

**Addendum No. 3**

SECTION 011100  
SUMMARY OF THE WORK

PART 1 GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section summarizes construction operations required by the Contract Documents, defines aspects of Prime Contractor's relationship with City and lists special City requirements.

1.2 RELATED WORK SPECIFIED ELSEWHERE

- A. Applicable provisions of Bidding Requirements, Contract Requirements in Division 0 and all applicable Division 1 sections.

1.3 PROJECT DESCRIPTION

- A. The Work covers the renovation/fit-out of floors 8, 9 and 10, plus related work on other floors, the site and the building exterior for the Office of Emergency Management located in the Philadelphia Public Services Building, 400 North Broad Street, Philadelphia, PA.

1.4 CONTRACTS

- A. Construct Work under a single Prime Contract for General Construction. The scope of Work for each Contract shall be as indicated below.
  - 1. Incidental Work provided by a one Prime Contractor but specified in a Division mainly the responsibility of a different Prime Contractor shall conform to the applicable specifications (i.e. earthwork required for Plumbing Work shall comply with the requirements of Division 2).
- B. General Construction Work: Provide all the Work of all Contracts, no matter where the information is located, except as specifically indicated to be performed by one of the other Prime Contractors.
  - 1. Selective demolition and new construction as required for new Mechanical., Plumbing and Electrical Work but only if indicated on the Demolition or Architectural Drawings. Cutting and patching required by the other Prime Contractors and not specifically indicated on the drawings are the responsibility of the respective Prime.
    - a. Remove conduit runs with wiring, boxes and devices built into existing walls, floors or roof slabs which are to be removed.
  - 2. Install access doors and panels, anchors, embedments, bolts, plates, sleeves, boxes, etc. furnished under other Contracts.
  - 3. Provide blocking, backing, box-outs, openings, recesses, etc. required for the Work of other Contracts.
  - 4. Provide a dumpster for the use of all Contractors.
  - 5. Provide periodic and final cleaning of building and site.

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6. Normal patching of sprayed-on fireproofing required because of the installation of Work required in other Contracts.
  7. Provide control lines and elevation benchmarks at central locations for the extension by other Prime Contractors.
  8. Provide temporary site perimeter fence and sidewalk cover if required.
  9. Provide temporary toilet facilities for all Contractors.
  10. Provide base flashing of roof-mounted curbs and rails provided under other Prime Contracts.
  11. Provide painting of all surfaces and equipment exposed to view in the finished Work, regardless of which Prime Contractor provided the surface or equipment.
  12. Furnish starters and disconnects for electrical components of systems included in the General Construction Work for installation under the Electrical Contract.
  13. **Provide specialized furniture in accordance with Section 012100 Allowances.**
  14. **Provide Audio-Visual Equipment in accordance with Section 012100 Allowances.**
- C. Mechanical Work, Plumbing Work, Electrical Work: In addition to the Work listed under Articles D, E, and F below, each of the three separate Prime Contractors shall provide the following:
1. All the Work including administrative and managerial procedures included in Divisions 0 and 1, indicated to be performed by each Prime Contractor.
  2. Excavation, bedding, de-watering, shoring, sheeting, backfill, and rough grading to indicated sub-grade plus removal of excess material as required for the Work of this Contract.
  3. Cutting and patching required to complete the Work of each respective Prime Contract, except where selective demolition and new construction are indicated in the General Contractors Work.
  4. Coordinate, layout and furnish to others for installation all anchors, embedments, bolts, plates, sleeves, boxes, etc. required for the Work of each respective Prime Contract.
  5. Coordinate and layout all blocking, backing, box-outs, openings, recesses, etc. required for the Work of each respective Prime Contract but located in the Work of others.
  6. Provide firesafing of fire-rated assemblies at penetrations caused by each respective Prime Contract. Provide sealant at all other penetrations.
  7. Provide concrete housekeeping pads, bases, thrust blocks, grouting, etc. required for the Work of each respective Prime Contract.
  8. Remove trash and debris created by the Work of each respective Prime Contract to the dumpster provided by the General Contractor. Provide

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daily clean-up of each area in which Work of each respective Prime Contract is performed.

