PROJECT MANUAL TABLE OF CONTENTS

TABLE OF CONTENTS

PROJECT MANUAL SEALS

DIVISION 00 – PROCUREMENT AND CONTRACTING REQUIREMENTS

DIVISION 01 – GENERAL REQUIREMENTS

DIVISION 06 – WOOD PLASTICS, AND COMPOSITES

DIVISION 07 – THERMAL AND MOISTURE PROTECTION

DIVISION 08 – OPENINGS

DIVISION 09 – FINISHES

DIVISION 10 – SPECIALTIES

END OF PROJECT MANUAL TABLE OF CONTENTS

SECTION 01 23 00 - ALTERNATES

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes: Administrative and procedural requirements for alternates.

1.3 DEFINITIONS

A. Alternate: An amount proposed by bidders and stated on the Bid Form for certain Work defined in the bidding requirements that may be added to or deducted from the base bid amount if Owner decides to accept a corresponding change either in the amount of construction to be completed or in the products, materials, equipment, systems, or installation methods described in the Contract Documents.
   1. Alternates described are part of the Work when enumerated in the Agreement.
   2. The cost or credit for each alternate is the net addition to or deduction from the Contract Sum to incorporate alternate into the Work. No other adjustments are made to the Contract Sum.

1.4 PROCEDURES

A. Coordination: Revise or adjust affected adjacent Work as necessary to completely integrate Work of the alternate into Project.
   1. Include as part of each alternate, miscellaneous devices, accessory objects, and similar items incidental to or required for a complete installation whether or not indicated as part of alternate.

B. Notification: Forty-eight (48) hours following award of the Contract, notify each party involved, in writing, of the status of each alternate. Indicate if alternates have been accepted, rejected, or deferred for later consideration. Include a complete description of negotiated revisions to alternates.

C. Execute accepted alternates under the same conditions as other Work of the Contract.

D. Schedule: A schedule of alternates is included at the end of this Section. Specification Sections referenced in schedule contain requirements for materials necessary to achieve the Work described under each alternate.

PART 2 - PRODUCTS *(Not Used)*

PART 3 - EXECUTION

A. SCHEDULE OF ALTERNATES
   1. ***Alternate No. 1***: Site Lighting
      a. Base bid: No lighting at road connecting to Hardy.
      b. Alternate: Lighting at road connecting to Hardy.
   2. ***Alternate No. 2***: Site Entrance
      a. Base bid: No track entrance at Cypresswood, including lighting, security.

b. Alternate: Track entrance at Cypresswood, including lighting, security.

3. ***Alternate No. 3***: Not Used
4. ***Alternate No. 4***: Not Used
5. ***Alternate No. 5***: Not Used
6. ***Alternate No. 6: Lighting Controls***
    a. ***Base bid: No BAS: Provide lighting control system in compliance with IECC 2015 as shown on plans. All interior zones will be provided with Occupancy or Vacancy sensor as shown. All exterior lighting shall turn on/off in response to daylight through the use of a photosensor. All exterior lighting shall turn off at a set time in the evening after normal business hours through the use of an astronomical time switch.***
    b. ***Alternate: BAS System: All interior spaces shall be provided with a Wattstopper Dimming Room Controller. Provide a Dimming Room Controller for exterior wall and canopy lighting for on/off and dimming control. Provide Wattstopper NWTL-111 BULIT wireless control node via Nema 7 pin socket at each exterior pole lighting fixture tied back to wireless network manager for on/off and dimming control of pole light fixtures. Provide relay panels, room bridges, network enclosures, segment managers, routers, and repeater devices as needed for complete networked building controls connected to BAS. BAS system shall be able to control and monitor each zone individually.***
7. ***Alternate No. 7***: Paving
    a. Base bid: Traditional concrete paving.
    b. Alternate: Rolled paving throughout with broom finish at parking lot.
8. ***Alternate No. 8***: Counter Finishes
    a. Base bid: Quartz counter tops throughout.
    b. Alternate: Plastic laminate counters in workroom.
9. ***Alternate No. 9***: Business Office
    a. Base bid: CMU walls for entire perimeter of Business Office.
    b. Alternate: Light gauge framing in lieu of CMU.
10. ***Alternate No. 10***: Restroom Tiling
    a. Base bid: Full height tile throughout per documents.
    b. ***Alternate: 8' of tile on wet wall (plumbing wall) only.***
11. ***Alternate No. 11***: Single Occupant Restroom Tiling
    a. Base bid: Tile on entire wall to ceiling
    b. Alternate: Tile only up to 4' high on all walls
12. ***Alternate No. 12***: Large Classroom
    a. Base bid: Standard gyp and stud wall, structure for folding partition above ceiling.
    b. Alternate: Folding partition and associated furr-downs and pockets.
13. ***Alternate No. 13***: HVAC
    a. Base bid: Gas-fired boilers and hydronic heating, per documents.
    b. ***Alternate: Alternate: VAV schedule with electric heat in lieu of heating***

FAN POWERED VARIABLE VOLUME TERMINAL UNITS (FPT)

TAG	INLET SIZE (INCH)	TYPE	PRIMARY AIR CFM		EXTERNAL STATIC PRES (IN WG)		FAN MOTOR (HP)	ELECTRIC HEATING			ELECTRICAL VOLTS / PH	MAKE AND MODEL
			MAX	MIN	INLET	OUTLET		EAT (°F)	POWER (kW)	LAT (°F)		
FPT-1-1	12	SERIES	1,580	632	0.5	0.5	1/2	62.8	14	90	480 / 3	PRICE - FDCA2
FPT-1-2	10	SERIES	1,200	480	0.5	0.5	1/2	62.8	10	90	480 / 3	PRICE - FDCA2
FPT-1-3	10	SERIES	1,300	520	0.5	0.5	1/2	62.8	11	90	480 / 3	PRICE - FDCA2
FPT-1-4	10	SERIES	1,300	520	0.5	0.5	1/2	62.8	11	90	480 / 3	PRICE - FDCA2
FPT-1-6	10	SERIES	1,300	520	0.5	0.5	1/2	62.8	11	90	480 / 3	PRICE - FDCA2
FPT-1-7	6	SERIES	400	160	0.5	0.5	1/3	62.8	3	90	277 / 1	PRICE - FDCA2
FPT-2-1	10	SERIES	960	384	0.5	0.5	1/2	62.8	8	90	480 / 3	PRICE - FDCA2
FPT-2-2	6	SERIES	330	132	0.5	0.5	1/3	62.8	3	90	277 / 1	PRICE - FDCA2
FPT-2-3	12	SERIES	1,560	624	0.5	0.5	1/2	62.8	13	90	480 / 3	PRICE - FDCA2
FPT-2-4	8	SERIES	610	244	0.5	0.5	1/3	62.8	5	90	277 / 1	PRICE - FDCA2
FPT-2-5	8	SERIES	510	204	0.5	0.5	1/3	62.8	4	90	277 / 1	PRICE - FDCA2
FPT-2-6	8	SERIES	405	162	0.5	0.5	1/3	62.8	3	90	277 / 1	PRICE - FDCA2
FPT-2-7	10	SERIES	1,175	470	0.5	0.5	1/2	62.8	10	90	480 / 3	PRICE - FDCA2
FPT-2-8	10	SERIES	770	308	0.5	0.5	1/2	62.8	7	90	480 / 3	PRICE - FDCA2
FPT-2-9	8	SERIES	440	176	0.5	0.5	1/3	62.8	4	90	277 / 1	PRICE - FDCA2
FPT-2-10	10	SERIES	1,000	400	0.5	0.5	1/2	62.8	9	90	480 / 3	PRICE - FDCA2
FPT-2-11	10	SERIES	1,000	400	0.5	0.5	1/2	62.8	9	90	480 / 3	PRICE - FDCA2
FPT-2-12	10	SERIES	1,000	400	0.5	0.5	1/2	62.8	9	90	480 / 3	PRICE - FDCA2
FPT-2-13	10	SERIES	1,260	504	0.5	0.5	1/2	62.8	11	90	480 / 3	PRICE - FDCA2
VAV-1-1	8	N/A	500	500	N/A							PRICE - SDV

14. ***Alternate No. 14***: Irrigation
    a. Base bid: Irrigation tap from MUD water supply, per documents.
    b. Alternate: Retention pond and pump, in lieu of a detention pond, to serve irrigation needs. Include separate line item for chain-link fence to surround pond.
15. ***Alternate No. 15***: Acoustic Insulation in Exterior Walls
    a. Base bid: No batts insulation in exterior walls.
    b. Alternate: Acoustic insulation batts in exterior walls.

END OF SECTION 01 23 00

SECTION 01 45 29 - STRUCTURAL TESTING AND INSPECTIONS

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

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

1.2 SUMMARY

A. Section includes requirements for quality assurance and quality control to be completed by the Testing Laboratory, Contractor, and/or the Geotechnical Engineer for the following structural items:

1. Concrete Forming and Accessories.
2. Concrete Reinforcing.
3. Cast-in-Place Concrete.
4. Structural Steel.
5. Metal Building Systems
6. Earthwork.

B. Related Requirements:

1. Specification 01 40 00 “Quality Requirements” for other independent testing agency procedures and administrative requirements.

1.3 PRICE AND PAYMENT PROCEDURES

A. Unit Prices:

1. Cost Proposal: The Testing Laboratory’s proposal to the Owner shall contain unit price stipulations for specified tests and inspections and on an hourly basis for personnel. A total estimated price shall also be submitted.

B. Measurement and Payment

1. Payment of the Testing Laboratory: The Owner will pay for the initial Laboratory services for inspection and testing of materials for compliance with the requirements of the Contract Documents.
2. Payment for Substitution Testing: The Contractor shall arrange for and pay for any additional samples and tests above those required by the Contract Documents as requested by the Contractor for his convenience in performing the work.
3. Payment for Retesting: When initial tests indicate work does not comply with the requirements of the Contract Documents, the Contractor shall be liable to the Owner for the cost for any additional inspections, sampling, testing, and retesting done by the Testing Laboratory.
4. Payment by Contractor: The Contractor shall furnish and pay for the following items if required:

a. Soil survey of the location of borrow soil materials, samples of existing soil materials, and delivery to the Contractor's Testing Laboratory.
b. Samples of concrete aggregates and delivery to the Contractor's Testing Laboratory.
c. Concrete mix designs as prepared by his concrete supplier.
d. Site-situated storage boxes for concrete cylinders
e. Concrete coring, tests of below strength concrete, and load tests, if ordered by the Owner, Architect, or Engineer.
f. Certification of reinforcing steel steel mill order.
g. Certification of structural steel mill order.
h. Certification of portland cement, lime, fly ash.
i. Certification of welders and preparation of Welding Procedure Specifications.
j. Tests, samples, and mock-ups of substitute material where the substitution is requested by the Contractor and the tests are necessary in the opinion of the Owner, Architect or Engineer to establish equality with specified items.
k. The making and testing of concrete cylinders for the purpose of evaluating strength at time of form stripping or the time spent evaluating the in situ strength of concrete using the Maturity Method.
l. Any other tests when such costs are required by the Contract Documents to be paid by the Contractor.

5. Payment for Tests of Suspected Deficient Work: If, in the opinion of the Building Official, Owner, Architect, or Engineer, any of the work of the Contractor is not satisfactory, the Contractor shall furnish and pay for all tests that the Owner, Architect, or Engineer deem advisable to determine its proper construction. The Owner shall pay all costs if the tests prove the questioned work to be satisfactory.

1.4 OWNER RESPONSIBILITIES

A. The Owner shall engage a Geotechnical Engineer to provide inspection services for the foundations as outlined below in Article 3.7.

B. The Owner shall provide a copy of the project plans and specifications to the Testing Laboratory prior to the start of construction and prior to any preinstallation meetings.

1.5 CONTRACTOR RESPONSIBILITIES

A. The Contractor shall not engage the same Testing Laboratory for construction services as the Owner has for Structural Testing Laboratory Services as defined herein unless agreed to by the Owner.

B. Furnishing Samples and Certificates: The Contractor shall provide to the laboratory certificates and representative samples of materials proposed for use in the work in quantities sufficient for accurate testing as specified.

C. Furnishing Casual Labor, Equipment and Facilities: The Contractor shall furnish casual labor, equipment, and facilities as required for sampling and testing by the laboratory and otherwise facilitate the required inspections and tests.

1.6 TESTING LABORATORY RESPONSIBILITIES

A. The Testing Laboratory shall sample and test materials as they are being installed for compliance with specified acceptance criteria. The Testing Laboratory will report and interpret the test results. The Laboratory shall monitor and report on the installation of construction work and shall perform tests on the completed construction as required to indicate Contractor's compliance with the various material specifications governing this work.

B. The Testing Laboratory shall serve as a Special Inspector to provide Special Inspection services for the items listed below. The scope of such services for each item shall be as defined in the Building Code or as defined in the local building code of the jurisdiction wherein the project is located. These inspections are mandatory for conformance to the legal requirements of the building code and shall be in addition to the inspections and tests otherwise defined in this specification.

1. Special Inspector Responsibilities:

    a. The special inspector shall observe the work assigned to ascertain that, to the best of his/her knowledge, it is in conformance with the approved design drawings and specifications.
    b. The special inspector shall furnish inspection reports to the Building Official, the Architect/Engineer, and the Owner. All discrepancies shall be brought to the immediate attention of the Architect/Engineer, Contractor, and Owner. A report that the corrected work has been inspected shall be sent to the Building Official, the Architect/Engineer, and the Owner.
    c. The special inspector shall create and maintain a log of all discrepancies throughout the duration of the Project. This log shall include, but is not limited to, discrepancy date, description of discrepancy, drawing and/or detail reference, description of as-built condition, description of any remedial work performed, and status of discrepancy. This log shall be submitted to the Architect/Engineer on a periodic basis for review and comment. Upon completion of the Project, this log shall be submitted in its entirety as an attachment to the final signed report described below.
    d. The special inspector shall submit a final signed report stating whether the work requiring special inspection was, to the best of the inspector's knowledge, in conformance to the approved plans and specifications and the applicable workmanship provisions of the building code.

C. The Testing Laboratory shall provide inspections on the following items:

1. Reinforcing steel placement.
2. Concrete work.
3. Welding of reinforcing steel.
4. Bolts to be installed in concrete.
5. Bolts, anchors, and reinforcing bars installed in hardened concrete (post-installed anchors).
6. Inspection of structural steel, bolting, and welding material.
7. Welding of structural steel.
8. High-strength bolting.
9. Compacted earth fill.
10. Pier foundations.

D. Notification of Deficiencies in the Work: The Testing Laboratory shall notify the Architect, Engineer, and Contractor within 24 hours of discovery of observed irregularities and deficiencies of the Work and other conditions not in compliance with the requirements of the Contract Documents. Notification shall be by telephone or e-mail and then in writing.

E. Accounting: The Testing Laboratory shall be responsible for separating and billing costs attributed to the Owner and costs attributed to the Contractor.

F. Monitoring Product and Material Certifications: The Testing Laboratory shall be responsible for monitoring the submittals of product and material certifications from manufacturers and suppliers as specified in the Specifications and shall report to the Owner, Architect, and Engineer when those submittals are not made in a timely manner.

G. Limitations of Authority: The Testing Laboratory is not authorized to revoke, alter, relax, enlarge upon, or release any requirements of the Specifications or to approve or accept any portion of the work or to perform any duties of the General Contractor and his Subcontractors.

1.7 ADMINISTRATIVE REQUIREMENTS

A. Coordination:

1. The Testing Laboratory shall cooperate with the Architect, Engineer, and Contractor and provide qualified personnel promptly on notice.
2. The Contractor shall cooperate with Testing Laboratory personnel and provide access to the work and to manufacturers' operations.
3. Notification of Source Change: The Contractor shall be responsible for notifying the Owner, Architect, Engineer, and Testing Laboratory when the source of any material is changed after the original tests or inspections have been made.

B. Preinstallation Meetings: The Testing Laboratory shall attend preinstallation meetings with the Architect, Engineer, Contractor, and material suppliers as required to coordinate materials inspection and testing requirements with the planned construction schedule and shall participate in such meetings throughout the course of the project.

C. Scheduling:

1. Advance Notice: The Contractor shall be responsible for notifying the Testing Laboratory sufficiently in advance of operations to allow for assignment of personnel and scheduling of tests. Failure to sufficiently notify may result in additional costs incurred by the Testing Laboratory that may be back-charged to the Contractor by the Owner.

1.8 SUBMITTALS

A. Quality Control Reports:

1. Information on Reports: The Testing Laboratory shall submit copies of reports of inspections and tests promptly. The reports shall contain at least the following information:

a. Project name.
b. Date report issued.
c. Testing Laboratory name and address.
d. Name and signature of inspector/technician.
e. Date of inspection and/or sampling.
f. Date of test.
g. Identification of product and Specification section.
h. Location in the project.
i. Identification of inspection or test.

j. Record of weather conditions and temperature (if applicable).
k. Results of test regarding compliance with Contract Documents.

2. Copies: The Laboratory shall electronically distribute PDF copies of test and inspection reports to individuals and/or to project websites, as designated by the Owner or Architect.

B. Discrepancy Log: The Testing Laboratory shall create and maintain a log of all discrepancies throughout the duration of the project.

1. Information on Log: This log shall include, but is not limited to:

a. Discrepancy date.
b. Description of discrepancy.
c. Drawing and/or detail reference.
d. Description of as-built condition.
e. Description of any remedial work performed.
f. Status of discrepancy.

2. Submission Schedule: This log shall be submitted to the Architect/Engineer on a periodic basis for review and comment. Upon completion of the Project, this log shall be submitted in its entirety as an attachment to the final signed report described below under Certifications.

