found to be fully compliant with the specifications and the BCAS subcontractor shall not request the commencement of acceptance testing until such time as a complete and thorough checkout of all equipment has been made by the BCAS subcontractor.

B. Any component furnished under this contract shall be made available for inspections or tests. As deemed necessary by the Owner and/or Consultant. Use of any component by the Owner shall not imply acceptance of the system or acceptability of any component. Availability and demonstration of the systems shall not be withheld, and the use of components shall not imply the start of the warranty period.

C. Testing of equipment requiring starting procedures may be performed by the Contractor, where manufacturer representatives are not required.

D. All costs associated with the required inspections, testing and commissioning shall be included in this scope of work. Additional charges will not be accepted.

PART 2 - PRODUCTS

2.01 BCAS WIRING MATERIALS

A. In exposed areas, wiring shall be jacketed cables installed with or without conduit as specified below or single conductors installed in conduit. Control wiring shall have minimum 300-volt insulation for low voltage wiring 600 volt insulation for the line voltage wiring.

B. Minimum requirements for control wiring shall be as follows:

1. Digital Functions: Control wiring for digital functions shall be No. 18 AWG copper minimum, with 300-Volt insulation. Multi-conductor wire shall have an outer jacket of polyvinyl chloride (PVC) where installed in conduit or UL-listed plenum rated jacket where installed without conduit.
2. Analog Functions: Control wiring for analog functions shall be No. 18 AWG copper minimum, with 300 volt insulation, twisted and shielded, 2-, 3-, or 4-wire to match analog function hardware. Multi-conductor wire shall have an outer jacket of PVC where installed in conduit or UL-listed plenum jacket where installed without conduit.
3. Sensor Wiring: Sensor wiring shall be No. 20 AWG copper minimum, twisted and shielded, 2-, 3-, or 4-wire to match analog function hardware. Multi-conductor wire shall have an outer jacket of PVC where installed in conduit or UL-listed plenum rated jacket where installed without conduit.
4. Low Energy Conductors: Class 2 low energy conductor sizes specified for digital and analog functions shall take precedence over any requirements for Class 2 low energy remote control and signal circuit conductors specified elsewhere, unless the NEC requires a larger conductor size.
5. LAN Cable: All Local Area Network (LAN) network cabling shall be Cat 5 or Cat 6, 24 gauge cable.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Before commencing testing, verify that systems are complete and operable to the following extent:

1. Equipment is operable and in a safe and normal condition. (By mechanical contractor)
2. Temperature control systems are installed complete and operable.
3. Proper thermal overload protection is in place for electrical equipment. (By electrical contractor)
4. All air filters are clean and in place. If required, install temporary media in addition to final filters. (By mechanical contractor)
5. Correct fan rotation. (By mechanical contractor)
6. Fire, smoke, and volume dampers are in place and open. (By electrical contractor)
7. Coil fins have been cleaned and combed. (By mechanical contractor)
8. Access doors are closed, and duct end caps are in place. (By mechanical contractor)
9. Air outlets are installed and connected. (By mechanical contractor)
10. Duct system leakage is below specified level. (By mechanical contractor)
11. Hydronic systems have been flushed, filled, and vented. (By mechanical contractor)
12. Proper strainer baskets are clean and in place. (By mechanical contractor)
13. Service and balance valves are open. (By mechanical contractor)

B. Report any defects or deficiencies noted during performance of services to Architect/Engineer.

C. Promptly report abnormal conditions in mechanical systems or conditions that prevent system balance.

D. If, for design reasons, system cannot be properly balanced, report as soon as observed.

E. Beginning of work means acceptance of existing conditions.

3.02 **PREPARATION (By mechanical contractor)**

A. Provide all material, equipment, and personnel, including factory personnel where specified or required, to fully check out and start up all equipment and systems as specified in accordance with manufacturer's requirements.

B. No water piping systems shall be "pumped" until all piping has been hydrostatically tested, flushed, cleaned and water treated as applicable.

C. Lubrication and fluid levels shall be checked prior to equipment start-up. Alignment on all motor driven equipment shall be checked and adjusted prior to start-up.

3.03 **BALANCING AND ADJUSTMENTS**

A. General: All building control and automation systems and equipment installed on the project shall be balanced and/or adjusted to provide proper operation or function in accordance with the drawings, specifications, and manufacturer's recommendations. The balancing and/or adjusting shall be completed prior to the system testing specified herein. All calibration, testing, and adjusting will be witnessed by the Owner's building engineer. Systems and equipment for which certification of balancing and adjusting is required, include, but are not limited to:

1. General: When all equipment start-up has been performed and the systems are ready for operation, the Contractor shall perform the following steps of control adjustment and balance. (By mechanical contractor)
2. Adjustment and Calibrate: All thermostats, dampers, operators, controllers, and other devices shall be adjusted and calibrated as required to put the BCAS in proper working order as designed and specified.
3. Zone Control: Measure, adjust, and record the control set points and control signal output at full cooling, calibration point, full bypass, and minimum and maximum heating when applicable.
4. Cold Deck Control: Measure and record the control signal output and air temperature with minimum cold deck airflow and maximum cold deck airflow.
5. Single Zone Air Handling Unit: Measure and record controller output signal at full cooling, minimum cooling, minimum heating, and maximum heating. Verify operation of all auxiliary controls such as outside air damper and firestat.

B. Certification: Submit four (4) copies of a letter certifying that the BCAS is properly and fully installed and fully adjusted and calibrated to operate as specified to the Engineer for review to final acceptance.

C. Completion Reports: Before the final inspection but after all testing, balancing, and adjusting, the Contractor shall furnish all labor, materials and devices necessary to prepare a completion report. (Refer also to Section 23 05 93).

3.04 **BCAS TESTING AND CERTIFICATION**

A. A complete BCAS checkout and test shall be performed by the BCAS Contractor to demonstrate and certify that the BCAS is 100% operational and adjusted upon completion of the installation, and that it complies with all applicable codes and specification requirements. The system checkout and test shall be performed within thirty (30) days of the completion of system installation, adjustment, and commissioning. Testing shall be performed by the BCAS Contractor

in two (2) parts and two-way radios for use by test observers shall be provided. The first part of the test shall be a full test of all system components, function, and alarms. All affected subcontractors shall participate in this test. All tests shall be witnessed and acknowledged by written signature of the Owner's Building Engineer. Test results shall be certified and submitted to the Engineer. This test shall be the basis for the System Acceptance document specified in this Section. The second part of the test shall be a demonstration of basic system functions and alarms for the Engineer and Owner's Representative, and the Commissioning Agent. Consult Specification Section 20 08 00 and Division 01 for complete details of all required Commissioning Testing to be supported and conducted by this Division and other related Divisions. Costs associated with all required inspections and testing by the Commissioning Specifications and all other specifications related to operation and functioning of the completed project shall be included in this Scope of Work. Additional charges will not be accepted.

B. This Contractor shall coordinate the test schedule with the General Contractor, Commissioning Agent, Electrical Contractor, Mechanical Contractor, Fire Protection Contractor, Fire Alarm Contractor, and other Contractors required to be present for a complete and functional test.

C. The system checkout and test shall be a comprehensive 100% inspection and functional test of all equipment and software and shall include, but not be limited to, the following:

1. Verification of manual and program control of all start/stop and alarm points, including status indication and alarms.
2. Verification of all controlled points including setpoint and actual point readouts, remote setpoint change and point alarm.
3. Verification that all system annunciation text and messages are correct and appropriate.
4. Functional test of the normal and emergency power building start-up and shutdown routines.
5. Testing to verify that all systems on emergency power operate as specified in the sequence of operation.
6. Testing to verify that all control functions specified in the sequence of operation are provided and fully functional as specified and required.
7. Testing to verify that all specified software is provided and fully implemented.
8. Test and verify interoperability between specified systems (lighting controls, HVAC controls, central plant controls, etc.)
9. Display and demonstrate such data entry template and show site specific customizing capability. Demonstrate parameter changes.
10. Execute menu tree.
11. Display graphics, demo update.
12. Execute digital and analog commands in English and graphic mode.
13. Demonstrate all specified diagnostics.
14. Demonstrate DDC loop precision and stability via trend logs of inputs and outputs (six loops minimum).
15. Demonstrate BCAS performance via trend logs and command printouts.
16. Demonstrate scan, update, and alarm responsiveness.
17. Other testing required by Section 25 05 93.

D. Fire Alarm System Interface Testing: Testing of the BCAS interface with the fire alarm system for smoke management, air handling unit shutdown, fire/smoke damper control, duct smoke detector annunciation and other specified interfaces shall be coordinated with the Division 28 fire alarm testing and certification.

E. Emergency Power Operation Testing: Testing of BCAS operation under emergency shall be coordinated with the Division 26 Contractor such that the testing is conducted along with the Division 26 emergency power system testing and certification.

3.05 SYSTEM ACCEPTANCE

A. The BCAS Manufacturer shall issue a report upon completion stating that the system is complete, has been adjusted, has had all hardware and software functions verified, and is operating in accordance with the specifications. Any deviations from specified settings or operations necessitated during system adjustment shall be specifically noted. A demonstration of complete system operation shall be made to the Engineer and Owner's Representative.

B. Upon receipt of a detailed punch list from the Engineer or Owner's Representative, an installation inspection report shall be prepared by the BCAS Contractor showing, by system, each outstanding item on the punch list. After all items appearing on the installation inspection report are completed, a second written request for system approval shall be made to the Owner's Representative. As each or all items are approved, an appropriate notation shall be entered on the system report at the time of joint inspection, with counter signature by the Owner's Representative and date. A copy of this report shall be made for the Owner's Representative.

C. Where it is required for the BCAS Contractor to modify, alter, add, or remove hardware or software programs of the building automation system or related accessories for the purpose of eliminating punch list items, off-line operation and testing to implement them shall be done as required by the BCAS Contractor until such time acceptance performance of the building automation system has been established.

D. Problems that occur within hardware or software shall be corrected in an appropriate fashion under guarantee. Any such occurrence shall not void previous approval; however, the BCAS Contractor shall be responsible to attend to and remedy such items within a reasonable amount of time. Appropriate logs, schedules, and reports shall be maintained to reflect these items and their redress.

3.06 OWNER INSTRUCTION

A. General: This Contractor and appropriate factory-trained representatives shall instruct the Owner's personnel in the proper operation and maintenance of all systems and equipment and shall explain all warranties.

B. Outline: Prior to instruction of Owner Personnel, prepare a typed outline, listing the subjects that will be included in this instruction.

C. Certification: At the conclusion of the instruction period obtain the signature of each person being instructed on each copy of the approved outline to signify that he has a proper understanding of the operation and maintenance of the systems.

D. Operator Training: Provide sixteen (16) hours of training encompassing:

1. Sequence of operation review.
2. Sign on - Sign off.
3. Selection of all displays and reports.
4. Commanding of points, English, and graphic mode.
5. Modifying English text.
6. Modifying alarm limits and start-stop times.
7. System initialization.
8. Download and initiation of data control points.
9. Purge and/or dump of historical data.
10. Use of portable operator’s terminal.
11. Troubleshooting of sensors (determining bad sensors).
12. Creating and modifying color graphics.

E. Supervisor Training: Provide an additional sixteen (16) hours of training encompassing:

1. Password assignment/modification.
2. Operator assignment/modification.
3. Operator authority assignment/modification.
4. Point disable/enable.
5. Terminal data segregation/modification.

F. Programmer Training: Provide up to an additional twenty-four (24) hours of training, at the Owner's discretion, encompassing:

1. Software review of Sequence of Operation programs.
2. Modification of control programs.
3. Add/Delete/Modify data points.
4. Use of diagnostics.
5. System maintenance procedures.
6. Review of initialization.
7. Upload/download and off-line archiving of all system software.

G. Operator and Supervisor Training shall be in a classroom format at the project site and shall be scheduled at the Owners convenience. Class size shall be approximately but not limited to eight per session.

H. Provide Owner eight (8) hours additional training eight (8) months after final acceptance to ensure proper operation of the BCAS during dissimilar weather conditions.

I. Training sessions shall be conducted in a classroom environment with sufficient "hands on" instruction for the attendees to become familiar and competent with the tasks demonstrated. Training may be video taped by Owner at Owner's discretion.

J. Other Requirements: Refer to other Division 25 Sections for additional Operator Training requirements.

3.07 WARRANTIES AND GUARANTEES

A. General: Contractor shall guarantee all material and equipment installed by him against defects in workmanship and material and provide service for a period of one (1) year after final acceptance of the work by the Owner and he shall repair or replace any materials or equipment developing such defects within that time, promptly on due notice given him by the Owner and at Contractor's sole cost and expense.

B. Service shall be accomplished, and guarantee fulfilled by qualified employees of the BCAS Contractor.

C. Warranty servicing shall include, but not limited to, the following:

1. Replacing defective parts and components as required.
2. Servicing by factory-trained and locally employed service representative of system contractor.
3. Maintaining of system programming to ensure application programs operate in accordance with the original sequence of operation.

3.08 INSTALLATION

A. General: Install system and materials in accordance with manufacturer's instructions, roughing-in drawings, and details on the Drawings. All components and appurtenances shall be installed in

accordance with the manufacturer's instructions, as shown, and as specified. All necessary interconnections, services, and adjustments required to prepare the building for interface to the BCAS shall be furnished. All electrical work shall be in accordance with Division 26. Instrumentation grounding as necessary to preclude ground loops and noise from adversely affecting equipment operations shall be installed. Final adjustment shall be performed by specially trained personnel in the direct employ of the manufacturer of the BCAS.

B. Electrical Wiring: Refer to the applicable Sections of Division 26 for electrical wiring and raceway installation requirements.

C. Mechanical Work: Refer to the applicable Sections of Division 23 and Division 25 for the installation of wells, valve bodies, and dampers in mechanical systems.

D. I/O Summary Tables shall be used in conjunction with the Drawings to identify the hardware required for each building control and automation system.

E. All temperature control and automation materials shall be applied and installed per the manufacturers' recommendations.

F. Remote bulbs shall be flange mounted in ductwork and casings and mounted with separable sockets in pipes and tanks. Where installed through insulation, flanges and sockets shall have extension necks to finish flush with the insulation surface.

G. All sensing elements for supply air temperature in ductwork or casings shall be averaging type with sensing length of number of elements to measure air temperature through the entire cross section of the duct or casing.

3.09 DDC PANEL AND ENCLOSURE LOCATIONS

A. General: Direct Digital Control (DDC) panels and enclosures, controllers, status/monitoring panels and other control panels shall be located where shown on the Drawings or as close to the controlled equipment as is feasible. Provide panels and enclosures for all NAC and other components of the BMCS, which are susceptible to physical or environmental damage.

B. Location: Panels and enclosures shall be located so as to provide adequate clearance for maintenance and shall not interfere with maintenance or code clearances for other equipment. Floor plan drawings showing the proposed locations of all control panels shall be submitted for approval.

C. Interior panels and enclosures shall meet, at minimum, the following requirements:

1. NEMA 1 rated painted steel panels with locking door.
2. Ventilated to prevent excessive heat build-up, where required.
3. Field cabling shall be terminated on a terminal strip fixed within the enclosure. Provide strain relief, as necessary.
4. Internal components shall be installed to allow easy access for diagnostics, maintenance, removal, or replacement of any component within the enclosure.
5. Cabling shall be neatly installed within wire guides with removable covers for easy access.

D. Interior panels and enclosures within plenum areas shall meet, at minimum, the following requirements:

1. NEMA 1 painted steel panels with locking door.
2. Field cabling shall be terminated on a terminal strip fixed within the enclosure. Provide strain relief, as necessary.

3. Internal components shall be installed to allow easy access for diagnostics, maintenance, removal, or replacement of any component within the enclosure.
4. Cabling shall be neatly installed within wire guides with removable covers for easy access.

E. Exterior and garage mounted panels and enclosures shall meet, at minimum, the following requirements:

1. NEMA 4 painted steel panels with locking door.
2. Field cabling shall be terminated on a terminal strip. Provide strain relief, as necessary.
3. Internal components shall be installed to allow easy access for diagnostics, maintenance, removal, or replacement of any component within the enclosure.
4. Cabling shall be within wire guides with removable covers for easy access.

F. Panels and enclosures shall be located as follows:

1. Central Plant.
2. Mechanical Rooms.
3. Pump Room.
4. Main Electrical Room.
5. Penthouse Electrical Room.
6. Selected Electrical Rooms in the parking levels.
7. Stair Pressurization Fan Room.

G. Mounting: Panels and enclosures shall be wall mounted or freestanding as required by the location and available space. Provide miscellaneous metals and unistrut supports as necessary to support freestanding panel locations.

H. Coordination: Panel location shall be coordinated with the Division 26 Contractor so that there is adequate lighting and convenience outlets at the panel location for panel use and maintenance.

I. Security: All panels shall be lockable with the same key, which shall be unique to the building. Provide the Owner with six (6) keys.

3.10 CONTROL POWER CIRCUIT SOURCES

A. General: Control power circuit sources are provided by Division 26 where shown to BCAS panel locations and at other locations shown on the Electrical Drawings. Control power transformers creating control power circuits are typically provided in motor starters on the project. All other control power circuit sources required by Division 25 shall be provided by Division 26 at the expense of Division 25.

B. Coordination: Control power circuit requirements and source locations shall be coordinated with the Division 26 contractor. This Contractor shall be responsible for any additional costs incurred to provide the required control power circuit sources. Input to the Division 26 Contractor shall include, but not be limited to:

1. Locations requiring control power.
2. Voltage, phase, and ampacity.
3. Power type, normal or emergency
4. Type of connection.

3.11 BCAS WIRING INSTALLATION

A. General: All wiring required for a complete and operational building control and automation system shall be provided by this Division.

B. All line voltage control wiring and low-voltage control wiring shall be installed in conduit. Low voltage wiring to HVAC terminal unit controllers, HVAC terminal unit temperature sensors, and the field level communications cable may be installed in concealed accessible locations using UL-listed plenum rated cable installed without a raceway. Cable shall not be installed without a raceway when exposed in the building, or in inaccessible locations (except individual sensor drops in drywall partitions). The main BCAS trunk LAN cabling shall be routed in conduit.

C. All low voltage control wiring which is routed through concealed accessible locations shall be UL-approved low smoke producing jacketed plenum cable. Wiring run without conduit shall be properly supported from the building structure on maximum 5' centers and shall not depend upon the ceiling grid for support.

D. Line and low voltage control wiring shall not be installed in the same conduit and control wiring shall not be installed in the same conduit with power wiring.

E. All conduit in exposed locations shall be run in a neat manner and shall be perpendicular and parallel to building lines. Coordinate conduit routing with field conditions so as not to interfere with code clearances for other equipment, maintenance access and walkways.

F. Flexible metal conduits and liquid-tight flexible metal conduits shall not exceed 3' in length and shall be supported at each end. Flexible metal conduit less than 1/2" electrical trade size shall not be used. In areas exposed to moisture, including chiller and boiler rooms, liquid-tight, flexible metal conduits shall be used.

G. All conduit and control wiring in concealed locations shall be installed in an orderly manner, generally perpendicular and parallel to building lines.

H. Permanently mark terminal blocks for identification. Protect all circuits to avoid interruption of service due to short-circuiting or other conditions. Line-protect from lightning and static electricity all wiring that comes from external sources to the site.

I. All BCAS conduit freeway shall be marked with yellow paint at 8'-0" o.c. All junction box covers shall be painted yellow.

J. Label or code each field wire at each end. Permanently label or code each point of all field terminal strips to show the instrument or item served. Color-coded cable with cable diagrams may be used to accomplish cable identification. The following table is provided for reference. Alternate color and identification schemes may be acceptable:

CABLE	COLOR IDENTIFICATION
LAN	PURPLE
BACNET	ORANGE
MODBUS	BLUE
INPUTS	YELLOW WITH PURPLE STRIPE
OUTPUTS	TAN WITH BLUE STRIPE

K. Signal Transmission System wiring shall be installed as follows:

1. Splices in shielded cables shall consist of terminations and the use of shielded cable couplers. Termination shall be in accessible locations. Cables shall be harnessed with cable ties.
2. Fit all equipment contained in cabinets or panels with service loops, each loop being at least 12" long. Equipment for fiber optics system shall be rack-mounted, as applicable, in

ventilated, self-supporting, code gauge steel enclosure. Cables shall be supported for minimum sag.

3. Keep cable runs as short as possible. Allow extra length for connecting to the terminal board.
4. Do not bend flexible coaxial cables in a radius less than ten times the cable outside diameter.
5. Use vinyl tape, sleeves, or grommets to protect cables from vibration at points where they pass around sharp corners, through walls, panel cabinets, etc.
6. Grounding shall be in accordance with NFPA 70. All ground wire shall be insulated conductors.
7. Ground wire shall be run to service entrance ground.
8. To prevent ground loops, conduit grounds shall be isolated from EMC panels by non-metallic couplings approved for installation in air plenums.

L. Refer to applicable Division 26 Sections for additional requirements for conduit and wiring materials and installation. All conduit and wiring shall be installed in accordance with all applicable requirements of the National Electrical Code and the city authorities having jurisdiction.

3.12 EQUIPMENT INSTALLATION

A. Temperature Instruments:

1. Temperature Instruments: When a temperature sensor/transducer is installed in pipes or is susceptible to corrosion and vibration, the sensor shall be installed in a stainless steel thermowell. Temperature sensors/transducers used for space temperature sensing shall include a housing suitable for wall mounting. Temperature sensor/transducers used for outside air sensing shall have an instrument shelter to minimize solar effects, and shall be mounted to minimize building effects. Assemblies shall be readily accessible and installed in a manner as to allow easy replacement without special tools. Mount duct sensors/transducers in locations to sense the correct temperature of the air only, within the vibration and velocity limits of the sensing element. Mount extended surface element, when used, securely within the duct and position to measure the average temperature. Thermally isolate elements from bracket and supports to respond to air temperature only. Securely seal duct penetrations.
2. Sensor Locations: Sensors shall be wall mounted in office areas; approximate locations are shown on the Drawings. Locate sensors to sense average return air temperature in the space monitored. Submit Drawings showing proposed locations of space and return air temperature sensors to the Engineer for review.
3. Temperature Switches: Temperature switches shall be installed as specified for temperature sensors. Temperature switches shall be adjusted to the proper setpoint and shall be verified by calibration. Switch contact ratings and duty shall be selected in accordance with NEMA ICS 1.
4. Relative Humidity Sensors/Transducers: Relative humidity sensors/transducers shall have air guards when installed in air flows of more than 50 fpm across the sensor element.

B. Pressure Instruments:

1. Pressure Sensors/Transducers: Pressure sensors/transducers (all types) installed on liquid lines shall have isolation and drain valves. Pressure sensors/transducers installed on steam lines shall have isolation and drain valves and siphons. All pressure sensors shall have valves for isolation, venting, and taps for calibration. Pressure sensors/transducers shall have nulling valves.
2. Pressure Switches: Pressure switches (all types) installed on liquid lines shall have drains. Pressure switches installed on steam lines shall have drains and siphons. All pressure switches shall have valves for isolation, venting, and taps for calibration.

Pressure switches shall be adjusted to the proper setpoint, and shall be verified by calibration. Pressure switches shall be mounted higher than the process connection. Differential pressure switches shall have nulling valves. Switch contact ratings and duty shall be selected in accordance with NEMA ICS 1.

C. Flow Instruments:

1. Flow Meters: Flow meters shall be installed in accordance with ASME Fluid Meters, and the manufacturer's recommendations for flow accuracy.
2. Venturi Tubes: Venturi tubes shall be installed in horizontal pipe runs. Venturi tubes shall be installed for ease of accessibility for periodic maintenance and as recommended by the manufacturers for flow accuracy.
3. Turbine Meters: Turbine meters shall be installed so that the sensor is located in the center of the fluid flow pipe on the main axis and as recommended by the manufacturers for flow accuracy.
4. Flow Switches: Flow switches shall be installed in such a manner as to minimize any disturbance in the flow of fluid while maintaining reliable operation of the switch.

D. Electric Power Devices:

1. Potential transformers and current transformers shall be installed in cabinets as shown or required.
2. Watt-hour meters, watt-hour demand meters, and current, voltage, and watt-hour transducers shall be installed in cabinets, unless provided in housing by manufacturer.

E. Output Devices:

1. Relays and Contactors: Install relays and contactors in control cabinets or as required.
2. Controllers: Install controller in control cabinets or as required.

F. Position Sensors:

1. End (Limit) Switch: Limit switch type and mounting shall be properly suited for the application to provide reliable switch operation.
2. Potentiometers: Potentiometer type and mounting shall be properly suited for the application to provide reliable operation.
3. Instrument Shelters shall be installed with bottom 4' above the supporting surface using legs and secured rigidly to minimize vibrations from winds. Instrument shelters shall be oriented facing north.

G. Carbon Dioxide (CO_2) Sensors: Install the CO_2 sensors in accordance with the manufacturer's written installation instructions and project design drawings. System checkout, start-up, calibration, and testing shall be performed by a field-service engineer in the direct employ of the BCAS manufacturer.

3.13 FINAL ADJUSTMENT OF EQUIPMENT

A. General: After completion of the installation, adjust thermostats, control valves, motors, and similar equipment provided as work of this Section. Final adjustments shall be performed by specially trained personnel in the direct employ of the manufacturer of the primary temperature control system.

3.14 **OWNERSHIP OF PROPRIETARY MATERIAL**

A. Project specific software and documentation shall become Owner's property at completion of project, including, but not limited to, graphics, record drawings, database, application programming code, application specification control configuration files, required licensed software, and project documentation.

END OF SECTION

SECTION 25 09 02 - PANELS AND CONTROLLERS

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Start-up, Testing, Adjusting, and Balancing - Section 23 05 93
5. Scope of Work - Section 25 05 01

1.02 SCOPE

A. Provide and install workstations, panels and controllers and associated network interconnections as specified here and as indicated on the Drawings.

B. Should additional panels and controllers be required to perform the scope of work as indicated on the drawings, the following specifications associated with those shall apply.

1.03 RELATED SECTIONS

A. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. All Division 25 Sections

PART 2 - PRODUCTS

2.01 GENERAL

A. Building Control and Automation System (BCAS): Provide a system capable of integrating multiple building functions including equipment supervision and control, alarm management, energy management, and historical data collection and archiving.

B. Hardware: The BCAS panel and controller hardware shall consist of the following, as required:

1. Network Area Controllers (NAC)
2. Expandable Custom Application Controllers
3. Standalone Application Specific Controllers (ASC)
4. Unitary Controllers (UC)

C. Expansion: The system shall be modular in nature, and shall permit expansion of both capacity and functionality through the addition of sensors, actuators, NAC, ASC, and operator devices.

D. System Architecture: System design shall eliminate dependence upon any single device for alarm reporting and control execution. Each NAC shall operate independently by performing its own specified control, alarm management, operator I/O, and historical data collection. The failure of any single component or network connection shall not interrupt the execution of control strategies at other operational devices.

1. Open, Interoperable, Integrated Architectures

    a. The intent of this specification is to provide a peer-to-peer networked, stand-alone, distributed control system with the capability to integrate OBIX (XML), OPC, SNMP, Lon works, BACnet IP, BACnet MSTP, Modbus TCP/IP, Modbus RTU, or proprietary legacy communication protocols in one open, interoperable system.
    b. The supplied computer software shall employ object-oriented technology (OOT) for representation of all data and control devices within the system. In addition, adherence to industry standards including ANSI / ASHRAE™ Standard 135-2001, BACnet and LonMark to assure interoperability between all system components is required. For each LonWorks device that does not have LonMark certification, the device supplier must provide an XIF file and a resource file for the device. For each BACnet device, hardware shall have a BACnet BTL (BACnet Testing Laboratories) listing and 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 (BACnet Ethernet/IP,) and/or RS-485 (BACnet MSTP) as specified. For each Modbus device supplier must provide a Registry of data points available on the system.
    c. All components and controllers supplied under this Division 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 standard Web browsers without requiring proprietary operator interface and configuration programs. An Open DataBase Connectivity (ODBC) or Structured Query Language (SQL) compliant server database is required for all system database parameter storage. This data shall reside on the Network Data Server for all database access. Systems requiring proprietary database and user interface programs shall not be acceptable.
    e. A hierarchical 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. Systems employing a "flat" single tiered architecture shall not be acceptable.

        1) 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.
        2) 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.

E. Reliability: Standalone NAC shall be able to access any data from, or send control commands and alarm reports directly to any other NAC or combination of panels on the network without dependence upon a central processing device. Standalone NAC shall also be able to send alarm reports to multiple operator workstations without dependence upon a central processing device.

F. Remote Access / Network Security: Controls manufacture shall provide secure remote access to the Building Automation System (BAS).

1. Secure remote access to the BAS shall be available anywhere, anytime, using a compatible client device (PC/tablet/phone).
2. Secure remote access to the BAS shall be maintained by controls manufacturer.
3. Secure remote access to the BAS shall not require additional software to be installed on the client device (i.e. VPN client).

4. Secure remote access to the BAS shall not require ANY inbound ports on a firewall to be “exposed” or “forwarded”.

G. Microcomputer based distributed control processors located in DDC panels and application specific controllers shall interface directly with sensors, actuators, and environmental delivery systems (i.e., HVAC units, chillers, lighting distribution systems, etc.). Functionality to be implemented at the NAC level shall include:

1. Individual input/output point scanning, processing and control
2. Direct digital control
3. Alarm detection and storage
4. Time, event and holiday scheduling
5. Bus communications interface and control
6. Local operator terminal interface
7. Central operator terminal interface
8. Trend data acquisition and storage

H. Analog and digital input and output points shall be resident in NAC and application specific controllers. All analog outputs shall be true analog current or voltage outputs. Floating control of digital outputs to provide "analog" outputs will be acceptable for HVAC terminal unit control.

I. All control functions related to any given smoke management sequence shall be resident in a single NAC or Application Specific Controller or if functions are resident in multiple controller, the smoke management initiation input and verification output shall be hardwired to each controller such that the smoke management functions are maintained with the BCAS communications network out of service.

J. A Local Area Network (LAN) shall allow data exchange between NAC, and PC operator terminals over BACnet TCP/IP. Direct communications between controllers and the operator terminals shall not be dependent on any other bus connected processor.

K. All system components shall be designed and built to be fault tolerant, including, but not limited to:

1. Satisfactory operation without damage at 110% above and 85% below rated voltage and a ±3 Hz variation in line frequency.
2. Static, transient, and short circuit protection on all inputs and outputs.
3. Communications lines protected against incorrect wiring, static transients, and induced magnetic interference.
4. Bus connected devices to be ac-coupled or equivalent so that any single device failure will not disrupt or halt bus communication.
5. All real time clocks and data file RAM to be battery backed for a minimum of 48 hours.

L. All computer operated system components receiving 120 Volt power from the building power systems shall include integral surge protection devices (SPD) for protection.

M. All software, real time graphics and accessory hardware required by the following specifications and the performance standards of other sections of this Division.

2.02 **DDC HARDWARE**

A. Network Area Controller - (NAC)

1. This contractor shall supply one or more Network Area Controllers (NAC) as part of this contract. Number of area controllers required is dependent on the type and quantity of devices being integrated to the system.

2. The Network Area Controller (NAC) 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 NAC. It shall be capable of executing application control programs to provide:

    a. Calendar functions
    b. Scheduling
    c. Trending
    d. Alarm Monitoring and routing
    e. Time synchronization
    f. Integration of controller data for each applicable protocol
    g. Network Management functions for all network devices

3. The Network Area Controller must provide the following hardware features as a minimum:

    a. One Ethernet Port - 10/100 Mbps
    b. One RS-232 port
    c. One RS-485 BACnet MS/TP port
    d. One LonWorks Interface Port
    e. One RS-485 ports (configured for Modbus RTU)
    f. Battery Backup
    g. Flash memory for long term data backup (If battery backup or flash memory is not supplied, the controller must contain a hard disk with at least 1 gigabyte storage capacity)
    h. The NAC must be capable of operation over a temperature range of -20 to 122°F
    i. The NAC must be capable of withstanding storage temperatures of between 0 and 158°F
    j. The NAC must be capable of operation over a humidity range of 5 to 90% RH, non-condensing

4. The NAC shall provide multiple user access to the system and support for ODBC or SQL. A database resident on the NAC shall be an ODBC-compliant database or must provide an ODBC data access mechanism to read and write data stored within it.
5. The NAC shall support standard Web browser access via the Intranet/Internet.
6. Control equipment and network failures shall be treated as alarms and annunciated.
7. Alarm actions may be initiated by user defined programmable objects created for that purpose.
8. Defined users shall be given proper access to acknowledge any alarm, or specific types or classes of alarms defined by the user.
9. A log of all alarms shall be maintained by the NAC and/or a server (if configured in the system) and shall be available for review by the user.
10. Provide a “query” feature to allow review of specific alarms by user defined parameters.
11. A separate log for system alerts (controller failures, network failures, etc.) shall be provided and available for review by the user.
12. An Error Log to record invalid property changes or commands shall be provided and available for review by the user

B. Expandable Custom Application Controllers

1. General:

    a. Expandable Custom Application controllers shall be capable of providing control strategies for the system based on information from any or all connected inputs. The program that implements these strategies shall be completely flexible and user-definable. Any systems utilizing factory pre-programmed global strategies

that cannot be modified by field personnel on-site though simple download are not acceptable. Changing global strategies using firmware changes is also unacceptable. Program execution of controller shall be a minimum of once per second.

b. Equipment Controllers shall be BTL listed BACnet Application Specific Controller (B-ASC) or BACnet Advanced Application Controller (B-AAC), as appropriate for the purpose of the controller.
c. Provide means to graphically view inputs and outputs on each program block in real-time as program is executing. This function may be performed using the operator's terminal or field computer.
d. The onboard, 7 day battery-backed real-time clock must support schedule operations and trend logs.
e. Global control algorithms and automated control functions should execute using 32-bit processor.
f. Controller operating conditions shall be between -67°F to 203°F temperature and 5% to 100% RH (non-condensing) humidity.
g. Controllers used indoors shall be mounted in a NEMA 1 enclosure at a minimum.
h. Controllers used outdoors and/or in wet ambient shall be mounted within NEMA 4 type waterproof enclosures, and shall be rated for operation at -40° F to 158° F.
i. Controller shall include both onboard 10Base-T/100Base-TX Ethernet BACnet communication over UTP and shall include BACnet IP communication. In addition, controller shall include BACnet Point-to-Point (PTP) connection port.
j. The base unit of the controller shall host expansion modules with various I/O combinations. These inputs and outputs shall include universal inputs, binary outputs, and analog outputs (0-10V or 0-20mA). Inputs shall support 3K and 10K thermistors, 0-5VDC, 0-10VDC, 4-20mA, dry contacts, dedicated static pressure input, and pulse inputs directly.
k. This item is basically for unreliable unit controller that need HOA switches.
l. Provide custom application controllers as required to comply with remainder of Division 25 specifications.