9. Provide lay-out and coordination of the Work of each respective Prime Contract from control points established by the General Contractor.
  10. Provide on-site temporary office and storage facilities required for the Work of each respective Prime Contract.
  11. Provide temporary drinking water for the Work of each respective Prime Contract.
  12. Provide miscellaneous steel framing, channels, supports, bracing, hangers, etc. required for the Work of each respective Prime Contract.
  13. Provide all curbs and rails required to support roof-mounted equipment required for the Work of each respective Prime Contract. Base flashings shall be by the General Contractor. Provide counterflashing required to make watertight the installation of equipment furnished under each respective Prime Contract.
- D. Mechanical Work: All the Work indicated in the “M” series drawings and all the Work indicated in the Division 23 Specifications excluding the Plumbing sections listed below, and except as specifically indicated to be performed by one of the other Prime Contractors and as follows:
1. All the Work listed in Article C above.
  2. All the Work including administrative and managerial procedures included in Divisions 0 and 1 indicated to be the Work of this Contract.
  3. Demolition of all existing mechanical equipment and systems which is associated with and/or determined to be part of the Work of this Contract.
  4. Provide the instrumentation and controls system for the mechanical equipment specified in Section 230923.
  5. Furnish starters and disconnects for electrical components of systems included in the Mechanical Work for installation under the Electrical Contract.
- E. Plumbing Work: All the Work indicated in the “P” and “FP series drawings and all the Work indicated in specification Divisions 21 and 22, except as specifically indicated to be performed by one of the other Prime Contractors and as follows.
1. All the Work listed in Article C above.
  2. All the Work including administrative and managerial procedures included in Divisions 0 and 1 indicated to be the Work of this Contract.
  3. Demolition of all existing plumbing and fire protection equipment and systems which is associated with and/or determined to be part of the Work of this Contract.
  4. Provide both interior below grade Plumbing Work and all below-grade site utilities with their above grade accessories, including but not limited to the following:

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- a. Site domestic water service.
  - b. Site storm drainage service
  - c. Site sanitary sewer service.
  - d. Site combined sewer service.
  - e. Site natural gas service.
  - f. Building sub-drainage and foundation drainage system.
5. Provide the temporary water service required in Division 1.
  6. Furnish starters and disconnects for electrical components of systems included in the Plumbing Work for installation under the Electrical Contract.
  7. Provide the fire extinguishing system specified in Division 21.
- F. Electrical Work: All the Work indicated in the "E" series drawings and all the Work indicated in the Division 16 Specifications except as specifically indicated to be performed by one of the other Prime Contractors and as follows:
1. All the Work listed in Article C above.
  2. All the Work including administrative and managerial procedures included in Divisions 0 and 1 indicated to be the Work of this Contract.
  3. Demolition of all existing electrical equipment and systems, except conduit runs with wiring, boxes and devices built into existing walls, which is associated with and/or determined to part of the Work of this Contract.
  4. Install starters and disconnects furnished under other Prime Contracts.
  5. Provide the fire alarm system specified in Section 284621.11.
  6. Provide the electrical service to the building.
  7. Provide all site lighting including foundations.
  8. Provide the temporary lighting and power systems required in Division 1.

#### 1.5 WORK BY OTHERS

- A. Work on this Project which will be executed prior to the start of Work of this Contract and which is excluded from this Contract, is as follows:
  1. Base building work, indicated as N.I.C. on the drawings.
- B. Work on this Project which will be executed during the time of construction of the Work of this Contract and which is excluded from this Contract, is as follows:
  1. Base building work, indicated as N.I.C. on the drawings.
  2. ~~Furniture installation and related Work.~~

#### 1.6 CONTRACTOR'S USE OF PREMISES

- A. Prime Contractors shall limit use of the premises for Work and for storage to allow:

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1. Work by others
  2. Owner occupancy
  3. Public use
- B. Coordinate use of premises with Project Coordinator
- C. Protect products stored on-site
- D. Store products to avoid interference with operations of City or other Prime Contractors
- E. Secure and pay for additional storage and work areas if required by Contractor.
- F. Do not overload structure with stored materials.