C. Certification: Upon completion of the job, the Laboratory shall furnish to the Owner, Architect, and Engineer of Record, a statement signed by a licensed professional engineer that, to the best of their knowledge, required tests and inspections were made in accordance with the requirements of the Contract Documents.

1.9 QUALITY ASSURANCE

A. Qualifications of Special Inspector: The special inspector shall be a qualified person who shall demonstrate competence, to the satisfaction of the Building Official, for inspection of the particular type of construction or operation being inspected. The Special Inspector shall meet the legal qualifications of the building code having jurisdiction.

B. Qualifications of Testing Laboratory:

1. The Testing Laboratory shall meet the basic requirements of ASTM E 329 and shall submit to the Owner, Architect, and Engineer evidence of current accreditation from the American Association for Laboratory Accreditation, the AASHTO Accreditation Program or the “NIST” National Voluntary Laboratory Accreditation Program.
2. The Testing Laboratory shall be an Approved Agency by the Building Official to perform Special Inspections and other tests and inspections as outlined in the applicable building code.
3. Tests and inspections shall be conducted in accordance with specified requirements, and if not specified, in accordance with the applicable standards of the American Society for Testing and Materials or other recognized and accepted authorities in the field.
4. Qualifications of Welding Inspectors

a. Inspectors performing visual weld inspection shall meet the requirements of AWS D1.1 Section 6.1.4. Inspectors shall have current certification as an AWS Certified Welding Inspector (CWI). Assistant inspectors, if any, shall be supervised by an Inspector and shall be qualified by training and experience to perform the specific functions to which they are assigned.

b. Inspectors performing nondestructive examinations of welds other than visual inspection (MT, PT, UT, and RT) shall meet the requirements of AWS D1.1, Section 6.14.6.

C. The Contractor shall not engage the same testing laboratory for construction services as the Owner has for quality assurance testing, unless agreed to by the Owner.

PART 2 - PRODUCTS (Not Used)

PART 3 - EXECUTION

3.1 SCOPE OF WORK

A. The work to be performed by the Testing Laboratory shall be as specified in this Section of the Specification and as determined in meetings with the Owner, Architect, and Engineer.

3.2 CONCRETE FORMING AND ACCESSORIES

A. Field Inspection:

1. Shallow Foundation Elements:

a. Verify element width, length, depth, and elevation.
b. Verify that forms are plumb and straight, braced against movement, and lubricated for removal.
c. Verify that carton forms, if any, are dry and neatly formed around piers.

2. Slabs-on-Grade:

a. Verify formwork at turndowns and slab edges is plumb and straight, braced against movement and lubricated for removal.

3. Columns and Walls:

a. Verify that forms are plumb and straight, braced against movement, lubricated for removal, and conform to approved shop drawings.
b. Verify proper dimensions and orientation.
c. Verify top of column elevation is set in form and that it is 1/2 inch below the future slab soffit.

4. In-Situ Concrete Strength Verification Prior to Form Stripping: The Testing Laboratory shall verify that the concrete has reached the required minimum strength before form removal by evaluating the specified tests.

3.3 CONCRETE REINFORCING

A. Quality Assurance:
1. Review the Welding Procedure Specification (WPS) submitted by the contractor for any reinforcing steel other than ASTM A 706 that is proposed to be welded for consistency with acceptable welding practices and AWS.

2. Review welder qualifications by certification or verify by retesting. Obtain welder certificates.

B. Field Testing: The following tests shall be completed by the Testing Laboratory:

C. Field Inspection: The scope of the work to be performed by the inspector on the jobsite shall be as follows:

1. Reinforcing Steel: The Testing Laboratory or designated Special Inspector shall inspect 100% of reinforcement before each concrete pour to verify the information noted below. Inspection reports shall be prepared and distributed in accordance with the local building code and as specified in this specification.

a. Primary and secondary longitudinal reinforcement has correct size and number in proper layers.
b. Longitudinal reinforcement has correct length and lap.
c. Ties and stirrups are of correct size, spacing, and number and have the proper termination hook geometry.
d. Unscheduled face reinforcement in beams are provided and are of correct size, number and spacing and have the proper end terminations.
e. Proper hooks are provided at bar ends as detailed.
f. Reinforcement is properly supported and braced to formwork to prevent movement during concrete placement.
g. Reinforcement has proper cover.
h. Sufficient spacing between reinforcement for concrete placement.
i. Dowel reinforcement is of proper size, at proper spacing, and has proper lap length and embedment length.
j. Welded wire reinforcement is composed of flat sheets, has proper wire gage and spacing, is properly supported, and is properly lapped.
k. Proper construction/control/expansion joint spacing and reinforcement.
l. Reinforcement around embedded items is placed according to details.
m. Welded reinforcement has been done according to AWS requirements.

3.4 CAST-IN-PLACE CONCRETE

A. Quality Assurance:

1. Concrete Mix Designs: The Testing Laboratory shall review the submitted mix designs for conformance to the specifications and for suitability for use in the project.
2. Preinstallation Meetings: The Testing Laboratory shall attend the preinstallation meetings as noted in Specification 03 30 00 “Cast-in-Place Concrete.”

B. Source Inspection:

C. Field Testing: The following tests shall be completed by the Testing Laboratory:

1. During Concrete Placement:

a. Record the amount of water added and note if it exceeds the amount allowed to be added shown in the approved mix design.
b. Mold concrete test cylinders as specified below in Paragraph 3.a.
c. Perform tests to determine slump, concrete temperature, unit weight, and air entrainment as specified below.
d. Record information for concrete test reports as specified below.

e. Pick up and transport to Laboratory cylinders cast the previous day.

2. After Concrete Placement:

a. Investigation of Low Strength Concrete Test Results:

1) Cost of Investigations for Low Strength Concrete: The Contractor shall reimburse the Owner for the costs of investigations of low strength concrete, as defined in Part I above.
2) Scope of Investigations: See Specification Section 03 30 00 “Cast-In-Place Concrete” for the investigations that may be required by the Engineer. The Testing Laboratory will conduct these investigations if required.

b. Post-Installed Anchors in Concrete:

c. Floor Flatness and Levelness Measuring: Perform tests as defined below.

d. Testing of Concrete Floor Slabs for Acceptability to Receive an Adhesive-Applied, Low-Permeable Floor Covering: Perform tests as defined below.

e. Testing of Non-Shrink Grout for Base Plates, Bearing Plates, and Precast Wall Panels:

1) Compressive Strength Tests: Compressive strength of grout shall be determined by testing grout cubes according to the requirements of ASTM C 109 - Modified. Test one set of three cubes at one day, and one set of three cubes at 28 days.
2) Frequency of Testing: One set of cubes (6 cubes) shall be made for every ten base plates and bearing plates or fraction thereof but not less than one set for each day's operation.

3. Standards for Concrete Tests:

a. Concrete Test Cylinders: Mold and test concrete cylinders as described below:

1) Cylinder Molding and Testing: Cylinders for strength tests shall be molded and Laboratory cured in accordance with ASTM C 31 and tested in accordance with ASTM C 39. Cylinders may be either 6” in diameter by 12” or 4” in diameter by 8”, however, the diameter of the cylinder shall be at least three times the nominal maximum size of the coarse aggregate in the mix tested. All of the cylinders for each class of concrete shall be of the same dimension for all sets of that class.
2) Field Samples: Field samples for strength tests shall be taken in accordance with ASTM C 172 **at the point of placement**.
3) Quantity of Cylinders: Each set of test cylinders shall consist of a minimum of four standard test cylinders. If concrete strength for form stripping is to be determined using field-cured cylinders, one additional cylinder per set will be required for formed slab and pan-formed beam floors for the purpose of evaluating the concrete strength at the time of form stripping. This cylinder shall be stored on the floor where form removal is to occur under the same exposure conditions as the floor concrete. The cylinder shall be cured under field conditions in accordance with ASTM C 31. Field-cured test cylinders shall be molded at the same time and from the same samples as laboratory-cured test specimens. The Contractor shall reimburse the Owner for the cost of making and testing these cylinders.

4) Frequency of Testing: A set of test cylinders shall be made according to the following minimum frequency guidelines:

   a) One set for each class of concrete taken not less than once a day.
   b) Piers, Straight Shaft Drilled Footings: One set for each 50 cubic yards or fraction thereof.
   c) Spread Footings: One set for each 50 cubic yards or fraction thereof.
   d) Floors: One set for each 150 cubic yards or fraction thereof but not less than one set for each 5,000 square foot of floor area.
   e) All Other Concrete: A minimum of one set for each 150 cubic yards or fraction thereof.
   f) No more than one set of cylinders at a time shall be made from any single truck.
   g) If the total volume of concrete is such that the frequency of testing as specified above would provide less than five strength tests for a given class of concrete, tests shall be made from at least five randomly selected batches or from each batch if fewer than five batches are used.
   h) The above frequencies assume that one batch plant will be used for each pour. If more than one batch plant is used, the frequencies cited above shall apply for each plant used.

5) The cylinders shall be numbered, dated, and the point of concrete placement in the building recorded.
6) For concrete specified on the drawings to reach the required strength at 28 days, break one cylinder of the set at seven days, two 6” by 12” cylinders or three 4” by 8” cylinders at 28 days, and keep one in reserve for testing at the Engineer’s direction.
7) Cylinder Storage Box: The Contractor shall be responsible for providing a protected concrete cylinder wooden storage box at a point on the job site mutually agreeable with the Testing Laboratory for the purpose of storing concrete cylinders until they are transported to the Laboratory. The box shall be constructed and equipped to maintain the environment specified for initial curing in ASTM C 31.
8) Transporting Cylinders: The Testing Laboratory shall be responsible for transporting the cylinders to the Laboratory in a protected environment such that no damage or ill effect will occur to the concrete cylinders including loss of moisture, freezing temperatures or jarring.
9) Information on Concrete Test Reports: The Testing Laboratory shall make and distribute concrete test reports after each job cylinder is broken. Such reports shall contain the following information:

   a) Truck number and ticket number.
   b) Concrete Batch Plant.
   c) Mix design number.
   d) Accurate location of pour in the structure.
   e) Strength requirement.
   f) Date cylinders made and broken.
   g) Technician making cylinders.
   h) Concrete temperature at placing.
   i) Air temperature at point of placement in the structure.
   j) Amount of water added to the truck at the batch plant and at the site and whether or not it exceeds the amount allowed by the mix design.
   k) Slump.
   l) Unit weight.
   m) Air content.

n) Cylinder compressive strengths with type of failure if concrete does not meet Specification requirements. Seven day breaks are to be flagged if they are less than 60% of the required 28 day strength. 28 day breaks are to be brought to the attention of the Architect and Engineer in writing if either cylinder fails to meet specification requirements.

b. Slump Tests: Slump Tests (ASTM C 143) shall be completed at the beginning of concrete placement for each batch plant and for each set of test cylinders made. The slump test shall be made from concrete taken from the end of the concrete truck chute. The concrete shall be considered acceptable if the slump is within the slump tolerance noted on the mix design submittal form for that class of concrete.

c. Air Entrainment: Air entrainment tests (ASTM C 231 or C 173, C 173 only for lightweight concrete) shall be made at the same time slump tests are made as cited above. Samples for air entrainment tests shall be taken **at the point of placement**.

d. Concrete Temperature: Concrete temperature at placement shall be measured (ASTM C 1064) at the same time slump tests are made as cited above.

e. Unit Weight Test: ASTM C 138.

4. Evaluation and Acceptance of Concrete:

a. Strength Test: A strength test shall be defined as the average strength of two six inch cylinder breaks or three four inch cylinder breaks from each set of cylinders tested at the time indicated above.

b. Acceptance Criteria: The strength level of an individual class of concrete shall be considered satisfactory if both of the following requirements are met:

1) The average of all sets of three consecutive strength tests equal or exceed the required f'c.
2) No individual strength test falls below the required f'c by more than the greater of 10% of f’c or 500 PSI.

c. If either of the above Acceptance Criteria requirements is not met, the Testing Laboratory shall immediately notify the Engineer by telephone. Steps shall immediately be taken to increase the average of subsequent strength tests.

D. Field Inspection: The scope of the work to be performed by the inspector on the jobsite shall be as follows:

1. Before Concrete Placement:

a. Inspect concrete formwork per Article 3.2.
b. Inspect concrete reinforcing per Article 3.3.
c. Inspect bolts and rods to be embedded in concrete for proper grade, size, length, and embedment.
d. For slabs-on-grade, verify that the moisture retarder is provided, is lapped properly, and is not torn or punctured.
e. Verify that there is no standing water in pour area and that all debris has been removed from the area and from the formwork.
f. Verify that openings and sleeves in slabs, walls or grade beams are correct size and location. Verify that the openings are shown on the structural drawings and notify the Engineer immediately of any openings in the field that are not shown on the drawings.

2. During Concrete Placement: Provide continuous monitoring to:

   a. Upon arrival of concrete, inspect the concrete to verify that the proper concrete mix number, type of concrete, concrete strength is being placed at the proper location. Verify that the mix meets the project specifications and is not over 90 minutes old at the time of placement. Report concrete not meeting the specified requirements and immediately notify the Contractor, Batch Plant Inspector, Architect, Engineer, and Owner.
   b. Inspect plastic concrete upon arrival at the jobsite to verify proper batching. Observe mix consistency and adding of water as required to achieve target slumps in mix designs. The responsibility for adding water to trucks at the job site shall rest only with the Contractor's designated representative. The Contractor is responsible that all concrete placed in the field is in conformance to the Contract Documents.
   c. Verify that the Contractor is following appropriate Hot Weather or Cold Weather concreting practices consistent with any extreme environmental conditions at the point of placement in the structure.
   d. Verify that concrete deposited is uniform and that vertical drop does not exceed six feet and is not permitted to drop freely over reinforcement causing segregation.
   e. Verify that the formwork has remained stable during the concreting operation.
   f. Verify that there are no cold joints.
   g. Verify that the concrete is properly vibrated.
   h. Inspect bolts embedded in concrete during concrete placement for verification that they have been properly installed to the specified embedment.
   i. Verify that the finishing of the concrete surface is done according to specifications.

   The Testing Laboratory shall report any irregularities that occur in the concrete at the job site or test results to the Contractor, Architect, Owner, and Engineer.

3. After Concrete Placement:

   a. Verify that the curing process is according to Specifications and that any curing compound used is applied in accordance with the manufacturer’s recommendations.
   b. Verify that sawcut control joints in slab-on-grades are cut within 12 hours of placement.
   c. Post-Installed Anchors in Concrete: Provide inspection of post-installed anchor installations at the frequency noted in the specifications and in accordance with the published, currently valid, Evaluation Service Report (ESR) for each anchor product. Post-installed anchors include anchors and reinforcing steel. Inspection of post-installed anchors shall include but not be limited to the following:

      1) Periodic Inspection: Verify initial installation of post-installed anchors in concrete for each individual installer with each individual anchor product in accordance with the requirements stated below for each type of anchor. Periodically inspect anchor installation after the initial verification.
      2) Continuous Inspection: Verify each installation of post-installed anchors in concrete in accordance with the requirements stated below for each type of anchor.
      3) All Post-Installed Anchors: Verify that the anchor is installed in accordance with manufacturer’s printed installation instructions as well as the following design requirements.

         a) Concrete type, concrete strength and concrete thickness are in accordance with design drawings.

b) Anchor manufacturer and product, including material, is in accordance with design drawings or approved substitution.
c) Anchor diameter, length and installed embedment depth.
d) Drill bit type and diameter.
e) Anchor edge distance and spacing.
f) Hole diameter and depth.
g) Hole cleaning procedure and cleanliness.
h) Anchor maximum tightening torque.

4) Adhesive Anchors: In addition to the requirements for All Post-Installed Anchors, verify adhesive identification and expiration date.

a) The installation of all adhesive anchors shall be continuously inspected when anchors are subject to sustained tension loads, such as anchors for shelf angles, or when anchors are installed in an upwardly inclined condition.

E. Causes for Rejection of Concrete: The Contractor shall reject concrete delivered to the site for any of the following reasons:

1. Wrong class of concrete (incorrect mix design number).
2. Environmental Conditions: Environmental condition limits shall be as follows unless appropriate provisions in concreting practices have been made for cold or hot weather:

a. Cold Weather: Air temperature must be 40°F and rising or the average daily temperature cannot have been lower than 40°F for 3 consecutive days unless the temperature rose above 50°F for at least one-half of any of those 24 hour periods.
b. Hot Weather: Environmental conditions must be such that cause an evaporation rate from the concrete surface of 0.2 lb./sq. ft./hr. or less as determined by Figure 2.1.5 in ACI 305R-91.

Concrete may be placed at other environmental condition ranges only with approval of the job inspector for the Testing Laboratory or other duly appointed representative.
3. Concrete with temperatures exceeding 95°F shall not be placed in the structure.
4. Air contents outside the limits specified in the mix designs.
5. Slumps outside the limits specified.
6. Excessive Age: Concrete shall be discharged within 90 minutes of plant departure or before it begins to set if sooner than 90 minutes unless approved by the Laboratory job inspector or other duly appointed representative.

F. Concrete Batch Trip Tickets: Concrete batch trip tickets shall be collected and retained by the Contractor. Compressive strength, slump, air, and temperature tests shall be identified by reference to a particular trip ticket. Tickets shall contain the information specified in ASTM C 94. Each ticket shall also show the amount of water that may be added in the field for the entire batch that will not exceed the specified water cement ratio for the design mix. The Contractor and Testing Laboratory shall immediately notify the Architect/Engineer and each other of tickets not meeting the criteria specified.