2. Schedules: Each custom application controller shall support a minimum of 50 BACnet Schedule Objects.

3. Logging Capabilities:

a. Each controller shall support a minimum of 25,000 samples. Any object in the system (real or calculated) may be logged. Sample time interval shall be adjustable at the operator's workstation.
b. Controller shall periodically upload trended data to system server for long-term archiving if desired.

4. Alarm Generation:

a. Alarms may be generated within the system for any object change of value or state (either real or calculated). This includes things such as analog object value changes, binary object state changes, and various controller communication failures.
b. Alarm log shall be provided for alarm viewing. Log may be viewed on-site at the operator's terminal or off-site using remote communications.
c. Controller must be able to handle up to 200 alarm setups stored as BACnet event enrollment objects, with system destination and actions individually configurable.

5. Serviceability: Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.

C. Application Specific Controllers - (ASC)

1. The BCAS Contractor shall provide Application Specific Controllers necessary to fulfill the project requirements per the specifications. ASC shall be freely programmable with pre-packaged operating sequences maintained in EEPROM or flash RAM.
2. Equipment Controllers shall be BTL listed BACnet Application Specific Controller (B-ASC) or BACnet Advanced Application Controller (B-AAC), as appropriate for the purpose of the controller.
3. The ASC shall be a node on one of the Automation LANs and shall control its own communications so that the failure of any one node, shall not inhibit communications on the network between the remaining nodes.
4. ASC shall be totally independent of other LAN nodes for their monitoring and control functions.
5. Provide each ASC with flash memory or EEPROM for the protection of volatile memory. Batteries on ASCs are not acceptable.
6. All associated applications programs shall reside at the ASC. ASC shall not require communication to any other panel for normal operating sequences other than time scheduled base commands.
7. 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.
8. Provide with each controller the BACnet configuration information including BIBB, address, controller configuration type, etc. to integrate the controller into the CMCS.
9. For future expansion and flexibility, the controller shall have either on board or through expansion, 20 hardware input/output points. Expansion points must communicate with the controller via an internal communications bus. Expansion points must be capable of being mounted up to 650ft. (200 m) from the controller. Expansion points that require the BACnet network for communication with the controller are not allowed.
10. Serviceability: Provide diagnostic LEDs for power, communication, and processor. All wiring connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
11. Application Descriptions:

    a. Fan Powered (FPTU) and Variable Air Volume (VAV) Terminal Unit Controllers:

        1) FPTU/VAV Terminal Unit Controllers shall support, but not be limited to, the control of the following configurations of terminal units to address current requirements as described in the Sequence of Operation section of this specification, and for future expansion:

            a) Single duct only (cooling only or cooling with reheat).
            b) Fan powered (series/on-off logic, dynamic fan speed).
            c) Supply/Exhaust.

        2) The modes of operation supported by the Terminal Unit Controllers shall minimally include, but not be limited to, the following:

            a) Day/Weekly schedules (may be via DDC panels)
            b) Comfort/Occupancy mode.
            c) Economy mode (standby mode, unoccupied, etc.).
            d) Temporary override mode.

3) Occupancy-based Standby/Comfort Mode Control: Each Terminal Unit Controller shall have a provision for occupancy sensing overrides. Based upon the contact status of either a manual wall switch or an occupancy sensing device, the Terminal Unit Controller shall automatically select either Deadband or Comfort mode to minimize the heating and cooling requirements while satisfying comfort conditions.

b. Fan Coil Unit (FCU) Controllers:

1) FCU Controllers shall support, but not be limited to, the control of the following configurations of terminal units to address current requirements as described in the Sequence of Operation section of this specification, and for future expansion:

a) Single duct only (cooling only or cooling with reheat).
b) Fan powered (series/on-off logic, dynamic fan speed).
c) Supply/Exhaust.

2) The modes of operation supported by the FCU Controllers shall minimally include, but not be limited to, the following:

a) Day/Weekly schedules (may be via DDC panels)
b) Comfort/Occupancy mode.
c) Economy mode (standby mode, unoccupied, etc.).
d) Temporary override mode.

3) Occupancy-based Standby/Comfort Mode Control: Each FCU Controller shall have a provision for occupancy sensing overrides. Based upon the contact status of either a manual wall switch or an occupancy sensing device, the FCU Unit Controller shall automatically select either Deadband or Comfort mode to minimize the heating and cooling requirements while satisfying comfort conditions.

D. Unitary Controllers - (UC)

1. Unitary Controllers shall support, but not be limited to, the following types of systems to address specific applications described in the Sequence of Operation section of this specification, and for future expansion:

a. Heat pumps.
b. Small package RTU’s.

2. Unitary controllers shall support the following types of point inputs and outputs:

a. Economizer Switchover Inputs:

1) Dry bulb.
2) Outdoor air enthalpy.
3) Differential temperature.
4) Binary input from a separate controller.

b. Economizer Output:

1) Integrated analog with minimum position.
2) Binary output to enable self-contained economizer actuator.

c. Heating and Cooling Outputs:

1) One to three stages.
2) Analog output with two-pipe logic.
3) Reversing valve logic for heat pumps.

d. Fan Output:

1) On/Off logic control.

3. Unitary Controllers shall support the following library of control strategies to address the requirements of the sequences described in the Sequence of Operation section of this specification, and for future expansion:

a. Daily/Weekly schedules (may be controlled via DDC controllers).
b. Comfort/Occupancy mode.
c. Economy mode.

1) Standby mode/economizer available.
2) Unoccupied/Economizer.
3) Shutdown.

d. Temporary Override Mode:

1) Temporary comfort mode (occupancy-based control).
2) Boost (occupant warmer/cooler control).

4. Occupancy-based Standby/Comfort Mode Control: Each Unitary Controller shall have a provision for occupancy sensing overrides. Based upon the contact status of either a manual wall switch or an occupancy sensing device, the Unitary Controller shall automatically select either standby or comfort mode to minimize the heating and cooling requirements while satisfying comfort conditions.

PART 3 - EXECUTION (NOT APPLICABLE)

END OF SECTION

SECTION 25 09 03 - DAMPERS, VALVES AND ELECTRONIC CONTROL AND AUTOMATION HARDWARE

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Start-up, Testing, Adjusting, and Balancing - Section 23 05 93
5. Scope of Work - Section 25 05 01

1.02 SCOPE

A. Provide all dampers, valves and electronic control and automation hardware required for a complete and fully functional Building Control and Automation System (BCAS).

1.03 RELATED SECTIONS

A. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. All Division 25 Sections

1.04 QUALITY ASSURANCE

A. Manufacturers:

1. Provide principal control and automation system equipment and materials produced by the BCAS Manufacturer. All equipment shall be supplied by and be the responsibility of that manufacturer.
2. Where the BCAS Manufacturer does not have all required equipment available, provide sensors, transducers, switches, and similar equipment and material produced by one of the following:

a. ABB (Taylor)
b. Barton
c. Bristol
d. Data Industrial Corporation
e. Dwyer
f. Foxboro
g. Kele and Associates
h. McDonnell and Miller
i. Mercoid
j. Onicon
k. Pre-Con Corporation
l. Veris Industries
m. Equal to be Submitted and Approved

3. Where the BCAS Manufacturer does not have all required equipment available, provide control valves, actuators, and similar equipment and materials produced by one of the following:

   a. Johnson Controls, Inc.
   b. Krueter Manufacturing, Inc.
   c. Keystone Control Valves
   d. Belimo Air controls, Inc
   e. Robertshaw
   f. Equal to be Submitted and Approved

4. Where a specific manufacturer and model number is listed in the specifications, the specific product shall be provided, or an equal product meeting all characteristics and quality of listed product.

B. Electrical Standards: Provide electrical products which have been tested, listed and labeled by Underwriters' Laboratories, Inc. (UL) and which comply with National Electrical Manufacturers' Association (NEMA) standards.

1. Local Control Panels and Standalone Controls used to sequence dampers and control equipment associated with the Fire Alarm smoke purge sequence shall have the following UL listing:

   a. UL 864 UDTZ (Smoke Evacuation)
   b. UL 864 UUKL (Smoke Evacuation)
   c. UL 916 PAZX

2. Equipment that is not listed for Smoke Removal/Evacuation may not be used to sequence dampers, Air Handlers and Exhaust Fans without hardwired interlocks to the Fire Alarm System.

C. Accuracy Standards:

1. Sensing elements and associated controllers or readout devices shall be field-adjustable to provide the minimum operating throttling range possible without control loop hunting. Variation from control point setting through the full control range shall be no more than ½ the throttling range. Space temperature control throttling range shall not exceed 2˚F and overall control system accuracy (end-to-end) shall be as listed below from set point for each control function, including the control element, wiring, relays, submaster devices, and similar items. All accuracy's defined as percentage shall be percentage of the actual reading within the specified range:

   a. ± 1.0°F for space temperature in the 0 to 130°F range.
   b. ± 1.0°F for duct temperatures in the 40 to 130°F range.
   c. ± 1.0°F for outside air temperatures in the -30 to 230°F range.
   d. ± 1.0°F for water temperatures in the 30 to 230°F range.
   e. ± 0.25°F for water temperatures used in BTU calculations.
   f. ± 1% for KWH and kW monitoring.
   g. ± 5% for relative humidity in the 5 to 95% range.
   h. ± 0.1 inch for static pressure in the 0 to 5 inch water gauge range.
   i. ± 0.1 inch for filter status differential in the 0 to 2 inch range.
   j. ± 1% for air flow from 10 to 150% of maximum flow.
   k. ± 2% for water flow from 10 to 150% of maximum flow.
   l. ± 2% for differential water pressure from 10 to 150% of maximum flow.
   m. ± 50 ppm for Carbon Monoxide readings.

n. ± 50 ppm for Carbon Dioxide readings.

2. Accuracy standards for individual sensors, transducers, devices, and systems shall be as specified for the individual components and systems.

1.05 **SUBMITTALS**

A. Refer to Schedule of Submittal Data, Section 25 05 04.

PART 2 - PRODUCTS

2.01 **GENERAL**

A. Provide temperature control products in the size, capacities, and quality indicated by these Specifications and as required, conforming to manufacturer's standard materials and components as published in their product information, designed and constructed as recommended by the manufacturer, and as required for the application indicated or required. These Specifications shall be considered minimum standards in all situations.

B. Provide all sensors, thermostats, relays, switches, control valves, dampers, operators, instrumentation, and other devices required for operation and interface of the Building Control and Automation System (BCAS).

2.02 **MISCELLANEOUS MATERIALS**

A. Ionization Smoke Detectors: These detectors shall be provided under Division 28. Coordinate all installation work. Verify proper compliance with the requirements of NFPA 90A.

2.03 **AUTOMATIC VALVES/ACTUATORS**

A. General: Provide factory-fabricated two-way or three-way valves with two position or modulating control actuators of the type, body material, and pressure class required for each application. Where type or body material is not indicated, provide selection as determined by manufacturer for installation requirements. Valve pressure class and rating shall be selected based on maximum pressure and temperature in the piping system in which it is installed.

B. Performance: All valves shall conform to the following minimum standards and selection requirements.

1. Valves shall be guaranteed to have a Class 5 shut off rating.
2. Maximum pressure drop at design flow shall be 5 psi or as noted on the Drawings.
3. Provide heavy-duty actuators, with proper close-off rating for each individual application.
4. The valve assembly shall be suitable for throttling control and for tight shut-off against pump shut-off head. All valves shall be certified by an authorized officer of the manufacturer to shut-off bubbletight against full system pump shut-off head.
5. All valves which are operated in sequence with damper motors, control switches, or other valves shall sequence properly without overlap. Provide positive positioners, oversized operators, or balanced trim if required for proper sequence control.
6. Valve schedules submitted for review shall clearly show shift in operator span for all valves operated in sequence and shut-off capability for all valves.
7. Zone valves shall be sized to meet the control application and they shall maintain their last position in the event of a power failure.

C. Valve Types: Control Valves ½" to 6": The BCAS contractor shall furnish all specified motorized control valves and actuators. BCAS contractor shall furnish all control wiring to actuators. The Division 23 Contractor shall install all valves. Equal Percentage control characteristic shall be

provided for all water coil control valves. Linear valve characteristic is acceptable for 3-way valves 2½ inches and above.

1. Globe Valves: Hydronic system globe valves shall have the following characteristics (Used for VAV Coils, FCU's, Hot Water Coils, and office building and school AHU coils. You will still need to have an autoflow circuit setter upstream for T&B):

    a. NPS 2 (DN 50) and Smaller: Class 125 bronze body, bronze trim, rising stem, renewable composition disc, and screwed ends with backseating capacity repackable under pressure.
    b. NPS 2-1/2 (DN 65) and Larger: Class 125 iron body, bronze trim, rising stem, plug-type disc, flanged ends, and renewable seat and disc.
    c. Internal Construction: Replaceable plugs and stainless-steel or brass seats.

        1) Single-Seated Valves: Cage trim provides seating and guiding surfaces for plug on top and bottom.
        2) Double-Seated Valves: Balanced plug; cage trim provides seating and guiding surfaces for plugs on top and bottom.

    d. Sizing: 5-psig (35-kPa) maximum pressure drop at design flow rate or the following:

        1) Two Position: Line size.
        2) Two-Way Modulating: Either the value specified above or twice the load pressure drop, whichever is more.
        3) Three-Way Modulating: Twice the load pressure drop, but not more than value specified above.

    e. Flow Characteristics: Two-way valves shall have equal percentage characteristics; three-way valves shall have linear characteristics.
    f. Close-Off (Differential) Pressure Rating: Combination of actuator and trim shall provide minimum close-off pressure rating of 150 percent of total system (pump) head for two-way valves and 100 percent of pressure differential across valve or 100 percent of total system (pump) head.

2. Pressure Independent Characterized Control Valves (PICCV): Forged brass body rated at no less that 400 psi, chrome plated brass ball and stem, female, NPT union ends. For all PICCV, 2" and smaller, up to 100 GPM. Refer to drawings for specified PICCV locations.

    a. The modulating control valves shall be pressure independent.
    b. The control valve shall accurately control the flow from 0 to 100% full rated flow with an equal percentage flow characteristic. The flow shall not vary more than +/- 5% due to system pressure fluctuations across the valve with a minimum of 5 PSID across the valve.
    c. Combination of actuator and valve shall provide a minimum close-off pressure rating of 200 PSI.
    d. The control valve shall require no maintenance and shall not include replaceable cartridges.
    e. The actuator shall be directly coupled to the valve at the factory.
    f. Running time shall be 100 seconds independent of the flow setting while rotating a maximum of 90 degrees.
    g. The actuator shall have a separate feedback wire, which will be capable of sending a signal back to the controller. This signal will translate to the actual flow (gpm) of the associated coil, which will be in direct relation to the magnitude of the feedback voltage.

h. All pressure independent characterized control valves shall be sized by the maximum coil capacity in GPM, not by the conventional CV method.
i. The manufacturer shall warrant all components for a period of 5 years from the date of production, with the first two years unconditional.
j. Balancing valves are not needed when using Pressure Independent Characterized Control Valves (PICCV).
k. Manufacturer shall be Belimo or approved equal.

3. Butterfly Valves: Where indicated on the Drawings or required by the Sequence of Control, utilize full lug butterfly-type control valves rated for the same operating pressure as the piping system in which such valves are installed. Valve construction shall be as specified in Section 23 05 10. Valves shall have Class 5 shut-off rating against either side of the valve when the flange is removed from the opposite side. Provide positive positioners or oversized operators if required for proper sequence control.
4. Differential Bypass Valves: Valves for control of differential bypass systems shall be of industrial quality with minimum 50:1 range ability, equal percentage characteristics, cast iron body, 316 stainless steel trim, position indicator, heavy duty operator, stainless steel stem, Teflon spring-loaded packed, and removable or non-removable cage type trim. All working parts (trim) of the valve shall be replaceable without removing the valve body from the line.
5. Steam Valves: Body and trim materials shall be in accordance with manufacturer's recommendations for design conditions and service with linear ports for modulating service. Sizing criteria:

a. Two-position service: pressure drop 10% to 20% of inlet psig.
b. Modulating service: 100 kPa (15 psig) or less; pressure drop 80% of inlet psig
c. Modulating service: 101 to 350 kPa (16 to 50 psig); pressure drop 50% of inlet psig.
d. Modulating service: over 350 kPa (50 psig); pressure drop as scheduled on plans.

D. Modulating Control Operators: Provide all modulating control valves 2-1/2" and larger and all size butterfly valves with a positive positioning power device. Such device shall operate independently of valve spring range or stem friction to ensure the repetition of valve position when related to the same signal increment value of controller output. Positioner sensitivity shall be sufficient to produce a stem travel reversal loss not exceeding 7% of the controller output range as it goes from its full to no-load position within its proportional band operation. Provide positioners whenever required to obtain close-off ratings or proper sequencing of valves with damper operators, relays or other valves.

E. Fail Position: Chilled water valves shall be normally open and hot water valves shall be normally open or normally closed as specified in the Sequence of Operation.

F. Valve Selection: All valves shall be suitable for the maximum design pressure of the system in which they are installed.

1. Valves shall be selected to provide tight-closing shut-off without chatter against the maximum pressure which can be encountered in the system in which they are installed.
2. Modulating valves shall be sized by the BCAS Manufacturer for fully modulating operation. Where valve size is smaller than line size, coordinate installation of increasers and reducers with the Division 23 Contractor. Line size transitions shall be provided at no additional cost to the Owner.
3. Two position valves shall be full line size with properly sized internal passages.
4. Water valves shall be sized with a minimum pressure drop equal to the pressure drop of the coil or heat exchanger served and a maximum pressure drop of 5 psi. Relief and bypass valves shall be sized according to the pressure available.

2.04 AUTOMATIC DAMPERS

A. General: Provide factory-fabricated opposed blade-type automatic control dampers as shown on the Drawings or required by the Sequence of Operation.

B. Construction: Dampers shall have galvanized bar or channel steel frames which are the full size of the duct or opening in which the damper is installed. Frames on dampers over 4 square feet shall have corner bracing. Damper frames shall be minimum 14 gauge formed galvanized steel with mounting holes for enclosed duct mounting, where applicable. Fabricate of not less than 16 gauge steel with corrosion-resistant galvanized finish. Damper blades shall have a maximum width of 8” and a maximum length of 48". All dampers shall be provided with nylon or oilite bearings, stainless steel or elastomer side seals, and zinc-plated hardware as standard. Axles shall be a minimum of 1/2" diameter and be locked to the blade with rivets or be welded. Blades shall have a minimum of four brakes. All blades on each damper section shall be interconnected to act in unison. Provide neoprene, vinyl polyester, or polyurethane blade edging. Maximum leakage rate through a 48" x 48" closed damper shall not exceed 10.0 cfm per square foot of damper face area at 2.5” of water pressure differential and a maximum closing torque of 50 inches/pounds. Damper leakage ratings shall be certified in accordance with AMCA Standards.

C. Damper Sizing: Modulating dampers shall be sized according to approach velocities, pressure drops, and similar criteria to obtain linearized characteristics. Maximum approach velocity shall be 1800 feet/minute. Damper free area shall be sized by the BCAS Manufacturer. Provide necessary blank-off plates between damper leaves to obtain the required free area. Damper sizing shall be submitted to the Engineer for approval.

D. Operating Temperature Range: Range shall be from -40˚F to 180˚F.

E. Operators: Dampers shall be normally closed unless otherwise specified, and shall be opened by actuators with sufficient power to open the damper as installed. Operators shall be as specified herein.

F. Operating Linkage: Linkage shall be factory-assembled and shall be capable of withstanding a load equal to twice the maximum operating force of the damper operator without deflection.

2.05 ELECTRONIC CONTROL AND AUTOMATION HARDWARE

A. Electronic Actuators

1. General: Provide fully proportioning electronic actuators of either the push-pull or rotary type, as required. Actuator motor shall be of the low voltage synchronous type and shall be non-overloading at a continuous stall. Provide each motor with corrosion protection. Actuators for outside air and exhaust applications shall have nonferrous motor housings and stainless steel shaft and linkage. Actuator control signal shall be 24-volt ac, 0-10 volts, 2-wire phase cut or three point floating as required.

    a. Provide spring return for normally open/closed positioning. Spring return actuators with more than 60 in-lb. torque capacity shall have a manual crank for this purpose.
    b. All non-spring return actuators shall have an external manual gear release to allow manual positioning of the damper when the actuator is not powered.

2. Selection: Size electronic actuators to operate their appropriate dampers and valves with sufficient reserve power to provide smooth modulating or two-position action as specified. Actuators shall be Underwriters Laboratories Standard 873 listed. Actuators shall be designed for a minimum of 60,000 full stroke cycles at the actuator's rated torque.

3. HVAC Terminal Unit Actuators: Where required by the Sequence of Operation, electronic actuators shall be suitable for use with the terminal unit controllers and terminal unit control dampers provided on the project. Coordinate provisions for actuator mounting with the HVAC terminal unit manufacturer selected for the project.

B. Temperature Sensors

1. General: Provide temperature sensors for space, duct, immersion, duct averaging, remote probe, and outside air applications.

a. DDC temperature sensors shall be of the 500 ohm, 1,000 ohm, or 3,000 ohm platinum type, or 10,000 ohm thermistor type. All sensors of a particular category shall be of the same type manufacturer and shall have an interchangeability of +0.1% at the reference temperature. Sensors shall provide high accuracy, long term stability, low hysteresis, fast response and a wide operating range.
b. Sensor time constant response to temperature change time shall be less than 3 seconds per degree change. Sensors requiring field-calibration shall not be acceptable. All sensors shall be precise and accurate so that they do not require adjustments or calibrations. Linearizing, (ranging and resistance change versus temperature curve interpretations, where required) shall be made by software programming.
c. Minimum sensor operating ranges shall be as follows:

1) Chilled Water:.....30°F to 100°F
2) Condenser Water System.....30°F to 150°F
3) Air Systems.....0°F to 150°F
4) Space.....30°F to 100°F
5) Outside Air.....50°F to 120°F

d. Sensor accuracy shall be ±0.1% at 32˚F for platinum sensors and ±0.4°F for thermistor sensors or as required to achieve overall system accuracy (end-to-end) as stated hereinbefore.

2. Wall-Mounted Space Sensors: As specified in the sequence of operations, provided wall sensor with setpoint adjustment capability.

a. Standard wall sensor shall use solid-state sensor and shall be packaged in aesthetically pleasing enclosure. Sensor shall provide override function, warmer/cooler lever for set point adjustment and port for plug-in of Field Service Tool for field adjustments. Override time shall be stored in controller and be adjustable on a zone-by-zone basis. Adjustment range for warmer/cooler lever shall also be stored in EEPROM on controller. All programmable variables shall be available to Field Service Tool through wall sensor port.
b. Temperature adjustment capability shall be enabled/disabled on a zone-by-zone basis through the BCAS. Temperature adjustment device/lever shall not have permanent markings on face of sensor indicating adjustment capability.
c. Sensor shall include push-button device for after-hours occupancy override setting. Override shall be enabled/disabled on a zone-by-zone basis through the BCAS. Override setting duration shall be initially programmed for 60 minutes (adjustable by zone or globally). Override function shall activate enough terminal units on the floor to ensure a stable load on the air handling unit. The program shall be written to energize the air handling unit serving the terminal unit, if it is not already. Likewise, a signal shall be sent out to the central plant to activate a chiller and its associated equipment if not already in operation. An alarm message shall record when a Tenant activates his HVAC System for after-hours

use. Run time shall be accumulated for each Tenant and automatically input into the BCAS billing spreadsheet separated by Tenant. Local override shall be tied into web-based Tenant override scheduling and reporting system.

3. Wireless Zone Sensors: In lieu of space temperature or intelligent room sensors, wireless zone sensors shall be specified as specified in the sequence of operations.

   a. Battery life shall be 15 years or greater to minimize the need for battery replacement in typical operating conditions.
   b. To check for proper operation, wireless space temperature sensors shall include a signal strength on the space sensor display.
   c. To allow local troubleshooting without specialized tools, error codes shall be displayed on the digital display. Error codes shall include: not associated, address to 000, improper software configuration, input voltage too high, or general sensor failure. Codes shall be indicated on inside of sensor back cover.

4. Duct Sensors: Provide flanged or threaded probe type sensors designed for duct type mounting. Sensor shall be encapsulated in a stainless steel probe 8" long. Sensors shall include a suitable junction box for terminating sensor wiring and shall include a lagging protrusion where installed in externally insulated ducts. Sensor shall be ACI T2 thermistor, or approved equal.
5. Immersion Sensors: Provide Immersion type sensors with a ½" OD threaded fitting for direct installation in a thermowell. Immersion sensors shall be provided with a separable stainless steel well. Pressure rating of well is to be consistent with the system pressure in which it is to be installed. The well must withstand the flow velocities in the pipe. Sensors shall include a suitable junction box for terminating sensor wiring. Wells for insulated piping shall have a 2-1/2" lagging protrusion. Locate wells so the sensing probe will give a true and correct reading. Install wells so as not to cause undue restriction in small piping. Where wells are located in pipe lines 1-1/2" and smaller, provide a section of pipe of such diameter that the net area of the pipeline will not be reduced by the thermometer well. All wells shall be filled with silicon and complete with caps and chains. Wells shall be installed in a 45-degree angle into the direction of water flow in the monitored piping. Sensor shall be ACI T2 thermistor, or approved equal. Temperature probes and wells shall have the following insertion lengths:

PIPE DIAMETER	INSERTION ORIENTATION	LENGTH
4"	HORIZONTAL	2-1/2"
4", 6"	VERTICAL	4-1/2"
6", 8"	HORIZONTAL	4-1/2"
8", 10"	VERTICAL	6-1/2"
>8"	HORIZONTAL	6-1/2"
>10"	VERTICAL	10"

6. Duct Averaging and Coil Leaving Air Averaging Sensors: Provide extended flexible probe averaging sensors for coil discharge temperature applications. Averaging sensors shall be a minimum of 5 ft in length per 10 ft^2 of duct cross section. Sensors shall include a suitable junction box for terminating sensor wiring and be installed in a serpentine fashion. Sensor shall be ACI T2 thermistor.
7. Outside Air Sensors: Provide shielded, weatherproof outside air sensors with sensing elements encapsulated in a nominal 2" stainless steel sheath suitable for outdoor applications. Sensors shall include a waterproof junction box or conduit body for terminating sensor wiring and a removable sun shield. Provide two sensors each located in separate monitoring locations. Sensor shall be equal to Dwyer Model RHP-2011.

C. Temperature Transducers

1. General: Provide temperature transducers consisting of a temperature sensor and a solid-state signal conditioner to provide a 4-20 mA or 0-10 volts dc true linear output corresponding to temperature. The signal conditioner shall be factory-calibrated and provided with zero and span trimmers for output adjustment.
2. Accuracy: Sensor accuracy shall be ±0.1% at 32˚F for platinum sensors and ±0.4˚F for thermistor sensors or as required to achieve overall system accuracy (end-to-end) as stated herein before.
3. Configurations: Temperature transducers shall be provided in configuration as specified hereinabove for TEMPERATURE SENSORS.

D. Thermostats/Temperature Safeties

1. Electric Type: Electric space thermostats shall be two position space thermostats with a SPST or SPDT switch activated by a bimetal sensing element, direct or reverse acting as required. The thermostat range shall be adjustable for 50˚F to 65˚F with a removable external adjustment knob. Each thermostat shall have a blank, impact resistant locking cover.
2. Proportional-Acting Room Thermostats: Proportional-acting thermostats shall have precision wound potentiometers that will give a variable voltage output directly proportional to temperature sensed. Thermostats shall have one or two potentiometers as necessary for the required sequence; and when two potentiometer types are required, potentiometers shall act in unison or in sequence as required. Thermostats shall have a range of approximately 55˚F to 85˚F, a throttling range of 3˚F to 8˚F, and adjustable stops. Provide locking-type covers without thermometers or external-adjusting device.
3. Freeze Protection Switches (Freezestats): Switches shall consist of a manual reset, line voltage, bellows activated switch with a 20' long sensing bulb and 4' capillary installed in a serpentine fashion. The sensor shall be responsive to the coldest section of the capillary. Switch contact shall open when the air temperature along any point on the capillary falls below 35˚F (adjustable). Provide double pole switches where required by the Sequence of Operation. Sensor shall be Kreuter Model 3017, or equal.
4. Low-Limit Thermostat: Low-limit airstream thermostats shall be UL listed, vapor pressure type, with an element of 20 ft minimum length. Element shall respond to the lowest temperature sensed by any 1 ft section. The low-limit thermostat shall be manual reset only.
5. Safety Temperature High Limit Switches (Firestats): Switches shall consist of a manual reset, line voltage, bimetal activated switches set to operate at 135˚F (adjustable from 100˚F to 250˚F). Switches shall be UL-labeled. Switch contacts shall open when the air temperature exceeds 135˚F. Provide double pole switches where required by the Sequence of Operation. Sensor shall be Kete Model TC-100-1A-3C, or equal.

E. Humidity Transducers

1. General: Provide space, duct, remote probe and outside air humidity transducers consisting of a solid-state humidity sensor and a solid*-state signal conditioner to provide a 4-20 mA or 0-10 volts dc true linear output corresponding to relative humidity (RH). Transducers shall not require periodic maintenance or calibration and shall not be affected by high airflow, dust, moisture saturation or power interruption.
2. Accuracy: Transducers shall provide long-term stability and low hysteresis with an accuracy of ±3% over a 20-80% RH range for room and duct / 20%-95% RH range for Outdoor Air humidity sensors RH range with ±0.5% RH repeatability and a maximum 30 second response time for a 50% RH change. Humidity sensor’s drift shall not exceed 1% of full scale per year.
3. Space Transducers: Provide transducers designed for wall mounting in occupied areas. Transducer shall be installed in a self-contained nonmetallic enclosure and shall be

mounted to the wall with tamperproof screws. Enclosures for space humidity transducers shall be identical in appearance to enclosures for space temperature sensors. Sensor shall be Dwyer Model RHTL-W, or equal.

4. Duct Transducers: Provide self-contained flanged or threaded probe type sensors designed for duct mounting. Transducers shall include a suitable junction box for terminating transducer wiring and shall include a lagging protrusion where installed in externally insulated ducts. Sensor shall be Dwyer Model RHTL-D, or equal.
5. Outdoor Air Transducers: Provide weather-sheltered sensors with a weatherproof junction box containing the signal conditioner and provision for terminating transducer wiring. Transducer assembly shall be suitable for outdoor applications. Sensor shall be equal to Dwyer Model RHP-2011.

F. Pressure Transducers

1. General: Provide pressure transducers for converting duct differential and static pressure, water/steam pressure, water differential pressure and pneumatic supply/branch pressures to analog output signals.
2. Duct Differential and Static Pressure Transducers: Provide transducers to convert static pressure signals from static pressure probes and airflow measurement devices to 4-20 mA or 0-10 volts dc analog outputs. Pressure shall be sensed by a solid-state pressure sensor which is mounted directly to the transducer enclosure and not physically attached to the transducer circuit board. The transducer shall be designed for operation with unfiltered monitored air and shall not be affected by mounting orientation, vibration or temperature. Transducer accuracy shall be ±1.0% with linearity of ±0.1%, repeatability of ±0.1% and hysteresis not exceeding ±0.1%. Transducers shall be factory-calibrated and shall have zero and span trimmers for field calibration. Transducers shall be provided with a steel enclosure for panel mounting or a NEMA 1 enclosure for remote mounting, a direct or reverse acting output, as required and a square root output for linearization, where required. Transducer range shall be selected to match the medium being monitored. Transducers shall be Mamac Systems Model PR-272 or an approved equal. Provide flange mounted aluminum duct static pressure sensing probes as required for monitoring duct static pressure. Probes shall be Dwyer MS Series or approved equal.
3. Water Pressure Transducers: Provide transducers to convert water pressure to 4-20 mA or 0-10 volts dc analog outputs. Pressure shall be sensed by a solid-state pressure sensor that is mounted directly to the transducer enclosure and not physically attached to the transducer circuit board. The transducer shall be designed for operation with unfiltered monitored media and shall not be affected by mounting orientation, vibration or temperature. Transducer accuracy shall be ±1.0% with linearity of ±0.1%, repeatability of ±0.1% and hysteresis not exceeding ±0.1%. Transducers shall be factory-calibrated and shall have zero and span trimmers for field calibration. Transducers shall be provided with a steel enclosure for panel mounting or a NEMA 1 enclosure for remote mounting, a direct or reverse acting output, as required and a square root output for linearization, where required. Transducer range shall be selected to match the medium being monitored. Transducers shall be Dwyer 628 Series or approved equal.
4. Water Differential Pressure Transducers: Provide transducers to convert differential pressures to 4-20 mA or 0-10 volts dc analog outputs. Pressure shall be sensed by a solid-state pressure sensor that is mounted directly to the transducer enclosure and not physically attached to the transducer circuit board. The transducer shall be designed for operation with unfiltered monitored media and shall not be affected by mounting orientation, vibration or temperature. Transducer accuracy shall be ±1.0% with linearity of ±0.1%, repeatability of ±0.1% and hysteresis not exceeding ±0.1%. Transducers shall be factory-calibrated and shall have zero and span trimmers for field calibration. Transducers shall be provided with a steel enclosure for panel mounting or a NEMA 1 enclosure for remote mounting, a direct or reverse acting output, as required and a square root output for linearization, where required. Transducer range shall be selected

to match the medium being monitored. Transducers shall be Veris PW2, Dwyer 629 Series, or approved equal.

5. Sensors installed in all liquid lines shall have an isolation valve and pigtail siphon installed between the sensor and its pressure source.