PART 2 PRODUCTS            Not Used

PART 3 EXECUTION        Not Used

- END -

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SECTION 012100

ALLOWANCES

PART 1 GENERAL

1.1 DESCRIPTION OF WORK

- A. This Section specifies each Prime Contractor's administrative and procedural requirements governing handling and processing allowances

1.2 RELATED WORK SPECIFIED ELSEWHERE

- A. Applicable provisions of Bidding Requirements, Contract Requirements in Division 0 and all applicable Division 1 sections.
- B. Each section of the specifications including an allowance.

1.3 COORDINATION

- A. Designate required selection and delivery dates for products under each allowance in the Contractor's Construction Schedule.
- B. Designate each allowance with extensions based on estimated quantities for unit price allowances on Contractor's Schedule of Values.

1.4 DEFINITIONS

- A. Refer to Section 007200 Standard Contract Requirements.

1.5 ALLOWANCES

- A. Include in Total Base Bid Amount, an amount equal to Two Percent (2%) of the base bid amount for payment of permit fees. This is a direct cost; no mark-ups will be permitted.
- B. Bidders are to include the amount equal to \$500,000 to provide all specialized furniture located in the Emergency Operations Center (EOC) and the Regional Information Center (RIC).

**1. Basis-of-Design Manufacturer: Subject to compliance with requirements, provide products manufactured by Evans Consoles Inc., Vienna, VA; or comparable products manufactured by the following:**

**a. Watson Consoles, Poulsbo, WA.**

- C. Bidders are to include the amount equal to \$250,000 for Owner Controlled Allowance.
- D. Bidders are to include the amount equal to \$2,300,000 to provide all Audio-Visual Equipment as shown on the documents.

**1. Basis-of-Design Manufacturer: Subject to compliance with requirements, provide products manufactured by CineMassive Displays, Atlanta, GA.**

- E. Amount of each allowance (excluding 1.5.A above) shall include:
  - 1. Net cost of product.

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2. Delivery to site.
3. Applicable taxes.
4. Preparing submittals.
- 5. Handling at site, including unloading, uncrating and storage.**
- 6. Protection from elements and from damage.**
- 7. Installation.**
- 8. Other expenses required to complete installation.**

F. In addition to amounts of allowances (excluding 1.5.A above), include in the base bid amount, the Contractor's cost for:

1. Assisting in selection and obtaining proposals from suppliers and subcontractors.
2. Processing submittals.
- 3. Coordination.**
- ~~3. Handling at site, including unloading, uncrating and storage.~~
- ~~4. Protection from elements and from damage.~~
- ~~5. Labor, installation and finishing.~~
- ~~6. Other expenses required to complete installation.~~
- 4 7. Overhead and profit.

#### 1.6 SELECTION OF PRODUCTS

- A. Design Professional shall issue by Change Order a full specification for the final selected product.
- B. Contractor's Duties
  1. Notify Design Professional of deadlines for specification of final products, allowing for Contractor's required submissions as required to meet Date of Completion.
  2. Provide cost proposals for products being considered when requested by Design Professional.
  3. Notify Design Professional of any effect anticipated by selection of product or supplier under consideration as it relates to:
    - a. Construction Schedule.
    - b. Contract Sum.
    - c. On notification of selection, enter into purchase agreement with designated supplier.
  - 4. Substitutions: Follow procedures outlined in Section 012500 Substitution Procedures.**
    - a. Acceptance of substitutions is subject to approval by the City.**

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1.7 INSTALLATION

- A. Comply with requirements of applicable specification section, including warranties/guarantees.