3.5 STRUCTURAL STEEL

A. Scope of Work:

1. Contract Obligations:

a. Owner Responsibility: The Owner shall pay for initial shop and field inspections and tests as required during the fabrication and erection of the structural steel.
b. Testing Laboratory Responsibility: The inspection by the Testing Laboratory of the Fabricator's work shall be in sequence, timely, and performed in such a manner so that corrections can be made without delaying the progress of the work. Inspections shall be performed by qualified technicians with a minimum of two years of experience in structural steel testing and inspection. Refer to Paragraph 1.9B.4 for special requirements for welding inspectors. The Testing Laboratory shall provide test reports of inspections. All test reports shall indicate types and locations of defects found during inspection, the measures required and performed to correct such defects, statements of final approval of welding and bolting of shop and field connections, and other fabrication and erection data pertinent to the safe and proper welding and bolting of shop and field connections. Weld inspection reports shall be signed by an inspector with current certification as an AWS Certified Welding Inspector (CWI). In addition to the parties listed in this Specification the Fabricator and Erector shall receive copies of the test reports.
c. Rejection of Material or Workmanship: The Owner, Architect, Engineer, and Testing Laboratory reserve the right to reject any material or workmanship not in conformance with the Contract Documents at any time during the progress of the work. However, this provision does not allow waiving the obligation for timely, in sequence inspections.

B. Quality Assurance:

1. Verify the fabrication shop's certification from AISC.
2. Verify that the fabricator's fabrication and quality control procedures provide a sound basis for inspection control of workmanship and of the ability to conform to construction documents and industry standards. Review the procedures for completeness and adequacy relative to code requirements for the fabricator's finished product.
3. Review field welder qualifications by certification or verify by retesting. Obtain welder certificates.

C. Field Testing: The Testing Laboratory shall provide the following tests in the field:

1. Test welds completed in the field according to Paragraph F "Weld Testing:" below.
2. Test bolted connections completed in the field according to Paragraph I "High-Strength Bolt Testing."
3. Perform bend tests on completed shear connectors attached to beams as required according to procedures outlined in AWS D1.1. In addition, perform field bend tests on an additional 2% of completed shear connectors on each beam but not less than one connector per beam.
4. Testing of Non-Shrink Grout for Base Plates and Bearing Plates:

a. Compressive Strength Tests: Compressive strength of grout shall be determined by testing grout cubes according to the requirements of ASTM C 109 - Modified. Test one set of three cubes at one day, and one set of three cubes at 28 days.
b. Frequency of Testing: One set of cubes (6 cubes) shall be made for every ten base plates and bearing plates or fraction thereof but not less than one set for each day's operation. One set of cubes shall be made for each day's operation of grouting wall panels.

D. Field Inspection: The Testing Laboratory shall provide the following inspections in the field:

1. Inspect galvanized HSS and other cold-worked structural steel members for cracking or other damage resulting from galvanizing process. Endeavor to complete inspections

prior to erection of these members. Immediately notify Contractor and Architect/Engineer of any irregularities discovered.

2. Provide continuous or periodic monitoring of field welding as described below in Paragraph E "Weld Inspection and Process Monitoring."
3. Provide continuous or periodic monitoring of field bolting as described below in Paragraph G "High-Strength Bolt Inspection and Process Monitoring" of high-strength bolt installation in pre-tensioned or slip-critical joints using turn-of-the-nut without match-marking or calibrated wrench method of bolt installation.
4. Inspect welded or bolted connections that were completed, but not inspected, in the shop. Perform inspections according to Paragraph E "Weld Inspection and Process Monitoring" and/or Paragraph G "High-Strength Bolt Inspection and Process Monitoring" as appropriate.
5. Obtain the planned erection procedure, and review with the Erector's supervisory personnel.
6. Check the installation of base plates for proper leveling, grout type, and grout application.
7. Check structural steel as received in the field for possible shipping damage, workmanship, and identification marking to conform to AISC 360 for structural steel and specified ASTM standards for other steel.
8. Verify that surveys are occurring as specified to check plumbness and frame alignment as erection progresses. Review the submitted survey report.
9. Periodically inspect the steel frame for such items as bracing and stiffening details, member locations, and joint details at each connection for compliance with approved construction documents.
10. Inspect 100% of the column compression and base joints for verification that gaps in contact bearing do not exceed 1/16 inch. Gaps greater than 1/16 inch but less than 1/4 inch shall be reported to the Owner and Engineer for assessment. All gaps greater than 1/4 inch shall be shimmed according to Specification 05 12 00 "Structural Steel Framing."
11. Endeavor to guard the Owner against the Contractor cutting, grinding, reaming, or making any other field modification to structural steel without the prior approval of the Engineer. Report any noted unauthorized modifications to the Owner and Engineer.

E. Weld Inspection and Process Monitoring: The Testing Laboratory shall make the following inspections of the welds and welding processes. Welds performed in the fabricating shop may be inspected in the field unless continuous monitoring of the welding process is herein specified or if access in the field due to other work or shop finishes makes field inspection impractical:

1. Approve Welding Procedure Specifications submitted by the Contractor. Approve any changes submitted by the Contractor to any WPS that has already been approved. Obtain the Welding Procedure Qualification Record (WPQR) for each successful WPS qualification.
2. Periodically verify welding electrodes to be used and other welding consumables as the job progresses.
3. Periodically observe joint preparation, assembly practice, welding techniques including preheating and sequence, and the performance of welders with sufficient frequency to assure compliance with code and contract document requirements. Check preheating to assure conformance with AWS D1.1, Section 5.6. Verify procedure for control of distortion and shrinkage stresses.
4. Periodically provide visual inspection of the root pass of partial and complete joint penetration welds.
5. Visually inspect 100% of welds for proper size, length, location, and weld quality in accordance with AWS D1.1 requirements. Unless specifically noted otherwise, all welding shall be considered statically loaded non-tubular connections.
6. In addition to the inspections above, perform the following:

    a. Continuously monitor and observe joint preparation, assembly practice, welding techniques including preheating and sequence, and the performance of welders for

100% of complete and partial joint penetration welds, plug and slot welds, multiple-pass fillet welds, and single-pass fillet welds greater than 5/16 inch. Check preheating to assure conformance with AWS D1.1, Section 5.6. Verify procedure for control of distortion and shrinkage stresses.

b. Periodically monitor welding of single-pass fillet welds that are less than or equal to 5/16 inch.

F. Weld Testing:

1. Perform nondestructive examination services using a qualified technician with the necessary equipment to perform the following:

   a. Nondestructive examination conducted in accordance with the specific requirements for the item being examined including radiographic (RT), ultrasonic (UT), magnetic particle (MT), or dye-penetrant inspection (PT). Nondestructive inspection procedures shall conform to AWS D1.1.
   b. Interpret, record, and report results of the nondestructive tests.
   c. Mark for repair, any area not meeting Specification requirements. Correction of rejected welds shall be made in accordance with AWS D1.1.
   d. Re-examine repair areas and interpret, record, and report the results of examinations of repair welds.
   e. Verify that quality of welds meet the requirements of AWS D1.1.

2. Fillet Welds: Provide the following:

   a. MT test a minimum of 10% of the length of each fillet weld exceeding 5/16".

3. Partial Joint Penetration (PJP) Welds, including Flare-Bevel Groove Welds: Provide the following:

   a. MT test a minimum of 25% of the length of each PJP weld exceeding 5/16" effective throat.
   b. Periodic MT testing of representative PJP welds 5/16” and less but need not exceed 10% of all such welds, except as required for high rejection rates as indicated in the following paragraph.
   c. Increase MT testing rate for welders having a high rejection rate as required to ensure acceptable welds.

4. Complete Joint Penetration (CJP) Welds: Provide the following:

   a. All CJP welds exceeding 5/16" thickness shall be 100% UT tested per AWS D1.1 Clause 6 Part F. The Testing Laboratory shall review the CJP joints to determine where geometry or accessibility precludes the use of standard scanning patterns per AWS D1.1 Clause 6 Part F. At these locations the testing laboratory shall develop and submit for approval a written testing procedure in accordance with AWS D1.1 Annex S.
   b. Periodic MT testing of representative CJP welds 5/16” and less not to exceed 10% of all such welds, except as required for high rejection rates as indicated in the following paragraph.
   c. Increase MT testing rate for welders having a high rejection rate as required to ensure acceptable welds.

5. Acceptance Criteria:

   a. Visual, MT, PT shall be per AWS D1.1 Table 6.1.

b. UT testing shall be per AWS D1.1 6.13.1 and Table 6.2.

6. Welds of Anchors to Embedded Plates:

   a. Headed Studs: Perform field bend tests according to AWS D1.1 on 2% of the studs welded to plates, but not less than one stud per plate.
   b. Deformed Bar Anchors: Perform MT testing on 10% of deformed bar anchors larger than #5 bar.

7. The costs of repairing defective welds and the costs of retesting by the Testing Laboratory providing services for the Owner shall be borne by the Contractor. If removal of a backing strip is required by the Testing Laboratory to investigate a suspected weld defect, such cost shall be borne by the Contractor.

G. High-Strength Bolt Inspection and Process Monitoring: The Testing Laboratory shall perform the following inspections for connections joined with high-strength bolts. Bolting performed in the shop may be inspected in the field unless continuous monitoring of the bolting operation is specified herein:

1. Observe preinstallation verification testing of the pretensioning method to be used in accordance with the requirements of the “Specification for Structural Joints Using High-Strength Bolts”.
2. Check daily the calibration of impact wrenches used in field bolted connections.
3. Inspect bolt installation for 100% of high strength bolted connections according to inspection procedures outlined in the "Specification for Structural Joints Using High-Strength Bolts".
4. Monitoring of Bolting Installation:

   a. Continuous Monitoring: The Testing Laboratory shall be continuously present and monitor the bolting installation for compliance with the selected procedure for installation as specified in the “Specification for Structural Joints Using High-Strength Bolts” for joints using high-strength bolts that are designated on the plans as Pretensioned (PT) or Slip-Critical (SC) type joints and that are being installed using the calibrated wrench method or the turn-of-nut without matchmarking method of installation.
   b. Periodic Monitoring: All other joint types and bolt installation methods shall be monitored on a periodic basis.

H. High-Strength Bolt Testing: The Testing Laboratory shall perform the following tests for connections joined with high-strength bolts:

1. Perform Arbitration Testing according to procedures outlined in the "Specification for Structural Joints using High-Strength Bolts" when a disagreement exists between the Testing Laboratory and the Fabricator as to the minimum tension of installed bolts that have been inspected according to paragraph below.

3.6 STEEL DECKING

A. Field Inspection:

1. Check steel deck as received in the field for possible shipping damage, workmanship, and identification marking to conform to specified ASTM standards for steel deck.
2. Periodically monitor the method of attaching the steel floor and roof decking to the structural frame.

3. Visually inspect 100% of the welding or other attachment method of steel deck to the structure and at sidelaps.

3.7 METAL BUILDING SYSTEMS

A. Refer to approved metal building shop drawings for additional requirements related to inspection and testing of metal building components (built-up columns and beams, purlins, girts and metal deck).

3.8 EARTHWORK

A. Quality Assurance:

1. Welder Qualifications: Verify welder qualifications either by certification and/or by retesting. Obtain welder certificates.

B. Field Testing:

1. Compacted Fill:

a. Verification of Fill Material: Perform classification and testing to verify that the fill material to be used complies with the project specifications.
b. Field Density Testing: Perform field density testing as described below:

1) Field density tests shall be run according to ASTM D 2937 or ASTM D 6938 as applicable.
2) Acceptance Criteria: The results of field density tests by the Laboratory will be considered satisfactory if the average of any three consecutive tests has a value not less than the required density with no single test falling more than 2 percent below the required density and the moisture content conforms to the requirements of the specification.
3) Test Frequency for Paved Areas and Building Slab Subgrade:

a) Make at least one field density test of the natural subgrade for every 2500 square feet of paved area or building slab but in no case less than three tests.
b) In each compacted fill layer or lift, make one field density test for every 2500 square feet of building slab or paved area but in no case less than three tests.

4) Test Frequency for Foundation Wall Backfill: Make at least one field density test for each 200 lineal feet of wall with a minimum of 4 tests for the basement walls around the perimeter of each building and a minimum of one test for every other type of foundation wall on the site. Tests shall be performed in random lifts along each wall.

c. Report Copies: Moisture-density curves and results of field density tests shall be submitted to the parties specified earlier in this section.
d. Additional Testing: If reports by the Laboratory indicate field densities lower than specified, additional tests will be run by the Laboratory with at least the frequencies scheduled above on recompacted fill and/or natural subgrade. The Testing Laboratory shall notify the Contractor on a timely basis for any required retesting

so as not to delay the work. The costs of such tests shall be liable to the Owner for repayment by the Contractor.

2. Drilled Piers:

a. Concrete Cylinders: Make and test concrete cylinders as specified for Cast-in-Place Concrete.

3. Spread (Excavated) Footings

a. Concrete Cylinders: Make and test concrete cylinders as specified for Cast-in-Place Concrete.

C. Field Inspection by the Testing Laboratory:

1. The Testing Laboratory shall provide inspection of materials used in foundation elements as described below.

2. Compacted Fill:

a. Subgrade below Compacted Fill: Observe and verify that the subgrade below compacted fill has been properly prepared before compact fill construction begins.
b. During placement and compaction of fill, determine that the material being used and the maximum lift thickness comply with the specifications.

3. Drilled Piers:

a. Reinforcing Steel: Inspect reinforcing steel for proper number and size of bars and confirm dowel or anchor rod placement into top of pier.

4. Spread (Excavated) Footings:

a. Reinforcing Steel: Inspect reinforcing steel size, number of bars, and placement and confirm dowel or anchor rod placement into footing.

D. Foundation Inspection by the Geotechnical Engineer: The Geotechnical Engineer of Record shall provide inspection service for the following items before and during foundation installation as appropriate for the foundation type. The Geotechnical Engineer shall submit written field inspection reports promptly after inspection to the parties listed above and report his findings after each inspection by telephone or e-mail to the Engineer.

1. Spread (Excavated) Footing:

a. Subgrade: Verify that foundation bearing conditions are consistent with soil report tests and that the footing is being installed in the proper soil strata at the proper elevation. Make recommendations regarding adjustment to subgrade or bearing elevation if subgrade is not adequate to support footing.

2. Drilled Piers:

a. Bearing Elevation: Observe that piers are founded in proper bearing strata as defined in the Geotechnical Report and that bottom of hole is clean and properly formed. Recommend appropriate action if specified bearing elevation does not provide proper strength.
b. Shaft Sizes: Verify that the shaft is within specified tolerances.

c. Shaft Stability: Observe the shaft sides as drilling proceeds and recommend appropriate action if sloughing becomes excessive.
d. Concrete Quantities: Record quantity of concrete placed in each pier and compare against theoretical quantity required. Report discrepancies to Engineer.
e. Placement Method: Observe that piers are placed by approved methods as defined in the Geotechnical Report and in the Specifications. Confirm that casings are being used as recommended in the Geotechnical Report. Confirm that concrete is not being contaminated by soil encroachment into pier.
f. Report: For each drilled shaft installed, prepare and submit a report indicating the following information:

1) Name of the Project.
2) Name of the drilling contractor
3) Name of the field superintendent.
4) Pier number and location.
5) Pier shaft diameter.
6) Bottom elevation.
7) Top elevation.
8) Pier length.
9) Theoretical volume of concrete in pier.
10) Estimate of actual volume of concrete placed.
11) Reinforcing steel size and depth actually placed.
12) Drilling start and finish time.
13) Concreting start and finish time.
14) Variation from specified tolerances including surveyed location and plumbness.
15) Construction method (dry method, casing method, or slurry displacement method).
16) Groundwater conditions (rate of water infiltration and depth of water in hole prior to concreting for dry piers; water elevation in hole for wet piers).
17) Elevation of top and bottom of any casing left in place.
18) Description of temporary or permanent casing (including purpose, diameter, wall thickness and length).
19) Description and elevation of any obstructions encountered and whether removal was obtained
20) Description of pier bottom including amount and extent of loose material.
21) Method of concrete placement.
22) Any difficulties encountered in drilling or concreting operations.
23) Any deviations from specifications.

The report shall be signed by a licensed engineer in the state where the project is located.

END OF SECTION 01 45 29

SECTION 23 09 23 - DIRECT DIGITAL CONTROL SYSTEMS FOR HVAC

PART 1 - GENERAL

1.1 PRODUCTS FURNISHED BUT NOT INSTALLED UNDER THIS SECTION

A. Heating piping:
   1. Control valves
   2. Flow switches
   3. Pressure and temperature sensor wells & sockets
   4. Temp sensor wells and sockets

B. Duct accessories

C. Airflow stations
   1. BAS control dampers
   2. Terminal unit controls

1.2 PRODUCTS NOT FURNISHED OR INSTALLED BUT INTEGRATED WITH THE WORK OF THIS SECTION

A. Communications with Third Party Equipment:
   1. Any additional integral control systems included with the products integrated with the work of this section shall be furnished with a BACnet interface for integration into the Direct Digital Control System described in this section (reference sequence of operations and points list for specifics). Those systems include:
      a. Switchgear

1.3 RELATED SECTIONS

A. The General Conditions of the Contract, Supplementary Conditions, and General Requirements are part of this specification and shall be used in conjunction with this section as part of the contract documents.

B. The following sections constitute related work:
   1. Section 00700 - General Conditions
   2. Section 02600 - Submittal Requirements
   3. Section 230500 - Basic Mechanical Materials and Methods
   4. Section 230593 - Testing, Adjusting, and Balancing
   5. Section 260500 - Basic Electrical Materials and Methods
   6. Section 260519 - Low-Voltage Electrical Power Conductors and Cables

1.4 DESCRIPTION

A. General: The control system shall consist of a high-speed, peer-to-peer network of DDC controllers and a web-based operator interface. Depict each mechanical system and building floor plan by a point-and-click graphics. A web server with a network interface card shall gather data from this system and generate web pages accessible through a conventional web browser on each PC connected to the network. Operators shall be able to perform all normal operator functions through the web browser interface. If individual software seat licenses or keys are required provide a minimum of four (4) additional licenses to accommodate multiple Owner operators.