G. Air Flow Transducers

1. Air Monitoring Stations: Provide air monitoring stations where indicated on the Drawings or required by the Sequence of Operation.

a. Each airflow measuring station shall measure airflow by means of a network of static and total pressure sensors factory-positioned and connected in parallel to produce an averaged velocity pressure. The measured velocity pressure converted to airflow (cfm) shall have an accuracy within 2% of the full scale throughout the velocity range from 700 to 4000 fpm when measured under laboratory conditions. The location of air monitoring stations shall meet manufacturer's guidelines so as to approach laboratory conditions.

b. The maximum resistance to air flow shall not exceed 0.6 times the velocity head. The unit shall be suitable to withstand up to a temperature of 250°F.

c. Airflow measuring stations shall be of heavy gauge metal construction and shall be furnished with an air velocity treatment, air straightening section with an open face area of not less than 97%.

d. Provide separate transducers, with integral square root extraction where applicable, to convert air monitoring station differential pressure to a 4-20 mA or 0-10 volt dc analog signal.

e. Provide local readout display at each Air Flow Measuring Station.

f. Air Monitoring Stations shall be Kele KMS series. Transducers shall be Modus T30 Series.

H. Carbon Dioxide (CO2) Sensors: Carbon Dioxide sensors shall measure CO2 in PPM in a range of 0-2000 ppm. Accuracy shall be +/- 3% of reading with stability within 5% over 5 years. Sensors shall be duct or space mounted as indicated in the sequence of operation. Sensors requiring more than one calibration per five-year period shall include sensor calibration kit/ software/etc. and provide owner instruction of calibration procedure during training and at end of warranty period. Approved sensors are TRANE 4190-4100 and Vaisala GMW21.

I. CARBON MONOXIDE (CO) METERS/TRANSDUCERS: Provide CO meter/transducer units to monitor CO levels using a maintenance free, solid state sensor and a solid state signal conditioner to provide a three digit local display of monitored CO level in ppm (0 to 400 ppm range) and a linear 4-20 mA analog output proportional to the monitored CO level in ppm. Readings shall be updated every 2-1/2 minutes. The Transducer and signal conditioner shall be mounted in a common NEMA 1 enclosure with the local display concealed inside the enclosure. Transducers shall be Kele & Associates Model WCO-1 or an approved equal. Provide one Model CM-FCK calibration kit and one spare transducer to the Owner at project substantial completion.

J. Water Flow Transducers

1. Insertion / Inline Turbine Flow Meters: Provide insertion type flow sensors as specified herein, where indicated on the Drawings, and as required by the Sequence of Operations.

a. Each flow metering system shall consist of a flow sensor installed in a pipe saddle or thread-o-let and an analog flow transmitter to provide a 4-20 mA or 0-10 volts DC flow signal to the BCAS.

b. The flow sensor shall be constructed of 316 stainless steel and nonmetallic wetted parts and shall be designed for hot tap installation in a 1" NPT pipe saddle

or thread-o-let. The sensor shall be suitable for use in pipe sizes from 1-1/4" to 40". Sensors installed in pipe size 2-1/2" and larger shall have two turbines. A multi-bladed flow wheel shall provide a flow signal to the flow transmitter. The sensor design shall be such that it is not affected by metallic or rust particles as found in metal piping systems. The sensor shall be adjustable to provide the manufacturers recommended insertion depth in the pipe being sensed. The sensor shall be suitable for pressures up to 400 psi and temperatures up to 220°F.

c. The analog flow transmitter shall convert the flow sensor output to an analog flow input to the BCAS.
d. The flow sensor shall be installed with a minimum of twenty upstream and ten downstream pipe diameters of straight pipe for uninterrupted flow and shall have an accuracy of ±3% at flow velocities from one foot (1') to 30' per second with ±0.1% repeatability and ±1% linearity.
e. Insertion type meters shall be provided at locations specified and where shown on the drawings.
f. Insertion flow metering systems shall be Onicon F-1110/F-1210, or an approved equal.

K. Position/Status Indicators

1. End (Limit) Switches: Limit switches shall be of the sealed or enclosed type as required for the application. Contacts shall be snap-action SPDT rated for the application. Damper end switches shall be industrial quality, shaft-mounted, enclosed switches set to sense open or closed position of damper blades. Switches shall be arranged to prevent "open-center" operation and for mounting as required. Switch enclosures shall be waterproof with a conduit entry seal where subject to moisture or water.
2. Potentiometers: Potentiometers may be either rotary or linear, depending on application of each position indicator. Position potentiometers shall have a linearity of +5% and shall indicate position on a percent open basis.
3. Key-Operated Switches: Hand-off automatic (H-O-A), off-automatic, and all similar use switches shall be key-operated with all switches keyed alike where switches are not located in access limited locations. All switches shall be rated for a minimum of 600 Volt ac, 5-A, and shall be mounted in an enclosure as specified or shown.
4. Current Sensitive Relays: Relays shall provide a self-powered, isolated SPDT contact closure to indicate a run condition of monitored equipment. The relay shall have contacts rated at 1 amp at 120 Volt ac, adjustable sensitivity and an adjustable operating point to match the current draw of the monitored equipment. Current sensitive relays shall be Veris H-800 or an approved equal.
5. Liquid Level Switches: Switches shall consist of a SPDT snap acting switch operated by a sealed float mechanism. Switch body shall be stainless steel and shall be suitable for mounting through a 1-1/2" thread-o-let. Float switches shall be KELE F7-SS or an approved equal.
6. Waterflow Sensors: Provide industrial quality thermal dispersion water flow sensor with 316 stainless steel wetted parts, vapor-proof construction with seal at conduit entry, rated for 300 psig, 300˚F, and voltage and current ratings as required. Sensors shall be thread-o-let or tee mounted and shall be IFM Efector solid state remote flow monitoring system or approved equal
7. Differential Pressure (DP) Water Flow Switches: Switches shall be double bellows type differential pressure switches with brass bellows directly actuating a snap-acting DPDT switch. Switches shall have visible setpoint adjusters. Switches exposed to weather shall be weatherproof. Switch ranges and setpoints shall be appropriate to the manufacturer's recommendations for the pressure at the point of application and the differential pressure being monitored. Differential pressure water flow switches shall be McDonnell and Miller, or approved equal.

8. Pressure Switches: Switches shall be brass button bourdon tube operated with a snap-acting switch directly activated by the bourdon tube. Switches shall have a repetitive accuracy of ±1% of their operating range and shall withstand up to 150% of rated pressure. Switch actuation shall be adjustable over the operating pressure range. Switches shall have snap-action DPDT contacts rated for this application. Switches exposed to weather shall be waterproof. Switch ranges and setpoints shall be appropriate to the manufacturer's recommendations for pressures at the point of application. Pressure switches shall be Dwyer or approved equal.
9. Differential Pressure (DP) Air Flow Switches: Switches shall be diaphragm operated to activate a DPDT snap switch. Motion of the diaphragm shall be transmitted to the switch button by means of a direct mechanical linkage. Switches shall be rated for pressures up to 50" WG and shall have 16-gauge steel, zinc-plated, dichromate dipped housing suitable for the environment in which the switch is installed. Switches exposed to unconditioned outside air and weather shall be moisture resistant. Switches exposed to weather shall have weatherproof housing. Switches shall have silicone rubber power and sealing diaphragms with aluminum supports and stainless steel calibration springs. Switch repetitive accuracy shall be 1% minimum. Switch ranges and setpoints shall be appropriate to the manufacturer's recommendation for the pressure drop access the equipment being monitored. Differential pressure air flow switches shall be Dwyer or approved equal.
10. Static Pressure Safety Switches: Switches shall be duct or unit mounted and shall consist of a manual reset static pressure sensitive diaphragm operated switch that is adjustable for positive or negative pressure actuation. When the switch pressure setpoint is exceeded, the switch contacts shall open.

L. Output Devices

1. Control Relays: Control relay contacts shall be rated for the application, with a minimum of two sets of SPDT contacts, enclosed in a dustproof enclosure. Relays shall be rated for a minimum life of one million operations. Operating time shall be 20 milliseconds or less, with release time of 10 milliseconds or less. Relays shall be equipped with coil transient suppression devices to limit transients to 150% of rated coil voltage. Control relays shall be Tyco, Veris, or approved equal.
2. Time Delay Relays: Time delay relay contacts shall be rated for the application with a minimum of two sets of SPDT contacts, enclosed in a dustproof enclosure. Relays shall be rated for a minimum life of one million operations. Relays shall be equipped with coil transient suppression devices to limit transients to 150% of rated coil voltage. Delayed contact opening or closing shall be adjustable from one (1) to 60 seconds with a minimum accuracy of ±2% of setting. Time delay relay shall be Veris or approved equal.
3. Latching Relays: Latching relay contacts shall be rated for the application with a minimum of two sets of SPDT contacts, enclosed in a dustproof enclosure. Relays shall be rated for a minimum life of one million operations. Operating time shall be 20 milliseconds or less, with release time of 10 milliseconds or less. Relays shall be equipped with coil transient suppression devices to limit transients to 150% of rated coil voltage. Catching relays shall be IDEC or approved equal.
4. Reed Relays: Reed relays shall be encapsulated in a container housed in a plastic, epoxy, or metal case. Contacts shall be rated for the application. Operating and release times shall be 1 millisecond or less. Relays shall be rated for a minimum life of 10 million operations and shall be equipped with coil transient suppression devices to limit transients to 150% of rated coil voltage.
5. Contactors: Contactors shall be of the single coil, electrically operated, mechanically or electrically held type. Positive locking shall be obtained without the use of hooks, latches, or semi-permanent magnets. Contacts shall be double break silver-to-silver type protected by arcing contacts where necessary. Number of contacts and ratings shall be selected for the application. Operating and release times shall be 100 milliseconds or

less. Contactors shall be equipped with coil transient suppression devices to limit transients to 150% of rated coil voltage.

6. Solid State Relays: Input-output isolation shall be greater than 1000 megohms with a breakdown voltage of 1500 Volt root mean square or greater at 60 Hz. Relays shall be rated for a minimum life of 10 million operations. The ambient temperature range shall be at least -20˚F to + 140˚F. Input impedance shall not be less than 500 ohms. Relays shall be rated for the application in accordance with NEMA ICS 1. Operating and release times shall be one millisecond or less. Transients shall be limited to 150˚F of control voltage. Solid state relays shall be Kele Model RSSDN or approved equal.

M. Electrical Power Instruments

1. Potential Transformers: Potential transformers shall be in accordance with ANSI C57.13.
2. Current Transformers: Current transformers shall be in accordance with ANSI C57.13.
3. Watt-Hour Meters: Watt-hour meters, with or without demand register shall be in accordance with ANSI C12 and have pulse initiators for remote monitoring of watt-hour consumption. Pulse initiator shall consist of Form C contacts with a current rating not to exceed 2 amperes and voltage not to exceed 500 volts, with combinations of VA not to exceed 100 VA, and a life rating of one billion operations. Meter sockets shall be in accordance with ANSI C12.
4. Watt-Hour Meters With Demand Register: Meters shall be in accordance with ANSI C12 and have pulse initiators for remote monitoring of watt-hour consumption and instantaneous demand. Pulse initiators shall consist of Form C contacts with a current rating not to exceed 2 amperes and voltage not to exceed 500 volts, with combinations of VA not to exceed 100VA, and a life rating of 1 billion operations. Meter sockets shall be in accordance with ANSI C12.
5. Current Transducers: Provide current transducers to convert 0 to 5 amperes input signals from standard current transformers to 4-20 mA or 0-10 volts dc analog signals with an accuracy of ±0.5% of CT rating. The transducer shall be factory-calibrated and provided with zero and span adjustments. Transducers shall be installed in dust tight metal enclosures with provisions for terminating current transformer and transducer wiring. Transducer shall be a Mamac Systems Model CU-230 or an approved equal.
6. Voltage Transducers: Provide voltage transducers to monitor three phase voltages on 208 or 480 Volt systems and provide discrete 4-20 mA outputs which are linear for each phase-to-phase voltage. Transducer shall be suitable for mounting in a NEMA 1 enclosure and shall have an accuracy of +0.25% of full voltage scale. Transducer shall be a Kele & Associates Model PVM-348 or an approved equal.
7. KW and KWH Transducers: Provide kilowatt and kilowatt-hour transducers to convert potential transformer or phase voltage outputs and current transformer current outputs to 4-20 mA outputs proportional to load kW and a pulsed output for kWH consumed. Transducer accuracy shall be ±2.0% at unity power factor and ±2.5% at 0.5 power factor. Transducer shall be provided with a NEMA 1 enclosure, a disconnect switch and current transformer shorting assembly, a phase monitor feature with digital outputs for loss of power, loss of voltage on any phase and undervoltage, and a kWH consumption and demand meter readout kit with LED or LCD readouts. kW and kWH transducers shall be EMON DMON, Kele & Associates WHU-238 Series or an approved equal.

N. Uniterrupted Power Source

1. Provide UPS surge suppression and battery protected outlets on the front end building controller, all programmable controllers, and any server / computer provided
2. Acceptable Manufacturers: Minuteman Entrust UPS.
3. Provide UPS with: automatic voltage regulation, spike and surge protection, and battery backup, all in a surprisingly compact package.
4. Provide UPS with eight total outlets to ensure that all devices in your system can be protected with surge and battery protected outlets.

5. 120/1 Voltage

O. Power Meter

1. The power meter shall be Veris E50H5A or equivalent.
2. The power meter shall be fully electronic with multi-line backlit LCD display showing measured parameters.
3. The power meter shall perform the following measurements:

    a. Accumulated Real Energy (kWh) for each phase and total of all phases.
    b. Accumulated Reactive Energy (kVARh) and Apparent Energy (kVAh) totals for all phases.
    c. Net Present Demand for Real (kW), Reactive (kVAR) and Apparent (kVA) Power over a user-specified interval (block or sliding window).
    d. Maximum (Peak) Real (kW), Reactive (kVAR) and Apparent (kVA) Demand Intervals.
    e. Instantaneous Real (kW), Reactive (kVAR) and Apparent Power (kVA), by phase and in total.
    f. Current (amps) for each phase and average of all phases.
    g. Phase-to-phase voltage for each phase and average of all phase pairs.
    h. Phase-to-neutral voltage for each phase pair and average of all phases.
    i. Power factor for each phase and average of all phases.
    j. AC frequency

4. The power meter shall communicate using the BacNET MS/TP protocol at speeds from 9600 to 115,200 baud (no parity). The meter shall provide a BacNET Device object, a set of writable Analog Value objects for remote configuration, a set of Analog Input objects to provide access to scaled 32-bit measurement values and their unit types, and a set of Binary Input objects for indicating individual alarm conditions.
5. The meter shall be UL/CUL listed to the latest applicable safety standards
6. Power meter models shall accept voltage input over the range of 90 to 600 VAC (50 or 60 Hz).
7. The power meter shall accept 0 to 0.333VAC input from up to three current transducers (U018 Rope Style CTs only) from 20 to 5000 amps.
8. The measured energy consumption shall be retained in non-volatile memory for the life of the product warranty.
9. The power meter shall have demand measurement programmable for up to 6 sub-intervals of 10 seconds to 546 minutes duration.
10. The power meter shall operate from -30°C to +70°C.
11. The power meter shall have dimensions not exceeding 4.2” x 3.6” x 2.3”.
12. The power meter shall meet both ANSI C12.20 0.5% and IEC 62053-22 Class 0.5S real power and energy accuracy specifications.
13. The power meter shall meet IEC 62053-22 Class 2 reactive power and energy accuracy specifications.
14. The power meter shall be configurable for operation on Single Phase (AN or AB), Split Phase (ABN), Delta (ABC), and Wye (ABCN) systems.
15. The power meter shall have automatic phase reversal compensation such that it is insensitive to the CT’s load orientation.
16. The power meter shall have separate control power inputs such that is may be powered from a different service than it measures.
17. The power meter shall have two user-configurable Pulse Contact inputs to support measurement of other related energy values (gas, water, steam, etc.) over BacNET using simple pulse-output transducers.
18. The power meter shall be configurable for use with potential transformers to 5000 volts.
19. The power meter shall calculate a maximum theoretical system power using the configuration parameters set by the user.

20. The power meter shall support warnings for low power factor (phase current or voltage miss-wired), current over range, voltage over range, and frequency out of range.
21. The power meter shall log and retain in non-volatile memory up to 5760 (up to 60 days at 15-minute intervals) measurement records at time intervals determined by the Demand Interval duration setting. These records shall contain any three 32-bit data values that the user selects from the list of supported Analog Input objects. These logged data records shall be readable over BacNET via three Trend Log objects.
22. The product shall have a 5-year warranty.

PART 3 - EXECUTION (NOT APPLICABLE)

END OF SECTION

SECTION 25 09 16 - BUILDING CONTROL AND AUTOMATION SYSTEM (BCAS) SOFTWARE

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Design Criteria - Section 20 05 02
2. Basic Division 20-28 Requirements - Section 20 05 03
3. Schedule of Submittal Data - Section 20 05 04
4. General Division 20-28 Materials and Methods - Section 20 05 05
5. Startup, Testing, Adjusting, and Balancing - Section 23 05 93
6. Scope of Work - Section 25 05 01

1.02 SCOPE

A. Provide a complete custom tailored software package with full web integration, custom graphics, clear and concise floor plan graphics with dynamic objects, pull down menus with custom tags, and trend, control, and billing capabilities as specified.

PART 2 - PRODUCTS

2.01 SYSTEM SOFTWARE

A. General:

1. System Graphics: Operator interface shall be graphically based and shall include at least one graphic per piece of equipment or occupied zone, graphics for each chilled water and hot water system, and graphics that summarize conditions on each floor of each building included in this contract. Indicate thermal comfort on floor plan summary graphics using colors to represent zone temperature relative to zone set point.

    a. Functionality. Graphics shall allow operator to monitor system status, to view a summary of the most important data for each controlled zone or piece of equipment, to use point and-click navigation between zones or equipment, and to edit set points and other specified parameters.
    b. Graphic imagery – graphics shall use 3D images for all standard and custom graphics. The only allowable exceptions will be photo images, maps, schematic drawings, and selected floor plans.
    c. Animation. Graphics shall be able to animate by displaying different Image lies for changed object status.
    d. Alarm Indication. Indicate areas or equipment in an alarm condition using color or other visual indicator.
    e. Format. Graphics shall be saved in an industry-standard format such as BMP, JPEG, PNG, or GIF. Web-based system graphics shall be viewable on browsers compatible with World Wide Web Consortium browser standards. Web graphic format shall require no plug-in (such as HTML and JavaScript) or shall only require widely available no-cost plug-ins (such as Active-X and Macromedia Flash).

2. Custom Graphics:

   a. The operator interface shall be capable of displaying custom graphics in order to convey the status of the facility to its operators.
   b. Graphical Navigation. The operator interface shall provide dynamic color graphics of building areas, systems and equipment.
   c. Graphical Data Visualization. The operator interface shall support dynamic points including analog and binary values, dynamic text, static text, and animation files.
   d. Custom background images. Custom background images shall be created with the use of commonly available graphics packages such as Adobe Photoshop. The graphics generation package shall create and modify graphics that are saved in industry standard formats such as GIF and JPEG.

3. Area and Floor Plan Graphics:

   a. Ariel View of the area served with hyperlinks to each building site like a Google Earth View. May include the customers logo or other identifying trademarks. Clicking on the hyperlink takes the user to the floorplan summary. A summary of ALL floorplans with full 7 color thermal graphics. This view is shown in 2D format. The building would have a 'thumbnail' view of each floorplan on the summary with the reporting 7 color thermal graphics reporting their color. This allows the user to quickly view all zones from one location. Clicking on the floorplans will then direct the user to the floorplan detail.
   b. From the floorplan summary the user can click on any of the floorplans to be directed to the floorplan detail. Each floorplan detail shall contain the following:

      1) Floorplan exterior/interior walls
      2) Show stairways and other identifying features such as:

         a) Room numbers and/or room names.
         b) Actual locations of HVAC Equipment such as Air Handlers, Terminal Units.
         c) The HVAC equipment shall have hyperlinks such that upon clicking on the link the user is directed to the HVAC equipment directly from the floor plan.
         d) Space Conditions for each zone at their physical location including temperature, humidity & CO2.

      3) Thermal Graphics color (Full Seven Color) Colors as follows:

         a) Green – At Setpoint
         b) Light Blue – Below Setpoint Step 1
         c) Dark Blue – Below Setpoint Step 2
         d) Yellow – Above Setpoint Step 1
         e) Brown – Above Setpoint Step 2
         f) Gray – Unoccupied
         g) Red – Zone Out of Range (Hi/Lo Temp)
         h) Purple/Gray – Loss of Comm

      4) The thermal graphic color shall be on the bottom such that all text, walls and details are visible thru the thermal color.
      5) Ductwork Overlay shall show all walls, stairways and identifiable structures.
      6) For All Equipment Graphics

         a) 3D format with cut away views

b) Black backgrounds
c) One graphic for each piece of equipment
d) Standard Animations associated with templated graphics
e) Custom Animation for Applied Air Handlers & Central Plants
f) Mobile Access Graphics shall be enabled for smart phone & tablet use
g) Dashboards shall be provided for the owner to customize.

4. Equipment & Application Pages:

a. The operator interface shall include standard pages for all equipment and applications. These pages shall allow an operator to obtain information relevant to the operation of the equipment and/or application, including:

1) Animated 3D Equipment Graphics for each major piece of equipment and floor plan in the System. This includes:

a) Each Chiller, Pump, Cooling Tower, Ice System (Build and Melt), AHU, VAV, FCU, Exhaust Fan, etc.. These graphics shall show all points dynamically as specified in the points list.
b) Animation capabilities shall include the ability to show a sequence of images reflecting the position of analog outputs, such as valve or damper positions. Graphics shall be capable of launching other web pages.
c) Optimization Sequence Points like Critical Valve Tag, Pump Pressure Optimization, Plant Capacity / Efficiency, Chiller Capacity / Efficiency, etc.

2) Alarms relevant to the equipment or application without requiring a user to navigate to an alarm page and perform a filter.
3) Historical Data (As defined in Automatic Trend Log section below) for the equipment or application without requiring a user to navigate to a data log page and perform a filter.

5. Engineering Units: Allow for selection of the desired engineering units (i.e. Inch pound or SI) in the system. Unit selection shall be able to be customized by user to select the desired units for each measurement.

B. System Applications: The central server shall serve operator interface web pages and provide off-line storage of system information. Provide the following applications within the system.

1. Automatic System Database Save and Restore. The central server shall store on the hard disk backup tables of data including trends, alarms, custom settings and user profiles. This data shall be backed up once a day. This database shall be updated whenever a change is made in the system. The storage of this data shall be automatic and not require operator intervention.
2. Manual Database Save and Restore. A system operator with the proper password clearance shall be able to archive the database manually at any time. The system operator shall have the ability to set limits on Alarm Log, Global Point Control Log, System Log, and User Change Log to manage database size.
3. System Configuration. The central server shall serve web pages as the interface for configuring the operator-level functions of the system. A user with proper security shall be able to configure the system to allow for future changes or additions.
4. On-Line Help and Training. Provide a context sensitive, on line help system to assist the operator in operation and editing of the system. On-line help shall be available for all

system functions and shall provide the relevant data for that particular screen. Additional help shall be available through the use of hypertext links onscreen.

5. System Security:

   a. The system shall support state-of-the-art encryption between server and web browser.
   b. Each operator shall be required to login to the system with a user name and password in order to view, edit, add, or delete data.
   c. User Profiles shall restrict the user to only the objects, applications, and system functions as assigned by the system administrator.
   d. Each operator shall be allowed to change their user password.
   e. The System Administrator shall be able to manage the security for all other users.
   f. The system shall include pre-defined “roles” that allow a system administrator to quickly assign permissions to a user.
   g. User logon/logoff attempts shall be recorded.
   h. The system shall protect itself from unauthorized use by automatically logging off following the last keystroke. The delay time shall be user definable.
   i. All system security data shall be stored in an encrypted format.
   j. The system shall support Active Directory for user set-up and management.
   k. The system shall track and record all user log-in activity and all changes done at the enterprise level including who made the change, when, what was changed, pervious value and new value.

6. System Diagnostics: The system shall automatically monitor the operation of all workstations, network connections, building management panels, and controllers. The failure of any device shall be annunciated to the operator.

7. Alarm/Event Notification:

   a. An operator shall be notified of new alarms/events as they occur while navigating through any part of the system via an alarm icon.
   b. The operator will have the option of selecting an audible alarm notification for all alarm classes they subscribe to.
   c. The system operator will have the option of setting specific times and days that that they will receive alarm notifications.
   d. Alarm/Event Log. The operator shall be able to view all logged system alarms/events from any Enterprise operator web interface.
   e. The operator shall be able to sort and filter alarms from events. Alarms shall be sorted in a minimum of 4 categories based on severity.
   f. Alarm/event messages shall use full language, easily recognized descriptors.
   g. An operator with the proper security level may acknowledge and clear alarms/events.
   h. All alarms/events that have not been cleared by the operator shall be stored by the building controller.
   i. The alarm/event log shall include a comment field for each alarm/event that allows a user to add specific comments associated with any alarm.
   j. Alarm logs shall provide the ability to navigate directly to object with one click.

8. Alarm Processing:

   a. The operator shall be able to configure any object in the system to generate an alarm when transitioning in and out of a normal state.
   b. The operator shall be able to configure the alarm limits, warning limits, states, and reactions for each object in the system.
   c. The operator shall be able to set up conditional alarm limits based on reference points.

9. User Change Log:

   a. The operator shall be able to view all logged user changes in the system from any operator web interface.
   b. An operator shall be able to group user changes by: date, affected, date & affected, user, date & user, transaction type, date & transaction type, or sort only.
   c. The operator will have the option of additional filtering capability of: date, transaction, type, user, affected, and details that can be used individually or in conjunction with other filters.

10. Data Trend Logs:

   a. Trend Logs Definition:

      1) The operator interface shall allow a user with the appropriate security permissions to define a trend log for any data in the system.
      2) The operator interface shall allow a user to define any trend log options as described in the Application and Control Software section.
      3) Trend intervals of 1, 5, 15, 30, and 60 minutes as well as user-defined intervals shall be selectable.

   b. Trend Log Viewer:

      1) The operator interface shall allow Trend Log data to be viewed and printed.
      2) The operator interface shall allow a user to view trend log data in text-based (time –stamp/value).
      3) The operator shall be able to view the data collected by a trend log in a graphical chart in the operator interface.
      4) Trend log viewing capabilities shall include the ability to show a minimum of 5 points on a chart.
      5) Each data point trend line shall be displayed as a unique color.
      6) The operator shall be able to specify the duration of historical data to view by scrolling and zooming.
      7) The system shall provide a graphical trace display of the associated time stamp and value for any selected point along the x-axis.

   c. Export Trend Logs:

      1) The operator interface shall allow a user to export trend log data in CSV or PDF format for use by other industry standard word processing and spreadsheet packages.

11. Standard and Custom Reports:

   a. The operator web interface shall provide a reporting package that allows the operator to select reports to run.
   b. The operator web interface shall provide the ability to schedule reports to run at specified intervals of time.
   c. The operator web interface shall provide the ability to email schedule reports at specified intervals of time.
   d. The operator web interface shall allow a user to create reports in either a pdf. or Excel format.
   e. Reports and logs shall be readily printed to the system printer.
   f. The operator web interface shall provide the ability to create and modify both standard and custom reports.

g. The following standard reports shall be available without requiring a user to manually design the report:

1) All Points in Alarm Report: Provide an on-demand report showing all current alarms.
2) All Points in Override Report: Provide an on-demand report showing all overrides in effect.
3) Site Commissioning Report: Provide a one-time report that lists all equipment with the unit configuration and present operation.
4) Air Handler Status Report: Current status and short historical operation of selected air handlers.
5) Air System Status Report: Current status and short historical operation of selected VAS.
6) Area Status Report: Current status and short historical operation of selected Area.
7) Chiller Plant Status Report: Current status and short historical operation of selected chiller plant.
8) Chiller Status (ASHRAE) Report: Standard points defined by ASHRAE 147-2013 for tracking and operation of air conditioning equipment.
9) Schedules Report: List of all weekly events for all schedules in selected buildings.
10) Space Comfort Analysis Report: List of spaces that meet selected criteria for potential comfort issues (temp variance, high, low, unoccupied).
11) Space List Report: Current status of multiple spaces in selected buildings.
12) Space Status Report: Current status and short historical operation of selected spaces

h. The following custom report functionality shall be available without requiring a third party reporting tool:

1) Bar Chart: Create a bar chart for any data log or custom report equation in the system.
2) Line Chart: Create a line chart for any data log or custom report equation in the system.
3) Scatter Plot: Create a scatter plot for any data log or custom report equation in the system.
4) Histogram: Create a Histogram for any data log, point, or custom report equation in the system.
5) Pie Chart: Create a Pie chart for any data log, point, or custom report equation in the system.
6) Single Values: Display single values from any point, data log, or equation on a custom report.
7) Values Table: Display a formatted table for point values from any family type (spaces, air handlers, chillers, areas, air systems, chiller plants, or programmable controllers).
8) Data Log Table: Create a formatted table from selected data logs.
9) User Change Log Table: Create a formatted table of user changes with date/time, user, what was changed, new/old value for any family type (spaces, air handlers, chillers, areas, air systems, chiller plants, or programmable controllers).
10) Text Box: Create a text boxes that can be placed and sized on any custom report.
11) Image: Download and place images that can be placed and sized on any custom report.
12) Size and position of ability of all items on a custom report.

13) Both standard and custom page size capabilities.
14) Save, edit, delete, and save as capability.
15) Equation capability on data logs or points that can be used in custom reports.

12. Reports and Logs:

a. The building operator web interface shall provide a reporting package that allows the operator to select reports.
b. The building operator web interface shall provide the ability to schedule reports to run at specified intervals of time.
c. The following standard reports shall be available without requiring a user to manually configure the report:
   1) All Points in Alarm Report: Provide an on demand report showing all current alarms.
   2) All Points in Override Report: Provide an on demand report showing all overrides in effect.

d. Commissioning Report: Provide a one-time report that lists all equipment with the unit configuration and present operation.
e. Provide ASHRAE Standard 147 Report:

   1) Chilled Water (or other fluid) inlet and outlet temperature
   2) Chilled Water (or other fluid) flow
   3) Chilled Water (or other fluid) inlet and outlet pressures
   4) Evaporator refrigerant pressure and temperature
   5) Evaporator approach temperature
   6) Condenser water inlet and outlet temperatures
   7) Condenser water flow
   8) Condenser refrigerant pressure and temperature
   9) Condenser approach temperature
   10) Oil pressure and temperature
   11) Oil level (if applicable)
   12) Compressor refrigerant discharge temperature
   13) Compressor refrigerant suction temperature
   14) Motor amperes per phase
   15) Motor volts per phase
   16) Purge exhaust time or discharge count
   17) Ambient temperatures (dry bulb and wet bulb)
   18) Date and time Data Logged
   19) Manual entry field for addition of refrigerant
   20) Manual entry field for addition of oil
   21) Manual entry field for vibration levels

f. VAV Air Systems

   1) System Mode
   2) System Occupancy
   3) Ventilation (Outdoor air flow) setpoint
   4) Ventilation (Outdoor air flow) status
   5) Air Handler Static pressure setpoint
   6) Air Handler Static pressure status
   7) Air Handler occupancy status
   8) Air Handler Supply air cooling and heating set points
   9) Air Handler minimum, maximum and nominal static pressure setpoints
   10) VAV box minimum and maximum flow

11) VAV box drive open and close overrides
12) VAV box occupancy status
13) VAV box Airflow to space
14) Space / Building pressure

g. Chilled Water Systems (only as applicable at AHU level)

1) System mode of the chiller plant
2) Chiller enable/disable status
3) System supply water setpoint
4) System Chilled and Condenser water supply and return temperatures
5) System Chilled and Condenser water pump status
6) Messages as to when an additional chiller will be added or removed from operational sequence
7) Chiller or system failure information
8) Chiller rotation information
9) Override capabilities to force an added chiller, subtract a chiller, or change of sequence.
10) Control to remove a chiller from a sequence temporarily for service purposes.
11) 24-hour dynamic trends of all temperature, dP, AMPS, flows, start/stop and status.
12) Building BTU/Hr consumption (with 24-hour trend at 15 minute intervals).
13) Chilled and condenser water pump speed and applicable points (refer to I/O Table).
14) Cooling tower status, fan speed.
15) Supply condenser water pressure.
16) Cooling tower automatic valve position

13. Workstation Applications Editors: The system web user interface shall support dedicated screens for editing of control system applications. The application programs shall be executed at the appropriate controller panels.
14. Custom Application Programming: Provide tools to create, modify, and debug custom application programming. The operator shall be able to create, edit, and download custom programs at the same time that all other system applications are operating. The system shall be fully operable while custom routines are edited, compiled, and downloaded.
15. Scheduling. A user shall be able to perform the following tasks utilizing the operator web interface:

a. Create a new schedule, defining the default values, events and membership.
b. Create exceptions to a schedule for any given day.
c. Apply an exception that spans a single day or multiple days.
d. View a schedule by day, week and month.
e. Exception schedules and holidays shall be shown clearly on the calendar.
f. Modify the schedule events, members and exceptions.
g. Create schedules and exceptions for multiple buildings.
h. Apply emergency schedule to multiple buildings.
i. Drag and drop scheduling editing
j. Global schedule and exceptions across multiple buildings

16. Manual Control and Override:

a. Point Control: Provide a method for a user to view, override, and edit if applicable, the status of any object and property in the system. The point status shall be available by menu, on graphics or through custom programs.

b. Temporary Overrides: The user shall be able to perform a temporary override wherever an override is allowed, automatically removing the override after a specified period of time.
c. Override Owners: The system shall convey to the user the owner of each override for all priorities that an override exists.
d. Provide a specific icon to show timed override or operator override, when a point, unit controller or application has been overridden manually.
e. Global Point Control. Provide a method for a user to view, override, and edit if applicable, the status of multiple object and properties in the system. The point status shall be available by menu, on graphics or through custom programs.

17. Critical Control:

a. The operator web interface shall provide a Critical Control package that allows the operator to designate points as critical points.
b. The operator web interface shall provide the ability to restrict access to who can create, edit, and change critical points.
c. The operator web interface shall require reentering user name and password when a user with proper rights makes a change to a critical point.
d. All changes to critical points shall be displayed in the user change log with identification of critical point change and any associated comments.
e. The operator web interface shall signify a point is a critical point with use of an identifying icon.