1.8 ADJUSTMENT OF COSTS

- A. Should actual purchase cost be more or less than specified amount of allowance, Contract Sum shall be adjusted by Change Order equal to amount of difference. A percentage to cover Contractor's overhead and profit, as stated in Standard Contract Requirements, will be applied to difference in cost.
- B. For products specified under unit cost allowance unit cost applies to quantity required to complete the Work as determined by the Contractor.
  - 1. Submit invoices or other data to substantiate quantity actually used.
- C. Submit request for other costs, claimed for additional work caused by increase over amount of allowance, prior to required submission for product.

PART 2 PRODUCTS            Not Used

PART 3 EXECUTION        Not Used

- END -



SECTION 06 26 14 – MINERAL PROFILE PANELING

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: Light weight composite mineral profile paneling and seam finishing materials to create a monolithic sculptured wall surface.
- B. Products Furnished But Not Installed/Used Under This Section: Installation kit.
- C. Related Requirements:
  - 1. Section 092900 Gypsum Board for substrate and seam finishing.
  - 2. Section 099123 Interior Painting for sealing and painting of modular screen wall.

1.3. REFERENCES

- A. Abbreviations and Acronyms:
  - 1. ASTM: American Society for Testing and Materials.
  - 2. GA: Gypsum Association.
- B. Reference Standards:
  - 1. ASTM D 256 Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics.
  - 2. ASTM D 696 Standard Test Method for Coefficient of Linear Thermal Expansion of Plastics between -30 C and 30 C with a Vitreous Silica Dilatometer.
  - 3. NFPA 286 Standard Methods of Fire Tests for Evaluating Contribution of Wall and Ceiling Interior finish to Room Fire Growth.
  - 4. ASTM E 84 Standard Test Methods for Surface Burning Characteristics of Building Materials.
  - 5. GA-214 Recommended Levels of Gypsum Board Finish.

1.4. ADMINISTRATIVE REQUIREMENTS

- A. Pre-installation Meetings:
  - 1. Convene meeting at project site within one week of scheduled start of installation with representatives of the following in attendance: Owner, Architect, General Contractor, Installer, Finisher, and Painter.

2. Review substrate conditions, requirements of related work, installation instructions, seam finishing, and painting instructions, storage and handling procedures, and protection measures.
3. Keep minutes of meeting including responsibilities of various parties and deviations from specifications and installation instructions.

1.5. ACTION SUBMITTALS

- A. Product Data: Each product specified.
- B. Sustainable Design Submittals:
  1. **Product Data:** For adhesives, indicating VOC content.
  2. **Laboratory Test Reports:** For adhesives, indicating compliance with requirements for low-emitting materials.
- C. Project List: Minimum 5 previous completed installations or 5 installations of similar materials and complexity. Include contact name and e-mail address or telephone number for each project.
- D. Shop Drawings: Show standard and project specific details including termination at adjacent surfaces.
- E. Samples: Minimum 15 by 15 inch panel of specified design(s).

1.6. INFORMATIONAL SUBMITTALS

- A. Manufacturer's installation instructions.
- B. Qualification Statements: Proof of manufacturer, installer, and finisher qualifications.

1.8. QUALITY ASSURANCE

- A. Qualifications:
  1. Manufacturer: Minimum five years experience in producing mineral profile paneling.
  2. Installer: Minimum three years experience in finish carpentry/architectural woodwork installation.
  3. Finisher: Minimum three years experience in executing Level 5 finish in accordance with GA-214.
- B. Field Samples:
  1. Provide in a location selected by Architect showing representative sample of installed product including finished seam.
  2. Minimum Size: 8 by 8 feet.
  3. Approved field samples may remain as part of completed Work.

1.8. DELIVERY, STORAGE, AND HANDLING

- A. Storage and Handling Requirements:
  1. Store panels in fully enclosed space, protected against damage from moisture, direct sunlight, and surface contamination.