B. If manufacturer offers a web-based BAS platform, the installing contractor shall provide the new web-based software and software updates required for this project. Additionally, the installing contractor shall provide all computer related components (BAS web server – reference specifi-

cations for hardware requirements) for the new software platform to function in a peer-to-peer environment.

C. The system shall directly control HVAC equipment as specified in Sequences of Operation. Each zone controller shall provide occupied and unoccupied modes of operation by individual zone. Furnish energy conservation features such as optimal start and stop, night setback, request-based logic, and demand level adjustment of setpoints.

D. System shall use the BACnet protocol for communication to the operator workstation or web server and for communication between control modules. Schedules, setpoints, trends, and alarms specified in Section 230993 (Sequences of Operation) shall be BACnet objects.

1.5 APPROVED CONTROL SYSTEMS

A. The following are approved control system suppliers, manufacturers, and product lines:
1. Automated Logic ~~Installed by UES~~
2. ***Climatech***
3. ***Johnson Controls Inc.***
4. ***Siemens***

1.6 QUALITY ASSURANCE

A. Installer and Manufacturer Qualifications
1. Installer shall have an established working relationship with Control System Manufacturer for a period of ten (10) years or greater. If the distributorship has not had duration of more than ten (10) years, the contractor will not be approved without the written approval prior to bid date (no exceptions).
2. Installer shall have successfully completed Control System Manufacturer's control system training. Upon request, Installer shall present record of completed training including course outlines.

1.7 CODES AND STANDARDS

A. Work, materials, and equipment shall comply with the most restrictive of local, state, and federal authorities' codes and ordinances or these plans and specifications. As a minimum, the installation shall comply with current editions in effect 30 days prior to receipt of bids of the following codes:
1. National Electrical Code (NEC), 2014 Edition
2. International Building Code (IBC), 2012 Edition with Harris County amendments
3. International Mechanical Code (IMC), 2012 Edition
4. ASHRAE/ANSI 135-2016: Data Communication Protocol for Building Automation and Control Systems (BACNET)

1.8 SYSTEM PERFORMANCE

A. Performance Standards. System shall conform to the following minimum standards over network connections. Systems shall be tested using manufacturer's recommended hardware and software for operator workstation (server and browser for web-based systems).
1. Graphic Display. A graphic with 20 dynamic points shall display with current data within 10 sec.
2. Graphic Refresh. A graphic with 20 dynamic points shall update with current data within 8 sec. and shall automatically refresh every 15 sec.
3. Configuration and Tuning Screens. Screens used for configuring, calibrating, or tuning points, PID loops, and similar control logic shall automatically refresh within 6 sec.

4. Object Command. Devices shall react to command of a binary object within 2 sec. Devices shall begin reacting to command of an analog object within 2 sec.
5. Alarm Response Time. An object that goes into alarm shall be annunciated at the workstation within 15 sec.
6. Program Execution Frequency. Custom and standard applications shall be capable of running as often as once every 5 sec. Select execution times consistent with the mechanical process under control.
7. Performance. Programmable controllers shall be able to completely execute DDC PID control loops at a frequency adjustable down to once per sec. Select execution times consistent with the mechanical process under control.
8. Multiple Alarm Annunciation. Each workstation on the network shall receive alarms within 5 sec of other workstations.
9. Reporting Accuracy. System shall report values with minimum end-to-end accuracy listed in Table 1.

Table 1
Reporting Accuracy

Measured Variable	Reported Accuracy
Space Temperature	±0.5ºC (±1ºF)
Ducted Air	±0.5ºC (±1ºF)
Outside Air	±1.0ºC (±2ºF)
Dew Point	±1.5ºC (±3ºF)
Water Temperature	±0.5ºC (±1ºF)
Delta-T	±0.15ºC (±0.25ºF)
Relative Humidity	±5% RH
Water Flow	±2% of full scale
Airflow (terminal)	±10% of full scale (see Note 1)
Airflow (measuring stations)	±5% of full scale
Airflow (pressurized spaces)	±3% of full scale
Air Pressure (ducts)	±25 Pa (±0.1 in. w.g.)
Air Pressure (space)	±3 Pa (±0.01 in. w.g.)
Water Pressure	±2% of full scale (see Note 2)
Electrical (A, V, W, Power Factor)	±1% of reading (see Note 3)
Carbon Monoxide (CO)	±5% of reading
Carbon Dioxide (CO_2)	±50 ppm

Note 1: 10% - 100% of scale
Note 2: For both absolute and differential pressure
Note 3: Not including utility-supplied meters

B. Control Stability and Accuracy. Control loops shall maintain measured variable at set point within tolerances listed in Table 2.

Controlled Variable	Control Accuracy	Range of Medium
Air Pressure	±50 Pa (±0.2 in. w.g.)	0-1.5 kPa (0-6 in. w.g.)

Controlled Variable	Control Accuracy	Range of Medium
	±3 Pa (±0.01 in. w.g.)	-25 to 25 Pa (-0.1 to 0.1 in. w.g.)
Airflow	±10% of full scale	
Space Temperature	±1.0ºC (±2.0ºF)	
Duct Temperature	±1.5ºC (±3ºF)	
Humidity	±5% RH	
Fluid Pressure	±10 kPa (±1.5 psi) ±250 Pa (±1.0 in. w.g.)	MPa (1-150 psi) 0-12.5 kPa (0-50 in. w.g.) differential

1.9 SUBMITTALS

A. Product Requirements: Provide six copies of shop drawings and other submittals on hardware, software, and equipment to be installed or furnished. Begin no work until submittals have been approved for conformity with design intent. Provide drawings as AutoCAD 2006 and 8 prints of each drawing on 8 ½" x 11" paper. When manufacturer's cutsheets apply to a product series rather than a specific product, clearly indicate applicable data by highlighting or by other means. Clearly reference covered specification and drawing on each submittal. 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. Provide submittals on the following:

1. Direct Digital Control System Hardware
   a. Complete bill of materials indicating quantity, manufacturer, model number, and relevant technical data of equipment to be used.
   b. Manufacturer's description and technical data such as performance curves, product specifications, and installation and maintenance instructions for items listed below and for relevant items not listed below:
      1) Direct digital controllers (controller panels)
      2) Transducers and transmitters
      3) Sensors (include accuracy data)
      4) Actuators
      5) Valves
      6) Relays and switches
      7) Control panels
      8) Power supplies
      9) Batteries
      10) Operator interface equipment
      11) Wiring
   c. Wiring diagrams and layouts for each control panel. Show termination numbers.
   d. Floor plan schematic diagrams indicating field sensor and controller locations.
   e. Riser diagrams showing control network layout, communication protocol, and wire types.
2. Central System Hardware and Software
   a. Complete bill of material indicating quantity, manufacturer, model number, and relevant technical data of equipment used.
   b. Manufacturer's description and technical data such as product specifications and installation and maintenance instructions for items listed below and for relevant items furnished under this contract not listed below:
      1) Central Processing Unit (CPU) or web server
      2) Monitors
      3) Keyboards

4) Power supplies
5) Battery backups
6) Interface equipment between CPU or server and control panels
7) Operating System software
8) Operator interface software
9) Color graphic software
10) Third-party software

c. Schematic diagrams of control, communication, and power wiring for central system installation. Show interface wiring to control system.
d. Network riser diagrams of wiring between central control unit and control panels.

3. Controlled Systems
   a. Schematic diagram of each controlled system. Label control points with point names. Graphically show locations of control elements.
   b. Schematic wiring diagram of each controlled system. Label control elements and terminals. Where a control element is also shown on control system schematic, use the same name.
   c. Instrumentation list (Bill of Materials) for each controlled system. List each control system element in a table. Show element name, type of device, manufacturer, model number, and product data sheet number.
   d. Complete description of control system operation including sequences of operation. Include and reference schematic diagram of controlled system. List I/O points and software points specified in Section 230993 Appendix A. Indicate alarmed and trended points.
4. Description of process, report formats, and checklists to be used in Section 230993 Article 3.15 (Control System Demonstration and Acceptance).

B. Schedules
   1. Within two (2) months of contract award, provide schedule of work indicating:
      a. Intended sequence of work items
      b. Start date of each work item
      c. Duration of each work item
      d. Planned delivery dates for ordered material and equipment and expected lead times
      e. Milestones indicating possible restraints on work by other trades or situations
   2. Monthly written status reports indicating work completed and revisions to expected delivery dates. Include updated schedule of work.

C. Project Record Documents. Submit 8 copies of record (as-built) documents upon completion of installation for approval prior to final completion. Submittal shall consist of:
   1. Project Record Drawings. As-built versions of submittal shop drawings provided as AutoCAD 2016 and six (6) prints of each drawing on 11" x 17" paper.
   2. Testing and Commissioning Reports and Checklists. Completed versions of reports, checklists, and trend logs used to meet requirements of Section 230993 Article 3.15 (Control System Demonstration and Acceptance).
   3. Operation and Maintenance (O&M) Manual. Printed, electronic, or online help documentation of the following:
      a. As-built versions of submittal product data.
      b. Names, addresses, and telephone numbers of installing contractors and service representatives for equipment and control systems.
      c. 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.
      d. 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.

e. 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.
f. Documentation of programs created using custom programming language including setpoints, tuning parameters, and object database. Electronic copies of programs shall meet this requirement if control logic, setpoints, tuning parameters, and objects can be viewed using furnished programming tools.
g. Graphic files, programs, and database on magnetic or optical media.
h. List of recommended spare parts with part numbers and suppliers.
i. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
j. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation or web server software, and graphics software.
k. Licenses, guarantees, and warranty documents for equipment and systems.
l. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.

D. Online As-builts – Contractor shall provide digital replications of as-builds that shall be accessible from equipment graphic locations from each piece of mechanical or electrical equipment controlled or monitored by the BAS.
1. Module Drawing.
a. Provide an electronic wiring diagram of each control module (as shown in submittal documentation). Diagram shall display wiring schematic and terminations to end devices.
b. Diagram shall display each input and output terminals and label those that are used for the control application.
c. Dynamic live data shall be displayed for each control point.
d. Diagram shall display module type/name and network address.
e. The module drawing shall be a separate graphic that is selectable at the applicable location for the control program.
2. Equipment Schematic.
a. Provide an electronic equipment schematic for each piece of mechanical equipment. In the event there are multiple quantities of a specific piece of mechanical equipment (i.e. variable volume box) the electronic schematic shall be viewable from each of these instances.
b. The schematic shall display all mechanical equipment characterizes including fans, dampers, valves, sensors and other applicable control devices.
c. The schematic shall show wiring terminations to each control device as shown in the submittal and as-build documentation.
d. Control devices shall be labeled by a symbol that can easily be identified in a bill of material that is shown on this graphic. The bill of material shall show the device symbol, description, manufacture and part number.
3. Sequences of Operation.
a. The sequence of operation shall be viewable for each piece of mechanical equipment and be in a text format as shown in the as built documentation.
b. The sequence of operation shall be selectable at the applicable location for the control program.
4. Bill of Material.
a. Provide a bill of material that indicates specific manufacture, part number, part description and quantity of each device for all system components.

E. Electronic Parts System – Contractor shall offer an electronic parts purchasing system. This system shall be accessed via a website with use of a user name and password. With use of

the electronic bill of material incorporated with the BAS the owner shall be able to identify and order needed parts for either inventory or replacement. This system shall provide owner the flexibility to identify past ordered products, check PO/order history and track open orders. Products availability shall include all DDC components installed for this project. The website shall have product cutsheets and installation information for each product available in a PDF format.

F. Training : The contractor shall provide free training for the life time of the system to owner personnel in a laboratory classroom environment. The Contractor shall provide training to owner personnel in a laboratory classroom environment. Each student shall be provided with a dedicated computer workstation utilizing a simulated BAS software platform that is installed for this project. The instructors shall have CEU accreditation for all training courses offered. Provide documentation for this requirement in the initial BAS submittal. If Contractor does not have CEU instructor or offer these courses locally include cost for tuition, travel and boarding to send students to manufacturer training facility. The owner shall not incur any additional cost for training classes as listed below for the first 3 years. The following training courses shall be conducted following substantial completion:
   1. Operator Overview – Consists of general system navigation, scheduling functions, setpoint modifications and parameter adjustments.
   2. Advanced Topics Overview – Detailed analysis of trend setup/configuration, trend historian, alarm setup, alarm actions (email, printing, etc.), point renaming, and detailed analysis of equipment parameters.
   3. Program/Logic Manipulation – Modify system programs as needed for additions and modifications.
   4. Graphic Manipulation – Modify system graphics as needed for additions and modifications.
   5. Hardware Troubleshooting – Classroom setup shall have HVAC mock-up systems. Operators shall be able to interact with this live system through the BAS utilized for this project. Class will provide students the ability to identify and repair common problems regularly encountered.
   6. Software Troubleshooting - Classroom setup shall have HVAC mock-up systems. Operators shall be able to interact with this live system through the BAS utilized for this project. Class will provide students the ability to identify and repair common issues that can be utilized via software modifications.
   7. Central Plant Operation – At a minimum the instructor shall thoroughly explain different types of central plant equipment and proper system modifications that can be made to enhance system performance and energy savings.
   8. HVAC System Training – Objective of this class is to provide basic HVAC system knowledge of various types of systems including types of air side distribution and water side distribution. Topics such as thermodynamics, psychometrics, de-humidification, and demand control ventilation shall be thoroughly explained.

1.10 WARRANTY

A. Warrant work as follows:
   1. Warrant materials for specified control system and peripheral control devices free from defects for a period of 1 year after final acceptance. Warrant all labor for a period of 1 year after final acceptance. Control system failures during warranty period shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner. Respond during normal business hours within 24 hours of Owner's warranty service request. Additionally contractor shall offer 24/7 after-hours support to include alarm monitoring and associated dispatch service.
   2. Provide graphic modifications for a period of 3 years from date of substantial completion. This shall include room number and equipment modifications as requested by the owner.
   3. Provide telephone support free to the owner for a period of 3 years after substantial completion. This service includes technical support for all BAS equipment and shall include

troubleshooting and problem resolution via the telephone or web services. Service shall be available during the hours of 7am to 5pm Monday – Friday.

4. Work shall have a single warranty date, even if Owner receives beneficial use due to early system start-up. If specified work is split into multiple contracts or a multi-phase contract, each contract or phase shall have a separate warranty start date and period.
5. Re-commissioning Procedure - After 9 months from the date of substantial completion the contractor shall confirm the equipment is still operating as designed by performing a recommissioning procedure. This procedure shall be conducted with an owner's representative present for all tests. All components shall be documented and signed by the BAS Project Manager then delivered to owner and engineer for record purposes. The recommissioning procedure shall include the following verifications:
    a. Temperature calibrations – Confirm the calibration of all space and discharge temperature sensors utilized for control purposes.
    b. Actuator operation verification – Confirm the operation of all outside air dampers. Dampers shall fully close when unit is unoccupied and fully open to the balanced position during occupancy. Confirm that valve actuators for chilled water and hot water applications stroke properly for temperature control.
    c. Test software functions such as humidity control, demand control ventilation, freeze protection, building shutdown, network broadcasting and other project specific software/hardware functions are operating properly.
    d. Verify that central plant increments and decrements states accordingly to provide adequate cooling without utilizing excessive tonnage.
    e. Verify actual building chilled water supply temperature is in accordance with design setpoints. Provide trend data over a period of a minimum of 7-days for verification.
    f. Confirm optimal start function is operating properly to ensure occupant comfort upon building occupancy.
    g. Verify sequence of operation is operating properly for each piece of mechanical equipment.
6. Provide updates to operator workstation or web server software, project-specific softwareEquipment Schematic.
7. Operator Overview – Consists of general system navigation, scheduling functions, setpoint modifications and parameter adjustments.
8. Advanced Topics Overview – Detailed analysis of trend setup/configuration, trend historian, alarm setup, alarm actions (email, printing, etc.), point renaming, and detailed analysis of equipment parameters.
9. Program/Logic Manipulation – Modify system programs as needed for additions and modifications.
10. Graphic Manipulation – Modify system graphics as needed for additions and modifications.
11. Hardware Troubleshooting – Classroom setup shall have HVAC mock-up systems. Operators shall be able to interact with this live system through the BAS utilized for this project. Class will provide students the ability to identify and repair common problems regularly encountered.
12. Software Troubleshooting - Classroom setup shall have HVAC mock-up systems. Operators shall be able to interact with this live system through the BAS utilized for this project. Class will provide students the ability to identify and repair common issues that can be utilized via software modifications.
13. Central Plant Operation – At a minimum the instructor shall thoroughly explain different types of central plant equipment and proper system modifications that can be made to enhance system performance and energy savings.
14. HVAC System Training – Objective of this class is to provide basic HVAC system knowledge of various types of systems including types of air side distribution and water side distribution. Topics such as thermodynamics, psychometrics, de-humidification, and demand control ventilation shall be thoroughly explained
15. from defects for a period of 1 year after final acceptance. Warrant all labor for a period of 1 year after final acceptance. Control system failures during warranty period shall be ad-

justed, repaired, or replaced at no additional cost or reduction in service to Owner. Respond during normal business hours within 24 hours of Owner's warranty service request. Additionally contractor shall offer 24/7 after-hours support to include alarm monitoring and associated dispatch service.