2.02 DDC 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 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 is desirable, but must be easily disengaged.
f. On/Off control with differential.

2. Equipment Cycling Protection: Control software shall include a passive provision for limiting the number of times each piece of equipment may be cycled within any one (1) 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 controller 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.

5. Chiller Sequencing: Provide applications software to properly sequence the chiller plant to minimize energy use. This application shall perform the following functions:

   a. The chiller plant control application shall have the ability to control chillers as detailed in the sequence of operations.
   b. This application shall be able to control both constant and variable flow systems as well as parallel, series and decoupled piping configurations.
   c. Diagnostics/Protection: The chiller plant application program shall be able to integrate individual chiller diagnostics into control action decisions.
   d. Event Processing: All chiller plant control and status events shall be recorded, at the operator's selection, in the building management system event log to facilitate troubleshooting.
   e. Alarm Indications: The chiller plant control status screens shall display chiller plant and individual chiller alarm messages.
   f. Add/Subtract Actions: The status screens shall provide information on when the next chiller add or subtract action will occur. The operator shall have the ability to manually force a chiller addition or a chiller subtraction.

C. Energy Management Applications:

1. Programs: DDC controllers shall have the ability to perform any or all of the following energy management routines:

   a. Distributed Power Demand: Distributed power demand program shall be based on a sliding window instantaneous demand algorithm. The DDC controller interface to the demand meter shall calculate the demand, forecast the demand trend, compare it to established demand limits and initiate load shedding action or reestablishment of loads as required. Shedding shall be on a sequential basis with least important loads shed first and restored last. Restoration cycle shall add the most important loads first. DDC controllers on the bus shall each have a four-tier shed table for assignment of shedable loads. When a request is issued to the bus to shed a specific number of kilowatts each controller will shed Tier 2 loads, etc. until the shed requirement is met. The power demand control software and programming logic, shall be furnished but shall not be implemented, unless directed by Owner/Engineer.

      1) Demand Limiting.

         a) The demand-limiting program shall monitor building power consumption from signals generated by a pulse generator (provided by others) mounted at the building power meter or from a watt transducer or current transformer attached to the building feeder lines.
         b) The demand-limiting program shall predict the probable power demand such that action can be taken to prevent exceeding the demand limit. When demand prediction exceeds demand limit, action will be taken to reduce loads in a predetermined manner. When demand prediction indicates the demand limit will not be exceeded, action will be taken to restore loads in a predetermined manner.
         c) Demand reduction shall be accomplished by the following means:

            (1) Reset air-handling unit supply temperature setpoint up by 1DC (2˚F).
            (2) Reset space temperature setpoints up by 1DC (2˚F).

(3) De-energize equipment based upon priority.

d) Demand-limiting parameters, frequency of calculations, time intervals, and other relevant variables shall be based on the means by which the local power company computes demand charges

e) Provide demand-limiting prediction and control for any individual meter monitored by the system or for the total of any combination of meters.

f) Provide the means for an operator to make the following changes online:

(1) Addition and deletion of loads controlled.
(2) Changes in demand intervals.
(3) Changes in demand limit for meter(s).
(4) Maximum shutoff time for equipment.
(5) Minimum shutoff time for equipment.
(6) Select rotational or sequential shedding and restoring.
(7) Shed/restore priority.

g) Provide the following information and reports, to be available on an hourly, daily, and monthly basis:

(1) Total electric consumption.
(2) Peak demand.
(3) Date and time of peak demand.
(4) Daily peak demand.

2) AHU System Level Operation

a) Minimum Required Outdoor Airflow Setpoint:

(1) The air handler Outdoor Air VAV terminal shall be controlled to deliver required outdoor airflow to each individual zone at all load conditions. The minimum outdoor airflow setpoint shall be determined using ASHRAE Standard 62-04, Equation 6.1. The actual outdoor airflow shall be sensed at VAV terminal.

(2) The ventilation fraction (design ventilation airflow for the zone divided by primary airflow) shall be continuously calculated for each zone. Continuously determine the maximum zone ventilation fraction (Z), the sum of the outdoor air requirements for all zones (Von) and the total supply airflow (Vst). This information shall be used in Equation 6.1 of ASHRAE Standard 62-04 to calculate the minimum required outdoor airflow (Vot). The minimum required outdoor airflow (Vot) setpoint shall be regularly recalculated based on the prevailing zone conditions.

(3) The contractor shall submit a written sequence of operation and sample programming required to determine the minimum required outdoor airflow (Vot) setpoint.

(4) Prior to final system acceptance, a trend log of actual air system operation over a typical forty-eight hour period shall be required by the engineer and owner. System

operating conditions to be logged include: critical space ventilation fraction, system supply air flow, calculated outdoor airflow setpoint, and actual measured outdoor airflow at 30-minute intervals.

3) Discharge Duct Static Pressure Setpoint

a) The building automation system shall continuously monitor the damper position of all VAV terminal units. The discharge duct static pressure shall be sensed directly at the discharge of each air handler. Mount sensor in a non-turbulent location.

b) When any damper is more than 95% (adj.) open, the supply fan discharge duct static pressure setpoint shall be reset upward by 5% (adj.) of the maximum system static pressure setpoint at a frequency of 10 minutes (adj.) until no damper is more than 95% open or the static pressure setpoint has reset upward to the system maximum setting or the inlet vanes (or frequency inverter) are at their maximum setting.

c) When all dampers are less than 85% (adj.) open, the supply fan discharge duct static pressure setpoint shall be reset downward by 5% (adj.) of the maximum system static pressure setpoint at a frequency of 10 minutes (adj.) until any damper is more than 85% open or the static pressure setpoint has reset downward to the system minimum setting or the frequency inverter are at their minimum setting.

d) The control bands, setpoint increment values, setpoint decrement values and adjustment frequencies shall be adjusted to maintain maximum static pressure optimization with stable system control and maximum comfort control.

PART 3 - EXECUTION (NOT APPLICABLE)

END OF SECTION

SECTION 25 09 93 - SEQUENCE OF OPERATION

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Design Criteria - Section 20 05 02
2. Basic Division 20-28 Requirements - Section 20 05 03
3. Schedule of Submittal Data - Section 20 05 04
4. General Division 20-28 Materials and Methods - Section 20 05 05
5. Scope of Work - Section 23 05 01
6. Start-up, Testing, Adjusting, and Balancing - Section 23 05 93

1.02 SCOPE

A. General: Sequence of Operation is hereby defined to mean the manner in which and methods by which the Building Control and Automation System functions. The requirements for each type of operation are specified in this Section.

B. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. Building Control and Automation System - Section 25 09 16
2. Input/Output Point Schedule - Section 25 09 33

1.03 SUPPLEMENTARY DEVICE REQUIREMENTS

A. Automatic Valves/Actuators: All automatic valves used for control of fluids shall be equipped with electric actuators complying with the requirements of Section 25 09 03, Dampers, Valves and Electronic Control and Automation Hardware.

B. Automatic Dampers/Actuators: All automatic dampers used for control of air flows shall be equipped with electric actuators complying with the requirements of Section 25 09 03, Dampers, Valves and Electronic Control and Automation Hardware.

C. HVAC Terminal Units: All HVAC terminal units (VAV, FPTU, etc.) shall be equipped with electric actuators and DDC controls complying with the requirements of Section 25 09 03, Dampers, Valves and Electronic Control and Automation Hardware. Coordinate unit controls with Section 23 36 00.

PART 2 - PRODUCTS

2.01 SEQUENCE OF OPERATION DDC SEQUENCES

A. Start/Stop Control: Heating, ventilating, and air conditioning equipment as listed herein shall be programmed to provide start and stop at predetermined times for optimal operation of the building. Provide individual start/stop function of the following equipment:

1. All air handling units, fan coil units, and heating and ventilating units.

2. All exhaust and ventilating fans except stair pressurization fans, fans interlocked with air handling units, and thermostatically controlled fans.
3. All chilled water pumps.
4. All fan powered terminal units (individual unit control).
5. All electric unit heaters.
6. Selected lighting circuits (i.e., outdoor lighting, garage lighting, etc.) where shown on the electrical Drawings.
7. Chilled water system (chilled & condenser water pumps).
8. Cooling Tower Fans.

B. Optimum Start Sequence: The BAS shall initiate the Optimal Start mode such that the equipment is scheduled to be occupied, to allow the zone temperature to reach the pending occupied heating or cooling setpoint. The system shall wait as long as possible before starting, so that the temperature in each zone reaches the occupied setpoint just in time for scheduled occupancy. Ventilation functions shall be disabled when the equipment is in Optimal Start mode. The BAS shall use a self-adjusting algorithm to calculate the actual time to initiate Optimal Start for the VAV Air System based on the occupied setpoint, space temperature, historical optimal start performance data and the associated heating or cooling optimal start rate. An early start limit shall be provided to prevent the BAS from starting prior to 120 minutes (adj.) before scheduled occupancy. The BAS shall transition from Optimal Start mode to Occupied mode when the current time is equal to the scheduled start time.

C. Optimum Stop Sequence: The BAS time-of-day scheduling application shall support Optimal Stop functionality. The BAS shall determine how early cooling or heating can be disabled for the equipment so that the zone temperature is allowed to drift no more than 2 deg. F from the occupied setpoint, by the end of the scheduled occupancy period. The early stop limit is 120 minutes (adj.). The RTU supply fan shall be energized until the end of the scheduled occupancy period. Ventilation functions shall continue to be enabled for components of the VAV Air System while the VAS is operating within the Optimal Stop Early Limit time period.

D. Unoccupied / Standby Mode: The BAS shall place the equipment into Unoccupied / Standby mode as determined by the user-adjustable time-of-day schedule for the system. The equipment shall control to their individual unoccupied temperature set points, and all ventilation functions shall be disabled. VAV box local reheat is allowed [disabled] while the VAS is in Unoccupied mode. After the VAV boxes have been commanded to unoccupied, the VAS shall command the associated AHU / RTU equipment to Unoccupied mode. Supply fan shall be shut down, heating and cooling shall be disabled, outdoor air damper shall be closed, and all ventilation functions shall be disabled.

E. Smoke Detectors: Most air handling units and fans shall be provided with smoke detectors furnished and installed under Division 28. Air handling units, supply air ventilation fans, exhaust air fans, and relief air fans (including stair pressurization) 2,200 CFM and greater will have smoke detectors installed in the discharge supply air ductwork and in the return air path. In general, each air handling unit and fan shall be stopped by the fire alarm system whenever its fire alarm zone is activated. Refer to Division 28, Section 28 31 00, Fire Alarm and Communication System for requirements.

F. High Limit Thermostats: Provide a high limit thermostat for every air handling unit, supply fan, and exhaust fan, which is not otherwise protected by a smoke detector (refer to Division 28) and as required by code.

G. Low Limit Control for units treating 100% outside air: If the air temperature entering the cooling coil falls below 35˚F, a low limit freeze protection switch (freezestat) with the elements mounted across the inlet face of the cooling coil shall through an ASC or stand-alone DDC panel automatically de-energize the air handling unit fan, close the outside air intake dampers, fully

open the chilled water control valve, and energize an alarm at the Building Control and Automation System operators terminal.

H. Automatic Dampers: Provide automatic dampers where indicated on the Drawings. These dampers shall be interlocked with their respective fan units. On a fan unit start signal, the automatic dampers shall open. Duct systems, dampers, and fans shall be protected from fan starting against closed systems. In general, after a time delay of 23 seconds (adjustable) for dampers to fully open, the fan shall start. In lieu of a time delay, certain sequences require the dampers to be proven open by actuation of a damper blade end switch before the fan is allowed to start.

I. Automatic Outside Air Intake Dampers: On a start signal, the outside air intake dampers shall open. On a stop signal, the fan shall stop and the dampers shall close. Dampers shall close on loss of control signal, on loss of electrical power, and whenever the air handling unit fan motor stops for any reason.

J. Fire Safety Sequences: The operation of certain exhaust and ventilating fans, combination fire, smoke and automatic dampers, control sequences, etc., will be governed by the fire alarm systems. Refer to Division 28, Section 28 31 00, Fire Alarm and Communication System for operation of these systems under special conditions. The fire safety, fire alarm, and fireman's manual override sequences shall take precedence over all other manual, safety, or automatic functions.

K. Motor or Motor Variable Frequency Drive Hand-Off-Auto Switch Operation: In general, each motor controller shall be provided with a 120 Volt control power transformer and a "HAND-OFF-AUTO" selector switch. When the sequence description requires a motor to be operated by an automatic device such as outside temperature, Building Control and Automation System (BCAS), etc., this sequence shall occur only when the selector switch is in the "AUTO" position. The "HAND" position may be used to operate the motor at any time, regardless of the functioning of the automatic device or circuit. All automatic functions such as damper opening, valve actuation, interlocks, etc., shall occur as described whether the motor is started and stopped in the "AUTO" position or manually by use of the "HAND" and "OFF" positions. Safety devices and circuits such as low limit thermostats, high limit thermostats, fire alarm contacts, etc., however, shall operate as described regardless of the position of the H-O-A switch.

L. Control Power Source: In general, all control circuits whenever possible shall originate from respective motor controller control power transformers. Confirm that each control power transformer and control fuse is adequately sized for all relays, coils etc., connected to the circuit. Provide all necessary interlock and circuit isolation relays required to perform the sequence of operation specified. Coordinate all requirements with the Contractor for Division 26.

M. Smoke Block Dampers: All air handling unit system smoke block dampers shall close upon a signal from the fire alarm system and shall open upon removal of the signal.

2.02 CONTROL TYPE B: DRAW-THROUGH VARIABLE VOLUME AIR HANDLING UNITS

A. General: Each of these units shall consist of a variable volume draw-through type air handling unit, chilled water cooling coil, variable frequency drive, pre-filters, final filters (where scheduled), fan, and related control system.

B. Start/Stop Control: The unit fan shall be program started and stopped as listed in the general DDC sequence from an ASC or stand-alone DDC panel when its HOA switch is in the "Auto" position. In the "Hand" position, the HOA switch shall allow local manual starting. After the start signal is given, the unit fan shall delay starting for 30 seconds (adjustable) to allow interlocked fan powered terminal units to start first.

C. Cooling Coil Control: Upon a call for cooling through the BCAS, an extended element averaging temperature sensor located in the cooling coil air discharge shall provide an input to an ASC or stand-alone DDC panel which outputs a signal to modulate an electrically actuated two-way control valve on the cooling coil as required to maintain a 50˚F (adjustable) discharge air temperature. The control valve shall close when the unit fan is off, and shall fail open upon loss of control signal. The averaging element shall be located in the coil discharge as recommended by the air handling unit manufacturer. The temperature transmitter shall be calibrated from the air temperature sensing point in the unit recommended by the air handling unit manufacturer. The averaging element shall be installed in a zig-zag fashion across the entire face of the cooling coil discharge and shall be mounted on insulated clips at each change in direction. The distance between changes in direction (and clips) shall not exceed two feet measured along the length of the averaging element. Temperature transmitter shall be calibrated to maintain no more than a ±1˚F variation in leaving air temperature from set point from full flow to minimum flow when measured at the point indicated above.

D. Discharge Duct Pressure Control: A duct mounted static pressure transducer located at the discharge of the AHU in a non-turbulent location shall serve as a back-up pressure signal to the critical damper zone fan pressure reset below. If the communication signal is lost, this back-up transducer shall provide an input signal to an ASC or stand-alone DDC panel which, shall through a PI control algorithm, output a signal to a variable frequency drive (VFD) to modulate the fan motor speed as required to maintain duct static pressure set point (adjustable). The static pressure setpoint shall be reset between the balanced static pressure (1.2 in. w.c. max determined by TAB contractor) and minimum of 0.1 in. w.g. (adj.) based on the critical terminal unit damper position (critical damper is defined as the most open damper of all terminal units on system). All terminal unit damper positions on the system shall be surveyed at minimum intervals of 15 minutes and new critical zones shall be enabled if applicable during the survey. The static pressure shall be reset to maintain the critical unit damper position between 80% (adj.) and 90% (adj.) open. If the critical unit damper position is greater than 90% (adj.) open, the supply fan static shall be reset upward by 0.1 in w.c. until the AHU VFD maximum speed setting. If the critical unit damper position is less than 80% (adj.) open, the supply fan static shall be reset upward by 0.1 in w.c. until the AHU VFD minimum speed setting. The control bands, setpoint increment values, setpoint decrement values and adjustment frequencies shall be adjusted to maintain maximum static pressure optimization with stable system control and maximum comfort control. The BAS shall have the capability to allow the operator to exclude “problem” zones that should not be considered when determining the optimized setpoint. The BAS shall display to the user on the floor plan graphics, the VAV box tag that serves the Critical Zone (that is, the zone with the most wide-open VAV damper), along with supply fan discharge static pressure. This information shall update dynamically as the location of the Critical Zone changes based on building load, and duct static pressure setpoint optimization control. The BAS shall also read the status of the supply air static pressure sensor and display the active duct static pressure reading on the status screen. The engineer will not sign-off on the control system completion and final payment until Critical Zone Reset testing is complete. Testing will consist of the engineer looking at the floor plan graphic to see which VAV box is the Critical Zone. The space temperature for another VAV box zone in the same VAV Air System will be lowered and the temperature of the current Critical Zone VAV box raised. The VAV boxes should then modulate to meet their new set-points. In the process the newly modified VAV box zone should become the Critical Zone and show-up on the floor plan graphic. Next, the engineer will raise the space temperature for all VAV boxes in a VAV Air System to 8 degrees above current temperatures. All VAV boxes in the VAV Air System should modulate closed, the static pressure setpoint will lower, and the displayed supply fan discharge static pressure will drop. Space temperature setpoints for all VAV boxes in the VAV Air System will be returned to normal and the engineer will test the next VAV Air System until all VAV Air Systems have been tested. A separate static pressure switch sensing air handling unit discharge pressure shall stop the air handling unit whenever its limit set point is exceeded. Set point shall be set below the ductwork pressure class designation to protect the ductwork system. Unit fan shall always start unloaded and increase static pressure gradually to set point.

E. Economizer: Outside air (OA) enthalpy is compared with a reference enthalpy point. The economizer is enabled when OA enthalpy is 0.5 BTU/LB less than reference enthalpy point. The economizer is disabled when OA enthalpy is 0.5 BTU/LB greater than reference enthalpy point. The supply air sensor shall measure the dry bulb temperature of the air leaving the evaporator coil while economizing. When economizing is enabled and the unit is operating in the cooling mode, the economizer damper shall modulate between its minimum position and 100% to maintain the space temperature setpoint. Minimum position shall be calculated based on supply fan speed. If the mixed air temperature starts to fall below 53.0 deg. F, the economizer starts to close, at 50.0 deg. F, the damper shall be at minimum position. Compressors shall be delayed from operating until the economizer has opened to 100% for 5 minutes.

F. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall turn on the exhaust fan and modulate the exhaust fan VFD to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall turn off the exhaust fan.

G. VAV Box Automatic Commission and Calibration: The building automation system shall provide the ability to automatically commission and calibrate the VAV Air System. A VAV Air System is a group of VAV boxes working with one air handling unit. The following tests shall be performed, at a minimum:

1. Calibration of the air valve / damper
2. Verification of air flow through the VAV box
3. Verification of local reheat performance for hydronic, as well as, multiple stages of electric reheat.
4. The building automation system (BAS) shall provide the ability to initiate the auto-commissioning /auto-calibration command directly from the user interface. Special service tools shall not be required.
5. The BAS shall provide the ability to stagger the auto-commissioning /auto-calibration sequence for groups of VAV boxes to allow the sequence to be performed during occupied hours, if necessary.
6. An auto-commissioning report for the VAV Air System shall be generated that contains the results of the auto-commissioning / auto-calibration tests. This report shall contain, at a minimum, the following information for each VAV box in the system:

    a. VAV box tag
    b. Date and time the VAV box was tested
    c. Presence of any alarms
    d. Space temperature and setpoint
    e. Active airflow (in CFM)
    f. Air valve / damper position when the VAV box reaches 40% of the maximum cooling airflow setpoint.
    g. Air valve / damper position when the VAV box reaches 100% of the maximum cooling airflow setpoint.
    h. Discharge air temperature when each stage of electric heat is energized, up to three stages of heat

H. VFD Drive Status: Monitor a contact closure in the VFD to indicate VFD drive failure to the BCAS.

I. Fan Status: Provide a fan airflow monitor (piezo-ring) transducer per fan to show if a fan has failed.

2.03 **CONTROL TYPE C: DRAW-THROUGH SINGLE ZONE VARIABLE VOLUME AIR HANDLING UNITS WITH ELECTRIC HEAT**

A. General: Each of these units shall consist of a variable volume draw-through type air handling unit, chilled water cooling coil, electric heating coil, variable frequency drive, pre-filters, final filters (where scheduled), fan, and related control system.

B. Start/Stop Control: The unit fan shall be program started and stopped as listed in the general DDC sequence from an ASC or stand-alone DDC panel when its HOA switch is in the "Auto" position. In the "Hand" position, the HOA switch shall allow local manual starting. After the start signal is given, the unit fan shall delay starting for 30 seconds (adjustable) to allow interlocked fan powered terminal units to start first.

C. Cooling Coil Control: Upon a call for cooling through the BCAS, an extended element averaging temperature sensor located in the cooling coil air discharge shall provide an input to an ASC or stand-alone DDC panel which outputs a signal to modulate an electrically actuated two-way control valve on the cooling coil as required to maintain a 55˚F (adjustable) discharge air temperature. The control valve shall close when the unit fan is off, and shall fail open upon loss of control signal. The averaging element shall be located in the coil discharge as recommended by the air handling unit manufacturer. The temperature transmitter shall be calibrated from the air temperature sensing point in the unit recommended by the air handling unit manufacturer. The averaging element shall be installed in a zig-zag fashion across the entire face of the cooling coil discharge and shall be mounted on insulated clips at each change in direction. The distance between changes in direction (and clips) shall not exceed two feet measured along the length of the averaging element. Temperature transmitter shall be calibrated to maintain no more than a ±1˚F variation in leaving air temperature from set point from full flow to minimum flow when measured at the point indicated above.

D. Electric Heating Coil Control: Upon a call for heating through the BCAS, the cooling coil valve shall close, and heating coil shall be energized and shall modulate to maintain the leaving air temperature using SCR control.

E. Fan Speed Control: During occupied periods, the supply fans shall run continuously and modulate between the minimum and maximum airflows scheduled. The unit controller shall control the supply fan variable frequency drive (VFD) to maintain the return air temperature setpoint (adj.) or space temperature setpoint (adj.) {please choose per what is on the drawings}. When the space temperature is satisfied in either cooling or heating mode, the supply fan shall operate at a minimum speed with the cooling valve closed and the electric heater off.

F. Economizer: Outside air (OA) enthalpy is compared with a reference enthalpy point. The economizer is enabled when OA enthalpy is 0.5 BTU/LB less than reference enthalpy point. The economizer is disabled when OA enthalpy is 0.5 BTU/LB greater than reference enthalpy point. The supply air sensor shall measure the dry bulb temperature of the air leaving the evaporator coil while economizing. When economizing is enabled and the unit is operating in the cooling mode, the economizer damper shall modulate between its minimum position and 100% to maintain the space temperature setpoint. Minimum position shall be calculated based on supply fan speed. If the mixed air temperature starts to fall below 53.0 deg. F, the economizer starts to close, at 50.0 deg. F, the damper shall be at minimum position. Compressors shall be delayed from operating until the economizer has opened to 100% for 5 minutes.

G. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above the desired setpoint, the AHU controller shall turn on the exhaust fan and modulate the exhaust fan VFD to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall turn off the exhaust fan.

H. VFD Drive Status: Monitor a contact closure in the VFD to indicate VFD drive failure to the BCAS.

I. Fan Status: Provide a fan airflow monitor (piezo-ring) transducer per fan to show if a fan has failed

2.04 **CONTROL TYPE D2: PACKAGED AIR CONDITIONING UNITS**

A. General: These units shall be equipped with self-contained, factory mounted single zone VAV controls.

B. Enable/Disable Control: Units shall be program enabled/disabled as listed in the general DDC sequence from an ASC or standalone DDC panel.

C. Space Temperature Monitoring: Provide a temperature sensor in the space served by the unit. Monitor the temperature through the BCAS and provide high and low temperature alarms with operator adjustable set points.

D. Fan Control: During occupied periods, the supply fan shall run continuously and the outside air damper shall open to maintain minimum ventilation requirements. The unit controller shall modulate the supply fan variable frequency drive (VFD) or ECM Motor between design airflow maximum setpoint and to maintain the occupied space temperature setpoint (adj.). The DX cooling shall stage to maintain the current discharge air temperature setpoint. If economizing is enabled the outside air damper shall modulate to maintain the current discharge air temperature setpoint.

E. Cooling Control: The unit controller shall monitor space temperature and space temperature cooling setpoint to determine when to initiate requests for cooling. When the space temperature rises above the space temperature cooling setpoint, the unit controller shall modulate the economizer or modulate the supply fan VFD or ECM Motor up and down between 220 CFM / ton and design airflow to maintain the space temperature cooling setpoint. The unit controller shall use the discharge air temperature sensor and discharge air temperature cooling setpoint to determine when to initiate requests for cooling. Discharge air setpoint shall be maintained by staging the DX cooling as required to maintain the discharge air setpoint.

F. Heating Control: The unit controller shall monitor space temperature and space temperature heating setpoint to determine when to initiate requests for heat. When the space temperature drops below the space temperature heating setpoint, the controller shall enable the first stage of heat. If additional heating capacity is required the second stage of heat shall be enabled. The supply fan will remain at 100% during heating operation. Once the space temperature rises above the setpoint, the heating stages shall be disabled and the supply fan speed will vary according to ventilation and cooling modes.

G. Economizer: Outside air (OA) enthalpy is compared with a reference enthalpy point. The economizer is enabled when OA enthalpy is 0.5 BTU/LB less than reference enthalpy point. The economizer is disabled when OA enthalpy is 0.5 BTU/LB greater than reference enthalpy point. The supply air sensor shall measure the dry bulb temperature of the air leaving the evaporator coil while economizing. When economizing is enabled and the unit is operating in the cooling mode, the economizer damper shall modulate between its minimum position and 100% to maintain the space temperature setpoint. Minimum position shall be calculated based on supply fan speed. If the mixed air temperature starts to fall below 53.0 deg. F, the economizer starts to close, at 50.0 deg. F, the damper shall be at minimum position. Compressors shall be delayed from operating until the economizer has opened to 100% for 5 minutes.

H. Building Pressure Control: A differential pressure transducer shall actively monitor the difference in pressure between the building (indoors) and outdoors. If the building pressure increases above

the desired setpoint, the AHU controller shall turn on the exhaust fan and modulate the exhaust fan VFD to control building pressure at setpoint. If the building pressure decreases below the desired setpoint, the controller shall turn off the exhaust fan.

2.05 CONTROL TYPE F1: FAN POWERED TERMINAL UNITS (FPTU'S) WITH HEAT

A. General: Each of these units shall consist of a series fan powered terminal unit (FPTU), variable speed fan with ECM, variable volume primary inlet air damper, flow cross/flow ring multi-point sensor, electric heating coil, and related control systems.

B. Fan Operation:

1. Program start the unit fan prior to starting the primary system air handling unit fan, and program stop the unit fan after stopping the primary system air handling unit fan.
2. Fan shall operate continuously when the primary system fan is in operation, when the space temperature drops below 55˚F (night setback), during the occupied heating cycle, and as otherwise commanded from the BCAS.
3. A wall mounted momentary contact switch integral with or adjacent to the space temperature sensor shall start the unit fan and controls for a programmed time period of two (2) hours (adjustable). Period of operation shall be logged into memory for after hours billing purposes.
4. Fan speed shall be controlled such that discharge cfm varies within the range scheduled on the Drawings. In cooling mode, fan discharge flow shall be at the scheduled maximum when primary airflow is at the scheduled maximum and at its scheduled minimum when primary air is at its scheduled minimum. When neither heating nor cooling is called for, fan shall remain at the minimum discharge airflow. In the heating mode, the fan shall first modulate from its minimum airflow to the heating airflow. When more heat is required, the fan is at its scheduled heating airflow, and the electric heater is energized the fan shall remain at the scheduled heating airflow.

C. Zone Control: A wall mounted space temperature sensor shall through an ASC modulate an electrically actuated primary air inlet damper from maximum CFM set point to minimum CFM scheduled set points and step the electric heating coil in sequence as required to maintain space temperature set point. The electric heating coil shall not be energized until the primary air inlet damper has closed to its minimum CFM set point.

D. Pressure Independent Operation: A flow cross/flow ring multipoint sensor in the primary air inlet shall through a pressure transducer and the ASC reset the control loop for terminal unit pressure independent operation. System shall employ a three-mode control algorithm to eliminate offset.

E. Primary Damper:

1. From maximum to minimum cooling, the primary air inlet damper shall modulate in tandem with the fan speed controller, providing scheduled maximum and minimum primary air flowrates for the conditions of maximum and minimum cooling CFM conditions in response to the room temperature sensor. The primary air inlet damper shall remain in its minimum CFM set point upon a call for heating.
2. The primary air inlet damper shall close when the unit fan is off.

F. Heating Coil: The electric heating coil shall be stepped as specified herein unless it has been disabled by a program schedule or as otherwise commanded from the BCAS. Refer to FPTU schedule for heating coil stages, SCR requirements and airflow set points.

G. Supply Air Temperature Monitor: An electronic duct sensor located in the unit discharge duct shall through the ASC indicate supply air temperature to the BCAS.

H. Communication: The unit shall be capable of transmitting the following information and receiving instructions to change setpoints in standard binary coded decimal format (DDC):

1. Primary air velocity.
2. Primary air maximum CFM set point.
3. Primary air minimum CFM set point.
4. Temperature at room thermostat.
5. Cooling temperature set point.
6. Heating temperature set point.
7. Fan operating status.
8. Supply air temperature.

2.06 CONTROL TYPE F2: FAN POWERED TERMINAL UNITS (FPTU'S) WITHOUT HEAT

A. General: Each of these units shall consist of a series fan powered terminal unit (FPTU), variable speed fan with ECM, variable volume primary inlet air damper, flow cross/flow ring multi-point sensor, and related control systems.

B. Fan Operation:

1. Program start the unit fan prior to starting the primary system air handling unit fan, and program stop the unit fan after stopping the primary system air handling unit fan.
2. Fan shall operate continuously when the primary system fan is in operation, when the space temperature drops below 55°F (night setback), during the occupied heating cycle, and as otherwise commanded from the BCAS.
3. A wall mounted momentary contact switch integral with or adjacent to the space temperature sensor shall start the unit fan and controls for a programmed time period of two (2) hours (adjustable). Period of operation shall be logged into memory for after hours billing purposes.
4. Fan speed shall be controlled such that discharge cfm varies within the range scheduled on the Drawings. In cooling mode, fan discharge flow shall track the primary flow such that it is at the scheduled maximum when primary airflow is at the scheduled maximum and at its scheduled minimum when primary air is at its scheduled minimum. If primary airflow is at its scheduled minimum and the space cooling temperature setpoint is undershot by 1°F the fan discharge flow shall be increased as far as its scheduled maximum to maintain space temperature setpoint. Upon space temperature overshoot the fan flow shall return to its minimum scheduled setpoint prior to increasing the primary air flow.

C. Zone Control: A wall mounted space temperature sensor shall through an ASC modulate an electrically actuated primary air inlet damper from maximum CFM set point to minimum CFM set point as required to maintain space temperature set point.

D. Pressure Independent Operation: A flow cross/flow ring multi-point sensor in the primary air inlet shall through a pressure transducer and the ASC reset the control loop for terminal unit pressure independent operation. System shall employ a three-mode control algorithm to eliminate offset.

E. Primary Damper:

1. From full cooling to full heating, the primary air inlet damper shall modulate closed to its minimum set point in response to the room temperature sensor.
2. The primary air inlet damper shall close when the unit fan is off.

F. Supply Air Temperature Monitor: An electronic duct sensor located in the unit discharge duct shall through the ASC indicate supply air temperature to the BCAS.

G. Communication: The unit shall be capable of transmitting the following information and receiving instructions to change set points in standard binary coded decimal format (DDC):

1. Primary air velocity.
2. Primary air maximum CFM set point.
3. Primary air minimum CFM set point.
4. Temperature at room thermostat.
5. Cooling temperature set point.
6. Fan operating status.
7. Supply air temperature.

2.07 CONTROL TYPE F3: VARIABLE VOLUME OUTSIDE AIR SUPPLY AIR TERMINAL UNIT (VAV)

A. General: Each of these units consists of a variable volume unit (VAV), primary cold air inlet damper, inlet airflow sensor, and shall be provided with related control systems.

B. Flow Setpoint - Outside Air: The outside air flow setpoint shall vary from minimum outside air setpoint to maximum outside air setpoint per CO_2-based Demand Controlled Ventilation Sequence.

C. Pressure Independent Operation: A flow cross/flow ring multipoint sensor in the primary air inlet shall through a pressure transducer and the ASC reset the control loop for terminal unit pressure independent operation. System shall employ a three-mode control algorithm to eliminate offset.

D. Air Inlet Damper:

1. Air inlet dampers shall modulate to maintain flow setpoint.
2. The air inlet dampers shall close when the outside air or exhaust air fan is off.
3. The air inlet dampers shall close when the main air handling unit on the same flow for which they serve is off.

E. Communication: The unit shall be capable of transmitting the following information and receiving instructions to change setpoints in standard binary coded decimal format (DDC):

1. Primary air velocity.
2. Primary air maximum CFM set point.
3. Primary air minimum CFM set point.
4. CFM set point.

2.08 CONTROL TYPE F4: VARIABLE VOLUME EXHAUST/RELIEF AIR TERMINAL UNIT (VAV)

A. General: Each of these units consists of a variable volume unit (VAV), air inlet damper, inlet airflow sensor, and shall be provided with related control systems.

B. Flow Setpoint - Exhaust: The exhaust air flow setpoint shall be a constant.

C. Flow Setpoint - Relief: The relief air setpoint shall be set equal to the sum of the Outside Air (flow) - Exhaust Air (flow) - Positive Pressure Offset (see VAV schedule) (adjustable).