2. Store panels vertically, in shipping crates, until ready to be installed. Loosen crate lids to allow for venting. Do not stack or lean against walls.
  3. Store panels in area of installation minimum 24 hours prior to installation.
- B. Packaging Waste Management: 100 percent of materials used to package components of this section shall be recyclable.

1.9. FIELD CONDITIONS

A. Ambient Conditions:

1. HVAC: Operate HVAC system to maintain occupancy level temperature and relative humidity conditions (35 to 67 percent) in the area of installation from 24 hours prior to delivery of panels to the installation area through remainder of construction period.
2. Lighting: Permanent project lighting, including any special lighting used to highlight the profiled panels, must be operational prior to seam finishing.

1.10. WARRANTY

- A. Manufacturer Warranty: Provide manufacturer's standard limited warranty.

PART 2 - PRODUCTS

2.1 MANUFACTURER

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

2.2 COMPONENTS – WA-2 **MPP-1**

- A. Profile Panel: Smooth surface mineral composite panel with light weight plant-based foam back.
1. Size: 32 by 32 by 1.0 inch maximum profile relief.
  2. Physical Properties:

|  |                                |
|--|--------------------------------|
| a. Izod Impact Strength: ASTM D 256                      | 9.4 ft-lb/in <sup>2</sup>      |
| b. Thermal Expansion: ASTM D 696                         | 3.8x10 <sup>-7</sup> in/in °F. |
| c. Compressive Strength: ASTM D 696                      | 2.3 ksi.                       |
| d. Room Corner Burn Test: NFPA 286                       | Pass                           |
| e. Flame Spread Index: ASTM E 84                         | 0                              |
| f. Smoke Development Index: ASTM E 84                    | 50                             |
| g. Weight (for all designs excluding MUDD formerly YUMA) | 1.5 psf                        |
| h. Weight (for MUDD design only)                         | 3 psf                          |
  3. Design: CLIF ©; vertical orientation.
- B. Installation Kit: Item quantities in parenthesis denote quantities for (Small Kit—up to 50 panels/Large Kit—up to 100 panels). (Not applicable to *EZ-Seam*™ Designs.)

1. Dry Mix Joint Compound: One 18 lb bag SHEETROCK® brand EASY SAND™ 45, or BEADEX® brand SILVER SET™ 40.
2. Acrylic Fortifier: (One/Two) quart THORO® ACRYL 60®.
3. Construction Adhesive: (12/24) 10.2 oz tubes PL® Polyurethane Premium Construction Adhesive.
  - a. Adhesives shall have a VOC content of 50 g/L or less.
4. Primer Sealer: (3/6) gal GLIDDEN® GRIPPER® WHITE PRIMER/SEALER GL-3210-1200.
5. Countersink Drill Bit with Depth Stop-Collar: (One/Two) No. 7.
6. Flexible Spreader: (One/Two) MUDTOOLS SMT-Y2.
7. Sandpaper: (15/30) sheets No-Load 220G, (10/20) sheets No-Load 150G.
8. Plastic Container: One 100 oz.
9. Measuring Cup: One 8 oz.

### 2.3 ACCESSORIES

- A. Anchors: 30 lb. self-drilling, drywall anchor.
- B. Screws: Coarse thread, drywall type, length as required by panel design and in accordance with Manufacturer's Installation Instructions.

### 2.4 SOURCE QUALITY CONTROL

- A. Fabrication Tolerances:
  1. Dimensions, length and width:  $\pm 1/16$  inch.
  2. Thickness:  $\pm 1/16$  inch.
  3. Weight:  $\pm 1/2$  lb.

## PART 3 - EXECUTION

### 3.1 EXAMINATION

- A. Examine substrates upon which profile paneling will be installed.
  1. Verify that substrate is a material listed as an acceptable substrate by the profile paneling manufacturer.
- B. Verify that permanent project lighting is in place and operational prior to start of seam finishing.
- C. Coordinate with responsible entity to correct unsatisfactory conditions.
- D. Commencement of work by installer is acceptance of substrate conditions.