16. Provide graphic modifications for a period of 3 years from date of substantial completion. This shall include room number and equipment modifications as requested by the owner.
17. Provide telephone support free to the owner for a period of 3 years after substantial completion. This service includes technical support for all BAS equipment and shall include troubleshooting and problem resolution via the telephone or web services. Service shall be available during the hours of 7am to 5pm Monday – Friday.
18. Work shall have a single warranty date, even if Owner receives beneficial use due to early system start-up. If specified work is split into multiple contracts or a multi-phase contract, each contract or phase shall have a separate warranty start date and period.
19. Re-commissioning Procedure - After 9 months from the date of substantial completion the contractor shall confirm the equipment is still operating as designed by performing a recommissioning procedure. This procedure shall be conducted with an owner's representative present for all tests. All components shall be documented and signed by the BAS Project Manager then delivered to owner and engineer for record purposes. The recommissioning procedure shall include the following verifications:
20. Provide updates to operator workstation or web server software, project-specific software, graphic software, database software, and firmware that resolve Contractor or Owner identified software deficiencies at no charge during warranty period. If available, Owner can purchase in-warranty service agreement to receive upgrades for functional enhancements associated with above-mentioned items. Do not install updates or upgrades without Owner's written authorization.
21. Exception: Contractor shall not be required to warranty existing devices except those that have been rebuilt or repaired during installation.
    a. Graphics
    b. Record drawings
    c. Database
    d. Application programming code
    e. Documentation
22. 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.
23. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the internetwork. Program and test all cross-controller links required to execute control strategies specified in Section 230993 Appendix A. 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.
24. 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.
25. 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.
26. For read or write requests, the system shall require user name and password authentication and shall support SSL (Secure Socket Layer) or equivalent data encryption.
27. or editing any data, and which can be configured to limit the privileges of an individual operator.
28. The ability to view and acknowledge any alarm in the system. Alarms or links to alarms shall be provided on a contiguous list so the operator can quickly view all alarms.
29. A summary page or pages for each piece of equipment in the system. This page shall include the current values of all critical I/O points and shall allow the operator to lock binary points on or off and to lock analog points to any value within their range.

30. Navigation links that allow the operator to quickly navigate from the home screen to any piece of equipment in the system, and then return to the home screen. These links may be arranged in a hierarchical fashion, such as navigating from the home screen to a particular building, then to a specific floor in the building, and then to a specific room or piece of equipment.
31. , graphic software, database software, and firmware that resolve Contractor or Owner identified software deficiencies at no charge during warranty period. If available, Owner can purchase in-warranty service agreement to receive upgrades for functional enhancements associated with above-mentioned items. Do not install updates or upgrades without Owner's written authorization.
32. Exception: Contractor shall not be required to warranty existing devices except those that have been rebuilt or repaired during installation.

1.11 METERING AND VERIFICATION REQUIREMENTS

A. Granular data, derived from the BAS and inherent to this specification, is to be handled in such a way as to support this certification. Granular data is defined as temperatures, set points, run times and utility monitoring. This data is to be monitored on a fifteen minute interval basis. It is to be stored in the BAS database. The BAS must have the inherent capability to trend and display the following:

B. Format the data in a user definable criteria.

C. Custom reports will be easily constructed and printed in a user friendly format. Daily roll-ups and other user definable report sets must be easily obtained by the user.

D. These reports will, at a minimum, contain the following:
1. Utility Consumption (electrical)
2. Utility Consumption per sqft
3. Utility Consumption per sqft, per hour of run time

E. Time frame is user definable

F. In addition to utility consumption data, classroom environmental data must be monitored. An environmental index must be maintained. Environmental Index is defined as a comparative analysis of setpoint vs actual reading for any input variable specified for any occupied area. Input variables are defined as, but not limited to:
1. Space temperature
2. Space humidity
3. Space CO_2 monitor

G. Monitoring software must include outside environmental condition data which affect building performance. Heating degree days and cooling degree days must be logged and formatted in such a way that the data may be used for comparative analysis of multiple facilities, this facilities and any Lone Star College facility on a historical basis over time.. This data must be imported from a reliable, certified, third party source. On site instrumentation is not acceptable.

H. Metering and Verification requirements must be inherent to the BAS. It cannot be a “bolt on” product. It shall be of no extra cost to the project. It shall be easily accessible from the graphical interface on the main screens. It shall also be accessible from the BAS navigation tree. Data must be retrieved and stored in the BAS module until it is archived on the BAS server. Data acquisition and storage must continue even if communication to the facility is lost. Data for utility consumption and environmental indexing must be stored on the server for a minimum of two years.

1.12 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

PART 2 - PRODUCTS

2.1 MATERIALS

A. Provide new products the manufacturer is currently manufacturing and selling for use in new installations. Do not use this installation as a product test site unless explicitly approved in writing by Owner. Spare parts shall be available for at least five years after completion of this contract.

2.2 COMMUNICATION

A. Control products, communication media, connectors, repeaters, hubs, and routers shall comprise a BACnet internetwork. Controller and operator interface communication shall conform to ASHRAE/ANSI Standard 135-2001, BACnet.

B. Use existing Ethernet backbone for network segments marked "existing" on project drawings.

C. Each controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.

D. Internetwork operator interface and value passing shall be transparent to internetwork architecture.
   1. An operator interface connected to a controller shall allow the operator to interface with each internetwork controller as if directly connected. Controller information such as data, status, and control algorithms shall be viewable and editable from each internetwork controller.
   2. Inputs, outputs, and control variables used to integrate control strategies across multiple controllers shall be readable by each controller on the internetwork. Program and test all cross-controller links required to execute control strategies specified in Section 230993 Appendix A. An authorized operator shall be able to edit cross-controller links by typing a standard object address or by using a point-and-click interface.

E. Controllers with real-time clocks shall use the BACnet Time Synchronization service. System shall automatically synchronize system clocks daily from an operator-designated controller via the internetwork. If applicable, system shall automatically adjust for daylight saving and standard time.

F. System shall be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring.

G. 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 specified by the Web Services Interoperability Organization (WS-I) Basic Profile 1.0 or higher. Web services support shall as a minimum be provided at the workstation or web server level and shall enable the system to both read and write data.

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 SSL (Secure Socket Layer) or equivalent data encryption.

2.3 OPERATOR INTERFACE

A. Operator Interface. Web server shall reside on the customers high-speed network. Each standard browser connected to server shall be able to access all system information. In addition to the primary operator interface, the system shall include a secondary interface compatible with a locally available commercial wireless network and viewable on a commercially available wireless device such as a Wireless Access Protocol (WAP) enabled cellular telephone or personal digital assistant (PDA). This secondary interface may be text-based and shall provide a summary of the most important data. As a minimum, the following capabilities shall be provided through this interface:
   1. An operator authentication system that requires an operator to log in before viewing or editing any data, and which can be configured to limit the privileges of an individual operator.
   2. The ability to view and acknowledge any alarm in the system. Alarms or links to alarms shall be provided on a contiguous list so the operator can quickly view all alarms.
   3. A summary page or pages for each piece of equipment in the system. This page shall include the current values of all critical I/O points and shall allow the operator to lock binary points on or off and to lock analog points to any value within their range.
   4. Navigation links that allow the operator to quickly navigate from the home screen to any piece of equipment in the system, and then return to the home screen. These links may be arranged in a hierarchical fashion, such as navigating from the home screen to a particular building, then to a specific floor in the building, and then to a specific room or piece of equipment.

B. Communication. Web server or workstation and controllers shall communicate using BACnet protocol. Web server or workstation and control network backbone shall communicate using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing as specified in ASHRAE/ANSI 135-2001, BACnet Annex J.

C. Hardware. Each workstation or web server shall consist of the following:
   1. Lone Star College currently has a BAS server dedicated to ALC that meets these specification requirements. This system shall reside on the existing server, the existing server is located at the District Services Facility.
   2. Hardware Base. Industry-standard hardware shall meet or exceed DDC system manufacturer's recommended specifications and shall meet response times specified in Section 230993 Paragraph 1.9. Hard disk shall have sufficient memory to store system software, one year of data for trended points specified in Appendix A, and a system database at least twice the size of the existing database at system acceptance. Configure computers and network connections if multiple computers are required to meet specified memory and performance. Web server shall be Compaq Rack Mounted Server with a minimum of:
      a. Dual Processor Intel Pentium 3.66 GHz processor
      b. 1 GB RAM
      c. 80 GB hard disk providing data at 100 MB/sec
      d. RAID 5 Configuration
      e. 128x CD-ROM drive
      f. Windows Server 2003 Operating System

g. Serial, parallel, and network communication ports and cables required for proper system operation

D. Operator Functions. Operator interface shall allow each authorized operator to execute the following functions as a minimum:
1. Dynamic colored Thermographs comparing actual space conditions to setpoints shall be provided on ALL floorplan graphics, including total building level, displayed on the front-end. This means that area blowups shall also use the thermographs to display space conditions. Displaying floorplans with only the numerical temperature values without dynamic color graphics on the front-end is unacceptable. All thermographs shall be visible via web interface as well as on the LAN. Graphics modification shall be included in the base bid and shall include one year of unlimited graphics modifications to support Lone Star College.
2. Log In and Log Out. System shall require user name and password to log in to operator interface.
3. Point-and-click Navigation. Operator interface shall be graphically based and shall allow operators to access graphics for equipment and geographic areas using point-and-click navigation.
4. View and Adjust Equipment Properties. Operators shall be able to view controlled equipment status and to adjust operating parameters such as setpoints, PID gains, on and off controls, and sensor calibration. Global modification of user definable parameters shall be provided standard to the operation of the system. Global modification is defined as the mass adjustment of user definable parameters across a defined group, area, facility, campus, or network. Parameters shall include, but not be limited to temperature setpoint (VAV boxes, AHU Discharge, VAV AHU Static Pressure Setpoints, etc.), equipment start/stop, equipment status, valve output signal, VFD speed control signal, and damper position signal. User shall be able to lock the definable parameter to a set value, or adjust a setpoint to an operator adjustable value. This function shall be accomplished through the standard graphical user interface/workstations
5. View and Adjust Operating Schedules. Operators shall be able to view scheduled operating hours of each schedulable piece of equipment on a weekly or monthly calendar-based graphical schedule display, to select and adjust each schedule and time period, and to simultaneously schedule related equipment. System shall clearly show exception schedules and holidays on the schedule display.
6. View and Respond to Alarms. Operators shall be able to view a list of currently active system alarms, to acknowledge each alarm, and to clear (delete) unneeded alarms.
7. View and Configure Trends. Operators shall be able to view a trend graph of each trended point and to edit graph configuration to display a specific time period or data range. Operator shall be able to create custom trend graphs to display on the same page data from multiple trended points.
8. View and Configure Reports. Operators shall be able to run preconfigured reports, to view report results, and to customize report configuration to show data of interest.
9. Manage Control System Hardware. Operators shall be able to view controller status, to restart (reboot) each controller, and to download new control software to each controller.
10. Manage Operator Access. Typically, only a few operators are authorized to manage operator access. Authorized operators shall be able to view a list of operators with system access and of functions they can perform while logged in. Operators shall be able to add operators, to delete operators, and to edit operator function authorization. Operator shall be able to authorize each operator function separately.

E. System Software.
1. Operating System. Web server or workstation shall have an industry-standard professional-grade operating system. Acceptable systems include Microsoft Windows XP Pro, Red Hat Linux, or Sun Solaris.
2. 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 dynamic colors to represent zone temperature relative to zone setpoint.

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 setpoints and other specified parameters.
b. Animation. Graphics shall be able to animate by displaying different image files for changed object status.
c. Alarm Indication. Indicate areas or equipment in an alarm condition using color or other visual indicator.
d. Format. Graphics shall be saved in an industry-standard format such as BMP, JPEG, 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 require widely available no-cost plug-ins (such as Active-X and Macromedia Flash).

F. System Tools. 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 IBM-compatible PCs 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. Controller Memory Download. Operators shall be able to download memory from the system database to each controller.
3. System Configuration. Operators shall be able to configure the system.
4. Online Help. Context-sensitive online help for each tool shall assist operators in operating and editing the system.
5. Security. System shall require a user name and password to view, edit, add, or delete data.
   a. Operator Access. Each user name and password combination shall define accessible viewing, editing, adding, and deleting functions in each system application, editor, and object. Authorized operators shall be able to vary and deny each operator's accessible functions based on equipment or geographic location.
   b. Automatic Log Out. Automatically log out each operator if no keyboard or mouse activity is detected. Operators shall be able to adjust automatic log out delay.
   c. Encrypted Security Data. Store system security data including operator passwords in an encrypted format. System shall not display operator passwords.
6. System Diagnostics. System shall automatically monitor controller and I/O point operation. System shall annunciate controller failure and I/O point locking (manual overriding to a fixed value).
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 specified in Section 230993 Appendix A (Sequences of Operation). Alarms shall be BACnet alarm objects and shall use BACnet alarm services.
8. Alarm Messages. Alarm messages shall use an English language descriptor without acronyms or mnemonics to describe alarm source, location, and nature.
9. Alarm Reactions. Operator shall be able to configure (by object) actions workstation or web server shall initiate on receipt of each alarm. As a minimum, workstation or web server shall be able to log, print, start programs, display messages, send e-mail, send page, and audibly annunciate.

10. Alarm Maintenance. Operators shall be able to view system alarms and changes of state chronologically, to acknowledge and delete alarms, and to archive closed alarms to the workstation or web server hard disk from each workstation or web browser interface.
11. Trend Configuration. 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. The contractor shall configure all physical control points and software control points to accumulate trend data. Analog values shall be configured utilizing time-based intervals and digital values shall be configured for COV. Provide at a minimum of 250 samples per control point. If data can be stored locally at the controller level this information shall be archived at the central server or all BAS workstations.
12. Object and Property Status and Control. Operator shall be able to view, and to edit if applicable, the status of each system object and property 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. 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.
        3) Operator Activity. At a minimum, system shall log operator log in and log out, control parameter changes, schedule changes, and alarm acknowledgment and deletion. System shall date and time stamp logged activity.
15. 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.
16. Graphics Generation. Graphically based tools and documentation shall allow Operator to edit system graphics, to create graphics, and to integrate graphics into the system. Operator shall be able to add analog and binary values, dynamic text, static text, and animation files to a background graphic using a mouse.
17. Graphics Library. Complete library of standard HVAC equipment graphics shall include equipment such as chillers, boilers, air handlers, terminals, fan coils, and unit ventilators. Library shall include standard symbols for other equipment including fans, pumps, coils, valves, piping, dampers, and ductwork. Library graphic file format shall be compatible with graphics generation tools.
18. Custom Application Programming. Operator shall be able 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 language 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.

19. BACnet. Web server or workstation shall have demonstrated interoperability during at least one BMA Interoperability Workshop and shall substantially conform to BACnet Operator Workstation (B-OWS) device profile as specified in ASHRAE/ANSI 135-2016, BACnet Annex L.

2.4 CONTROLLER SOFTWARE

A. Building and energy management application software shall reside and operate in system controllers. Applications shall be editable through operator workstation, web browser interface, or engineering workstation.

B. System Security. See Paragraph 2.3.F.5 (Security) and Paragraph 2.3.F.15.c (Operator Activity).

C. Scheduling. See Paragraph 2.3.D.4 (View and Adjust Operating Schedules). System shall provide the following schedule options as a minimum:
1. Weekly. 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).
2. Exception. Operator shall be able to designate an exception schedule for each of the next 365 days. After an exception schedule has executed, system shall discard and replace exception schedule with standard schedule for that day of the week.
3. Holiday. Operator shall be able to define 24 special or holiday schedules of varying length on a scheduling calendar that repeats each year.

D. 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.

E. Binary and Analog Alarms. See Paragraph 2.3.F.7 (Alarm Processing).

F. Alarm Reporting. See Paragraph 2.3.F.9 (Alarm Reactions).

G. 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.

H. Demand Limiting.
1. System shall monitor building power consumption from building power meter pulse generator signals or from building feeder line watt transducer or current transformer.
2. 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 Section 230993 Appendix A (Sequences of Operation). When demand drops below adjustable levels, system shall restore loads as specified.

I. Maintenance Management. System shall generate maintenance alarms when equipment exceeds adjustable runtime, equipment starts, or performance limits. Configure and enable maintenance alarms as specified in Section 230993 Appendix A (Sequences of Operation).

J. Sequencing. Application software shall sequence chillers, boilers, and pumps as specified in Section 230993 Appendix A (Sequences of Operation).

K. 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.

L. 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.

M. Energy Calculations.
1. System shall accumulate and convert instantaneous power (kW) or flow rates (L/s [gpm]) to energy usage data.
2. 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.
3. System shall calculate a fixed-window average. Window interval start shall be defined by utility meter digital input signal to synchronize system's and utility's fixed-window averages.

N. Anti-Short Cycling. Binary output objects shall be protected from short cycling by means of adjustable minimum on-time and off-time settings.

O. On and Off Control with Differential. System shall provide direct- and reverse-acting on and off algorithms with adjustable differential to cycle a binary output based on a controlled variable and setpoint.

P. Runtime Totalization. System shall provide an algorithm that can 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 specified in Section 230993 Appendix A (Sequence of Operations).

2.5 CONTROLLERS

A. General. Provide Building Controllers (BC), Advanced Application Controllers (AAC), Application Specific Controllers (ASC), and Smart Actuators (SA) as required to achieve performance specified in Section 230993 Article 1.9 (System Performance).

B. Network level controllers shall have a CPU requirement of 16 BIT processors only. All applications programs and associated operating sequences shall reside in the controller.

C. All controllers including air handling units and terminal unit controllers shall communicate with the BAS network at speeds of operate at speeds of 112k or greater.