D. Pressure Independent Operation: A flow cross/flow ring multipoint sensor in the primary air inlet shall through a pressure transducer and the ASC reset the control loop for terminal unit pressure independent operation. System shall employ a three-mode control algorithm to eliminate offset.

E. Air Inlet Damper:

1. Air inlet dampers shall modulate to maintain flow setpoint.
2. The air inlet dampers shall close when the outside air or exhaust air fan is off.
3. The air inlet dampers shall close when the main air-handling unit on the same floor for which they serve is off.

F. Communication: The unit shall be capable of transmitting the following information and receiving instructions to change setpoints in standard binary coded decimal format (DDC):

1. Primary air velocity.
2. Primary air maximum CFM set point.
3. Primary air minimum CFM set point.
4. CFM set point.

2.09 CONTROL TYPE G: ENERGY RECOVERY OUTSIDE AIR HANDLING UNITS

A. General: Each of these units shall consist of a variable volume draw-through air handling unit, intake air dampers, filter gauge, total enthalpy energy recovery wheel(s), variable speed wheel motor(s), chilled water cooling coil, outside air fan(s), exhaust air fan(s), and related control systems.

B. Start/Stop Control: The unit fan shall be program started and stopped as listed in the general DDC sequence from an ASC or stand-alone DDC panel when its HOA switch is in the "Auto" position. In the "Hand" position, the HOA switch shall allow local manual starting.

C. Cooling Coil Control: An extended element averaging temperature sensor sensing the air temperature leaving the air handling unit shall provide an input to an ASC or stand-alone DDC panel which outputs a signal to modulate an electrically actuated two-way valve in the chilled water line to maintain a 53˚F (adjustable) discharge air temperature. The cooling coil control valve shall close to the coil when the unit fan is off, and shall fail open to the coil upon loss of control signal.

D. Supply Discharge Duct and Exhaust Entering Duct Pressure Control: Supply and Exhaust air duct mounted static pressure transducers located at the supply discharge and exhaust entering respectively of the ERV AHU in a non-turbulent location shall serve as a back-up pressure signals to the OA supply and EA return critical damper zone fan pressure resets below. If the communication signal is lost, this back-up transducer shall provide an input signal to an ASC or stand-alone DDC panel which, shall through a PI control algorithm, output a signal to the OA supply and EA return variable frequency drives (VFD's) to modulate the OA and EA fan motor speeds as required to maintain duct static pressure set points (adjustable) respectively. The OA and EA static pressure setpoints shall be reset between the balanced static pressure (1.2 in. w.c. max determined by TAB contractor) and minimum of 0.1 in. w.g. (adj.) based on the critical terminal unit damper positions (critical damper is defined as the most open damper of all terminal units on system). All terminal unit damper positions on the system shall be surveyed at minimum intervals of 15 minutes and new critical zones shall be enabled if applicable during the survey. The static pressure shall be reset to maintain the critical unit damper position between 80% (adj.) and 90% (adj.) open. If the OA or EA critical unit damper position is greater than 90% (adj.) open, the OA supply or EA return respectively fan static shall be reset upward by 0.1 in w.c. until the OA supply or EA return respectively fan VFD maximum speed setting. If the OA or EA critical unit damper position is less than 80% (adj.) open, the OA supply or EA return respectively fan static shall be reset upward by 0.1 in w.c. until the OA supply or EA return respectively VFD minimum speed setting. The control bands, setpoint increment values, setpoint decrement values and adjustment frequencies shall be adjusted to maintain maximum static pressure optimization with stable system control and maximum comfort control. The BAS shall have the capability to allow the operator to exclude "problem" zones that should not be considered when

determining the optimized setpoint. The BAS shall display to the user on the floor plan graphics, the VAV box tag that serves the Critical Zone (that is, the zone with the most wide-open VAV damper), along with supply fan discharge static pressure. This information shall update dynamically as the location of the Critical Zone changes based on building load, and duct static pressure setpoint optimization control. The BAS shall also read the status of the supply air static pressure sensor and display the active duct static pressure reading on the status screen. The engineer will not sign-off on the control system completion and final payment until Critical Zone Reset testing is complete. Testing will consist of the engineer looking at the building riser graphic to see which OA and EA VAV's boxes are the Critical Zones. The engineer shall turn off the AHU corresponding to the OA or EA VAV box. The riser should show another floor as the Critical Zone and show-up on the building riser graphic. Next, the engineer change the global CO2 override amount lowering the need for OA to all floors. All OA VAV boxes in the OA VAV Air System should modulate closed, the static pressure setpoint will lower, and the displayed OA fan discharge static pressure will drop. At the same time, all EA VAV boxes in the EA VAV Air System track the OA VAV boxes and should modulate closed, the static pressure setpoint will lower, and the displayed EA fan return static pressure will drop. The global CO2 override will be removed from the system and the system will be returned to normal. Separate static pressure switches sensing ERV AHU OA discharge and EA return pressures shall stop the ERV AHU whenever its limit set point(s) is exceeded. Set points shall be set below the ductwork pressure class designation to protect the ductwork system. Unit fans shall always start unloaded and increase static pressure gradually to set points.

E. OA & EA VAV Box Automatic Commission and Calibration: The building automation system shall provide the ability to automatically commission and calibrate the VAV Air System. A VAV Air System is a group of VAV boxes working with one air handling unit. The following tests shall be performed, at a minimum:

1. Calibration of the air valve / damper
2. Verification of air flow through the VAV box
3. Verification of local reheat performance for hydronic, as well as, multiple stages of electric reheat.
4. The building automation system (BAS) shall provide the ability to initiate the auto-commissioning /auto-calibration command directly from the user interface. Special service tools shall not be required.
5. The BAS shall provide the ability to stagger the auto-commissioning /auto-calibration sequence for groups of VAV boxes to allow the sequence to be performed during occupied hours, if necessary.
6. An auto-commissioning report for the VAV Air System shall be generated that contains the results of the auto-commissioning / auto-calibration tests. This report shall contain, at a minimum, the following information for each VAV box in the system:

    a. VAV box tag
    b. Date and time the VAV box was tested
    c. Presence of any alarms
    d. Space temperature and setpoint
    e. Active airflow (in CFM)
    f. Air valve / damper position when the VAV box reaches 40% of the maximum cooling airflow setpoint.
    g. Air valve / damper position when the VAV box reaches 100% of the maximum cooling airflow setpoint.
    h. Discharge air temperature when each stage of electric heat is energized, up to three stages of heat

F. Low Limit Control: If the air temperature at the inlet to the cooling coil falls below 35˚F, a low limit freeze protection switch (freezestat) with the elements mounted across the inlet face of the cooling coil shall automatically de-energize all unit fans, close the outside air and exhaust

dampers, fully open the chilled water control valve, and energize an alarm at the Building Control and Automation System operators terminal.

G. Automatic Intake Dampers: On a start signal, the outside air intake dampers shall open and upon activation of a damper blade end switch the air handling unit fan shall start. On a stop signal, the fan shall stop and the dampers shall close. Dampers shall close on loss of control signal, on loss of electrical power, and whenever the air handling unit fan motor stops for any reason.

H. Fan Status: Provide a fan airflow monitor (piezo-ring) transducer per fan to show if a fan has failed.

I. Air Flow Measurement: Air monitoring stations shall be provided in the outside air and exhaust air ductwork downstream from the air handling unit. Separate transducers shall convert air monitoring station differential pressure to an analog signal. The analog signal shall input to an ASC or stand-alone DDC controller for flow monitoring by the BCAS.

2.10 CONTROL TYPE G2: CO_2-BASED DEMAND CONTROL VENTILATION SYSTEM (DCVS)

A. General: This control sequence consists of operation of a variable volume supply and exhaust energy recovery unit, outside air variable volume terminal units, exhaust air variable volume terminal units, relief air variable volume terminal units, and related control system.

B. Start/Stop Control: The energy recovery unit supply and exhaust fan shall be program started and stopped as listed in the general DDC sequence from an ASC or stand-alone DDC panel when its HOA switch is in the "Auto" position. In the "Hand" position, the HOA switch shall allow local manual starting. This DCVS sequence shall be enabled except when overridden by the economizer sequence of the Energy Recovery Unit.

C. Flow Control - Outside Air: Floor CO_2 sensor(s) located in the return air opening of the mechanical room and in any deemed critical zones of each floor (as shown on drawings) shall provide an input to an ASC or stand-alone DDC panel which outputs a signal to modulate the flow valve of the outside air terminal unit between minimum and maximum scheduled CFM as required to maintain a space CO_2 setpoint of 700ppm (adjustable) above ambient CO_2 ppm. An ambient CO_2 sensor shall be provided in the outside air intake ductwork of the ERU. The BCAS shall be alarmed is the space CO_2 differential exceeds 770ppm for more than 30 minutes (adjustable).

D. Fan Status: Fan status shall be indicated to the BCAS by a differential pressure air flow switch or current sensing relay.

2.11 CONTROL TYPE H: DRAW-THROUGH FAN/COIL UNITS (FCU)

A. General: Each of these units shall consist of a constant volume draw through fan/coil air handling unit, pre-filter, chilled water cooling coil, electric heater (where scheduled), and related control system.

B. Start/Stop Control: The unit fan shall be program started and stopped as listed in the general DDC sequence from an ASC or stand-alone DDC panel when its HOA switch is in the "Auto" position. In the "Hand" position, the HOA switch shall allow local manual starting.

C. Temperature Control: A space temperature sensor wall mounted, or located in the return air path, as indicated on the plans, shall provide an input to an ASC or stand-alone DDC panel which outputs a signal to modulate the supply fan between design and minimum CFM's as required to maintain space temperature setpoint. The electrically actuated two-way control valve on the cooling coil and step the electric duct heater shall modulate to maintain the units leaving air temperature. The cooling coil control valve shall close when the unit fan is off, and shall fail to the

open position upon loss of control signal. The electric duct heater shall not be energized until the cooling coil control valve is fully closed. The outside air damper shall modulate as the supply fan modulates between design and minimum CFM's to meet the design scheduled OA CFM as set-up by the T&B contractor. The T&B contractor shall balance the OA with the supply fan at design CFM and at minimum CFM.

D. Fan Status: Fan status shall be indicated to the BCAS by a differential pressure air flow switch or current sensing relay.

E. Condensate Overflow Monitoring: If the condensate level reaches the trip point, a condensate overflow diagnostic shall be annunciated at the BAS. To prevent the condensate drain pan from overflowing and causing water damage to the building the fan shall be disabled and the chilled water valve shall close.

2.12 CONTROL TYPE L1: EXHAUST FANS

A. Start/Stop Control: Each general exhaust fan shall be program started and stopped as listed in the general DDC sequence from an ASC or stand-alone DDC panel when its HOA switch is in the "Auto" position. In the "Hand" position, the HOA switch shall allow local manual starting.

B. Automatic Exhaust Dampers: The exhaust automatic dampers shall open on a fan start signal, and close on a fan stop signal. Dampers shall fail closed upon loss of control signal.

C. Fan Status: Fan status shall be indicated to the BCAS by a current sensitive relay or the supply fan status shall be monitored by the ECM motor controller. If the supply fan fails, the fan shall be commanded off and an alarm shall be annunciated at the BAS. A manual reset shall be required to restart the fan.

2.13 CONTROL TYPE L4: INTERLOCKED FANS

A. General: Each of these fans are to be hardware interlocked with other air handling units or systems as indicated in the Schedule of Equipment.

B. Start/Stop Control: Each fan shall be hardware interlock started and stopped along with it's associated primary equipment when it's HOA switch is in the "Auto" position. In the "Hand" position, the HOA switch shall allow local manual starting.

C. Fan Status: Fan status shall be indicated to the BCAS by a current sensitive relay or the supply fan status shall be monitored by the motor controller. If the supply fan fails, the fan shall be commanded off and an alarm shall be annunciated at the BAS. A manual reset shall be required to restart the fan.

2.14 CONTROL TYPE O: PUMPS

A. Start/Stop Controls: The unit shall be program started and stopped as listed in the general DDC sequence from an ASC or stand alone DDC panel when it's HOA switch is in the "AUTO" position. In the "Hand" position, the HOA switch shall allow local manual starting.

B. Pump Status: Pump status shall be indicated to the BCAS by a differential pressure water flow switch.

C. Strainer: A switch in the differential pressure gauge at each pump strainer shall provide a signal to the BCAS to indicate that the strainer requires service.

2.15 CONTROL TYPE P: COOLING TOWER BASIN SWEEPER/SIDE STREAM FILTER SYSTEM

A. Only one cooling tower cell may be swept at one time. Basin sweeping shall be enabled for a lag cooling tower cell whenever it is not in operation. The BCAS shall track the runtime of each cooling tower cell. For every 4 hours (adjustable) of cell runtime the sweeper shall run for 1 hour (adjustable) on that cell. If the schedule allows and a lag cell is not in operation the supply and return basin sweeper isolation valves at the lag cell shall open and the sand filter pump shall start. Whenever a cell is in operation and there is no call for basin sweeping that cell's supply basin sweeper isolation valves shall be closed.

B. When two or more cells are operating the side stream filtration mode shall be enabled. The return basin sweeper isolation valves shall be closed, the supply basin sweeper isolation valves shall be opened, the sidestream bypass valve shall open and the sand filter pump shall be energized.

C. Controls provided with the sand filtration system shall send a signal to the BCAS when it goes into its automated purge cycle. Purge shall only occur during unoccupied hours. For the duration of the purge the basin sweeper isolation valves shall be closed and the side stream valve shall be open.

D. When the ambient temperature falls below 35˚F (adjustable) and there is no call for basin sweeping the basin sweeper isolation valves shall be closed, the side stream valve shall open, and the pump shall be energized.

2.16 CONTROL TYPE Q: FLOW METERS

A. Monitor flow meter signal, supply and return chilled water temperatures, and calculate GPM and BTUH. Provide a display module adjacent to the meter with output in GPM and BTUH.

2.17 CONTROL TYPE X: COOLING TOWER

A. Refer to and reinstall existing Controls Sequence and reference below as necessary to fill in gaps.

B. Start/Stop Controls: The unit shall be program started and stopped as listed in the general DDC sequence from an ASC or stand alone DDC panel when it's HOA switch is in the "AUTO" position. In the "HAND" position, the HOA switch shall allow local manual starting.

C. Multiple Cell Control: Cooling tower sequence shall be rotated on a weekly schedule. From the BAS or the service tool an operator shall be able to manually change the staging sequence. The BCAS shall track the runtime of each cooling tower cell. Every 24 hours the cell with the least amount of total runtime shall be set as the lead cell. Each cooling tower shall have a VFD to modulate based on the outdoor wet bulb temperature while optimizing the total chiller / tower power usage. If a system does not have the capability to look at the minimizing the cooling tower and chiller energy usage, set the cooling tower fans to modulate so that the condenser supply water temperature equals outdoor air wet bulb + 5 degrees above 78 degree wet bulb and wet bulb +7 degrees below 76 degree wet bulb. When a chiller is operating and the cooling tower basin temperature rises to 2.0 deg. F (adj.) above the current tower leaving water set point, the lead cooling tower fan shall be turned on at minimum speed and the DDC control loop enabled. The system shall then delay adding additional towers for 3 minutes (adj.). When the operating fans are operating at 55 percent speed or higher (adj.), an additional tower shall be enabled and controlled at the same speed as the operating fans until all active cooling towers are enabled. When operating fans are running below 40 percent speed and the tower supply water temperature is 5.0 deg. F (adj.) below the current tower leaving water set point, the most lag tower fan shall be turned off. The system shall then delay subtracting additional fans for 3 minutes (adj.). Cooling tower fans shall have 5 minute (adj.) minimum on and off delays.

D. Variable Frequency Drive (VFD) Status: Monitor a contact closure in the VFD to indicate VFD drive failure to the BCAS.

E. Fan Status: The BAS controller shall detect tower fan status by a VFD current switch. If the lead tower fan start/stop relay is enabled and the current switch status is off for more than 15 seconds (adj.), the BAS controller shall annunciate a tower fan failure alarm to the BAS and start the next tower cell in the sequence. When a tower fan failure exists, lead/lag automation shall be disabled and the currently running tower cell becomes lead cell. Once the problem has been corrected, the operator shall be able to clear the alarm failure from the BAS controller, from a BAS, or by momentarily overriding the fan on. This action shall re-enable the lead/lag sequence.

F. Isolation Valves: Cooling towers shall operate with condenser water pumps. Tower isolation valves shall control in conjunction with the condenser water system and allow tower temperature control to function.

G. Condenser Water Tower / Pump Speed Reset for Low Ambient Times: When the condenser water system is enabled and the condenser water return temperature (from the chillers) falls below 62 degrees or 20 degrees above the chilled water supply from the chillers (whichever is higher), the operating cooling tower fans shall ramp to a minimum 30% speed (if they are running faster than 30%). If the condenser return water temperature does not rise above 62 degrees or 20 degrees above the chilled water supply from the chillers (whichever is higher) within 5 minutes, the control system shall cycle the cooling tower fans off. If the condenser return temperature does not rise above 62 degrees or 20 degrees above the chilled water supply from the chillers (whichever is higher) within 5 minutes, the condenser water pumps shall start to ramp down in speed until the condenser return water temperature from the operating chillers is above 62 degrees or 20 degrees above the chilled water supply from the chillers (whichever is higher). If the condenser return water temperature does not rise above 62 degrees or 20 degrees above the chilled water supply from the chillers (whichever is higher) within 5 minutes and the condenser water flow rate for operating chiller falls the minimum flow rate scheduled per chiller (XXX GPM * number of operating chillers – refer to existing controls), the condenser water pumps shall stop ramping down and the condenser water tower bypass valve shall gradually open until the condenser water return temperature from the operating chillers is above 62 degrees or 20 degrees above the chilled water supply from the chillers (whichever is higher). As the condenser return water temperature rises above 68 degrees or 25 degrees above the chilled water supply from the chillers (whichever is lower), the control system shall start to reverse course by closing the condenser water tower bypass valve first, then speeding the condenser water pumps back to design speed, then starting the cooling tower fans at minimum spend, and finally ramping the cooling tower fans up and down per the normal control routine.

H. Cooling Tower Condenser Water Bypass Valve Control: The cooling tower condenser water bypass valve shall remain closed all the time except for the low ambient sequence described above. The cooling tower condenser water bypass valve shall also be exercised for 5 minutes one time per quarter.

2.18 **INTERLOCKING SEQUENCE**

A. Interlocking and starting of mechanical equipment shall be as shown and described herein and shall be fully detailed in the BCAS Submittal. Interlocking and controls shall include, but not be limited to:

1. Chillers shall be controlled by a Control Panel mounted ON-OFF-AUTO switch which shall in the AUTO position be wired for automatic start when enabled by an interlock with its respective chilled water pump starter auxiliary contacts. Chillers shall also be hardware interlocked with chilled water and condenser water flow switches which must

prove flow prior to chiller start-up. Chilled water systems shall be software interlocked via the BCAS to operate if any air handling unit is started.

2. Chilled water pumps shall be controlled by a starter-mounted HOA switch with the AUTO position wired for starting by the BCAS. An off delay relay shall be provided and adjusted to allow the chiller to fully shutdown for 5 minutes (adjustable) before the chilled water pump is shutdown. An additional interlock shall be provided such that the primary chilled water pump cannot be shutdown via its HOA switch while the chiller it serves is operating.
3. Condenser water pumps shall be controlled by a starter mounted HOA switch with the AUTO position wired for automatic starting by an auxiliary contact in the corresponding chilled water pump starter.
4. Cooling tower fans shall be controlled by a starter-mounted HOA switch with AUTO position controlled by the condenser water temperature controls and interlocked with the cooling tower vibration switches.
5. Smoke "block" dampers shall be interlocked with their respective air handling units to close upon shutdown and open on unit start-up.

2.19 **WATER SYSTEM SEQUENCE OF OPERATION**

A. Existing sequence of operation for water systems are to remain in place and are not part of this scope to be replaced. Contractor to reinstall sequence as required.)

PART 3 - EXECUTION

3.01 **SUBMITTAL**

A. Shop drawing submittal shall include the following:

1. Complete control drawings showing all control components, control wiring diagrams, and Fire Alarm System interface.
2. Written control sequences for each control function.
3. Additional information as required by Section 20 05 03 and Section 25 09 16.

END OF SECTION

DIVISION 26 - ELECTRICAL INDEX

SECTION	DESCRIPTION
26 00 00	ELECTRICAL INDEX
26 05 01	SCOPE OF WORK
26 05 07	TESTING
26 05 19	CONDUCTORS
26 05 23	MOTOR AND CONTROL WIRING
26 05 26	GROUNDING
26 05 33	CONDUIT
26 05 34	OUTLET BOXES
26 08 00	ELECTRICAL COMMISSIONING
26 27 26	WIRING DEVICES
26 28 13	FUSES
26 28 16.16	SAFETY AND DISCONNECT SWITCHES
26 29 13	INDIVIDUAL MOTOR CONTROLLERS
26 51 13	LIGHTING FIXTURES

END OF INDEX

SECTION 26 05 01 - SCOPE OF WORK

PART 1 - GENERAL

1.01 **RELATED DOCUMENTS**

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Refer to Specification Section 20 05 00 for related required Codes and Standards.

C. Refer to Specification Section 20 05 04 for related required Schedule of Submittal Data.

D. Requirements of Division 20 apply to all Work of Divisions 20-28.

1.02 **SCOPE**

A. Work Included: The Work includes but is not limited to the following systems, equipment, and services:

1. Switchboard, power distribution equipment, power distribution panels, panelboards, residential load centers, individual motor controllers, transformers, SPD systems, etc.
2. A complete system of electrical conductors installed in conduit for electrical service equipment, bussed weatherhead equipment, switchboard, distribution panelboards, panelboards, general equipment, motors, refrigeration equipment, space heating equipment, lighting fixtures, wiring devices, disconnect switches, and special systems.
3. Connection of all motors, equipment, interlocks, interconnections, and other components, including all motor controllers.
4. Lighting fixtures, receptacles, switches, etc. Refer to the Architect for exact location of all these Devices.
5. Lighting and power junction boxes including homeruns, in the unfinished areas.
6. A system of empty conduits and other provisions as required for installation of the telephone system, data system, and fire alarm system shall be provided.
7. If exposed low voltage wires/cables, plenum rated or otherwise, are routed above ceilings, provide conduit raceways where these wires/cables enter or transition mechanical rooms, electrical rooms, or other rooms without ceilings. Exception: telephone and data cables within dedicated MDF, IDF, or server rooms.
8. Place all conduits and boxes in slabs, walls and ceilings in cooperation with other trades.
9. Lightning protection system.

1.03 **WORK OF OTHER DIVISIONS**

A. The following is a partial list of work not included in Division 26:

1. Building Controls shall be furnished and installed under Division 25. Control power for Temperature Control equipment shall be provided by Division 26. Refer to Division 25 for additional requirements.

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION (NOT APPLICABLE)

END OF SECTION

SECTION 26 05 07 - TESTING

PART 1 - GENERAL

1.01 **RELATED DOCUMENTS**

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. General Division 20-28 Materials and Methods - Section 20 05 05
3. Schedule of Submittal Data - Section 20 05 04
4. Scope of Work - Section 26 05 01

1.02 **SCOPE**

A. All building electrical system additions and new equipment shall be tested and adjusted for proper operation. All faulty equipment and material shall be repaired or replaced. Specified tests requiring submittal of test results are outlined herein and in other sections.

B. All instruments, materials, personnel, and documentation of test results shall be included in the Work of this contractor.

C. Provide all testing of the electric system required by the Authorities Having Jurisdiction. Tests shall include but shall not be limited to the items specified herein.

D. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. Conductors - Section 26 05 19
2. Grounding - Section 26 05 26
3. Service Provisions - Section 26 05 44
4. Dry Type Transformers – Section 26 22 13
5. Switchboards - Section 26 24 13
6. Circuit Breaker Distribution Panels – 26 24 16
7. Circuit Breaker Lighting and Power Panelboards – 26 24 17
8. Dual Purpose Docking Stations – 26 25 50
9. Elevator Distribution Equipment – 26 27 29
10. Safety and Disconnect Switches – 26 28 16 16
11. Individual Motor Controllers – 26 29 13

PART 2 - PRODUCTS (NOT APPLICABLE)

PART 3 - EXECUTION

3.01 **SUBMITTALS**

A. Submittals shall include, but not be limited to, the following:

1. Four (4) copies of certified test results for each test indicated herein, for approval and future references.
2. Certifications as required herein.
3. Additional information as required in Section 20 05 03.

3.02 **CONDUCTOR TESTS (600 VOLTS OR LESS)**

A. Prior to energizing of all new feeders, test all conductors for continuity of circuitry and for short circuits. No submittal is required for this test. Each wiring system with devices connected must test free from short circuits and grounds.

B. Each new feeder conductor shall have its insulation resistance tested after its installation is completed except for connection at its source and point of termination.

C. Test shall be made using a Biddle Megger or equivalent at a voltage of not less than 1000 VDC, and after one minute of operation at slip speed. Resistance shall be measured by connecting one terminal of megger to conductor and other terminal to conduit in which conductor is installed. Reading shall be observed after 15 seconds of operation of the megger.

D. Conductors which do not meet or exceed the following insulation resistance values shall be removed, replaced, and retested.

WIRE SIZE (AWG)	INSULATION RESISTANCE (OHMS)
NO. 12	1,000 K
NO. 10 THROUGH NO. 8	250 K
NO. 6 THROUGH NO. 2	100 K
NO. 1 THROUGH NO. 4/0	50 K
LARGER THAN NO. 4/0	25 K

E. Conductor test results shall indicate weather conditions, temperature, relative humidity, date and time, feeder tested, conductor size and type and resistance measurements.

3.03 **SERVICE SWITCHBOARD GROUND RESISTANCE TEST**

A. Perform a ground resistance test on the switchboard grounding system for comparison of future inspection and testing data by the Owner. Overall system resistance shall not exceed 10 ohms. Eliminate any stray currents, shorts, or non-consistencies in the grounds system.

B. The test shall be performed using a Biddle Megger Earth Tester or equivalent test instrument and shall not be performed during the 48 hours immediately following wet weather conditions.

C. Switchboard ground resistance test results shall indicate weather conditions for test, grounding system tested, grounding configuration and test results.

3.04 **GROUND FAULT PROTECTION SYSTEM TESTS**

A. Factory test: The switchboard ground fault protection system shall be factory tested prior to shipment. The switchboard manufacturer shall provide factory ground fault interlocking and protection system test for circuit testing, and verification of interlocking and tripping characteristics. The manufacturer shall pass predetermined values of current through the relay sensors, and measure the relay tripping time for each phase, and neutral. The measured time/current relationships shall be compared to the relay trip characteristics curves. If the relay trips outside the range of values indicated on the curve, the relay shall be replaced. This test shall include verification of polarity of the ground sensor circuits' interconnection.

B. Certified "factory test" results shall indicate relay number, device served, actual characteristic curves, design characteristic curves and overall test results.

C. Field test: Following completion of the construction and prior to final acceptance testing, the ground fault protection system shall be field tested and reset to the manufacturer's recommended setting for both time and current, by a representative of the Manufacturer's Engineering Service Department. The field test shall be conducted in a similar manner to the factory test in that a cable from a low voltage, high-current test set shall be passed through each current sensor. This test shall also demonstrate the complete system reliability in that it must operate the associated shunt trips and show that the overcurrent devices which they operate will actually open.

D. Certified "field test" results shall indicate relay tested, relay settings, and test results.

3.05 ARC ENERGY REDUCING SYSTEM TESTS

A. Factory test: For equipment requiring Arc Energy Reduction per NEC or per this specification, The Arc Energy Reducing(AER) system shall be factory tested prior to shipment. The manufacturer shall provide factory interlocking and system testing with verification of performance.

B. Certified "factory test" results shall indicate panel, device served, settings, actual characteristic curves with and without AER system engaged, and overall test results.

C. Field test: Following completion of the construction and prior to final acceptance testing, the AER system shall be field tested by a representative of the Manufacturer's Engineering Service Department. The field test shall be conducted in a similar manner to the factory test. This test shall also demonstrate the complete system reliability.

D. Certified "field test" results shall indicate AER system tested, panel name, device served, settings, and test results.

3.06 DRY-TYPE TRANSFORMER - LOAD, VOLTAGE AND TAP SETTING

A. Measure and record load current and voltage on each dry-type transformer, while loaded, to verify proper tap setting. Include tap selection with submittal data.

B. Transformer test results shall show transformer tested, load current (secondary), input and output voltage, neutral/ground bond verification, and tap setting.

3.07 BALANCING OF ELECTRICAL CIRCUITS

A. The system of feeder and branch circuits for power and lighting shall be connected to panelboard buses in such a manner that loads connected thereto will be balanced on all phases as close a practicable.

B. Should there be any unfavorable condition of imbalance on any part of the electrical system phase to phase measured on average over 5 business days, the electrical contractor shall make such changes that may be necessary to remedy the imbalanced condition.

C. Prior to completion of the project, provide a complete list of all panels stating the measured loads on each phase. Test results shall indicate panels tested, amperage per phase, and any remedial action taken.

3.08 **OPERATIONAL TESTING**

A. Take voltage and currents readings for each feeder and motor circuit under maximum operating conditions. Questionable readings shall be repeated at no cost for confirmation.

B. Controls for lighting and receptacle circuits shall be demonstrated.

C. Demonstrate running of motors with controls and interlocks.

D. Demonstrate operation of electrical equipment appliances.

3.09 **THERMOGRAPHIC TESTS**

A. Contractor shall provide a thermographic test using an independent testing laboratory. Testing shall apply to, but not be limited to, the following:

1. Switchboards
2. Distribution Panelboards
3. Panelboards
4. Other electrical distribution devices

B. After the entire electrical system has been checked and adjusted and is under load but just prior to project completion, equipment and connections shall be subjected to a thermographic test using an infrared temperature scanning unit. Any connections found to have higher temperature than acceptable shall be corrected as required and re-tested.

END OF SECTION

SECTION 26 05 19 - CONDUCTORS

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Scope of Work - Section 26 05 01
5. Testing - Section 26 05 07

1.02 SCOPE

A. Furnish and install conductors for all new circuits as shown, scheduled, specified, and required. All conductors for power and lighting shall be installed in conduit.

B. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. Testing - Section 26 05 07
2. Conduit - Section 26 05 33

1.03 QUALITY ASSURANCE

A. Manufacturers: If they comply with these specifications and requirements, products of the following manufacturers will be acceptable:

1. Wire and Cable:

a. Southwire
b. Cerro
c. Encore Wire Corporation
d. Service Wire

2. Cable Lugs and Termination Fittings:

a. T&B
b. Burndy
c. Ideal
d. Ilsco
e. Penn Union
f. Thomas & Betts

3. Pre-Insulated Spring Type Connectors:

a. Buchanan
b. Ideal
c. 3-M Scotchlock
d. GB

B. Codes and Standards: All conductors furnished and installed shall comply with the requirements and latest revisions of the National Electrical Code (NEC), National Electrical Safety Code (NESC), and Standards of the Underwriter's Laboratories (UL), National Electrical Manufacture's Association (NEMA), Institute of Electrical and Electronic Engineers (IEEE).

PART 2 - PRODUCTS

2.01 CONDUCTORS

A. General:

1. All feeder and branch circuit conductors shall be soft drawn, annealed copper, having a conductivity of not less than 98% of that of pure copper, and meeting before stranding, the requirements of ASTM B-3, "Standard Specifications for Soft or Annealed Copper Wire for Electrical Purposes", latest edition.
2. Aluminum conductors with type XHHW-2 insulation and AA-8000 series aluminum alloy, compact stranded configuration will be acceptable for conductors larger than #1 AWG where specifically indicated on Drawings.

B. Insulation:

1. No. 10 and Smaller: Unless otherwise specified or noted, all conductors No. 10 and smaller shall be solid copper THHN or THWN-2 with an insulating outer jacket suitable for conductor temperatures of 75ºC wet or 90ºC dry, except for NEC Class 1, 2, or 3 conductors which may be stranded if terminated as required herein.
2. No. 8 and Larger: Unless otherwise specified or noted, all conductors No. 8 and larger shall be THWN-2/THHN, 600 volts, stranded, with a thermoplastic insulating compound and an outer jacket suitable for conductor temperatures of 75ºC wet or 90ºC dry, inclusive. Stranded wire shall be terminated as specified herein.
3. High Temperature Areas: In the ceiling areas of equipment rooms where the temperature may exceed 102ºF under operating conditions, higher temperature insulation shall be used on conductors. Acceptable types are RHH, THHN, and XHHW.

PART 3 - EXECUTION

3.01 SUBMITTALS

A. Shop drawing submittals shall include, but not be limited to, the following:

1. The Contractor shall submit to the Engineer for review, a list of the proposed manufacturers of conductors, cable lugs, cable connectors, and termination fittings listed herein. The Contractor may install wire, cable, cable lugs, cable connectors and termination fittings furnished by any manufacturer listed on the approved submittal.
2. Cut sheets on all 600-volt conductors with manufacturers name, ratings and capacities, insulation characteristics, and available colors, clearly listed.
3. Cut sheets indicating all cable lugs, termination fittings and cable connectors.
4. Cut sheets indicating types of conductor identification bands.
5. Additional information as required in Section 20 05 03.

3.02 INSTALLATION

A. Mains and feeders are to be run their entire length in continuous pieces without joints or splices, unless otherwise indicated.

B. Conductors may be run in multiple sizes 1/0 through 750 MCM inclusive, provided all multiple conductors are the same size, length, and type of insulation, and they shall be so arranged and terminated as to insure equal division of the total current between all conductors involved.

C. All underground feeders shall be type THWN-2.

D. Home Runs: Except where specifically indicated, provide branch circuit home runs with not more than two different line conductors and a common neutral in a single raceway for 3-wire, single-phase systems, no more than three different line conductors and a common neutral in a single raceway for 4-wire, 3-phase systems. For all ground fault circuits, provide a separate neutral conductor for each GFI breaker. A maximum of nine (9) current carrying conductors are allowed in a single conduit. NEC conduit fill ratio shall not be exceeded. Use home run circuit numbers as indicated for panelboard connections.

E. For 20 ampere branch circuits operating at 150 volts or less line to neutral, utilize No. 10 AWG wire minimum for the entire branch circuit when the last outlet is in excess of 75 feet of cable length from the panelboard.