D. BACnet.
   1. Building Controllers (BCs). Each BC shall have demonstrated interoperability during at least one BMA Interoperability Workshop and shall substantially conform to BACnet Building Controller (B-BC) device profile as specified in ASHRAE/ANSI 135-2001, BACnet Annex L.
   2. Advanced Application Controllers (AACs). Each AAC shall conform to BACnet Advanced Application Controller (B-AAC) device profile as specified in ASHRAE/ANSI 135-2001, BACnet Annex L and shall be listed as a certified B-AAC in the BACnet Testing Laboratories (BTL) Product Listing.
   3. Application Specific Controllers (ASCs). Each ASC shall conform to BACnet Application Specific Controller (B-ASC) device profile as specified in ASHRAE/ANSI 135-2001, BACnet Annex L and shall be listed as a certified B-ASC in the BACnet Testing Laboratories (BTL) Product Listing.
   4. Smart Actuators (SAs). Each SA shall conform to BACnet Smart Actuator (B-SA) device profile as specified in ASHRAE/ANSI 135-2001, BACnet Annex L and shall be listed as a certified B-SA in the BACnet Testing Laboratories (BTL) Product Listing.
   5. BACnet Communication.
      a. Each BC shall reside on or be connected to a BACnet network using ISO 8802-3 (Ethernet) Data Link/Physical layer protocol and BACnet/IP addressing.
      b. BACnet routing shall be performed by BCs or other BACnet device routers as necessary to connect BCs to networks of AACs and ASCs.
      c. Each AAC and 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. Communication.
   1. Service Port. Each controller shall provide a service communication port for connection to a Portable Operator's Terminal. Connection shall be extended to space temperature sensor ports where shown on drawings.
   2. Signal Management. BC and ASC operating systems shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and to allow for central monitoring and alarms.
   3. Data Sharing. Each BC and AAC shall share data as required with each networked BC and AAC.
   4. Stand-Alone Operation. Each piece of equipment specified in Section 230993 Appendix A 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.

F. Environment. Controller hardware shall be suitable for anticipated ambient conditions.
   1. Controllers used outdoors or in wet ambient conditions shall be mounted in waterproof enclosures and shall be rated for operation at -29℃ to 60℃ (-20℉ to 140℉).

2. Controllers used in conditioned space shall be mounted in dust-protective enclosures and shall be rated for operation at 0°C to 50°C (32°F to 120°F).

G. Real-Time Clock. Controllers that perform scheduling shall have a real-time clock.

H. Serviceability.
1. Controllers shall have diagnostic LEDs for power, communication, and processor.
2. Wires shall be connected to a field-removable modular terminal strip or to a termination card connected by a ribbon cable.
3. 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.

I. Memory.
1. Controller memory shall support operating system, database, and programming requirements.
2. Each BC and AAC shall retain BIOS and application programming for at least 72 hours in the event of power loss.
3. Each ASC and SA shall use nonvolatile memory and shall retain BIOS and application programming in the event of power loss. System shall automatically download dynamic control parameters following power loss.

J. Immunity to Power and Noise. Controllers shall be able to operate at 90% to 110% of nominal voltage rating and shall perform an orderly shutdown below 80% nominal voltage. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios up to 5 W at 1 m (3 ft).

K. Transformer. ASC power supply shall be fused or current limiting and shall be rated at a minimum of 125% of ASC power consumption.

2.6 INPUT AND OUTPUT INTERFACE

A. General. Hard-wire input and output points to BCs, AACs, ASCs, or SAs.

B. Protection. Shorting an input or output point to itself, to another point, or to ground shall cause no controller damage. Input or output point contact with up to 24 V for any duration shall cause no controller damage.

C. Binary Inputs. Binary inputs shall monitor the on and off signal from a remote device. Binary inputs shall provide a wetting current of at least 12 mA and shall be protected against contact bounce and noise. Binary inputs shall sense dry contact closure without application of power external to the controller.

D. Pulse Accumulation Inputs. Pulse accumulation inputs shall conform to binary input requirements and shall 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 send a pulsed low-voltage signal for pulse width modulation control or an on-or-off signal for on and off control. Building Controller binary outputs shall have three-position (on-off-auto) override switches and status lights. Outputs shall be selectable for normally open or normally closed operation.

G. Analog Outputs. Analog outputs shall send a modulating 0-10 Vdc or 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. Pulse-Width Modulation. Control actuators designed for pulse-width modulation with a single binary output that cycles with variable on and off times as determined by the application software. Pulse-width modulation 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.

J. 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.

2.7 POWER SUPPLIES AND LINE FILTERING

A. Power Supplies. Control transformers shall be UL listed. Furnish Class 2 current-limiting type or furnish over-current protection in primary and secondary circuits for Class 2 service in accordance with NEC requirements. Limit connected loads to 80% of rated capacity.
   1. DC power supply output shall match output current and voltage requirements. Unit shall be full-wave rectifier type with output ripple of 5.0 mV maximum peak-to-peak. 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

2.8 AUXILIARY CONTROL DEVICES

A. Motorized Control Dampers.
   1. Type. Control dampers shall have linear flow characteristics and shall be parallel- or opposed-blade type as specified below or as scheduled on drawings.
      a. Outdoor and return air mixing dampers and face-and-bypass dampers shall be parallel-blade and shall direct airstreams toward each other.
      b. Other modulating dampers shall be opposed-blade.
      c. Two-position shutoff dampers shall be parallel- or opposed-blade with blade and side seals.
   2. Frame. Damper frames shall be 2.38 mm (13 gauge) galvanized steel channel or 3.175 mm (1/8 in.) extruded aluminum with reinforced corner bracing.

3. Blades. Damper blades shall not exceed 20 cm (8 in.) in width or 125 cm (48 in.) in length. Blades shall be suitable for medium velocity (10 m/s [2000 fpm]) performance. Blades shall be not less than 1.5875 mm (16 gauge).
4. Shaft Bearings. Damper shaft bearings shall be as recommended by manufacturer for application, oil impregnated sintered bronze, or better.
5. Seals. Blade edges and frame top and bottom shall have replaceable seals of butyl rubber or neoprene. Side seals shall be spring-loaded stainless steel. Blade seals shall leak no more than 50 L/s·m 2 (10 cfm per ft 2) at 1000 Pa (4 in. w.g.) differential pressure. Blades shall be airfoil type suitable for wide-open face velocity of 7.5 m/s (1500 fpm).
6. Sections. Damper sections shall not exceed 125 cm - 150 cm (48 in. - 60 in.). Each section shall have at least one damper actuator.
7. Linkages. Dampers shall have exposed linkages.

B. Electric Damper and Valve Actuators.
1. Stall Protection. Mechanical or electronic stall protection shall prevent actuator damage throughout the actuator's rotation.
2. Spring-return Mechanism. Actuators used for power-failure and safety applications shall have an internal mechanical spring-return mechanism or an uninterruptible power supply (UPS).
3. Signal and Range. Proportional actuators shall accept a 0-10 Vdc or a 0-20 mA control signal and shall have a 2-10 Vdc or 4-20 mA operating range.
4. Wiring. 24 Vac and 24 Vdc actuators shall operate on Class 2 wiring.
5. Manual Positioning. Operators shall be able to manually position each actuator when the actuator is not powered. Non-spring-return actuators shall have an external manual gear release. Spring-return actuators with more than 7 N·m (60 in.-lb) torque capacity shall have a manual crank.

C. Control Valves.
1. General. Select body and trim materials in accordance with manufacturer's recommendations for design conditions and service shown.
2. Type. Provide two- or three-way control valves for two-position or modulating service as shown.
3. Water Valves.
   a. Valves providing two-position service shall be quick opening. Two-way valves shall have replaceable disc or ball. Ball valves without some form of characterization for linear flow are not acceptable.
   b. Close-off (Differential) Pressure Rating. Valve actuator and trim shall provide the following minimum close-off pressure ratings.
      1) Two-way: 100% of total system (pump) head.
      2) Three-way: 300% of pressure differential between ports A and B at design flow or 100% of total system (pump) head.
   c. Ports. Valves providing modulating service shall have equal percentage ports.
   d. Sizing.
      1) Two-position service: line size.
      2) Two-way modulating service: select pressure drop equal to the greatest of twice the pressure drop through heat exchanger (load), 50% of the pressure difference between supply and return mains, or 35 kPa (5 psi).
      3) Three-way modulating service: select pressure drop equal to the smaller of twice the pressure drop through the coil exchanger (load) or 35 kPa (5 psi).
   e. Fail Position. Water valves shall fail normally open or closed as follows unless otherwise specified.
      1) Water zone valves: normally closed.
      2) Heating coils in air handlers: normally closed.
      3) Chilled water control valves: normally open.
      4) Other applications: as scheduled or as required by sequences of operation.
4. Steam Valves.

a. Close-off (Differential) Pressure Rating. Valve actuator and trim shall provide minimum close-off pressure rating equal to 150% of operating (inlet) pressure.
b. Ports. Valves providing modulating service shall have linear ports.
c. Sizing.
    1) Two-position service: select pressure drop equal to 10%-20% of inlet psig.
    2) Modulating service at 100 kPa (15 psig) or less: select pressure drop equal to 80% of inlet psig.
    3) Modulating service at 101-350 kPa (16-50 psig): select pressure drop equal to 50% of inlet psig.
    4) Modulating service at over 350 kPa (50 psig): select pressure drop as scheduled on drawings.

D. Binary Temperature Devices.
1. Low-Voltage Space Thermostats. Low-voltage space thermostats shall be 24 V, bimetal-operated, mercury-switch type, with adjustable or fixed anticipation heater, concealed setpoint adjustment, 13°C-30°C (55°F-85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.
2. Line-Voltage Space Thermostats. Line-voltage space thermostats shall be bimetal-actuated, open-contact type or bellows-actuated, enclosed, snap-switch type or equivalent solid-state type, with heat anticipator, UL listing for electrical rating, concealed setpoint adjustment, 13°C-30°C (55°F-85°F) setpoint range, 1°C (2°F) maximum differential, and vented ABS plastic cover.
3. Low-Limit Thermostats. Low-limit airstream thermostats shall be UL listed, vapor pressure type. Element shall be at least 6 m (20 ft) long. Element shall sense temperature in each 30 cm (1 ft) section and shall respond to lowest sensed temperature. Low-limit thermostat shall be manual reset only.

E. Temperature Sensors.
1. Type. Temperature sensors shall be Resistance Temperature Device (RTD) or thermistor.
2. Duct Sensors. Duct sensors shall be single point or averaging as shown. Averaging sensors shall be a minimum of 1.5 m (5 ft) in length per 1 m^2(10 ft^2) of duct cross-section.
3. Immersion Sensors. Provide immersion sensors with a separable stainless steel well. Well pressure rating shall be consistent with system pressure it will be immersed in. Well shall withstand pipe design flow velocities.
4. Space Sensors. Space sensors shall have setpoint adjustment, override switch, display, and communication port as shown.
5. Differential Sensors. Provide matched sensors for differential temperature measurement.

F. Humidity Sensors.
1. Duct and room sensors shall have a sensing range of 20%-80%.
2. Duct sensors shall have a sampling chamber.
3. Outdoor air humidity sensors shall have a sensing range of 20%-95% RH and shall be suitable for ambient conditions of 40°C-75°C (40°F-170°F).
4. Humidity sensors shall not drift more than 1% of full scale annually.

G. Flow Switches. Flow-proving switches shall be paddle (water service only) or differential pressure type (air or water service) as shown. Switches shall be UL listed, SPDT snap-acting, and pilot duty rated (125 VA minimum).
1. Paddle switches shall have adjustable sensitivity and NEMA 1 enclosure unless otherwise specified.
2. Differential pressure switches shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.

H. Relays.

1. Control Relays. Control relays shall be plug-in type, UL listed, and shall have dust cover and LED "energized" indicator. Contact rating, configuration, and coil voltage shall be suitable for application.
2. Time Delay Relays. Time delay relays shall be solid-state plug-in type, UL listed, and shall have adjustable time delay. Delay shall be adjustable ±100% from setpoint shown. Contact rating, configuration, and coil voltage shall be suitable for application. Provide NEMA 1 enclosure for relays not installed in local control panel.

I. Override Timers.
1. Unless implemented in control software, override timers shall be spring-wound line voltage, UL Listed, with contact rating and configuration required by application. Provide 0-6 hour calibrated dial unless otherwise specified. Flush mount timer on local control panel face or where shown.

J. Current Transmitters.
1. AC current transmitters shall be self-powered, combination split-core current transformer type with built-in rectifier and high-gain servo amplifier with 4-20 mA two-wire output. Full-scale unit ranges shall be 10 A, 20 A, 50 A, 100 A, 150 A, and 200 A, with internal zero and span adjustment. Unit accuracy shall be ±1% full-scale at 500 ohm maximum burden.
2. Transmitter shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized.
3. Unit shall be split-core type for clamp-on installation on existing wiring.

K. Current Transformers.
1. AC current transformers shall be UL/CSA recognized and shall be completely encased (except for terminals) in approved plastic material.
2. Transformers shall be available in various current ratios and shall be selected for ±1% accuracy at 5 A full-scale output.
3. Use fixed-core transformers for new wiring installation and split-core transformers for existing wiring installation.

L. Voltage Transmitters.
1. AC voltage transmitters shall be self-powered single-loop (two-wire) type, 4-20 mA output with zero and span adjustment.
2. Adjustable full-scale unit ranges shall be 100-130 Vac, 200-250 Vac, 250-330 Vac, and 400-600 Vac. Unit accuracy shall be ±1% full-scale at 500 ohm maximum burden.
3. Transmitters shall meet or exceed ANSI/ISA S50.1 requirements and shall be UL/CSA recognized at 600 Vac rating.

M. Voltage Transformers.
1. AC voltage transformers shall be UL/CSA recognized, 600 Vac rated, and shall have built-in fuse protection.
2. Transformers shall be suitable for ambient temperatures of 4°C-55°C (40°F-130°F) and shall provide ±0.5% accuracy at 24 Vac and 5 VA load.
3. Windings (except for terminals) shall be completely enclosed with metal or plastic.

N. Power Monitors.
1. Power monitors shall be three-phase type and shall have three-phase disconnect and shorting switch assembly, UL listed voltage transformers, and UL listed split-core current transformers.
2. Power monitors shall provide selectable output: rate pulse for kWh reading or 4-20 mA for kW reading. Power monitors shall operate with 5 A current inputs and maximum error of ±2% at 1.0 power factor or ±2.5% at 0.5 power factor.

O. Current Switches.

1. Current-operated switches shall be split-core, self-powered, solid-state with adjustable trip current. Select switches to match application current and DDC system output requirements.

P. Pressure Transducers.
1. Transducers shall have linear output signal and field-adjustable zero and span.
2. Continuous operating conditions of positive or negative pressure 50% greater than calibrated span shall not damage transducer sensing elements.
3. Water pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Transducer shall have 4-20 mA output, suitable mounting provisions, and block and bleed valves.
4. Water differential pressure transducer diaphragm shall be stainless steel with minimum proof pressure of 1000 kPa (150 psi). Over-range limit (differential pressure) and maximum static pressure shall be 2000 kPa (300 psi.) Transducer shall have 4-20 mA output, suitable mounting provisions, and 5-valve manifold.

Q. Differential Pressure Switches. Differential pressure switches (air or water service) shall be UL listed, SPDT snap-acting, pilot duty rated (125 VA minimum) and shall have scale range and differential suitable for intended application and NEMA 1 enclosure unless otherwise specified.

R. Pressure-Electric (PE) Switches. PE switches shall be UL listed, pilot duty rated (125 VA minimum) or motor control rated, metal or neoprene diaphragm actuated, operating pressure rated for 0-175 kPa (0-25 psig), with calibrated scale minimum setpoint range of 14-125 kPa (2-18 psig).
1. Provide one- or two-stage switch action (SPDT, DPST, or DPDT) as required by application.
2. Switches shall be open type (panel-mounted). Exception: Switches shall be enclosed type for remote installation. Enclosed type shall be NEMA 1 unless otherwise specified.
3. Each pneumatic signal line to PE switches shall have permanent indicating gauge.

S. Air Flow Measuring Stations:
1. EAMS as manufactured by Ruskin Company.
2. Size: As indicated on drawings.
   a. Sleeve Length: 12 inches (305 mm).
3. Construction:
   a. Frame Material: Galvanized steel.
   b. Frame Fabrication: Minimum 20 gage (1.0 mm).
   c. Air Scoop Manifold: 3/4 inch (19 mm) copper pipe and fittings.
   d. Electronic Sensor: Heated mass flow sensor.
4. Operation:
   a. Electronic Transmitter: The transmitter shall provide an isolated 4 to 20 MA output proportional to the velocity.
   b. Output Signal: 4-20 mA, isolated 24V source, 3 or 4 wire connection.
   c. Output Filter: Factory set and field adjustable 0.5 - 15 (seconds).
   d. Loop Resistance: 600 ohms maximum.
5. Performance Data:
   a. Assembly: Factory assemble components and furnish as a single factory calibrated unit.
   b. Humidity Limit: Non-condensing.
   c. Maximum Operating Temperature:
      1) 1. Sensor: Process air in airstream. -40 degrees F (-40 degrees C) to +176 degrees F (+80 degrees C).
      2) 2. Transmitter: Ambient air. 32 degrees F (0 degrees C) to +140 degrees F (+60 degrees C).
6. Accuracy: Per AMCA 610 based on 400 FPM to 2000 FPM.
   a. ±3 Percent: 32 degrees F to 120 degrees F (0 to 50 degrees C).

b. ±4 Percent: -40 degrees F to 32 degrees F and 120 degrees F to 176 degrees F (-40 degrees C to 0 degrees C and 50 degrees C to 80 degrees C)

T. Carbon Dioxide sensor/transmitters.
1. Duct Mounted
a. Sensor shall employ non-dispersive infrared technology (N.D.I.R.).
b. Sensor repeatability shall be +/- 20 ppm +/- 1% of measured value.
c. Sensor accuracy shall be +/- 30ppm +/-5% of measured value.
d. Sensor response time shall be less than 1 minute.
e. Sensor shall employ reference channel design for long-term stability.
f. Sensor shall have field selectable 0-10VDC, 0-5VDC, or 4-20mA output.
g. Sensor power requirement shall be less than 3W.
h. Sensor input voltage shall be 20 to 30VAC/DC.
i. Sensor operating temperature range shall be 0^{o}C to 50^{o}C.
j. Sensor shall be Veris Industries model CDL or approved equivalent.
k. Sensor shall have a field programmable set-point relay.
l. Sensor shall have an LCD standard, displaying C02 ppm.
m. Sensor shall be provided with a five-year factory warranty.
2. Wall Mounted
a. Sensor shall employ non-dispersive infrared technology. (N.D.I.R.)
b. Sensor repeatability shall be +/- 20 ppm. 0-2000 or 0-5000 ppm range.
c. Sensor accuracy shall be <= 75 ppm over 0-1500 ppm range.
d. Sensor response time shall be less than 1 minute.
e. Sensor shall employ reference channel design for long term stability.
f. Sensor shall have field selectable 0-10VDC, 0-5VDC, or 4-20mA outputs.
g. Sensor power requirement shall be less than 3W.
h. Sensor input voltage shall be 20 to 30VAC/DC.
i. Sensor operating temperature range shall be 0oC to 50oC.
j. Sensor shall have provision for wall mounting.
k. Sensor shall have built-in LCD display.
l. Sensor shall be Veris Industries model CWL or approved equivalent.
m. Sensor shall have a programmable set-point relay.
n. Sensor shall be provided with a five-year factory warranty.