F. For 20 ampere branch circuits operating at 150 volts or less line to neutral, utilize No. 8 AWG wire minimum for the entire branch circuit when the last outlet is in excess of 150 feet of cable length from the panelboard. This minimum requirement applies to general purpose outlets. This requirement shall not apply to dedicated circuits with load less than 10 amps.

G. For 20 ampere branch circuits operating at 151 to 300 volts line to neutral, utilize No. 10 AWG wire minimum for the entire branch circuit when the last outlet is in excess of 150 feet of cable length from the panelboard.

H. For 20 ampere branch circuits operating at 151 to 300 volts line to neutral, utilize No. 8 AWG wire minimum for the entire branch circuit when the last outlet is in excess of 300 feet of cable length from the panelboard. This minimum requirement shall not apply to any circuits with load less than 10 amps.

I. No conductor smaller than No. 12 AWG copper shall be used for power or lighting purposes, including switch legs.

J. Control circuit conductors may be No. 14 AWG and may be run in the same conduit with power wiring, subject to compliance with control system performance requirements and NEC conductor insulation requirements. No conductor smaller than No. 18 AWG shall be used for control circuits.

K. Conductors for connection to individual light fixtures in grid type ceilings, using 72-inch-long (max.) by 3/8 inch (minimum) flexible metal conduit fixture-tails, from their associated junction boxes, shall be #14 AWG THHN, 600 volts, solid, with a thermoplastic insulating compound and an outer jacket suitable for conductor temperature of 90ºC. MC cable will also be acceptable for this application. Reference conduit section for MC cable requirements.

L. All conductors in vertical conduits or raceways shall be supported in the manner set forth in the latest edition of the National Electric Code.

M. Lighting fixtures shall not be used for raceways for circuits other than parallel wiring of fixtures.

N. On communication and signal systems, minimum conductor size shall be 18 gauge. Multi-conductor PVC insulated, and jacketed cables shall be used unless otherwise noted.

O. Before any conductor is pulled into any conduit, the conduit shall be thoroughly swabbed in such a manner as to remove all foreign material and to permit the wire itself to be pulled into a clean, dry conduit.

P. Powdered soapstone, Ideal Yellow 77, or Polywater may be used as a lubricant where necessary.

Q. Wire pulling lubricant shall not be used when installing branch circuit conductors from panelboards with "isolation" transformers.

R. All conductors shall be new, unused, in good condition, and shall be delivered in standard coils, packaged, or rolls. Samples of all conductors shall be submitted by the Contractor when requested by the Engineer for the purpose of determining acceptability.

S. Wire which has been rejected by the Engineer shall not be used again. Decisions as to the quality of the wire furnished, and the acceptance of such wire shall be made by the Owner's duly authorized representative.

3.03 IDENTIFICATION OF 600 VOLT CONDUCTORS

A. Reference Division 20 for requirements.

3.04 COLOR CODING OF 600 VOLT CONDUCTORS

A. The color of the insulation of the conductors shall be selected to conform in all instances to the following table. However, if colored insulation is not available, three bands of adhesive-backed colored tape corresponding to the color required by the following table shall be wrapped at every termination or tap of the conductor.

COLOR PHASE TABLE FOR INSULATED WIRE			
PHASE	**120V/208V SYSTEM COLOR OF WIRE**	**120V/240V SYSTEM COLOR OF WIRE**	**480V/277V SYSTEM COLOR OF WIRE**
A	BLACK	BLACK	BROWN
B	RED	ORANGE	PURPLE
C	BLUE	BLUE	YELLOW
NEUTRAL	WHITE	WHITE	GRAY
GROUND	GREEN	GREEN	GREEN

B. Gray and white colors shall be used only as specified above. All control conductors shall be distinctively color coded, and where run in the same conduit as power conductors, shall be of different colors to the power conductors.

3.05 SPLICES, TAPS, AND TERMINATIONS FOR 600 VOLT CONDUCTORS

A. Splices and taps on branch circuits shall occur only when such circuits divide and shall consist of one "through" circuit to which the remaining circuit shall be spliced or tapped.

B. No splices or taps shall be made in any conductor except in outlet boxes, junction boxes, splice boxes, or other devices and equipment in exposed and accessible locations approved for the purpose by the latest edition of the NEC.

C. All No. 10 AWG and smaller solid conductors shall be spliced with pre-insulated spring connectors. All No. 10 AWG and smaller stranded conductors for NEC Class 1, 2, 3 wiring shall

be terminated with AMP "PIDG" UL, listed premium grade insulated fork connectors, or approved equal, and shall be spliced in a junction box with AMP "Plastic-Grip" UL listed standard grade insulated butt splices, or approved equal.

D. All No. 8 AWG and larger copper conductors shall be connected with high conductivity, wrought copper, color-keyed compression connectors. Compression connectors for all feeders shall be Thomas & Betts Series 54200, or equal, two-hole connectors. Where equipment or devices cannot be provided by the manufacturer to accept two-hole connectors, T & B Series 54100, or approved equal, single-hole connectors with anti-rotation lug or restraint shall be used. Where equipment or devices cannot be provided by the manufacturer to accept either two-hole or single-hole compression connectors, set-screw type connectors may be used.

E. All No. 8 AWG and larger copper conductors which are to be spliced or tapped in wireways, gutters, or junction boxes shall be sliced or tapped using hydraulically applied, high conductivity compression connector, T & B 54700 or approved equal, compression taps, and 3-M electrical tape or manufactured connector covers approved for the purpose.

F. The manufacturer's recommended installing tool shall be used for the installation of all hydraulically applied compression type lugs or connectors. Modifications of connectors are not acceptable.

G. All bolt and screw connections shall be torqued in accordance with the manufacturer's recommendations. Submittals shall include these recommendations.

H. Where conductor splices or reducers are specifically noted on the drawings or where specifically approved by the engineer, Polaris #ISR series insulated splicer/reducers shall be used. Contractor shall provide a junction box of suitable size for the splice and associated conductors. Splices shall not be made in equipment enclosures.

3.06 **FIELD TESTING**

A. Refer to Section 26 05 07 for field testing of 600-volt wire and cable.

END OF SECTION

SECTION 26 05 23 - MOTOR AND CONTROL WIRING

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements – Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Scope of Work - Section 26 05 01
5. Testing – Section 26 05 07

1.02 SCOPE

A. General: Furnish and install all equipment power connections and control wiring as shown, specified, and required.

B. Types: The types of motor power connections and control wiring include, but are not limited to, the following:

1. Motor and Equipment Power Connections
2. Miscellaneous Control Power and Control Wiring
3. HVAC Temperature Control Wiring

C. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. Owner and Contractor Furnished Equipment - Section 20 05 06
2. Conductors - Section 26 05 19
3. Conduit - Section 26 05 33
4. Individual Motor Controllers - Section 26 29 13

PART 2 - PRODUCTS

2.01 MOTOR AND EQUIPMENT POWER CONNECTIONS

A. All power connections to motors, and equipment furnished by other Divisions shall be made by this Division, unless noted otherwise on the Drawings. This Division shall provide and install all power wiring and shall make all final connections.

B. Refer to the Drawings, approved Shop Drawings, Divisions 20-28 and other applicable Divisions for required power connections to equipment and motors.

C. In general, motorized or electrically operated equipment with integrally mounted starters, controls and disconnect switches will be set in place by the furnishing Division. The furnishing Division will furnish for installation and connection by this Division all starters, controllers and disconnect switches, which are furnished with their equipment, but not integrally mounted.

D. This Division shall furnish, install and connect all required overcurrent protection devices, starters and disconnect switches, which are not provided with the served equipment. Where disconnect

switches are not provided with served equipment and are required by the NEC or the local inspection department, then they shall be provided under this Division.

E. This division shall furnish and install all interconnecting power wiring and make all connections ready for operation between overcurrent protection devices, motors, starters and control devices, as required by wiring diagrams from approved Shop Drawings provided by the Division furnishing the Equipment.

2.02 MISCELLANEOUS CONTROL POWER AND CONTROL WIRING

A. This Division shall furnish miscellaneous 120 Volt control power circuits and control wiring as required for systems and equipment furnished by this and other Divisions. This control power and control wiring shall be furnished by this Division for all systems and equipment and where shown on the Drawings or approved Shop Drawings by the Division furnishing the system or equipment.

B. In general, all starters and controllers for non-120 Volt equipment and motors shall be furnished with control power transformers, and control power circuits will not be required. Where control power transformers are not furnished, then 120 Volt control power circuits shall be furnished by this Division.

C. Systems and devices requiring control power circuits and control wiring shall include, but not be limited to:

1. Automatic temperature control air compressors (where applicable).
2. Automatic temperature control BCAS panels.
3. Domestic water pump, surge tank alarm, and domestic water system controls.
4. Fire pump controls and alarms, including wiring to remote panels.
5. Sprinkler alarms.
6. Emergency generator and automatic transfer switch controls, battery charger, and jacket water heaters.
7. Landscape sprinkler systems.
8. Elevator and escalator controls.
9. Lighting and power control contactors and relays.
10. Start/stop stations where required for remote motor controllers.
11. Interlock control wiring.
12. Contractor furnished equipment controls.
13. Owner furnished equipment controls.
14. Sewage ejector and sump pump controls and alarms.
15. Water chilling unit control wiring for units with remote starters.
16. Refrigerant monitoring controls.
17. Cooling tower vibration switches.
18. Water treatment systems.
19. Fire alarm system.
20. Fireman's HVAC override system.
21. Smoke dampers.
22. Remote annunciators, alarm panels, alarms and signaling devices/systems.
23. Power circuits to security device locations.
24. Fuel oil system controls, monitoring, and alarms.
25. Additional control power, control wiring, and safety devices as shown, specified, or required.

2.03 HVAC CONTROL WIRING

A. HVAC temperature control wiring is specified and provided under Division 25. The only HVAC temperature control wiring and work included in the Work of this Division is providing 120 Volt

control power circuits for temperature controls and coordination of Fire Alarm and smoke control feature connections to the temperature control system.

PART 3 - EXECUTION

3.01 **INSTALLATION**

A. Motor and Equipment Power Connections: Furnish and install all interconnecting power wiring and make all connections between overcurrent protection devices, motors, starters, and control devices.

B. Miscellaneous Control Power and Control Wiring:

1. In general, miscellaneous control power circuits shall be obtained from spare breakers in building normal power panels. Where emergency system control power is required, or control power requirements are large or significantly greater than normal, notify the Architect/Engineer in writing of the requirements.
2. All control devices, which are part of smoke control features, the Life Safety System, and equipment and devices served with emergency power shall have their control power circuits derived from an emergency source.

C. Control wiring shown on the drawings or specified in other Division 20-28 sections is not an inclusive listing of all control wiring required on the project. All required control wiring, unless noted otherwise herein, shall be furnished and installed by the Division 26 Contractor.

END OF SECTION

SECTION 26 05 26 - GROUNDING

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Scope of Work - Section 26 05 01
5. Testing - Section 26 05 07

1.02 SCOPE

A. General: Furnish and install ground equipment as specified, shown, and required.

B. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. Lightning Protection Systems - Section 26 41 13

1.03 QUALITY ASSURANCE

A. Manufacturers: If they comply with these specifications and requirements, products of the following manufacturers will be acceptable:

1. Burndy
2. Copperweld
3. Cooper
4. Erico
5. ThermOweld

B. Codes and Standards:

1. National Electrical Code (NEC), Article 250.
2. UL 467

PART 2 - PRODUCTS

2.01 GROUNDING SYSTEM MATERIALS

A. Ground Clamps: Connections of connecting grounding conductors to copper, brass, or lead pipes should be made with ground clamps made of copper and if pipes are of steel or iron, the ground clamps should be made of galvanized iron. These clamps shall be designed to provide permanent and positive pressure and to avoid mechanical injury to the pipe.

B. Grounding Conductors and Jumpers: Grounding conductors and jumpers shall be connected to each other and to items to be grounded by means of approved type compression connectors, approved by the Owner's duly authorized representative. No solder connections shall be made.

C. All concrete encased or direct buried underground grounding electrode conductors shall be of bare copper, Class B, stranded.

D. Bonding conductors shall be bare copper, sized as indicated or larger if required by code.

E. Grounding Rods: Grounding rods shall be a minimum of 3/4 inch diameter by 10 feet long, copper clad steel with high-strength steel core and electrolytic-grade copper outer sheath, molten welded to the core.

F. Fusion Welds: Connections to grounding rods, building steel, reinforcing steel, inaccessible locations, and downleads shall be made with a U.L. approved exothermic fusion weld similar to ThermOweld, or engineer approved equal. All welds are to be done with a clean mold to prevent "blowout" of the weld metal.

PART 3 - EXECUTION

3.01 SUBMITTALS

A. Shop drawing submittals shall include, but not be limited to, the following:

1. Cut sheets of grounding electrodes, clamps, connectors, and accessories.
2. Additional information as required in Section 20 05 03.

3.02 INSTALLATION

A. General: The electrical distribution system shall be grounded in accordance with Article 250 of the National Electrical Code (NEC), as shown and specified, and recognized industry practices to ensure that products serve the intended functions.

B. Grounding Electrode System:

1. The grounding electrode system shall be as specified herein. A ground conductor shall be bonded together with the grounding electrodes, the incoming cold-water metallic piping system to the building, the building metal frame, the concrete encased metal frame of the building, and the concrete encased steel reinforcing bars in the building footings. This bonding shall serve as the grounding electrode system in accordance with the requirements of the Code.
2. The grounding electrode conductor from the point of connection at the grounding electrode system to the system neutral in the service entrance equipment shall be insulated stranded copper installed in a separate conduit and shall be without joints or splices over its entire length.
3. Bonding Conductors: Splices shall be made only where connections are made to the ground ring.
4. Ground Ring: A bare copper conductor encircling the structure shall be installed in direct contact with the earth at a depth below earth surface not less than 2'-6". Size shall be minimum #3/0 or as indicated on the Drawings. The loop thus formed shall be bonded together with the Grounding Electrode System.

C. Building Equipment Grounding System: The building equipment grounding system shall consist of the equipment ground wire, and electrically continuous metallic conduit system as shown. Every item of equipment served by the electrical system shall be bonded to the building equipment grounding system. All conduit systems, cabinets, junction boxes, motor frames, equipment skids, electrically operated and/or controlled cooling-heating units, luminaires, miscellaneous equipment, etc., shall be grounded with an equipment ground conductor. Portions of metallic piping and duct systems that are electrically isolated shall be bonded to the equipment grounding system with a flexible bonding jumper.

D. System Neutral: The system neutral shall be grounded to the grounding electrode system at the service entrance only and shall be kept isolated from the building. Separately derived systems shall be grounded at one point as specified herein below.

E. Miscellaneous: Provide bonding and grounding wires run in conduit and sized per the NEC and in accordance with the local electrical inspection department. Metallic piping and duct systems which enter the building shall be bonded at the point of entry to the building, in accordance with the NEC.

F. Continuity: Continuity of the building equipment grounding system shall be maintained throughout the project. Grounding jumpers shall be installed across conduit expansion fittings, all liquid-tight flexible metal conduit, light fixture pigtails in excess of 6 feet, and all other non-electrically continuous raceway fittings. Any point of poor or incomplete continuity of a raceway system being used as a ground conductor shall have a jumper connected across this point.

G. Special Grounding: Provide special grounding systems where shown.

H. Separately Derived System Grounding: Bond the case and neutral of each transformer directly to the nearest available effectively-grounded structural metal member of the structure and water piping. Provide a transformer grounding distribution system in accordance with NEC separately derived system grounding requirements. Flexible conduit shall not be used as a ground path to a transformer. Generators shall be separately derived where indicated on Drawings.

I. Telephone Equipment Grounding: Provide a ground conductor from the telephone service equipment to the building grounding system as required by the local Telephone Company.

J. Lighting Fixtures: Carefully and securely ground all lighting fixture bodies to the conduit grounding system. Flexible conduit longer than 6 feet shall not be considered a ground path.

K. Receptacles: Ground all grounding-type receptacles with ground clips, properly installed using a separate ground wire.

L. Motor Frames: Ground the frame of each motor with a properly sized separate ground wire around the flexible conduit.

M. Lightning Protection System: Lightning protection system ground terminals shall be bonded to the building grounding electrode system per NEC.

3.03 **TESTING**

A. Ground Resistance Test: Refer to Section 26 05 07 for test requirements.

END OF SECTION

SECTION 26 05 33 - CONDUIT

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Scope of Work - Section 26 05 01
5. Testing - Section 26 05 07

1.02 SCOPE

A. General: Furnish and install conduit and raceways as shown, scheduled, specified, and required.

B. Types: The types of conduit and raceways include, but are not limited to, the following:

1. Rigid Steel Conduit
2. PVC Coated Rigid Steel Conduit (Plastibond)
3. Electrical Metallic Tubing (EMT)
4. Aluminum EMT and Rigid
5. Flexible Metal Conduit
6. Liquid-Tight Flexible Metal Conduit
7. High Density Polyethylene (HDPE)
8. Type "MC" Metal Clad Cable
9. Type "MI" Cable (2-Hour Fire Resistive)
10. Type "HCF" Armored Cable
11. PVC Conduit
12. Surface Metal Raceway
13. Underfloor Metal Raceway

C. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section. These may include, but not be limited to, the following sections:

1. Conductors - Section 26 05 19

1.03 QUALITY ASSURANCE

A. Codes and Standards: Conduit, raceways, hangers, supports, and their installations shall comply with all requirements of the National Electrical Code (NEC).

PART 2 - PRODUCTS

2.01 METAL CONDUIT

A. Furnish and install metal conduit as specified herein and as indicated on the drawings.

B. All electrical conductors shall be installed in conduit, or surface metal raceways. Conduit shall be as specified herein. In addition, empty conduit or surface metal raceways shall be installed for

the telephone system, and for other systems as indicated on the Drawings and in the Specifications.

C. For the purpose of this Specification, the term "metal conduit" shall be defined as rigid steel conduit and steel electrical metallic tubing.

D. Rigid Steel Conduit:

1. Rigid steel conduit shall be used where conduit is underground, in a concrete slab with a vapor barrier, exposed to the weather, in damp or other wet locations, where exposed to view, where subject to physical damage, or in sizes greater than 4" in diameter. Use locator tape 12” above conduits for all underground conduit outside slab area.
2. All exterior conduit shall be rigid galvanized. Locknuts for exterior applications shall be sealing type.
3. Conduit shall be joined with threaded couplings and shall be secured in cabinets, outlets, etc., with double locknuts and shall be provided with insulated bushings as manufactured by Crouse-Hines (Midwest), Steel City (Thomas & Betts), Raco, OZ - Gedney, Appleton, Bridgeport Fittings, Myers Electrical Products, Picoma Industries, etc., shall be threaded.
4. All conduit and fittings shall in all respects, meet the requirements of the latest edition of Underwriters' Laboratories Standards for Rigid Metallic Conduit.
5. Rigid steel conduit shall be hot-dipped galvanized in accordance with the National Electrical Code - Article 344, inside and out. Full lengths of pipe with threads on both ends or unicouple shall have galvanized or zinc-coated produced to ANSI Specifications C-80.1 and Federal Specifications WW-C-581E and shall carry the Underwriters Laboratories Label.
6. Rigid steel conduit shall be Allied Tube and Conduit, Wheatland Tube, and Western Tube and Conduit, or approved equal.
7. Pulling Elbows are to be malleable iron only. Die cast aluminum is not acceptable. Where conduit is required to have epoxy coating, pulling elbows are to be “Plasti-Bond” coated or equal to match.

E. PVC Coated Rigid Steel Conduit

1. All rigid steel conduit and fittings exposed to extreme humidity such as adjacent to cooling towers shall be Rob Roy "Plasti-Bond", Occidental Coating Co., Perma-Cote Industries, or approved equal.

F. Electrical Metallic Tubing (EMT):

1. EMT may be used indoors where concealed or exposed above grade, except where rigid steel conduit is required. Electrical metallic tubing shall be made of thin-wall steel tubing up to 4" conduit size, and shall be galvanized inside and outside.
2. EMT shall be joined with steel set screw type couplings and conduits shall be secured with steel set screw type connectors at panels, junction boxes, outlets, etc. EMT, which is cast in concrete, shall be joined using concrete-tight compression fittings. Die-cast type connectors are not acceptable.
3. EMT and fittings shall, in all respects, meet the requirements of the latest edition of the National Electrical Code - Article 358, and Underwriters' Laboratories Standards for Electrical Metallic Tubing.
4. Provide insulating bushings at terminations, and on the open end of conduits not terminated in panels, junction boxes, outlets, etc. Provide insulated throats for sizes 3/4" and 1", and provide nylon bushings for sizes 1-1/4" and larger conduits.
5. If it complies with these Specifications, conduit manufactured by one of the following manufacturers will acceptable: LTV Steel, Allied Tube and Conduit, Wheatland Tube, and Western Tube and Conduit, or approved equal.

6. If it complies with these Specifications, connectors manufactured by one of the following will be acceptable: Crouse-Hines (Midwest), Steel City (Thomas & Betts), Raco, OZ - Gedney, Appleton, Bridgeport Fittings, Picoma Industries, etc., or approved equal.

2.02 ALUMINUM CONDUIT

A. Aluminum rigid conduit shall be manufactured of 6063 alloy in temper designation T-1. Fittings shall be of same alloy. Conduit shall be listed under UL 6 "Standard for Rigid Metal Conduit," shall be manufactured to ANSI C80.5, and shall in all respects meet the requirements of the latest edition of the National Electrical Code - Article 344.

B. Aluminum EMT shall be manufactured of 6005 alloy. Fittings shall be of same alloy. EMT and elbows shall be listed under UL/ANSI 797, "Standard for Electrical Metallic Tubing", and shall in all respects, meet the requirements of the latest edition of the National Electrical Code - Article 358. Aluminum set screw couplings shall be listed under UL 514B "Standard for Fittings for Cable and Conduit."

C. Conduit shall be joined and secured as described in Subsection 2.01; however, all materials must be aluminum or UL approved for the application. Provide insulated bushings and throats for EMT as described in Subsection 2.01.

D. Aluminum conduit and fittings shall be manufactured by Sapa Extrusions, or approved equal.

E. All rigid aluminum conduit and fittings exposed to weather shall be PVC coated conduit by Sapa Extrusions or approved equal.

2.03 FLEXIBLE METAL CONDUIT

A. Furnish and install flexible metal conduit as specified herein and as shown on the drawings.

B. Flexible metal conduit shall be hot-dipped galvanized steel strip, spirally wound and interlocked, and shall be provided with insulated anti-short bushings at all terminations.

C. Flexible Metal Conduit shall be secured with galvanized or sherardized connectors with insulating bushings suitable for connection to the associated boxes and conduits. Die cast connectors are not acceptable.

D. Flexible Metal Conduit may be used indoors at any height, in lengths not to exceed 48 inches, to extend conduit connections to motors, transformers, busway switches, air distribution terminal units, control equipment and devices, permanently connected equipment or appliances, or for equipment and devices requiring adjustment and/or removal for maintenance. Flexible metal conduit shall not be used for Utility Connections and in Elevator Machine Rooms. A "green" insulated copper grounding conductor shall be installed with the circuit conductors and sized in accordance with Table 250-122 of the latest edition of the National Electrical Code. Refer to the CONDUCTORS section for wiring and color coding requirements.

E. Flexible Metal Conduit (minimum 3/8" diameter) may be used for fixture-tails, for connection of individual lighting fixtures to their associated lighting system junction boxes in lengths not to exceed 6 feet, and provided the circuit conductors contained therein are protected by overcurrent devices rated at 20 amperes or less. A "green" insulated copper grounding conductor shall be installed with the circuit conductors and sized in accordance with Table 250-122 of the latest edition of the National Electrical Code. Refer to the CONDUCTORS section for wiring and color-coding requirements. Verify maximum length with the City Electrical Inspection Department. MC Cable is also acceptable for this application.

F. Continuity of the equipment ground across flexible metal conduit connections shall be maintained for all systems that are over 150 volts to ground. The continuity shall be maintained by installing a bare copper bonding conductor sized in accordance with Table 250-122 of the latest edition of the National Electrical Code. The bare copper bonding conductor shall be installed outside the flexible conduit and shall be connected on one end of the flexible conduit by a suitable binding post and similarly connected on the opposite end with another suitable binding post.

G. If it complies with these Specifications, flexible metal conduit manufactured by one of the following will be acceptable: American Flexible Conduit Company, Anamet, Alfex or Electriflex.

H. If it complies with these Specifications, connectors manufactured by one of the following will be acceptable: Crouse Hines (Midwest), Appleton, or Steel City (Thomas & Betts), Raco, OZ - Gedney, Appleton, Bridgeport Fittings, etc., or approved equal.

I. Flexible Metal conduit shall not be used for Patient Care Areas in Healthcare Facilities except where specifically permitted by NEC Article 517.

2.04 LIQUID-TIGHT FLEXIBLE METAL CONDUIT

A. Furnish and install liquid-tight flexible metal conduit as specified herein and as shown on the drawings.

B. When equipment or motor connections are exposed to the weather or other wet locations and for Utility Connections and in Elevator Machine Rooms, liquid-tight flexible metal conduit with PVC jacket and water-tight insulated throat fittings shall be used, in lengths not to exceed 48".

C. Liquid-tight flexible metal conduit may also be used in lengths not to exceed 48 inches, to extend conduit connections to motors, transformers, control equipment and devices, permanently connected equipment or appliances, or for equipment and devices requiring adjustment and/or removal for maintenance that are exposed to the weather or other wet locations (i.e., kitchens or associated areas).

D. Liquid-tight flexible metal conduit shall be complete with a "green" insulated copper grounding conductor installed inside the conduit with the phase conductors. Refer to Section 26 05 19 for conductor and conductor color coding requirements.

E. If it complies with these Specifications, liquid-tight flexible metal conduit manufactured by one of the following will be acceptable: American Flexible Conduit Company "American Tite", Electric-flex "Liquatite".

F. If it complies with these specifications, fittings for liquid-tight flexible metal conduit manufactured by one of the following will be acceptable: Crouse-Hines (Midwest), Steel City (Thomas & Betts), Raco, OZ - Gedney, Appleton, Bridgeport Fittings, etc., or approved equal.

G. Shall not be used for Patient Care Areas in Healthcare Facilities except where specifically permitted by NEC Article 517.

2.05 TYPE "MC" METAL CLAD CABLE

A. Metal clad cable "MC" is only acceptable for connection of lighting fixture whips no greater than 6’ in length. In such instances, MC cable shall have #12 through #8 "THHN OR XHHN" solid copper insulated phase conductors with an equipment grounding conductor as required for said terminations

B. Metal clad cable shall be provided with insulated anti-short bushings at all terminations. Metal clad cable connectors shall be steel galvanized, suitable for connection to associated boxes. Die cast connectors are not acceptable.

C. Type “MC” Cable shall have a full color-coding system which will allow for identification of assembly voltage. Voltage assembly for 120/208 and 277/480 shall have color-coded conductor/s to provide full phase identification for application requirements.

D. Type “MC” Cable shall be high strength, lightweight steel with a high degree of EMI shielding. Aluminum wound sheath is not acceptable.

E. If it complies with the specifications, Metal clad cable manufactured by one of the following will be acceptable: American Flexible Conduit, General Cable, Alfex.

F. If it complies with the specifications, connectors manufactured by on of the following will be acceptable: Crouse-Hines (Midwest), Steel City (Thomas & Betts), Raco, OZ - Gedney, Appleton, Bridgeport Fittings, etc., or approved equal.

G. Metal Clad Cable shall not be used in laboratory paces, hazardous locations, or exposed work. Metal Clad cable shall be permitted for individual drops to receptacles and switches in offices, classrooms, café, and conference rooms. MC Cable shall not be used for runs between junction boxes and shall not be run horizontally in partitions.

2.06 PVC CONDUIT

A. Furnish and install PVC conduit as specified herein and as shown on the drawings.

B. PVC conduit may be used for underground raceways except where specifically indicated or specified to be galvanized rigid steel conduit. Use locator tape 12” above conduits for all underground conduit outside slab area.

C. PVC conduit shall not be used above the ground floor slab in the building unless it is encased in a minimum of 3 inches of concrete.

D. An insulated ground wire sized per Article 250 of the NEC shall be included in each PVC conduit. It shall be the Contractor's responsibility to verify and provide the proper size of conduit for the feeder with the added ground wire.

E. PVC conduit shall consist of 90°C, UL listed, Schedule 40, high impact virgin polyvinyl chloride. PVC conduit used for primary and secondary service feeders and distribution feeders shall be concrete encased burial Type EB, UL labeled utility duct, rated 90°C. Concrete encasement shall be red in color.

F. If it complies with these Specifications, PVC conduit manufactured by one of the following will be acceptable: Carlon, Cantex, or JM Manufacturing.

2.07 CABINETS AND PULL BOXES

A. Cabinets for lighting and power or any other purposes hereinafter specified or shown on the Drawings shall be constructed of panelboard code gauge galvanized steel with sides formed and corner seams welded before galvanizing.

B. All cabinets and boxes shall be made of sheet metal unless otherwise indicated on drawings, and shall be provided with standard knockouts by the manufacturer, or without knockouts and shall be cut in the field by an approved cutting tool which will provide a clean, symmetrically cut opening.

C. Pull boxes shall include all boxes used to reduce the run of conduit to the required number of feet or bends for cable, supports, taps, troughs, and similar applications and shall likewise be constructed as specified above.

D. All cabinets and boxes shall be provided with panelboard code gauge fronts or doors as required which may be hinged or screwed as specified.

E. Where required by the nature of the application or where specified, locks shall be provided and shall be Yale spring latch for single doors or vault type for double doors.

F. Site pull or junction boxes shall be Quazite PC style or PG style polymer concrete or approved equal. Provide Tier 22 rating for boxes 10 feet or less from vehicular drives or parking areas. Tier 8 rating is acceptable for areas more than 10 feet from vehicular drives and parking areas.

G. Pull or Junction boxes located in vehicular drives and parking areas shall be heavy duty re-enforced concrete type, traffic rated, and shall meet AASHTO H-20 unless specified otherwise on drawings.

H. Boxes or cabinets shall not be less than 4-1/2" inches deep and their minimum size shall be determined per as follows:

1. For straight pulls involving conductors of No. 4 and larger and for raceways of 3/4 inch and larger, the length shall be minimum of eight (8) times the diameter of the largest raceway plus the sum of the diameters of all other raceways in the same side of box or cabinet.
2. For angle pulls or direction changes, distance between any entering raceway and the opposite side of the box shall be minimum of six (6) times the diameter of the largest raceway, and the minimum distance between raceway entries enclosing the same conductor shall not be less than six (6) times the diameter of the larger raceway. Additional raceways in the same wall shall require increase of these dimensions by the sum of the diameters of the other raceways.
3. For below grade boxes in low voltage cable applications, the minimum size shall be 36 inches in the direction of travel and 24 inches wide for straight pulls. For angle pulls the minimum size shall be 36”x36”.

I. In no event shall any cabinet or box contain more than 20% of its cross-sectional area in conductors.

J. Where conductors cross a box, a maximum of nine conductors may be laid parallel without the use of a barrier or compartment.

K. Where junction box or pull box has dimensions over 36 inches on any side, conductors crossing such distances must be supported on approved racks or clamps in such a manner as to avoid unsupported spans greater than 36 inches.

L. Where such boxes exceed 60 inches in any dimension, all conductors shall be supported, regardless of direction of travel.

M. No conductors entering or leaving a cabinet or box shall be deflected in such a manner as to cause pressure to exist on the conductor insulation.

N. All conduit, entering or leaving a cabinet or box shall be provided with insulated throat bushings or fittings for each size conduit involved.

2.08 **SURFACE METAL RACEWAY**

A. Unless otherwise specified on drawings, furnish and install Wiremold surface metal type 2400 Plugmold and G-4000 series raceways, or an approved equal, as specified herein.

B. The G-4000 raceway shall be divided into two separate compartments, one for data/communications cable and the remaining compartment for power. Provide appropriate receptacles, Cat 3 and Cat 5/6 data outlets as indicated on the Drawings.

C. The 2400 Plugmold raceway shall have 20-amp single receptacles (white for normal power and red for emergency power) spaced every 12 inches on centers.

D. Raceways shall be constructed with 0.050 inch galvanized steel and painted per Architect's specifications. The raceway shall be a minimum of 4-3/4 inches width and 1-3/4 inches deep.

E. The coverplate shall be constructed of 0.040 inch galvanized steel and painted to match the raceway finish.

F. Cover plates for receptacles shall match each device style. Data and telephone outlets shall have grommeted knockouts. Coverplate for all devices and outlets shall be gang under a common coverplate.

G. The raceway system shall be installed with all required accessories needed for a complete surface metal raceway system.

PART 3 - EXECUTION

3.01 **SUBMITTALS**

A. Shop drawing submittals shall include, but not be limited to, the following:

1. The Contractor shall submit to the Engineer for review, a list of the proposed manufacturers for each type of conduit, fittings and hangers selected from the manufacturers listed herein. The Contractor may install conduit, fittings and hangers furnished by any manufacturer listed on the approved submittal.
2. Cut sheets of all conduits and fittings proposed.
3. Additional information as required in Section 20 05 03.

3.02 **INSTALLATION - GENERAL**

A. Conduit:

1. All conduits shall be concealed in pipe chases, walls, furred spaces, or above the ceilings of the building unless otherwise indicated. Conduit shall not be embedded in any structural slab or structural member unless approved in writing by the structural engineer.
2. Conduit may be run exposed in mechanical rooms, duct and piping chases, but only where necessary. All exposed conduit shall be run in the neatest, most inconspicuous manner, and parallel or perpendicular to the building lines.
3. Boxes shall be installed in accessible locations.
4. Conduit shall be sized in accordance with the percent fill requirements of the National Electrical Code, and as indicated on the drawings.
5. All conduit and surface raceways shall be adequately and properly supported from the building structure by means recommended by the manufacturer, or by the use of hanger rods or clamps as herein specified.