U. Local Control Panels.
1. Indoor control panels shall be fully enclosed NEMA 1 construction with hinged door key-lock latch and removable sub-panels. A common key shall open each control panel and sub-panel.
2. Prewire internal and face-mounted device connections with color-coded stranded conductors tie-wrapped or neatly installed in plastic troughs. Field connection terminals shall be UL listed for 600 V service, individually identified per control and interlock drawings, with adequate clearance for field wiring.
3. Each local panel shall have a control power source power switch (on-off) with overcurrent protection.

2.9 WIRING AND RACEWAYS

A. General. Provide copper wiring, plenum cable, and raceways as specified in applicable sections of Division 26.

B. Insulated wire shall use copper conductors and shall be UL listed for 90°C (200°F) minimum service.

PART 3 - EXECUTION

3.1 EXAMINATION

A. Thoroughly examine project plans for control device and equipment locations. Report discrepancies, conflicts, or omissions to Architect or Engineer for resolution before starting rough-in work.

B. Inspect site to verify that equipment can be installed as shown. Report discrepancies, conflicts, or omissions to Engineer for resolution before starting rough-in work.

C. Examine drawings and specifications for work of others. Report inadequate headroom or space conditions or other discrepancies to Engineer and obtain written instructions for changes necessary to accommodate Section 230993 work with work of others. Controls Contractor shall perform at his expense necessary changes in specified work caused by failure or neglect to report discrepancies.

3.2 PROTECTION

A. Controls Contractor shall protect against and be liable for damage to work and to material caused by Contractor's work or employees.

B. Controls Contractor shall be responsible for work and equipment until inspected, tested, and accepted. Protect material not immediately installed. Close open ends of work with temporary covers or plugs during storage and construction to prevent entry of foreign objects.

3.3 COORDINATION

A. Site.
   1. Assist in coordinating space conditions to accommodate the work of each trade where work will be installed near or will interfere with work of other trades. If installation without coordination causes interference with work of other trades, Contractor shall correct conditions 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. Provide Test and Balance Contractor a single set of necessary tools to interface to control system for testing and balancing.
   2. Train Test and Balance Contractor to use control system interface tools.
   3. Provide a qualified technician to assist with testing and balancing the first 20 terminal units.
   4. Test and Balance Contractor shall return tools undamaged and in working condition at completion of testing and balancing.

C. Life Safety.
   1. Duct smoke detectors required for air handler shutdown are provided and wired under Division 26.
   2. Smoke dampers and actuators required for duct smoke isolation are provided under Division 23 and wired by Division 26.
   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 26.

D. Coordination with Other Controls. Integrate with and coordinate controls and control devices furnished or installed by others as follows.
   1. Communication media and equipment shall be provided as specified in Article 2.2 (Communication).

2. Each supplier of a controls product shall configure, program, start up, and test that product to meet the sequences of operation described in Section Appendix A regardless of where within the contract documents those products are described.
3. Coordinate and resolve incompatibility issues that arise between control products provided under this section and those provided under other sections or divisions of this specification.
4. Controls Contractor shall be responsible for integration of control products provided by multiple suppliers regardless of where integration is described within the contract documents.

3.4 GENERAL WORKMANSHIP

A. Install equipment, piping, and wiring or raceway horizontally, vertically, and parallel to walls wherever possible.

B. Provide sufficient slack and flexible connections to allow for piping and equipment vibration isolation.

C. Install equipment in readily accessible locations as defined by National Electrical Code (NEC) Chapter 1 Article 100 Part A.

D. Verify wiring integrity to ensure continuity and freedom from shorts and ground faults.

E. Equipment, installation, and wiring shall comply with industry specifications and standards and local codes for performance, reliability, and compatibility.

F. The controls contractor shall provide an additional two (2) year on-site maintenance warranty on their installed EMS system.

3.5 FIELD QUALITY CONTROL

A. Commissioning and start-up of the BAS system shall be performed factory certified employees of the BAS contractor or manufacturer. Under no instances shall electrical subcontractors perform this work.

B. Work, materials, and equipment shall comply with rules and regulations of applicable local, state, and federal codes and ordinances as identified in Article 1.8 (Codes and Standards).

C. Continually monitor field installation for code compliance and workmanship quality.

D. Contractor shall arrange for work inspection by local or state authorities having jurisdiction over the work.

3.6 WIRING

A. To differentiate BAS wiring from that of other trades, all cable except for underground will have a yellow outer jacket (no exceptions).

B. Division 26 contractor shall supply 120vac power to a junction box in each mechanical room for use by the BMCS.

C. A Conduit fill based on plenum 18 gauge 2 conductor:
1. 1/2 inch - No more than 4 conductors.
2. 3/4 inch - No more than 8 conductors.
3. 3. 1 inch - No more than 12 conductors.

D. Control and interlock wiring and installation shall comply with national and local electrical codes, Division 26, and manufacturer's recommendations. Where the requirements of Section 230923 differ from Division 26, Section 230923 shall take precedence.

E. All wires whether control network or device wire shall be marked with Brady-type markers.

F. NEC Class 1 (line voltage) wiring shall be UL listed in approved raceway as specified by NEC and Division 26.

G. Low-voltage wiring shall meet NEC Class 2 requirements. Subfuse low-voltage power circuits as required to meet Class 2 current limit.

H. NEC Class 2 (current-limited) wires not in raceway but in concealed and accessible locations such as return air plenums shall be UL listed for the intended application.

I. Install wiring in raceway where subject to mechanical damage and at levels below 3 m (10ft) in mechanical, electrical, or service rooms.

J. Do not install Class 2 wiring in raceway 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).

K. Install Class 1 and Class 2 wiring in separate raceways. Boxes and panels containing high-voltage wiring and equipment shall not be used for low-voltage wiring except for the purpose of interfacing the two through relays and transformers.

L. Do not install wiring in raceway containing tubing.

M. Run exposed Class 2 wiring parallel to a surface or perpendicular to it and tie neatly at (5 ft) intervals.

N. Contractor shall install all low voltage communication wiring as per all TIA/EIA communication cabling standards. All cabling shall be installed in dedicated cabling support such as j-hook, d-rings, or saddles. All supports shall be supported directly from building structure. Do not support cabling or supports from ceiling grid wire, conduit, ductwork, piping, or other system cabling. All cabling must be installed in independent support for that given system and may not share supports or run in same conduit or support. All cabling shall be supported every 5'-0" from approved cabling support method. Contractor shall bundle all system cabling and label all wiring for system they serve. All cabling passing thru walls shall require dedicated conduit sleeves with bushing to protect cabling during installation. Contractor shall provide 1 meter service loops at all device termination locations and 3 meter service loops at all headend termination locations. All low voltage HVAC control cabling shall be yellow in color unless specified otherwise. Do not use ductwork, electrical raceways, piping, or ceiling suspension systems to support or anchor cables.

O. Secure raceways with raceway clamps fastened to structure and spaced according to code requirements. Raceways and pull boxes shall not be hung on or attached to ductwork, electrical raceways, piping, or ceiling suspension systems.

P. Size raceway and select wire size and type in accordance with manufacturer's recommendations and NEC requirements.

Q. Include one pull string in each raceway 2.5 cm (1 in.) or larger.

R. Use color-coded conductors throughout.

S. Locate control and status relays in designated enclosures only. Do not install control and status relays in packaged equipment control panel enclosures containing Class 1 starters.

T. Conceal raceways except within mechanical, electrical, or service rooms. Maintain minimum clearance of 15 cm (6 in.) between raceway and high-temperature equipment such as steam pipes or flues.

U. Adhere to requirements in Division 26 where raceway crosses building expansion joints.

V. Install insulated bushings on raceway ends and enclosure openings. Seal top ends of vertical raceways.

W. Terminate control and interlock wiring related to the work of this section. Maintain at the job site updated (as-built) wiring diagrams that identify terminations.

X. Flexible metal raceways and liquid-tight flexible metal raceways shall not exceed 1 m (3 ft) in length and shall be supported at each end. Do not use flexible metal raceway less than ½ in. electrical trade size.

Y. Install raceway rigidly, support adequately, ream at both ends, and leave clean and free of obstructions. Join raceway sections with couplings and according to code. Make terminations in boxes with fittings. Make terminations not in boxes with bushings.

3.7 COMMUNICATION WIRING

A. Communication wiring shall be low-voltage Class 2 wiring and shall comply with Article 3.7 (Wiring).

B. Install communication wiring in separate raceways and enclosures from other Class 2 wiring.

C. During installation do not exceed maximum cable pulling, tension, or bend radius specified by the cable manufacturer.

D. Verify entire network's integrity following cable installation using appropriate tests for each cable.

E. Install lightning arrestor according to manufacturer's recommendations between cable and ground where a cable enters or exits a building.

F. Each run of communication wiring shall be a continuous length without splices when that length is commercially available. Runs longer than commercially available lengths shall have as few splices as possible using commercially available lengths.

G. Label communication wiring to indicate origination and destination.

H. Ground coaxial cable according to NEC regulations article on "Communications Circuits, Cable, and Protector Grounding."

3.8 FIBER OPTIC CABLE

A. During installation do not exceed maximum pulling tensions specified by cable manufacturer. Post-installation residual cable tension shall be within cable manufacturer's specifications.

B. Install cabling and associated components according to manufacturers' instructions. Do not exceed minimum cable and unjacketed fiber bend radii specified by cable manufacturer.

3.9 INSTALLATION OF SENSORS

A. Install sensors according to manufacturer's recommendations.

B. Mount sensors rigidly and adequately for operating environment.

C. Install room temperature sensors on concealed junction boxes properly supported by wall framing.

D. Air seal wires attached to sensors in their raceways or in the wall to prevent sensor readings from being affected by air transmitted from other areas.

E. Use averaging sensors in mixing plenums and hot and cold decks. Install averaging sensors in a serpentine manner vertically across duct. Support each bend with a capillary clip.

F. Install mixing plenum low-limit sensors in a serpentine manner horizontally across duct. Support each bend with a capillary clip. Provide 3 m (1 ft) of sensing element for each 1 m^2 (1 ft^2) of coil area.

G. Install pipe-mounted temperature sensors in wells. Install liquid temperature sensors with heat-conducting fluid in thermal wells.

H. Install outdoor air temperature sensors on north wall at designated location with sun shield.

I. Differential Air Static Pressure.
   1. Supply Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.
   2. Return Duct Static Pressure. Pipe high-pressure tap to duct using a pitot tube. Make pressure tap connections according to manufacturer's recommendations.
   3. Building Static Pressure. Pipe pressure sensor's low-pressure port to the static pressure port located on the outside of the building through a high-volume accumulator. Pipe high-pressure port to a location behind a thermostat cover.
   4. Piping to pressure transducer pressure ports shall contain a capped test port adjacent to transducer.
   5. Pressure transducers, except those controlling VAV boxes, shall be located in control panels, not on monitored equipment or on ductwork. Mount transducers in a vibration-free location accessible for service without use of ladders or special equipment.
   6. Mount gauge tees adjacent to air and water differential pressure taps. Install shut-off valves before tee for water gauges.

   A. Smoke detectors, freezestats, high-pressure cut-offs, and other safety switches shall be hard-wired to de-energize equipment as described in the sequence of operation. Switches shall require manual reset. Provide contacts that allow DDC software to monitor safety switch status.

3.10 FLOW SWITCH INSTALLATION

A. Use correct paddle for pipe diameter.

B. Adjust flow switch according to manufacturer's instructions.

3.11 ACTUATORS

A. General. Mount actuators and adapters according to manufacturer's recommendations.

B. Electric and Electronic Damper Actuators. Mount actuators directly on damper shaft or jackshaft unless shown as a linkage installation. Link actuators according to manufacturer's recommendations.
   1. For low-leakage dampers with seals, mount actuator with a minimum 5° travel available for damper seal tightening.
   2. To compress seals when spring-return actuators are used on normally closed dampers, power actuator to approximately 5° open position, manually close the damper, then tighten linkage.
   3. Check operation of damper-actuator combination to confirm that actuator modulates damper smoothly throughout stroke to both open and closed positions.
   4. Provide necessary mounting hardware and linkages for actuator installation.

3.12 IDENTIFICATION OF HARDWARE AND WIRING

A. Label wiring and cabling, including that within factory-fabricated panels, with control system address or termination number at each end within 5 cm (2 in.) of termination.

B. Label pneumatic tubing 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 instrument or item served.

D. Label control panels with minimum 1 cm (½ in.) letters on laminated plastic nameplates.

E. Label each control component with a permanent label. Label plug-in components such that label remains stationary during component replacement.

F. Label valves with nameplates.

G. Manufacturers' nameplates and UL or CSA labels shall be visible and legible after equipment is installed.

H. Label identifiers shall match record documents.

3.13 PROGRAMMING

A. Point Naming. Name points as shown on the equipment points list provided with each sequence of operation. See Section (Sequences of Operation). 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.

B. Software Programming. Programming shall provide actions for each possible situation. Graphic- or parameter-based programs shall be documented. Text-based programs shall be modular, structured, and commented to clearly describe each section of the program.
   1. Application Programming. Provide application programming that adheres to sequences of operation specified . Program documentation or comment statements shall reflect language used in sequences of operation.
   2. System Programming. Provide system programming necessary for system operation.

C. Operator Interface.
   1. Standard Graphics. Provide graphics as specified in Article 2.3 Paragraph E.2 (System Graphics). Show on each equipment graphic input and output points and relevant calculated points such as indicated on the applicable Points List A. Point information on graphics shall dynamically update.

2. Install, initialize, start up, and troubleshoot operator interface software and functions (including operating system software, operator interface database, and third-party software installation and integration required for successful operator interface operation).
3. DDC screen graphic room numbers shall be based on final room graphics package. Obtain Architect/Owner approval of final room numbers prior to programming.

3.14 CONTROL SYSTEM CHECKOUT AND TESTING

A. Startup Testing. Complete startup testing to verify operational control system before notifying Owner of system demonstration. Provide Owner with schedule for startup testing. Owner may have representative present during any or all startup testing.
1. Calibrate and prepare for service each instrument, control, and accessory equipment furnished under Section 230923
2. Verify that control wiring is properly connected and free of shorts and ground faults. Verify that terminations are tight.
3. Enable control systems and verify each input device's calibration. Calibrate each device according to manufacturer's recommendations.
4. Verify that binary output devices such as relays, solenoid valves, two-position actuators and control valves, and magnetic starters, operate properly and that normal positions are correct.
5. Verify that analog output devices such as I/Ps and actuators are functional, that start and span are correct, and that direction and normal positions are correct. Check control valves and automatic dampers to ensure proper action and closure. Make necessary adjustments to valve stem and damper blade travel.
6. Prepare a log documenting startup testing of each input and output device, with technician's initials certifying each device has been tested and calibrated.
7. Verify that system operates according to sequences of operation. Simulate and observe each operational mode by overriding and varying inputs and schedules. Tune PID loops and each control routine that requires tuning.
8. Alarms and Interlocks.
    a. Check each alarm with an appropriate signal at a value that will trip the alarm.
    b. Trip interlocks using field contacts to check logic and to ensure that actuators fail in the proper direction.
    c. Test interlock actions by simulating alarm conditions to check initiating value of variable and interlock action.