6. Where limited space is available above the ceilings and below concrete beams or other deep projections, conduit shall be hung below them and in a manner to provide maximum above-floor clearance with full coordination with other trades.
7. Run conduit to avoid proximity to heat producing equipment, piping and flues, keeping a minimum of 8 inches clear.
8. Whenever possible, install horizontal conduit runs above water piping.
9. Conduit systems which are exposed to the weather or water, or installed underground shall be made watertight. All exterior conduit shall be rigid galvanized. Use locator tape 12" above conduits for all underground conduit outside slab area.
10. Conduit routed above grade for telephone, signal, communication, fire alarm, security, audio/visual, or other low voltage systems shall be provided with pull boxes of approved sizes at intervals not exceeding 100 feet in length or after 270 degrees of bends, whichever occurs first, and/or where indicated on drawings.
11. Conduit routed below grade for telephone, signal, communication, fire alarm, audio/visual, security, or control systems shall be provided with pull boxes of approved sizes at intervals not exceeding 350 feet in length or after 270 degrees of bends, whichever occurs first, and/or where indicated on drawings.
12. Install all conduits to allow for adequate maintenance and access clearances to all equipment.
13. The Contractor shall study all Construction Documents and carefully lay out all work in advance of fabrication and erection in order to meet the requirements of limited spaces. Where conflicts occur, the Contractor shall take all steps necessary to resolve the conflict prior to erection of any work in the area involved.

B. Hangers and Supports:

1. All supports required for the proper installation of equipment and conduit shall be provided as hereinafter specified unless otherwise indicated on the Drawings.
2. All conduits throughout the building shall be supported 8 feet on centers horizontally and supported 6 feet on centers vertically, unless specifically noted differently on the Drawings or in the Specifications. The supports shall be from the structure on line of grade, with proper provision for expansion, contraction, vibration elimination, and anchorage.
3. Vertical conduits shall be supported from floor lines with riser clamps sized to fit the conduit and to adequately allow for contraction. At the bases of conduit, where required for proper support, provide anchor base fittings or other approved supports.
4. Conduit shall not be supported from ductwork, piping, ceiling suspension wires, ceiling support system, or other equipment.
5. All electrical conduits and surface raceways shall be run parallel or perpendicular to the adjacent building construction. All hangers shall be fastened to the building structure as specified herein.
6. Single conduits running horizontally in concealed areas shall be supported by B-line series, or approved equal, adjustable conduit hangers.
7. Where multiple conduits are run horizontally in concealed areas, they may be supported by trapeze channels suspended on rods or pipes. Channels shall be as manufactured by Kindorf, B-Line, Unistrut or approved equal.
8. Vertical conduits, both concealed and exposed, shall be supported by clamping to vertical surfaces or by means of clamps resting on adjacent beams, or floor slabs, or both as required by the installation.
9. Conduits and raceways run against building surfaces shall be supported by means recommended by the manufacturer, or by means of single or two hole rigid conduit clamps located 4 feet on center. Two-hole clamps shall be provided where size of conduit and installation conditions warrant.

C. Attachment:

1. The load and spacing on each hanger and/or insert shall not exceed the safe allowable load for any component of the support system, including the concrete which holds the inserts. Reinforcement at inserts shall be provided as required to develop the strength required.
2. All conduits not embedded in concrete or masonry shall be securely and independently supported so that no strain will be transmitted to outlet box and pull box supports, etc. Supports shall be rigid enough to prevent distortion of conduits during wire pulling.
3. Inserts shall be of a type which will not interfere with structural reinforcing, and which will not displace excessive amounts of structural concrete. All methods of attachment to the structure and the use of afterset inserts shall be approved in writing by the Structural Engineer.
4. All supports shall be designed and installed to avoid interference with all other conduits, hangers, ducts, building structures, piping, and equipment.

D. Excavation and Backfill: The Contractor shall perform all excavation and backfill required for the installation of the underground raceway systems, duct banks and similar items, and shall resurface with materials to match the existing surface in all respects.

3.03 METAL CONDUIT - INSTALLATION

A. Metal conduit shall be of ample size to permit the ready insertion or withdrawal of conductors without abrasion. All joints shall be cut square, reamed smooth, and drawn up tight. No non-flexible metal conduit shall be smaller than 3/4".

B. Metal conduit shall not be embedded in structural slabs without prior written permission from the Structural Engineer. Metal conduits embedded in structural slabs shall be installed in the middle of the slab below the top and above the bottom reinforcing steel. Maintain a minimum concrete coverage of 1" except where penetration is made. Metal conduits embedded in structural slabs shall have watertight metal joints.

C. Do not locate conduit in the following construction:

1. In concrete slab where conduit has an outside diameter greater than one third of slab thickness.
2. In a concrete slab less than 3-1/2" thickness. Local offsets are an exception.
3. Between concrete slab reinforcing steel and bottom of slab.

D. Concealed metal conduits shall be run in a direct manner, basically parallel to, and at right angles with the lines of the building, and with as long a bend as possible. Exposed metal conduit shall be run parallel to and at right angles with the lines of the building. All bends shall be field made using an approved bending machine designed for the purpose, or using standard ells having a radius no less than that shown in Chapter 9 - Table 2 of the National Electrical Code, and with approved fittings or connectors. All bends shall be free from dents or flattening. Not more than the equivalent of four quarter bends shall be used in any run between terminals and cabinets, or between outlets, junction or pull boxes.

E. Keep conduits within the furring lines established on the architectural drawings unless conduits are shown or noted exposed.

F. Provide all necessary sleeves and chases required where conduits pass through floors or walls. Seal all openings with approved fire stopping material to maintain integrity of wall or floor being penetrated. Finish to match adjacent surfaces after installation.

G. Metal conduit shall be continuous from outlet to outlet, or from outlet to cabinets, junction or pull boxes, and shall enter and be secured at all boxes in such a manner that each system shall be electrically continuous throughout.

H. Terminals of all conduit shall be furnished with bushings, double locknuts, connectors, etc., as specified herein and as required by the NEC. Install insulating bushings on the open ends of conduit not terminated in a panel, junction box, outlet, etc.

I. So far as practicable, all exposed metal conduit shall be run without traps. Where traps or dips are unavoidable, a junction or pull box shall be placed at each low point.

J. Metal conduit hangers and fasteners shall be of the types appropriate in design and in dimension for the particular applications and shall be securely fastened in place as specified herein.

K. Each entire metal conduit system shall be installed complete before any conductors are drawn in. To guard against obstructions and omissions, each run of conduit shall be finished before plastering is installed. All metal conduits shall be swabbed after plaster is finished and dry.

L. As soon as conduit has been permanently installed in place, conduit shall be capped or plugged with standard accessories.

M. Where galvanized rigid steel conduit is used for underground raceways, they shall be field wrapped with 0.010-inch-thick anti corrosion tape 3M scotchwrap 51 or equal, applied with a 50% overlap, or shall have a factory-applied plastic resin, epoxy, or coal-tar coating system. The coating system or field wrapping shall be applied in all locations conduit is in contact with earth or in contact with concrete. Wrapping or coating shall encompass fittings. Zinc coating may be omitted from steel conduit which has a factory-applied epoxy system.

N. At the Contractor's option, PVC conduit may be used for underground raceways in lieu of the galvanized rigid steel conduit or PVC coated rigid aluminum.

O. Use locator tape 12” above conduits for all underground conduit outside slab area.

P. All empty conduit systems shall have a 1/8" braided polypropylene rope or #14 galvanized steel pull wire installed. At least 12" of properly secured rope or wire shall be folded back into each end of the empty conduits. All empty conduits shall be labeled with a purpose.

Q. Furnish and install approved expansion fittings with bonding jumpers where metal conduits cross building expansion joints. Expansion fittings shall be as manufactured by: OZ Gedney, Appleton or Crouse-Hinds.

3.04 **FLEXIBLE METAL CONDUIT, LIQUID TIGHT FLEXIBLE METAL CONDUIT, MC CABLE - INSTALLATION**

A. Flexible metal conduit, liquid tight flexible metal conduit and MC cable shall be secured no less than every 54" and within 12" of a junction box. It is not acceptable to lay cables on ceiling, ductwork, etc.

B. Where permitted by the local authority - MC Cable may be used indoors only for individual light fixture whips - provided the following conditions are met:

1. The branch circuit homerun wiring is installed in the accessible ceiling plenum using metal conduit.
2. Junction boxes are located in the accessible ceiling plenum in which fixtures are installed.
3. Length of horizontal MC cable above ceiling is not greater than 6’-0”.
4. MC Cable shall not be run horizontally in partitions or to connect junction boxes.

C. MC cable shall not be used for homerun wiring. Homeruns shall be hard piped with the use of metal conduit.

3.05 **PVC CONDUIT - INSTALLATION**

A. Where PVC is used for cable systems with cable provided by other divisions, such as utility primary and low voltage systems, all elbows shall be Rigid Metal (RMC) with 36” minimum radius unless otherwise specified by the cable installer.

B. For PVC conduit systems with cabling provided in this division, elbows shall be Rigid Metal (RMC). Bend radius may be standard or long sweep.

C. All stub-ups above finished grade or finished floor shall be galvanized rigid steel(RMC) where exposed.

D. All underground PVC conduit installed in ductbanks shall be installed using 2" duct spacers on 10' centers. All PVC conduits in slabs shall be securely tied and shall be run in a neat and orderly manner.

E. Provide expansion fittings for PVC conduits where runs cross a building expansion joint, or where conduit is above grade and crosses from conditioned to unconditioned space.

F. Unless otherwise noted on drawings, PVC conduit used for underground primary and secondary service or distribution shall be encased in minimum 3 inches of concrete with adequate steel reinforcing as required, and shall be installed using duct spacers on minimum 10' centers. The sides of trenches shall be formed in a manner to result in a concrete encasement plumb, straight, true without rough surfaces, off-sets, voids, or honeycomb. Reference Utility Company standards for additional information.

3.06 **SURFACE METAL RACEWAY SYSTEM**

A. Surface metal raceway system shall be installed per manufacturers specifications and recommendations.

B. Devices shall not be installed facing upwards unless specifically listed for this purpose.

C. The raceway system shall be installed at the height specified by the Architect. The exact length of the raceway may require field adjustment in order to fit into the allocated space.

D. The complete raceway shall be painted a color to match the Architects requirements.

E. All receptacle devices and data outlets shall be installed at locations indicated on Drawings.

END OF SECTION

SECTION 26 05 34 - OUTLET BOXES

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Scope of Work - Section 26 05 01
5. Testing - Section 26 05 07

1.02 SCOPE

A. Furnish and install outlet, switch and junction boxes as shown, scheduled, specified and required.

1.03 QUALITY ASSURANCE

A. Codes and Standards: Outlet, switch, and junction boxes and their installations shall comply with all requirements of the National Electric Code (NEC).

PART 2 - PRODUCTS

2.01 OUTLET, SWITCH, AND JUNCTION BOXES

A. All metal outlet and junction boxes, except where otherwise specified, shall be of one- piece construction, and shall be protected against corrosion by an appropriate sheradizing process.

B. All junction boxes shall be provided with covers of the same manufacturer as the boxes. The type of cover selected shall meet the conditions imposed in every case. All such boxes shall be left in a neat, clean and workmanlike manner.

C. Outlet, switch and junction boxes for various uses shall be as manufactured by Appleton or an approved equal and shall be of the following types:

1. CONCRETE BOXES:

a. In concrete slabs, where no fixtures are involved and the conduit size is 1/2 inch and 3/4 inch, the following shall be used: 4-inch octagonal concrete boxes of the appropriate depth, No. OCR Series; and No. OCP no-stud back plates.
b. In concrete slabs, where fixtures are involved and the conduit size is 1/2 inch and 3/4 inch, the following shall be used: No. OCR Series inch octagonal concrete boxes of the appropriate depth, No. OCR Series; and No. OCP 3/8 back plate with fixture stud.
c. All floor boxes containing power & data outlets are to be cast iron. Floor boxes shall be multi-gang recessed style with flip-top cover. No cast metal fittings. PVC floor boxes are not acceptable.
d. For kitchen and wet areas provide tombstone outlet installed above floor surface area. Do not install floor boxes in wet areas such as kitchen, locker rooms, or training rooms.

e. All floor boxes are to be recessed and shall have flush-mounted brass or stainless steel cover.
f. If it complies with these Specifications, floor box equipment manufactured by one of the following will be acceptable: Hubbell, Wiremold, FSR.

2. RECEPTACLE BOXES:

a. In standard partitions, where 3/4-inch conduits are employed: 4-inch square by 2-1/8-inch-deep boxes with 1-gang or 2-gang plaster covers shall be used, No. 4SD-SPL.
b. In standard partitions, where conduits of a size greater than 3/4-inch are employed: 4-11/16-inch square by 2-1/8-inch-deep boxes with 1-gang or 2-gang plaster covers shall be used, No. 4SJD Series.
c. In thin partitions measuring 3-1/2 inches or less: 4-inch square by 1-1/2-inch-deep boxes with 1-gang or 2-gang plaster covers shall be used, No. 4S-SPL.

3. WALL FIXTURE BOXES: For wall or bracket lighting fixture outlets, provide No. 400-SPL boxes in standard walls and No. 40SPL boxes in thin walls.
4. SWITCH BOXES:

a. In standard partitions, where 3/4-inch conduits are employed: 4-inch square by 2-1/8-inch-deep boxes with 1-gang or 2-gang plaster covers shall be used, No. 4SD-SPL.
b. 3-gang and up switch boxes, in standard walls or partitions, shall be 2-1/2" deep drawn style device boxes, with appropriate "gang" plaster covers as required. Field ganged type boxes are not acceptable for use.
c. 1-gang/2-gang switch boxes in thin walls or partitions, shall be 1-1/2" deep square corner boxes with appropriate mounting bracket for attachment to studs, No. 222V Series.
d. Provide gang barriers where required by the NEC.

D. If it complies with these Specifications, equipment manufactured by one of the following will be acceptable: Raco, Steel City, or Appleton.

E. Junction boxes and covers shall with identified and painted with the following scheme:

1. Lighting System: Yellow
2. Emergency Power System: Red
3. 120V Power System: Blue
4. HVAC System Power: Green
5. Panel and circuit number shall be completely legible on junction box cover at the completion of the project, prior to final punch list walk through.

2.02 **TYPE FS AND FD SERIES UNILET BOXES**

A. Furnish and install type FS and FD series (copper free) Unilet boxes as specified herein and as shown on the drawings. Die-cast aluminum boxes are not acceptable.

B. Type FS or FD Series (copper free) Unilet boxes with gasket cover plates shall be used in the following areas:

1. Where an atmosphere laden with moisture exists.
2. Exterior areas where exposed to the weather or other wet locations. PVC coated.
3. In commercial kitchens and associated areas. PVC coated.
4. In Parking Garages 6'-0" AFF and below.

C. If it complies with these specifications, equipment manufactured by one of the following manufacturers will be acceptable: Appleton, Crouse-Hinds, Killark, Red-Dot.

PART 3 - EXECUTION

3.01 SUBMITTALS

A. Shop drawing submittals shall include, but not be limited to, the following:

1. A list of the proposed manufacturers for each type of outlet, switch and junction boxes selected from the manufacturers listed herein. The Contractor may install outlet, switch and junction boxes furnished by any manufacturer listed on the approved submittal.
2. Cut sheets of outlet, switch and junction boxes clearly highlighted.
3. Additional information as required in Section 20 05 03.

3.02 INSTALLATION - GENERAL

A. Refer to architectural drawings to determine whether outlets occur in wainscot or cabinet spaces and coordinate mounting heights as required by architectural form. For example, mounting heights of outlets occurring in a tile or brick wall should be adjusted so that the outlet may occur entirely within a single course. However, all outlets in a given space shall be mounted at the same height. Exact location of all outlets shall be as shown on the Architectural Drawings and as approved by the Architect.

B. In general, unless noted otherwise on Architectural or Electrical Drawings, mounting heights to device centerline shall be as follows:

EQUIPMENT/DEVICE	MOUNTING HEIGHT TO CENTERLINE
WALL SWITCHES	42" ABOVE FINISHED FLOOR.
RECEPTACLES, TELEPHONE, AND DATA OUTLETS	18" ABOVE FINISHED FLOOR.
RECEPTACLES	6" ABOVE COUNTERTOPS WITHOUT SPLASHBACKS AND 4" ABOVE SPLASHBACKS FOR COUNTERTOPS WITH SPLASHBACKS, MOUNTED WITH THEIR LONG AXIS HORIZONTAL.
CLOCK OUTLETS	90" ABOVE FINISHED FLOOR.
PANELBOARDS	72" FROM FINISH FLOOR TO TOP OF PANELBOARD.
STAIRWAY LIGHTING FIXTURES	WALL MOUNTED 7'-6" ABOVE FINISHED FLOOR OR MID-LANDING
FIRE ALARM PULL STATIONS	42" ABOVE FINISHED FLOOR. COORDINATE WITH ARCHITECTURAL GRAPHICS PACKAGED FOR ACTUAL MOUNTING HEIGHTS.
FIRE ALARM WALL MOUNTED AUDIO/VISUAL SIGNALS	6'-8" ABOVE FINISHED FLOOR.
WALL TELEPHONE OUTLETS	42" ABOVE FINISHED FLOOR.

C. All receptacles shall be mounted with their long axis vertical, unless noted otherwise.

3.03 OUTLET, SWITCH AND JUNCTION BOXES - INSTALLATION

A. All junction boxes shall be marked to identify the circuit(s) within the box.

B. Junction boxes utilized for emergency circuits shall be painted red in color where emergency circuits are indicated on drawings.

C. Outlet boxes with plaster rings shall be finished to 1/8 inch of the finished surface.

D. Outlet boxes installed in fire-rated partitions (2 hour or less) shall not exceed 16 square inches, with a maximum of 100 square inches of wall opening per 100 square feet of wall area.

E. The outlet boxes on opposing sides of fire and smoke rated partitions shall be located whereby no two (2) outlet boxes are installed closer than 24" on center laterally, and securely attached to the partition studs, with at least one (1) partition stud separating the outlet boxes.

F. Where outlet or switch boxes are not supported from studs or joints directly, they shall be supported by expandable clip type bar hangers, Appleton Catalog No. SX 18 or SX 26. In no case shall conduit be used to support switch or outlet boxes. It is not acceptable to support switch or outlet boxes from drywall material only.

G. The following requirements shall apply to exposed as well as concealed conduit systems when "gang" boxes shall be used. These "gang" boxes shall have dimensions which are not smaller than those shown in the following table:

NUMBER IN GANG	SIZE
3	4-1/2" x 8-5/8"
4	4-1/2" x 10-1/2"
5	4-1/2" x 10-1/2"
6	4-1/2" x 14"

H. In instances in which "gang" boxes are located in woodwork, wooden partitions, or all plaster partitions; the depth of the boxes shall be reduced to 1-5/8".

I. Switch boxes shall not be used as junction boxes.

J. On all ceiling outlets involving fixture-hanging boxes, 1/2" no-bolt fixture studs shall be used for heavy loads.

K. Pull boxes, junction boxes, and outlet boxes shall be located no more than 30” above an accessible ceiling or 30” above an access panel unless noted otherwise on drawings.

3.04 **FS AND FD UNILET BOXES - INSTALLATION**

A. Standard wiring devices may be used for cord and cap connection of portable equipment provided the FS or FD Unilet boxes are mounted not less than 18 inches above the finish floor or finish grade, and the gasketed cover plates employed shall be adapted for the particular application involved. In all cases, brass screws shall be used.

B. Type FS or FD Series (copper-free) Unilet boxes used for connections to permanently install, free standing equipment in all areas of kitchens and associated areas shall be provided with gasketed cover plates and shall be wired to the equipment utilizing plates and shall be wired to the equipment utilizing water tight flexible metal conduit and approved watertight fittings. Boxes shall be installed no less than 18" above finish floor or finish grade.

C. Due provisions shall be made in all cases for the escape of any condensate which might accumulate.

END OF SECTION

SECTION 26 05 34 - OUTLET BOXES

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Scope of Work - Section 26 05 01
5. Testing - Section 26 05 07

1.02 SCOPE

A. Furnish and install outlet, switch and junction boxes as shown, scheduled, specified and required.

1.03 QUALITY ASSURANCE

A. Codes and Standards: Outlet, switch, and junction boxes and their installations shall comply with all requirements of the National Electric Code (NEC).

PART 2 - PRODUCTS

2.01 OUTLET, SWITCH, AND JUNCTION BOXES

A. All metal outlet and junction boxes, except where otherwise specified, shall be of one- piece construction, and shall be protected against corrosion by an appropriate sheradizing process.

B. All junction boxes shall be provided with covers of the same manufacturer as the boxes. The type of cover selected shall meet the conditions imposed in every case. All such boxes shall be left in a neat, clean and workmanlike manner.

C. Outlet, switch and junction boxes for various uses shall be as manufactured by Appleton or an approved equal and shall be of the following types:

1. CONCRETE BOXES:

a. In concrete slabs, where no fixtures are involved and the conduit size is 1/2 inch and 3/4 inch, the following shall be used: 4-inch octagonal concrete boxes of the appropriate depth, No. OCR Series; and No. OCP no-stud back plates.
b. In concrete slabs, where fixtures are involved and the conduit size is 1/2 inch and 3/4 inch, the following shall be used: No. OCR Series inch octagonal concrete boxes of the appropriate depth, No. OCR Series; and No. OCP 3/8 back plate with fixture stud.
c. All floor boxes containing power & data outlets are to be cast iron. Floor boxes shall be multi-gang recessed style with flip-top cover. No cast metal fittings. PVC floor boxes are not acceptable.
d. For kitchen and wet areas provide tombstone outlet installed above floor surface area. Do not install floor boxes in wet areas such as kitchen, locker rooms, or training rooms.

e. All floor boxes are to be recessed and shall have flush-mounted brass or stainless steel cover.
f. If it complies with these Specifications, floor box equipment manufactured by one of the following will be acceptable: Hubbell, Wiremold, FSR.

2. RECEPTACLE BOXES:

a. In standard partitions, where 3/4-inch conduits are employed: 4-inch square by 2-1/8-inch-deep boxes with 1-gang or 2-gang plaster covers shall be used, No. 4SD-SPL.
b. In standard partitions, where conduits of a size greater than 3/4-inch are employed: 4-11/16-inch square by 2-1/8-inch-deep boxes with 1-gang or 2-gang plaster covers shall be used, No. 4SJD Series.
c. In thin partitions measuring 3-1/2 inches or less: 4-inch square by 1-1/2-inch-deep boxes with 1-gang or 2-gang plaster covers shall be used, No. 4S-SPL.

3. WALL FIXTURE BOXES: For wall or bracket lighting fixture outlets, provide No. 400-SPL boxes in standard walls and No. 40SPL boxes in thin walls.
4. SWITCH BOXES:

a. In standard partitions, where 3/4-inch conduits are employed: 4-inch square by 2-1/8-inch-deep boxes with 1-gang or 2-gang plaster covers shall be used, No. 4SD-SPL.
b. 3-gang and up switch boxes, in standard walls or partitions, shall be 2-1/2" deep drawn style device boxes, with appropriate "gang" plaster covers as required. Field ganged type boxes are not acceptable for use.
c. 1-gang/2-gang switch boxes in thin walls or partitions, shall be 1-1/2" deep square corner boxes with appropriate mounting bracket for attachment to studs, No. 222V Series.
d. Provide gang barriers where required by the NEC.

D. If it complies with these Specifications, equipment manufactured by one of the following will be acceptable: Raco, Steel City, or Appleton.

E. Junction boxes and covers shall with identified and painted with the following scheme:

1. Lighting System: Yellow
2. Emergency Power System: Red
3. 120V Power System: Blue
4. HVAC System Power: Green
5. Panel and circuit number shall be completely legible on junction box cover at the completion of the project, prior to final punch list walk through.

2.02 **TYPE FS AND FD SERIES UNILET BOXES**

A. Furnish and install type FS and FD series (copper free) Unilet boxes as specified herein and as shown on the drawings. Die-cast aluminum boxes are not acceptable.

B. Type FS or FD Series (copper free) Unilet boxes with gasket cover plates shall be used in the following areas:

1. Where an atmosphere laden with moisture exists.
2. Exterior areas where exposed to the weather or other wet locations. PVC coated.
3. In commercial kitchens and associated areas. PVC coated.
4. In Parking Garages 6'-0" AFF and below.

C. If it complies with these specifications, equipment manufactured by one of the following manufacturers will be acceptable: Appleton, Crouse-Hinds, Killark, Red-Dot.

PART 3 - EXECUTION

3.01 SUBMITTALS

A. Shop drawing submittals shall include, but not be limited to, the following:

1. A list of the proposed manufacturers for each type of outlet, switch and junction boxes selected from the manufacturers listed herein. The Contractor may install outlet, switch and junction boxes furnished by any manufacturer listed on the approved submittal.
2. Cut sheets of outlet, switch and junction boxes clearly highlighted.
3. Additional information as required in Section 20 05 03.

3.02 INSTALLATION - GENERAL

A. Refer to architectural drawings to determine whether outlets occur in wainscot or cabinet spaces and coordinate mounting heights as required by architectural form. For example, mounting heights of outlets occurring in a tile or brick wall should be adjusted so that the outlet may occur entirely within a single course. However, all outlets in a given space shall be mounted at the same height. Exact location of all outlets shall be as shown on the Architectural Drawings and as approved by the Architect.

B. In general, unless noted otherwise on Architectural or Electrical Drawings, mounting heights to device centerline shall be as follows:

EQUIPMENT/DEVICE	MOUNTING HEIGHT TO CENTERLINE
WALL SWITCHES	42" ABOVE FINISHED FLOOR.
RECEPTACLES, TELEPHONE, AND DATA OUTLETS	18" ABOVE FINISHED FLOOR.
RECEPTACLES	6" ABOVE COUNTERTOPS WITHOUT SPLASHBACKS AND 4" ABOVE SPLASHBACKS FOR COUNTERTOPS WITH SPLASHBACKS, MOUNTED WITH THEIR LONG AXIS HORIZONTAL.
CLOCK OUTLETS	90" ABOVE FINISHED FLOOR.
PANELBOARDS	72" FROM FINISH FLOOR TO TOP OF PANELBOARD.
STAIRWAY LIGHTING FIXTURES	WALL MOUNTED 7'-6" ABOVE FINISHED FLOOR OR MID-LANDING
FIRE ALARM PULL STATIONS	42" ABOVE FINISHED FLOOR. COORDINATE WITH ARCHITECTURAL GRAPHICS PACKAGED FOR ACTUAL MOUNTING HEIGHTS.
FIRE ALARM WALL MOUNTED AUDIO/VISUAL SIGNALS	6'-8" ABOVE FINISHED FLOOR.
WALL TELEPHONE OUTLETS	42" ABOVE FINISHED FLOOR.

C. All receptacles shall be mounted with their long axis vertical, unless noted otherwise.

3.03 OUTLET, SWITCH AND JUNCTION BOXES - INSTALLATION

A. All junction boxes shall be marked to identify the circuit(s) within the box.

B. Junction boxes utilized for emergency circuits shall be painted red in color where emergency circuits are indicated on drawings.

C. Outlet boxes with plaster rings shall be finished to 1/8 inch of the finished surface.

D. Outlet boxes installed in fire-rated partitions (2 hour or less) shall not exceed 16 square inches, with a maximum of 100 square inches of wall opening per 100 square feet of wall area.

E. The outlet boxes on opposing sides of fire and smoke rated partitions shall be located whereby no two (2) outlet boxes are installed closer than 24" on center laterally, and securely attached to the partition studs, with at least one (1) partition stud separating the outlet boxes.

F. Where outlet or switch boxes are not supported from studs or joints directly, they shall be supported by expandable clip type bar hangers, Appleton Catalog No. SX 18 or SX 26. In no case shall conduit be used to support switch or outlet boxes. It is not acceptable to support switch or outlet boxes from drywall material only.

G. The following requirements shall apply to exposed as well as concealed conduit systems when "gang" boxes shall be used. These "gang" boxes shall have dimensions which are not smaller than those shown in the following table:

NUMBER IN GANG	SIZE
3	4-1/2" x 8-5/8"
4	4-1/2" x 10-1/2"
5	4-1/2" x 10-1/2"
6	4-1/2" x 14"

H. In instances in which "gang" boxes are located in woodwork, wooden partitions, or all plaster partitions; the depth of the boxes shall be reduced to 1-5/8".

I. Switch boxes shall not be used as junction boxes.

J. On all ceiling outlets involving fixture-hanging boxes, 1/2" no-bolt fixture studs shall be used for heavy loads.

K. Pull boxes, junction boxes, and outlet boxes shall be located no more than 30” above an accessible ceiling or 30” above an access panel unless noted otherwise on drawings.

3.04 **FS AND FD UNILET BOXES - INSTALLATION**

A. Standard wiring devices may be used for cord and cap connection of portable equipment provided the FS or FD Unilet boxes are mounted not less than 18 inches above the finish floor or finish grade, and the gasketed cover plates employed shall be adapted for the particular application involved. In all cases, brass screws shall be used.

B. Type FS or FD Series (copper-free) Unilet boxes used for connections to permanently install, free standing equipment in all areas of kitchens and associated areas shall be provided with gasketed cover plates and shall be wired to the equipment utilizing plates and shall be wired to the equipment utilizing water tight flexible metal conduit and approved watertight fittings. Boxes shall be installed no less than 18" above finish floor or finish grade.

C. Due provisions shall be made in all cases for the escape of any condensate which might accumulate.

END OF SECTION

SECTION 26 08 00 - ELECTRICAL AND LIFE SAFETY SYSTEMS TECHNICAL COMMISSIONING REQUIREMENTS

PART 1 - GENERAL

1.01 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. Specifications throughout all Divisions of the Project Manual are directly applicable to this Section, and this Section is directly applicable to them.

1.02 SUMMARY

A. The purpose of this Section is to define responsibilities in the Commissioning Process. Other electrical system testing is required under other Division 26 Specification Sections. National Electrical Installation Standards (NEIS) NECA 90-2004, “Recommended Practice for Commissioning Building Electrical Systems”, 27th Volume of the NEIS Series, provides additional guidance for the commissioning of electrical systems.

B. Commissioning requires the participation of the Contractor to ensure that all systems are operating in a manner consistent with the Contract Documents. General Commissioning Requirements are provided separately, and coordination is detailed in Division 01. Division 26 and 28 Contractors shall be familiar with all parts of Division 01, the General Commissioning Requirements and the Commissioning Plan issued by the Owner’s CxA, shall execute all Commissioning responsibilities assigned to them in the Contract Documents and include the cost of Commissioning in the Contract price.

C. Electrical Testing Agency (ETA)

1. The Contractor shall retain an independent Electrical Testing Agency (ETA). Their specific testing responsibilities are delineated in individual technical sections within Division 26. This generally requires checking and testing of the electrical power distribution equipment per National Electrical Testing Association (NETA) Acceptance Testing Standards (ATS).
2. Attend, as needed, Pre-Commissioning Meeting(s), Pre-Installation Meeting(s), and other Project meetings scheduled by the Contractor, Owner or CxA to facilitate the Commissioning process.
3. Obtain all required manufacturer’s data to facilitate tests.
4. Provide assistance to the CxA in preparation of the specific System Verification Checklists (SVC) and Functional Performance Test procedures.
5. Generally, the ETA shall provide their standard forms to document the NETA tests to be incorporated into the System Verification Checklists and Functional Performance Test records.
6. The ETA shall assist the Contractor in completing required SVC information such as relay settings, protective overload settings, and equipment ratings utilizing the protocols in the Commissioning Plan.
7. Perform and clearly document all completed Start-up and system operational checkout procedures, providing a copy to the Contractor.
8. Clearly indicate any deficiencies identified during testing and add to an action list for resolution and tracking. The field technicians shall keep a running log of events and issues.

9. Provide skilled technicians to execute testing. Ensure that they are available and present during the agreed-upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem solving.

D. Electrical systems to be commissioned include the following:

1. Unit Substations / Electrical Switchboards
2. Secondary Normal Power Distribution
3. Emergency / Standby Power Distribution
4. Branch Power Distribution and Components
5. Emergency Generators, Automatic Transfer Switches and Paralleling Switchgear
6. Uninterruptible Power Supplies (UPS)
7. Lighting Controls - Occupancy Sensors
    a. Sample rate - 25%, if greater than 25 sensors installed or 100% if less than 25 sensors installed.
    b. Sample rate above is by room type.
8. Lighting - Daylight Controls (100%)
9. Lighting - Time Switch Controls (100%)
10. Photovoltaic Array Systems, including but not limited to, batteries, inverters and associated controls.

1.03 DEFINITIONS

A. Refer to Division 01: General Commissioning Requirements for definitions.

1.04 SUBMITTALS

A. Contractor shall provide Owner and / or CxA with documentation required for Commissioning Work. At minimum, documentation shall include: Detailed Start-up procedures, full sequences of operation, Operating and Maintenance data, performance data, control drawings, and details of Owner-contracted tests.

1. Shop drawings and product submittal data related to systems or equipment to be commissioned.

B. Contractor shall submit to Owner, Engineer and / or CxA installation and checkout materials actually shipped inside equipment and actual field checkout sheet forms used by factory or field technicians.

C. Where installation testing may be performed in a progressive manner (ie. grounding systems, insulation resistance, etc.), the Contractor shall prepare and submit to the Owner, A/E team and CxA a testing plan that details how the progressive testing will be performed, documented and presented for approval prior to the start of any testing activities.

D. Contractor shall provide Owner with documentation required for Commissioning work. At minimum, documentation shall include: Detailed Start-up procedures, Full sequences of operation, Operating and Maintenance data, Performance data, Functional Performance Test Procedures, Control Drawings, and details of Owner-Contracted tests.

E. Contractor shall provide any additional documentation needed to complete the requirements of the Commissioning Process

1. Factory Performance Test Reports: Review and compile all factory performance data to assure that the data is complete prior to executing the FPTs.

2. Incorporate manufacturer's initial energizing / startup procedures with System Verification Checklists.
3. Final Electrical Testing Agency (ETA) Reports documenting all NETA requirements indicated in the Project Documents
4. Pre-functional Performance Checklists: review and compile all information associated with the piece of equipment to be commissioning ensure the equipment is ready for final commissioning.
5. Completed equipment Start-up certification forms along with the manufacturer's field or factory performance and Start-up test documentation.
6. Operating and Maintenance (O&M) information per the requirements of the Technical Specifications and Division 01 requirements.

PART 2 - PRODUCTS

2.01 GENERAL

A. All materials and installation shall meet or exceed all applicable referenced standards, federal, state and local requirements, and conform to codes and ordinances of authorities having jurisdiction.

B. Refer to the General Commissioning Requirements for other work products related to the Commissioning Process

C. Contractor is required to follow all applicable industry and site specific safety practices, lockout tagout requirements, specialized PPE requirements, and provide qualified, trained personnel to execute Commissioning Process requirements.

2.02 TEST EQUIPMENT

A. The Contractor shall provide all specialized tools, test equipment and instruments required to execute Start-up, checkout, and testing of equipment.

B. All specialized tools, test equipment, and instruments required to execute Start-up, checkout, and testing of equipment shall be of sufficient quality and accuracy to test and/or measure system performance within specified tolerances. A testing laboratory must have calibrated test equipment within the previous twelve (12) months. Calibration shall be NIST traceable. Contractor must calibrate test equipment and instruments according to manufacturer's recommended intervals and whenever the test equipment is dropped or damaged. Calibration tags must be affixed to the test equipment or certificates readily available.

PART 3- EXECUTION

3.01 CONSTRUCTION PHASE

A. In each purchase order or subcontract that is written for changes in scope, include the appropriate requirements for submittal data, Commissioning documentation, testing assistance, Operating and Maintenance (O&M) data, and training, as a minimum.

B. Attend Pre-Commissioning Meeting(s), Pre-Installation Meeting(s), and other Project meetings scheduled by the Owner, CxA or Contractor to facilitate the Commissioning process.

C. Provide manufacturer's data sheets and shop drawing submittals of equipment.

D. Provide additional requested documentation to the Owner and / or CxA, prior to O&M manual Submittals, for development of System Verification Checklists and Functional Performance Testing procedures.

1. Typically, this will include detailed manufacturer's installation and Start-up, operating, troubleshooting and maintenance procedures, full details of any Owner-contracted tests, full factory testing reports, if any, and full warranty information.
2. In addition, the installation, Start-up, and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Contractor and / or CxA.
3. This information and data request may be made prior to normal submittals.

E. With input from the Lighting Controls, PCMS vendors and A/E, clarify the operation and control of commissioned equipment in areas where the Specifications, control drawings, or equipment documentation are not sufficient for writing detailed test procedures.

F. During the installation, Start-up and initial checkout process, execute and document related portions of the System Verification Checklists for all commissioned equipment according to the procedures indicated in the Commissioning Plan.

G. Factory Start-ups: Factory Start-ups are specified for certain equipment. Factory Start-ups generally are Start-up related activities that will be reviewed and checked prior to Functional Performance Tests. All costs associated with factory Start-ups shall be included with the contract price unless otherwise noted. Notify the Commissioning Team of the factory Start-up schedule and coordinate these factory Start-ups with witnessing parties. The Commissioning Team members may witness these Start-ups at their discretion.

H. Independent Testing Agencies: For systems that specify testing by an independent testing agency, the cost of the test shall be included in the Contract price unless otherwise noted. Testing performed by independent agencies may cover aspects required in the System Verification Checklists, Start-ups, and Functional Performance Tests. Coordinate with the independent testing agency so that CxA, Owner and/or A/E can witness the test to ensure that applicable aspects of the test meet requirements.

I. Provide skilled technicians to execute starting of equipment and to assist in execution of Functional Performance Tests. Ensure that they are available and present during the agreed-upon schedules and for a sufficient duration to complete the necessary tests, adjustments, and problem solving.

J. Correct deficiencies (differences between specified and observed performance) as interpreted by the Owner's Project Manager and A/E and retest the system and equipment.

1. CxA shall participate in one retesting effort at no cost to the Owner nor contractor. Should a 2nd retesting effort be required due to system indicating the same or similar issue, then the contractor shall be charged for their effort and the Owner retains the right to withhold the cost of the CxA's additional attendance from the contractor retainage at a maximum of $2,500 per occurrence.

K. During construction, maintain as-built marked-up Drawings and Specifications of all Contract Documents and Contractor-generated coordination Drawings. Update after completion of Commissioning activities (include deferred tests).

L. Provide training of the Owner's operating personnel as specified.

M. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.

3.02 **WARRANTY PHASE**

A. Execute seasonal or deferred tests, witnessed by the CxA and Owner, according to the Specifications.

1. Complete deferred tests as part of this Contract during the Warranty Period. Schedule this activity with the Owner.

B. Correct deficiencies and make necessary adjustments to O&M manuals, Commissioning documentation, and as-built drawings for applicable issues identified in any deferred or seasonal testing.

3.03 **INSTALLATION**

A. Installation shall meet or exceed all applicable federal, state and local requirements, referenced standards and conform to codes and ordinances of authorities having jurisdiction.

B. All installation shall be in accordance with the Project Documents.

3.04 **TRAINING**

A. Refer to the individual section of this Specification for specific training requirements on each system.

1. Refer to the General Commissioning Requirements and Division 01 of the Project Specifications for overall training requirements related to the Commissioning process and this project.

END OF SECTION

SECTION 26 27 26 - WIRING DEVICES

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Scope of Work - Section 26 05 01
5. Testing - Section 26 05 07

1.02 SCOPE

A. General: Furnish and install wiring devices as shown, scheduled, specified, and required.

B. Types: The types of wiring devices include, but are not limited to, the following:

1. Receptacles
2. Plugs
3. Wall Switches
4. Wall Plates
5. Wall Box Dimmer Switches

C. All wiring devices shall be side-wired.

1.03 QUALITY ASSURANCE

A. Manufacturers: If they comply with these specifications and requirements, products of the following manufacturers will be acceptable:

1. Hubbell
2. Leviton
3. Lutron
4. Pass & Seymour-Legrand

PART 2 - PRODUCTS

2.01 WIRING DEVICES – ALL TYPES

A. All devices shall be specification grade or higher.

B. Wiring device color shall be reviewed with the owner/architect and required local codes and standards.

1. General purpose receptacles: Gray
2. Isolated ground receptacles: Orange
3. Emergency receptacles: Red

C. All device wall plates shall be stainless steel.

D. All wiring devices shall be rated for 20 amps minimum.

2.02 **RECEPTACLES – NON-TAMPER RESISTANT**

A. Public facing duplex receptacles shall be flush, NEMA 5-20R, 20A, 125V, 3 wire, integral one-piece grounding backstrap, decorator style. Receptacles shall be specification grade.

B. Non-public facing duplex receptacles in equipment rooms or similar locations shall be NEMA 5-20R, 20A, 125V, 3 wire, side and back wire, integral one-piece grounding backstrap, standard style. Fed Spec W-C-596. Receptacles shall be specification grade.

2.03 **RECEPTACLES – TAMPER RESISTANT**

A. Duplex receptacles shall be flush, NEMA 5-20R, 20A, 125V, 3 wire, grounding, type. Receptacles shall be specification grade, decorator style, tamper resistant with Brass mounting strap.

2.04 **RECEPTACLES – TYPICAL REQUIREMENTS**

A. Ground Fault Circuit Interruption (GFI) duplex receptacles wired to "normal" power circuits shall be flush, NEMA 5-20R, 20A, 125V, 2 pole, 3 wire, self-test technology, weather resistant duplex, decorator style with nominal sensitivity to earth leakage of 4-6 mill amperes, and feed through capabilities. Receptacles shall be specification grade.

B. USB Charger type receptacles shall be 20A, 125V commercial specification grade, tamper resistant with two USB Type 2.0 ports, minimum 5.0A, 5V DC output total Decorator Type Duplex receptacle.

C. Special receptacles shall be provided with NEMA configuration as shown on the drawings and a matching NEMA configuration plug for installation on the equipment cord.

D. Twist lock receptacles shall be industrial grade Hubbell Twist-Lock Series, Leviton locking series, or Pass & Seymour "Black and White" series.

E. All weatherproof duplex receptacles shall have cast aluminum or stainless steel weatherproof while-in-use cover with NEMA 3R rating and flip lid; Hubbell #WP26E series or approved equal.

2.05 **PLUGS**

A. Cord connectors and plugs with twist lock devices shall be industrial specification grade Hubbell Twist-Lock series, Pass & Seymour "Turnlock" series.

B. Cord connectors and plugs with straight blade shall be specification grade Hubbell Insulgrip Plugs and Connector Bodies, Pass & Seymour "Black and White" series.

2.06 **WALL SWITCHES**

A. All locally switched lighting circuits in public areas, such as those areas accessible to employees, residents, or patrons shall be supplied with 20A, 120/277 Volt, specification grade, AC quiet, rated for 50,000 operations, decorator style rocker type switches as follows:

1. Single pole rocker switches shall be Hubbell DS120X, Leviton #5621-2X.
2. Double pole rocker switches shall be Hubbell DS220 X, Leviton #5622-2 X.
3. Three-way rocker switches shall be Hubbell DS320 X, Leviton #5623-2 X.
4. Four-way toggle switches shall be Hubbell DS420 X, Leviton #5624-2 X.
5. Locally switched "emergency" power lighting circuits shall be supplied with toggle switches similar to "normal" power circuits specified above, except color shall be "red, Hubbell DSx20R series."

B. All locally switched normal power lighting circuits in non-public areas, such as equipment rooms, shall be supplied with 20A, 120/277 Volt, specification grade, AC quiet, toggle type switches as follows:

1. Single pole toggle switches shall be Hubbell #1221X, Pass & Seymour CSB20AC1X
2. Double pole toggle switches shall be Hubbell #12212X, Pass & Seymour SB20AC2X.
3. Three-way toggle switches shall be Hubbell #1223X, Pass & Seymour CSB20AC3X.
4. Four-way toggle switches shall be Hubbell #1224X, Pass & Seymour CSB20AC4X.
5. Locally switched "emergency" power lighting circuits shall be supplied with toggle switches similar to "normal" power circuits specified above, except color shall be "red".

C. Key-operated switches shall be specification grade Hubbell #HBL1221LW, Leviton #1221-2WL with white key guide, or Pass & Seymour #PS20AC1L and shall meet all the requirements of the rocker type switches. Key-operated switches shall have full size key cylinders that shall utilize Fort Bend ISD standard key way locks. Coordinate with Fort Bend ISD for key way type.

D. General purpose toggle type (snap) disconnect switches for single phase equipment (i.e., water heaters, etc.) shall be Hubbell #HBL3031-I, Pass & Seymour #PS30AC1-I, 30A 120/277-volt, grounding, and shall be mounted in metallic single gang box with coverplate, located adjacent to the unit or equipment being served.

E. Timer switches shall be Intermatic #FD series, 125 Volt, 20 Amp, 3 Wire, 10 Amp @ 277V, 1 Horsepower or as specified on Drawings. Equals will be accepted.

2.07 **WALL PLATES**

A. Device plates for single and multi-gang wiring devices in all areas shall be 302 stainless steel configured to match the installed device, unless specified otherwise. Multi-gang installations shall be provided with a common coverplate.

B. Combination receptacle, TV and communication outlets shall be combined with a single wall plate to match each outlet.

C. Twistlock receptacles shall be provided with a 302 stainless steel coverplate for interior spaces to match the installed device, Hubbell SS series.

2.08 **WALL BOX DIMMER SWITCHES**

A. Where wall box dimmer switches are indicated or specified, they shall be solid-state, specification grade, with stainless steel coverplate to match adjacent wiring devices, as follows:

1. 600W single pole, Lutron #NT-600.
2. 1000W single pole, Lutron # NT-1000.
3. 1500W single pole, Lutron # NT-1500.
4. 1500W single pole, low voltage, Lutron #NTLV-1500

PART 3 - EXECUTION

3.01 SUBMITTALS

A. Submittals shall include, but not be limited to, the following:

1. Cut sheets of the specified receptacles, wall switches, wall plates, dimmer switches, etc.
2. Additional information as required in Section 20 05 03.

3.02 INSTALLATION

A. Receptacles throughout shall be installed with the ground pin receiver in the “up” position.

B. Special purpose switches and/or outlets not covered by the specifications but noted on the drawings shall be of the amperage, voltage rating, and NEMA configuration indicated. The switches and/or outlets shall be specification grade of the same quality as those specified.

C. Coordinate with the owner the exact receptacle type required for owner furnished equipment.

D. When equipment only, or J-Box only, is indicated for equipment, it shall be the responsibility of the Electrical Sub-contractor to obtain from the supplier, the complete data as related to the electrical portion of the equipment, including rough-ins, mounting height, type of outlet, items furnished by the supplier, etc. The Electrical Sub-contractor shall be responsible for furnishing and installing all materials that are usually the Electrical Subcontractor's responsibility with the installation of the equipment.

E. For typical areas, multi-gang wall plates shall be used for each group of ganged devices. Mounting screws shall be installed for each device covered by the wall plate.

F. Wall plates for concealed work shall be flush against the finished wall and shall completely cover the wall opening. Wall plates shall not be installed until all painting has been completed. Devices shall be protected by masking tape or other coverage until painting is complete. Any device with paint on it shall be replaced at no expense to the Owner.

G. Where normal power and emergency power receptacles or switches are ganged together in one box, install a permanent partition to separate normal and emergency power.

END OF SECTION

SECTION 26 28 13 - FUSES

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Scope of Work - Section 26 05 01
5. Testing - Section 26 05 07

1.02 SCOPE

A. General: Furnish fuses as shown, scheduled and specified.

1.03 QUALITY ASSURANCE

A. Manufacturers: If they comply with these specifications and requirements, products of the following manufacturers will be acceptable:

B. Fuses:

1. Bussmann
2. Ferraz Shawmut
3. LittleFuse

C. Codes and Standards:

1. Fuses shall be listed by Underwriter's Laboratories and shall bear the UL label.

PART 2 - PRODUCTS

2.01 FUSES

A. Furnish and install all fuses as specified and as indicated on the drawings.

B. Fuses shall not be installed until equipment is ready to be energized. This measure prevents fuse damage during shipment of the equipment from the manufacturer to the job-site or from water that may contact the fuse before the equipment is installed.

C. All fuses shall be furnished and installed by the Electric Contractor. Fuse holders shall be labeled inside the cover to indicate the type and ampacity of fuses installed. All fuses shall be of the same manufacturer.

D. Mains, Feeders, and Branch Circuits 601 to 6000 Amperes shall be protected by UL Class L, current limiting fuses, BUSSMAN LOW-PEAK time delay Type "KRP-C-SP". Fuses shall be time-delay type and must hold 500% of rated current for a minimum or 4 seconds, clear 20 times rated current in .01 seconds or less and shall be listed by Underwriters Laboratories Inc., with an interrupting rating of 300,000 Amperes RMS symmetrical.

E. Mains, Feeders, and Branch Circuits 0 to 600 Amperes shall be protected by UL Class RK1, current limiting fuses, BUSSMANN LOW-PEAK dual-element fuses, Type "LPN-RK-SP" (250 Volts) and "LPS-RK-SP" (600 Volts) unless otherwise noted. Fuses shall be time delay type must hold 500% of rated current for a minimum of 10 seconds and clear 20 times rated current in .01 seconds or less and shall be listed by Underwriters Laboratories Inc., with an interrupting rating of 300,000 Amperes RMS symmetrical. Fused Busway plug type switches shall utilize Class J fuses, Bussmann "LPJ-SP".

F. All individual motor circuits with full load ampere ratings of 480 amperes or less, shall be protected by BUSSMANN LOW-PEAK dual element fuses "LPN-RK-SP", or "LPS-RK-SP".

1. The following guidelines apply for motors protected by properly sized overload relays: fuses for motors with a marked service factor not less than 1.15 shall be installed in ratings of 125 percent of motor full load current (or next larger if 125 percent does not correspond to a fuse size) except where high ambient temperatures prevail, or where the motor drives a heavy revolving part which cannot be brought up to full speed quickly, such as large fans. Under such conditions, the fuse may be 150 percent to 175 percent of the motor full load current. Larger H.P. motors shall be protected by BUSSMANN LOW-PEAK Time-Delay "KRP-C-SP" fuses of the ratings shown on the Drawings. For all other motors, (such as 1.0 service factor motors) fuses shall be sized in ratings of 115 percent of the motor full load current (or next larger if 115 percent does not correspond to a fuse size) except as noted above.
2. The following guidelines apply where fuses are used as the only overload protection for the motor: for motors with a 1.15 service factor or more, fuses should be sized at 125 percent of motor full load current or next size smaller if 125 percent does not correspond with to a fuse size. For all other motors, fuses should be sized at 115 percent of motor full load current, or next size smaller, if 115 percent does not correspond to a fuse size. The fuses shall be U.L. Class RK1, dual-element time-delay.

G. All other fused switches shall be provided with cartridge fuses which shall be of the knife blade or ferrule type with capacities as indicated on the Drawings. Fuses shall be Bussmann "Fusetrons" of the proper voltage.

H. Spare Fuses:

1. Upon completion of the building, the Electrical Contractor shall provide the Owner with spare fuses as shown below:

a. 10% (minimum of 3) of each type and rating of installed fuses shall be supplied as spares.
b. BUSSMANN Catalog No. SFC or equal spare fuse cabinets with engraved nameplates shall be provided to store the above spare fuses.

I. The contractor shall base his proposal upon the fuses specified. If the contractor wishes to use fuses other than those specified, written request shall be submitted to the Engineer for approval review as required in the BASIC DIVISION 20-28 REQUIREMENTS Section 20 05 03, under "PRIOR APPROVAL", together with proof that the substituted fuses "are equal", and that all proposed fuses have been selected for proper fuse coordination with all components of the power system.

PART 3 - EXECUTION

3.01 FUSES

A. Shop drawings submittal shall include, but not be limited to, the following:

1. Cut sheet submittal shall be provided for all fuse types required for the project.
2. Cut sheet submittal shall be provided for in-line fuse holders for all required lighting fixtures.
3. Additional information as required in Section 20 05 03.

B. Installation

1. Install appropriate fuses in switches after switch and related enclosure installation, wiring and testing is complete.
2. Install fuse-identifying labels on the door of each fused device. Labels shall indicate the type and ratings of the proper fuse to be used in the switch.

END OF SECTION

SECTION 26 28 16 - SAFETY AND DISCONNECT SWITCHES

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Scope of Work - Section 26 05 01
5. Testing - Section 26 05 07
6. Power System Studies - Section 26 05 73

1.02 SCOPE

A. General: Furnish and safety and disconnect switches as shown, scheduled and specified.

B. All service equipment shall be marked in the field to comply with NEC Section 110.

1.03 QUALITY ASSURANCE

A. Manufacturers: If they comply with these specifications and requirements, products of the following manufacturers will be acceptable:

B. Safety and Disconnect Switches:

1. GE by ABB
2. Square D
3. Siemens

C. Codes and Standards:

1. Safety and disconnect switches shall be listed by Underwriter's Laboratories and shall bear the UL label.

PART 2 - PRODUCTS

2.01 SAFETY AND DISCONNECT SWITCHES

A. Furnish and install safety switches as specified herein and as indicated on the drawings with number of switched poles as indicated.

B. Safety switches shall be heavy duty type, dead-front, sheet steel enclosed, surface mounted, of the type and size indicated. Safety switches shall be rated for the voltage of the circuit in which they are installed. Safety switches used as motor disconnects shall be horsepower rated for the motor served.

C. Safety switches shall be quick-make, quick-break type with permanently attached arc suppressor and constructed such that blades are visible in the OFF position with the door open. All current carrying parts shall be constructed of high conductivity copper with silver-plated switch contacts.

Lugs shall be suitable for copper cable, shall accept compression connectors where required, and shall be front removable. Fuse clips shall be positive pressure rejection-type, suitable for use with UL Class R fuses typical. Provide class J fuse holders for fused busway plug in switches and any switches used in series rating combinations. The operating handle shall be part of the box, not of the cover.

D. The switch shall have provisions to padlock in the off position. Safety switches shall have a cover interlock to prevent unauthorized opening of the switch door when the switch mechanism is in the "on" position. Cover interlock shall have an override mechanism to permit switch inspection by authorized personnel.

E. For switches serving fire pumps, provide padlocking provisions in both the open and closed positions. Provide auxiliary contacts for monitoring switch in closed position.

F. Where a neutral is present in the circuit, furnish an isolated solid neutral block with the safety switch. Where a ground conductor is present in the circuit, furnish a solid ground block with the safety switch. Where an isolated ground is present in the circuit, furnish an isolated ground block.

PART 3 - EXECUTION

3.01 SAFETY AND DISCONNECT SWITCHES

A. Shop drawing submittal shall include, but not be limited to, the following:

1. Cut sheets of the safety and disconnect switches with ratings, voltage, poles, and all associated accessories clearly indicated.
2. Additional information as required in Section 20 05 03.

B. Installation

1. Indoors: Safety switches installed in indoor locations shall be NEMA 1 general purpose enclosures, unless otherwise indicated.
2. Outdoors: Safety switches installed in outdoor locations shall be NEMA 3R (water resistant) enclosures, unless otherwise indicated.
3. Wet Areas: Safety switches installed at cooling towers, kitchen and laundries and in other wet areas, shall be NEMA 4X (stainless steel) enclosures, unless otherwise indicated.
4. Provide all safety switches where shown and at each motor which is out of site of, or greater than 50 feet from, the switch or panel from which the motor circuit is fed.
5. Provide all safety and disconnect switches with galvanized angle iron, unistrut, or other suitable supports where mounting on wall or other rigid surface is impractical. Where devices are mounted on drywall surfaces, provide galvanized back plate on opposite side of drywall for anchoring support. Switches shall not be supported by conduit alone.
6. Switches shall not be mounted on equipment when provided by this division. They shall be independently supported and shall not inhibit removal of any service panels or interfere with any required access areas.
7. Install disconnect switches used with motor-driven appliances, motors, and controllers within site of the controller position unless otherwise indicated.
8. Refer to Section 20 05 05 for engraved nameplates.

END OF SECTION

SECTION 26 29 13 - INDIVIDUAL MOTOR CONTROLLERS

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Design Criteria - Section 20 05 02
2. Basic Division 20-28 Requirements - Section 20 05 03
3. Schedule of Submittal Data - Section 20 05 04
4. General Division 20-28 Materials and Methods - Section 20 05 05
5. Scope of Work - Section 26 05 01
6. Testing - Section 26 05 07

1.02 SCOPE

A. General: Furnish and install individual motor controllers as shown, scheduled and specified.

B. Provide Arch Flash Hazard Analysis to comply with NFPA 70E Section 130.3.

1.03 QUALITY ASSURANCE

A. Manufacturers: If they comply with these specifications and requirements, products of the following manufacturers will be acceptable:

B. Codes and Standards:

1. Individual motor controllers shall be listed by Underwriter's Laboratories and shall bear the UL label.

PART 2 - PRODUCTS

2.01 INDIVIDUAL MOTOR CONTROLLERS

A. General: Furnish and install motor controllers as specified herein and as shown on the Drawings. The extent of motor controllers work is as shown and scheduled, as indicated by the requirements of this Section, and as specified elsewhere in these Specifications. Motor starters shall be provided for all 3-phase motors (i.e. fans & pumps) where motor control is not provided by others.

B. Starter: Individual one-speed motor controllers shall consist of an integrally mounted, magnetic, full-voltage non-reversing (FVNR) starter. Individual two-speed motor controllers shall consist of an integrally mounted, magnetic two-speed, two-winding (2S-2W) or two-speed, one-winding (2S-1W) starter. Starter enclosures shall be heavy duty type, dead front, surface mounted sheet steel enclosure. Size and number of poles shall be as shown and as required for the equipment served. All controllers shall be constructed and tested in accordance with the latest NEMA standards.

C. Contacts: Magnetic motor controller contacts shall be solid silver cadmium oxide alloy, and shall not require any filing, dressing, or cleaning throughout the life of the starter.

D. Coils: Operating coils shall be 120 volts and shall be pressure molded and designed so that accidental exposure to excessive voltage up to 480 volts will not damage the coil. The starter design shall also be such that when a coil fails due to an over-voltage condition, the starter shall definitely open and shall not freeze in the closed position.

E. Overload Relays: Motor controllers shall have manual-reset, trip-free overloads relays in each phase conductor. Three phase FVNR starters shall have three overload relays. Single phase motor controllers shall have overload protection for ungrounded conductors. Two-speed, full-voltage magnetic starters shall have overload relays in all six control legs. Overload relays shall not be field convertible from manual to automatic reset. Overload relays that change to automatic reset from manual reset when the reset mechanism is blocked are not acceptable.

F. Pilot Lights: Provide green RUNNING pilot lights for all motor controllers. Furnish additional pilot lights for motor starters where shown. Pilot lights shall be operated from an interlock on the motor controller and shall not be placed across the operating coil. The pilot lights shall be mounted in the controller enclosure cover. The pilot lights shall be heavy duty 30 mm type with LED long life lamps

G. Selector Switches: Motor controllers shall be provided with 3-position HAND/OFF/AUTO heavy duty 30 mm selector switches unless other selector switches are specified on Drawings such as speed selector switches, or START-STOP pushbuttons as required, with appropriate labels.

H. Control Power Transformer: A single-phase control power transformer shall be included integral with each starter for 120-volt control power. The primary shall be fused and connected to the line side of the starter. The secondary shall have one leg fused and the other leg grounded. Arrange the transformer terminals so that wiring to terminals will not be located above the transformer. The control power transformer shall have sufficient capacity for all lights, coils, actuators, dampers, DDC controllers, etc. that are connected to it with 100 VA spare capacity.

I. Auxiliary Contacts: Each starter shall have one normally open and one normally closed auxiliary contacts in addition to the number of contacts required for the "holding interlock" and control wiring. In addition, it shall be possible to field-install one or more additional auxiliary contacts without removing existing wiring or removing the starter from its enclosure.

J. Power Monitor Relay: The starter for 3-phase motors of 5 HP or greater shall be provided with a 3-phase power monitor relay which shall drop out upon loss of any phase, undervoltage on any and all phases, or phase reversal from A-B-C sequence. The relay shall be adjustable for the trip range and shall automatically reset upon correction of trouble. The 3-phase power monitor shall be Time Mark Corporation Model #A258B (480V) and Model #258B (208V/240V) or approved equal. Where starters are provided as an integral part of the control panel, the power monitors shall be provided with the furnished control panel.

K. Pre-Wired: The starter unit shall be completely pre-wired to terminals to eliminate any interior field wiring except for connection of power supply conductors to switch line side terminals, motor leads to the starter load side terminals, and control conductors to holding coil terminals. All internal conductors shall be copper.

L. Enclosures: All motor starter enclosures shall be NEMA 1, heavy-duty, general-purpose type, unless exposed to the weather or otherwise indicated. Enclosures exposed to the weather shall be NEMA 3R. Enclosures installed at cooling towers shall be NEMA 4 (stainless steel).

M. Internal Wiring Diagram: Every starter shall have an internal wiring diagram attached to the inside of the starter cover and shall be labeled inside the cover to indicate the type and ampacity of thermal overloads installed.

N. Two Speed Controllers: Two-speed motor controllers for two-speed motor shall have a "decelerating relay" between high and low speed.

2.02 **MANUAL MOTOR DISCONNECT (SNAP) SWITCHES**

A. General: Toggle type disconnect switches (horsepower rated) may be used as the disconnecting means for individual fractional HP motors having resettable, integrally mounted, thermal overload protection, provided each motor full-load rating does not exceed 10 amperes and the motor branch circuit over-current device does not exceed 30A at 120V-1 phase, 30A at 208V-1 phase, 30A at 208V-1 phase, or 20A at 277V-1 phase.

B. For 120V, 208V-1 Phase, 240V-1 Phase, or 277V motors and equipment meeting the requirements indicated in subsection 2.02(A) - toggle type (HP rated) disconnect switches shall be Legrand #CS20AC1 series, or approved equal, 30A, 120/277 Volt, extra heavy duty specification grade, ivory, and shall be mounted in a metallic single gang box with coverplate, located adjacent to the unit or equipment being served.

C. Manual motor starter enclosures shall be NEMA 1, general purpose type, unless indicated otherwise.

PART 3 - EXECUTION

3.01 **MOTOR CONTROLLERS**

A. Shop drawing submittal shall include, but not be limited to, the following:

1. Cut sheets of individual and combination motor controllers with construction, ratings, voltage, poles, internal wiring diagram, power monitor relay, and all associated accessories clearly indicated.
2. Cut sheets of manual motor starters with ratings, voltage, poles, and all associated accessories clearly indicated.
3. Cut sheets of manual motor disconnect switches with ratings, voltage, poles, and all associated accessories clearly indicated.
4. Additional information as required in Section 20 05 03.

B. Installation

1. Install motor controllers where shown, in accordance with the manufacturer's written instructions, and the applicable requirements of the NEC recognized industry practices to ensure that products serve the intended function.
2. Install overload heaters in each motor controller. Heater ratings shall be based on actual motor nameplates full load amps.
3. Motor controllers shall be provided to properly coordinate with motors as furnished by Divisions 20-28. Motor starter controls shall be provided to properly coordinate with controls specified in Division 23.
4. Provide all individual and combination motor starters with galvanized angle or other suitable supports where impractical. Starters shall not be supported by conduit alone. Motor starters shall not be mounted on equipment served, Manual motor starters shall be installed plumb and aligned in the plans of the wall in which they are installed.
5. Refer to Section 20 05 05 for engraved nameplates.
6. Check motor starters for continuity of circuits and for short circuits.
7. Subsequent to wire and cable hook-ups, energize motor starter and demonstrate satisfactory functioning.

END OF SECTION

SECTION 26 51 13 - LIGHTING FIXTURES

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. The requirements of the General Conditions, Supplementary Conditions, Division 1, Division 20, and Drawings apply to all Work herein.

B. Requirements of the following Division 20-28 Sections apply to this section:

1. Basic Division 20-28 Requirements - Section 20 05 03
2. Schedule of Submittal Data - Section 20 05 04
3. General Division 20-28 Materials and Methods - Section 20 05 05
4. Scope of Work - Section 26 05 01
5. Testing - Section 26 05 07

1.02 SCOPE

A. General: Furnish and install lighting fixtures complete with lamps for every lighting outlet as shown, scheduled, and specified.

B. Types: The types of lighting fixtures include, but are not limited to, the following:

1. Exterior LED Lighting Fixtures.

C. Related Sections: Other Division 20-28 Sections contain requirements related to the work of this Section.

1.03 QUALITY ASSURANCE

A. Codes and Standards: All lighting fixtures furnished by this Division shall conform to the standards of Underwriters' Laboratories, Inc. and shall bear the U.L. label.

B. Manufacturers:

1. Philips Signify – Basis of Design
2. Cooper
3. Lithonia
4. Lutron

PART 2 - PRODUCTS

2.01 LED LIGHTING FIXTURES

A. General: Furnish and install LED lighting fixtures of the types and manufacturers scheduled on the Drawings. Fixtures shall be furnished with all required accessories and trim for the complete installation in the ceiling type shown on the Architectural Drawings.

B. Performance Criteria:

1. LED fixture manufacturer shall have performed LM79 testing and provide reports upon request.
2. LED fixtures shall be LM80 tested. LED fixtures shall provide minimum of 70% of initial lumen output after 50,000 hours of operation.

3. LED fixtures shall have a minimum of 80lpw (lumens per watt) initially
4. LED fixtures shall be available in 3500, 4000, and 5000k variants or other as specified on drawings
5. LED fixtures shall be fully dimmable using a low voltage signal down to 20% or lower output as specified on drawings.
6. LED fixtures in finished areas shall have a minimum of 80 CRI. LED fixtures outdoors or in non-finished areas shall have a minimum of 70 CRI unless otherwise indicated on Drawings.
7. All recessed LED fixtures shall be maintainable and upgradable from below the ceiling
8. All LED fixtures shall have a 5-year parts warranty which covers fixture construction and all LED components, including drivers.

C. LED DRIVERS

1. Provide driver type (non-dimmed, step-dimmed, continuous-dimming, etc.) as indicated on the lighting fixture schedule on the drawings.
2. Minimum Warranty of 5 years (not pro-rated) to include LED driver and all LED components.
3. Driver shall have a rated life of 50,000 hours, minimum.
4. Driver and LEDs shall be furnished as a unit from a single manufacturer to ensure compatibility.
5. Driver shall have a minimum power factor (pf) of 0.9 and a maximum crest factor (cf) of 1.5 at full input power and across voltage range of + / - 10% of nominal.
6. Driver shall operate normally for input voltage fluctuations of plus or minus 10 percent.
7. Driver shall have a maximum Total Harmonic Distortion (THD) of $\leq$20% at full input power and across specified voltage range.
8. Wiring connections to LED drivers shall utilize polarized quick-disconnects for field maintenance.
9. Fuse Protections: All luminaires shall have built-in fuse protection. All power supply outputs shall be either fuse protected or be Polymeric Positive Temperature Coefficient (PTC)-protected as per Class 2 UL listing.
10. Provide all of the following data on submittals:

    a. Input watts
    b. Power Factor (pf)
    c. Crest Factor (cf) at full input power
    d. Total Harmonic Distortion (THD).

PART 3 - EXECUTION

3.01 SUBMITTALS

A. Shop drawings submittals shall include, but not be limited to, the following:

1. Cut sheets on all lighting fixtures with all accessories and details clearly indicated.
2. Cut sheets on integral batteries.
3. Cut sheets and complete technical data.
4. Photometric performance data.
5. Additional information as required in Section 20 05 03.

3.02 INSTALLATION

A. All lighting fixtures shall be furnished complete with mounting accessories to suit the specific service and installation intended. The Electrical Contractor shall verify the required fixture ceiling/trim coordination prior to releasing light fixture orders.

B. Chain-suspended lighting fixtures shall be connected to the outlet box mounted directly above the fixture using flexible metallic conduit, and the flexible metallic conduit or MC cable shall be strapped to the fixture chain.

C. Connect each fixture housing to the equipment grounding conductor be means of a crimped spade-type terminal connector secured to the housing with a self-tapping screw.

D. All fixtures shall be clean at the time of acceptance of the Work and shall be properly aimed or adjustable as required. No extra will be permitted for cleaning, aiming or adjustable fixtures to meet the requirements of the Engineer at the time of acceptance of the Work.

E. All lamps used during construction and prior to final inspection, shall be replaced prior to final acceptance of the building by the Owner.

F. The locations indicated for outlet boxes of lighting fixtures are diagrammatic. Outlets shall be located as required to coincide with suspension hangers where they occur and with structural an architectural element of the building and shall be located in accordance with the Architectural Reflected Ceiling Plan.

G. Recessed light fixtures installed in fire rated ceilings shall be provided with UL listed fire rated covers Tenmat #FF series or approved equal with dimensions and fire rating suitable for the fixtures specified.

END OF SECTION