3.15 CONTROL SYSTEM DEMONSTRATION AND ACCEPTANCE

A. Demonstration. Prior to acceptance, perform the following performance tests to demonstrate system operation and compliance with specification after and in addition to tests specified in Article 3.17 (Control System Checkout and Testing). Provide Engineer with log documenting completion of startup tests.
1. Engineer will be present to observe and review system demonstration. Notify Engineer at least 10 days before system demonstration begins.
2. Demonstration shall follow process submitted and approved under Section 230993 Article 1.10 (Submittals). Complete approved checklists and forms for each system as part of system demonstration.
3. Demonstrate actual field operation of each sequence of operation as specified in Section 230993 Appendix A. Provide at least two persons equipped with two-way communication. Demonstrate calibration and response of any input and output points requested by Engineer. Provide and operate test equipment required to prove proper system operation.
4. Demonstrate compliance with Section 230993 Part 1 (System Performance).
5. Demonstrate compliance with sequences of operation through each operational mode.
6. Demonstrate complete operation of operator interface.
7. Demonstrate each of the following.

a. DDC loop response. Supply graphical trend data output showing each DDC loop's response to a setpoint change representing an actuator position change of at least 25% of full range. Trend sampling rate shall be from 10 seconds to 3 minutes, depending on loop speed. Each sample's trend data shall show setpoint, actuator position, and controlled variable values. Engineer will require further tuning of each loop that displays unreasonably under- or over-damped control.
b. Demand limiting. Supply trend data output showing demand-limiting algorithm action. Trend data shall document action sampled each minute over at least a 30-minute period and shall show building kW, demand-limiting setpoint, and status of setpoints and other affected equipment parameters.
c. Building fire alarm system interface.
d. Trend logs for each system. Trend data shall indicate setpoints, operating points, valve positions, and other data as specified in the points list provided with each sequence of operation in Section 230993 Appendix A. Each log shall cover three 48-hour periods and shall have a sample frequency not less than 10 minutes or as specified on its points list. Logs shall be accessible through system's operator interface and shall be retrievable for use in other software programs as specified in Section 230993 Article 2.3 Paragraph E.11 (Trend Configuration).

8. Tests that fail to demonstrate proper system operation shall be repeated after Contractor makes necessary repairs or revisions to hardware or software to successfully complete each test.

B. Acceptance.
1. After tests described in this specification are performed to the satisfaction of both Engineer and Owner, Engineer will accept control system as meeting completion requirements. Engineer may exempt tests from completion requirements that cannot be performed due to circumstances beyond Contractor's control. Engineer will provide written statement of each exempted test. Exempted tests shall be performed as part of warranty.
2. System shall not be accepted until completed demonstration forms and checklists are submitted and approved as required in Section 230993 Article 1.10 (Submittals).

3.16 CLEANING

A. Each day clean up debris resulting from work. Remove packaging material as soon as its contents have been removed. Collect waste and place in designated location.

B. On completion of work in each area, clean work debris and equipment. Keep areas free from dust, dirt, and debris.

C. On completion of work, check equipment furnished under this section for paint damage. Repair damaged factory-finished paint to match adjacent areas. Replace deformed cabinets and enclosures with new material and repaint to match adjacent areas.

3.17 CENTRALIZED REPORTING DATABASE

A. A centralized reporting database shall be used to store all information related to utility and environmental data. Monitored data shall be extracted from the BAS with web services via XML/SOAP and stored automatically in the centralized database. Building and utility billing information shall be entered manually through a graphical user interface and updated monthly.

B. Environmental Monitoring Provide benchmarking for the building by use of an environmental index (EI). The environmental index shall be an indicator of the indoor conditions as compared to the temperature, humidity, and CO_2 setpoints during occupancy. Any deviation from setpoint shall degrade the environmental index rating. Data shall be assembled in a manner that gives an indexed rating on a 0 to 100 scale. The entire building shall be evaluated by collecting environmental data as listed below at every zone at intervals of at least 15 minutes. There shall be

a building level index (score) based on the average of the data collected from every zone. This index shall be graphically displayed on a Facility Performance graphic and trended along with the number of active zones that are currently being monitored. This information shall be utilized to verify building environmental conditions and conformance with ASHRAE Standard 55-2004 Thermal Environmental Conditions for Human Occupancy, and that energy conservation measures do not adversely affect the indoor environment.

1. Environmental data used for calculating the Environmental Index;
2. Zone Occupancy
3. Zone Temperature & Setpoint
4. Zone Relative Humidity & Setpoint
5. Zone CO2 & Setpoint
6. Return Air CO2 (weighted by number of zones represented)
7. Return Air Humidity (weighted by number of zones represented)

C. Runtime Monitoring Occupancy and runtime data shall be recorded for each building. A user defined number of occupied zones shall be used to consider the building running in an occupied mode. The number of occupied hours shall be logged on a daily, weekly, monthly, and yearly basis. The chiller and heating water plants runtimes shall be independently monitored and logged on a daily, weekly, monthly, and yearly basis. The accumulated data shall be graphically displayed along with the daily trend for each on a Facility Runtime graphic.

D. Utility Data Monitoring Utility monitoring shall use revenue grade metering. Utility reporting shall monitor and record consumption at a minimum of 15 minute intervals.

1. Utility data shall be recorded for each building for the following values;
2. Electric Demand (kW)
3. Electric Usage (kWh)
4. The buildings total monitored energy consumption shall be converted to an instantaneous kBtuh. This energy intensity number shall be trended and integrated into a daily kBtu usage. The daily, monthly, and yearly kBtu usage shall be logged for operator review. The current energy intensity shall also be compared to a programmed high and low target range and shall be graphically displayed as to how the building is operating when compared to the target range. The target energy intensity should be dependant on the percentage of occupied zones and season. The current energy intensity along with the daily, monthly, yearly kBtu usage, environmental index, and number of occupied zones shall be graphically displayed on a Facility Performance graphic.

E. Weather Data The daily NOAA Quality Controlled Local Climatological weather data, from the closest weather station to each building, shall be collected and updated in the database at least weekly for use with utility and environmental analysis. High accuracy outside air monitoring may be used as a substitute if calibrated annually and not affected by solar load or building conditions.

F. BAS Data Retention The Building level BAS data listed below shall be collected at 15 minute intervals and stored for a minimum of 1095 days.

1. BAS Data collected for long term analysis;
2. Occupancy
3. Number of zones occupied
4. Environmental Index
5. Chilled water and heating water plant runtimes
6. Utility meter usage
7. Outside air temperature if the high accuracy outside air monitoring is used instead of NOAA weather data

G. Building Information Building data shall be collected and input into a centralized reporting database. This data shall be assimilated by the BAS contractor by site survey. Data from drawings or schedules is unacceptable on its own, and must be field verified.

1. The following data shall be collected for all buildings;
2. Building square footage over time from the date of construction to the present
3. Percent of square footage that is conditioned space
4. Building population over time from original occupancy to the present
5. Standard hours of operation
6. Number of computers
7. Relationship/assignment of utility meters (Electric, Gas, & Water) to each building
8. Current utility budget by building

H. Utility Billing Information: The utility account information associated with each meter along with the monthly utility bill usage and cost information shall be recorded in a central database.

I. Reporting Reports shall be generated which configure the Central Reporting Database data in a user-friendly format and all reports shall be available via a standard Internet browser. The report data shall be easily sorted to identify excessive consumption or environmental issues. User definable alarm thresholds shall be enabled to clearly identify problem areas. All Reports shall be user configurable based on user-defined timeframes. At a minimum, the reports shall consist of the following;
   1. Budget Report – Analysis of budgeted costs versus actual costs.
   2. Baseline Report – Trend consumption and occupancy for each day of a user defined period.
   3. Comparative Analysis Report – Data shall be sorted by the following criteria; building type, usage, usage per square foot, usage per hours of occupancy, usage per square foot per hours of occupancy, cost per square foot, cost per occupant, & hours of occupancy.
   4. Return on Investment Report – comparative data based on consumption history before, and consumption history after an Energy Conservation measure is executed.
   5. Performance Report - Summarize the building operation based on consumption, environmental index, and current Energy Star rating.

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SECTION 23 36 00

AIR TERMINAL UNITS

PART 1 - GENERAL

1.1 SECTION INCLUDES

A. Furnish and install air terminal units of constant volume fan powered type for use in variable volume central systems, including:

1. Fan powered terminal units.
2. Variable volume regulators.
3. Integral heating coils.
4. Integral damper motor operators.
5. Integral controls.

1.2 RELATED SECTIONS

A. Section 230716 – HVAC Equipment Insulation.

B. Section 232113 –Hydronic Piping.

C. Section 233100 – HVAC Ducts and Casings.

D. Section 233300 – Air Duct Accessories.

E. Section 230993 –Direct-Digital Control System for HVAC.

F. Section 230593 – Testing, Adjusting, and Balancing for HVAC.

1.3 REFERENCES

A. NFPA 90A – Insulation of Air Conditioning and Ventilation Systems.

B. UL 181 – Factory-Made Air Ducts and Connectors.

C. ADC 1062 – Air Distribution and Control Device Test Code.

1.4 CERTIFIED INDEPENDENT TESTING

A. Prior to providing Submittals, the unit manufacturer is required to submit one powered terminal unit of each size to be used on this project. Unit shall be shipped to the TAB Contractor for testing in their test facility.

B. Units found to be in compliance with specifications will be returned to unit manufacturer (at their expense) and may be submitted to the A/E for review.

C. Units found to be in compliance with specifications will be returned to unit manufacturer (at their expense) for modification and/or re-design. All unit sizes will be re-tested by the TAB Contractor (at the expense of the unit manufacturer) until they are brought into total

compliance with specifications.

1.5 SUBMITTALS

A. Indicate on product data the configuration, general assembly, and materials used in fabrication.

B. Include manufacturer's installation instructions.

C. Include certified factory test results indicating the noise criteria and sound power and performance characteristics for each unit. Include maximum and minimum cfm ratings at 0.50-inch wg with the unit on fully bypass or fully primary air with the fan running a medium speed, radiated sound power and discharge sound pressure with the fan on and unit on full bypass, fan horsepower and fan curve, pressure drop through the unit with heating coil and dampers on full bypass. Include schedules listing discharge and radiated sound power level for each of second through sixth octave band at inlet static pressures on one to 4 inch wg (250 to 1,000 Pa).

D. Provide operation and maintenance manual. Include directions for resetting constant volume generator.

PART 2 - PRODUCTS

2.1 MANUFACTURERS

A. Nailor (Preferred supplier)

B. Krueger

C. Titus

D. Price

2.2 MANUFACTURED UNITS

A. Constant volume, fan powered, supply air control terminal for connection to single medium pressure duct, central air system, with variable volume controls, hot water heating coils and fused disconnect switch.

B. Identify each airflow unit with clearly marked identification label and airflow indicator. Include unit nominal air flow, maximum factory set air flow, minimum factory set air flow, and coil type on label.

2.3 FABRICATION

A. Casings: Minimum 22 gauge casing with 20 gauge bottom for seize 6 to 8 and minimum 20 gauge casing with 18 gauge bottom for sizes 10 and above. Provide stiffeners and construct with sufficient rigidity to prevent vibration due to the action of turbulent air on the panel of the cabinet. Provide entire assembly capable of withstanding a maximum static pressure of 3.0 inches WG. Units shall have full or divided removable bottom access panels with quarter-turn mechanical locks. Unit casing shall all incorporate a minimum of four (one at each corner) galvanized steel angle brackets to accept minimum ½" diameter all-thread rod and vibration isolator. Brackets shall be located as required to allow removal of ductwork, heating coil and air filter without removing unit and shall be a minimum of 1" above bottom of unit casing.

B. Lining: Provide neoprene or vinyl coated fibrous glass insulation meeting, NFPA 90A 1 inch thick, 1.5 pounds per cubic foot density, or 3/4-inch thick dual density, 4 pounds per cubic foot to 1.5 pounds per cubic foot requirements and UL 181 erosion requirements. Cover all exposed parts, such as braces, etc. in contact with exterior surfaces, to prevent condensation on the exterior of the cabinet and minimize both heat and sound transmission.

C. Assembly: Air volume damper, fans and controls in single cabinet including inlet sound attenuator and renewable media filter in permanent frame.

D. Plenum Air Inlets: Round/Oval stub connections for duct attachment.

E. Air Outlets: S and drive connections or 1 inch flange duct attachment.

F. Limit air leakage from cabinet to a maximum of three percent at 3.0 inches WG interior casing pressure.

2.4 VOLUME DAMPER

A. Locate air volume damper assembly inside unit casing. Construct from extrude aluminum or 20 gage galvanized steel components. Key damper blades into shaft with nylon fitted pivot points. Secure damper to independent damper rod with a minimum of four screws. Tap damper rod to allow the set screw of the control arm to penetrate the damper rod.

B. Provide automatic flow control assembly which combines spring rates matched for each volume regulator size with machined dashpot for stable operation.

C. Mount automatic flow control assembly externally or provide access doors.

D. Provide factory calibrated assembly consisting of damper and damper shaft extension for connection to externally mounted control actuator.

E. Provide externally mounted electronic actuator to position damper, normally open, as indicated.

2.5 FAN ASSEMBLY

A. Forward curved centrifugal type fan of metal construction. Motors must be GE ICM2+. DC and brushless. Motor must be complete with and operated by a single phase integrated controller/inverter that operates the wound stator and senses rotor position to electrically comminuted the stator. All motors must be deigned for synchronous rotation. Motor rotor must be permanent magnet type with near zero rotor losses. Motor must have built in soft start and soft speed change ramps. Motor must be able to be mounted with shaft in horizontal or vertical orientation. Motor must be permanently lubricated with ball bearings. Sleeve bearings will not be acceptable. Motor shall be direct coupled to the blower. Motor must maintain a minimum of 70% efficiency over its entire operating range.

B. The manufacturer of the terminal units must set the fan CFM at the factory. Fan CFM must be constant within +/-5% regardless of changes in static whether upstream or downstream of the terminal unit after it is installed. Fan CFM is to be set with a potentio-meter. Neither SCRs nor rheostats are acceptable means of setting fan CFM. A speed adjustment device must be include with the motor for field adjustment should construction or design changes become necessary.

C. Provide backdraft damper at the return air inlet to prevent backflow of primary air.

D. Internally suspend and isolate fan/motor assembly from casing on rubber isolator to prevent noise and vibration transmission from the fan/motor assembly to the casing.

E. Provide fan/ motor assembly with a service life of 15 years.

F. Provide capacitor or controls to allow rotation of the fan only in the proper direction regardless of condition of fan at start up.

G. Provide non-overloading type system with fan/motor assembly sized to supply all downstream static pressure requirements.

2.6 HEATING COIL

A. Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch, and rated for a minimum working pressure of 200 psig at a maximum water temperature of 220 deg F. Include manual air vent and drain valve.

2.7 WIRING

A. Factory mount and wire controls. Mount electrical components in control box with removable cover. Incorporate single point electrical connection to power source.

B. Factory mount transformer for control voltage on electric and electronic control units. Provide terminal strip in control box for field wiring of thermostat and power source.

C. Factory wire fan to terminal strip.

D. Provide factory installed fused disconnect switch.

2.8 CONTROLS

A. Automatic Damper Operator:

1. Operate: Air volume damper and automatic volume control.

2. Electric Damper Operator: 24 volt.

3. Maximum Volume Controller and Probe: Electronic, with calibration pressure taps for high flow limited proportional variable air volume control.

a. Velocity Reset Controller and Probe: Electronic, with calibration pressure taps for pressure independent proportional variable air volume with means for pressure independent compensating for varying inlet static pressure, with minimum and maximum limits set at reset device, mounted in control box.

2.9 FAN POWERED UNIT CONTROLS

A. Contain in NEMA-1 enclosure with access panel sealed from air flow and mounted on side of unit. The Terminal Equipment Controllers (TEC) shall be furnished by the BMCS System Manufacturer to the unit manufacturer for installation, wiring and testing at their factory. The factory mounted controls shall accomplish the following specified Sequence of Operation.

B. Electronic Control Occupied Mode:

1. When duct pressure is sensed indicating primary air system operating, and primary variable volume damper proportions air flow from BMCS and fan operates.

2. As space sensors senses reduced cooling demand, volume damper closes. As cooling demand continues to fall, volume damper closes.

3. Velocity reset primary air control (pressure independent) with maximum and minimum limits.

4. Hi-limit device, factory set, limits maximum primary air flow.

5. As space sensor calls for less cooling, control system closes volume damper to minimum stop from central system primary air duct before heating is initiated. On sensing further need for heat, heating coil is energized.

C. Electronic Control – Unoccupied Mode:

1. DDC Control System cycles fan and controls at reduced temperature (day/night setback).

2.10 SOUND PERFORMANCE CRITERIA

A. The following chart reflects maximum allowable discharge and radiated sound power level

				Maximum Radiated Sound Power Level, dB, at Band No. and Center Freq., Hz				
Unit Size	Inlet Dia.	Fan and 100% Primary, CFM	2 125	3 250	4 500	5 1,000	6 2,00	7 4,00
4	8	250 to 500	55	55	50	42	39	31
4	10	501 to 800	63	60	56	49	44	37
4	12	801 to 1,150	70	65	61	55	49	43
6	12	1,151 to 1,400	68	64	58	53	47	42
6	14	1,401 to 1,600	71	66	60	56	50	44
6	16	1,601 to 2,050	75	70	64	60	55	49
				Maximum Discharge Sound Power Level, dB, at Band No. and Center Freq., Hz				
Unit Size	Inlet Dia.	Fan and 100% Primary, CFM	2 125	3 250	4 500	5 1,000	6 2,00	7 4,00
4	8	250 to 500	62	57	55	51	47	47
4	10	501 to 800	68	64	59	58	55	55
4	12	801 to 1,150	73	69	64	63	61	61
6	12	1,151 to 1,400	72	63	63	62	60	60
6	14	1,401 to 1,600	74	66	65	64	63	60
6	16	1,601 to 2,050	78	69	69	67	66	65
Note: All ratings at 1.0” wc Inlet Static Pressure adn0.25” wc Discharge Static Pressure Up to +2dB variation allowed. Based Upon Titus TQS Constant Volume with ECM (for Extended Range Operation)								

PART 3 - EXECUTION

3.1 INSTALLATION

A. Install in accordance with manufacturer's instructions.

B. Ensure 3 feet accessibility around the unit.

C. Provide ceiling access doors or locate units above easily removable ceiling components.

D. Support units individually from building structure. Do not support from adjacent ductwork. (No Exceptions.)

E. Refer to Section 233100 for connections to equipment.

F. Install heating coils in accordance with detail on Drawings.

G. Install disposable filters in accordance with Section 234100.

END OF SECTION

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