### 3.2 INSTALLATION

- A. Install profile paneling in accordance with Manufacturer's Installation Instructions except that seam finishing shall be performed under Section 092900 "Gypsum Board", and sealing and painting shall be performed under Section 099123 "Interior Painting".

3.3 ADJUSTING AND CLEANING

- A. Repair damaged and defective paneling, where possible, to eliminate functional and visual defects. Where not possible to repair, replace paneling. Adjust for uniform appearance.
- B. Clean profile paneling in accordance with manufacturer's recommendations. Touch up shop-applied finishes to restore damaged or soiled areas.

3.4 PROTECTION

- A. Protect finished work from damage during remainder of construction period.

END OF SECTION 06 26 14

SECTION 09 51 13 - ACOUSTICAL PANEL CEILINGS

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 acoustical panels and exposed suspension systems for interior ceilings.

1.3 PREINSTALLATION MEETINGS

- A. Preinstallation Conference: Conduct conference at Project site.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product.
- B. Sustainable Design Submittals:
  - 1. **Product Data:** For recycled content, indicating postconsumer and preconsumer recycled content and cost.
  - 2. **Laboratory Test Reports:** For ceiling products, indicating compliance with requirements for low-emitting materials.
- C. Samples: For each exposed product and for each color and texture specified.

1.5 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Reflected ceiling plans, drawn to scale, and coordinated with each other, using input from installers of the items involved.
- B. Product test reports.
- C. Research reports.
- D. Field quality-control reports.

1.6 CLOSEOUT SUBMITTALS

- A. Maintenance Data: For finishes to include in maintenance manuals.

1.7 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
  - 1. Acoustical Ceiling Units: Full-size panels equal to 2 percent of quantity installed.
  - 2. Suspension-System Components: Quantity of each exposed component equal to 2 percent of quantity installed.
  - 3. Hold-Down Clips: Equal to 2 percent of quantity installed.
  - 4. Impact Clips: Equal to 2 percent of quantity installed.

1.8 QUALITY ASSURANCE

- A. Source Limitations: Obtain each type of acoustical ceiling panel and supporting suspension system through one source from a single manufacturer.

1.9 DELIVERY, STORAGE, AND HANDLING

- A. Deliver acoustical panels, suspension-system components, and accessories to Project site and store them in a fully enclosed, conditioned space where they will be protected against damage from moisture, humidity, temperature extremes, direct sunlight, surface contamination, and other causes.
- B. Before installing acoustical panels, permit them to reach room temperature and a stabilized moisture content.

1.10 FIELD CONDITIONS

- A. Environmental Limitations: Do not install acoustical panel ceilings until spaces are enclosed and weathertight, wet-work in spaces is complete and dry, work above ceilings is complete, and ambient temperature and humidity conditions are maintained at the levels indicated for Project when occupied for its intended use.
  - 1. Pressurized Plenums: Operate ventilation system for not less than 48 hours before beginning acoustical panel ceiling installation.

1.11 COORDINATION

- A. Coordinate layout and installation of acoustical panels and suspension system with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, and partition assemblies.

PART 2 - PRODUCTS

2.1 PERFORMANCE REQUIREMENTS

- A. Ceiling products shall comply with the requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."
- B. Seismic Performance: Suspended ceilings shall withstand the effects of earthquake motions determined according to ASCE/SEI 7.
- C. Surface-Burning Characteristics: Comply with ASTM E 84; testing by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
  - 1. Flame-Spread Index: Class A according to ASTM E 1264.
  - 2. Smoke-Developed Index: 50 or less.

2.2 ACOUSTICAL PANELS – **APC-1**

- A. Basis-of-Design Product: Subject to compliance with requirements, provide USG Corporation; Mars High-NRC 87200 or a comparable product by one of the following:
  - 1. Armstrong World Industries, Inc.
  - 2. CertainTeed Corporation.
- B. Acoustical Panel Standard: Manufacturer's standard panels according to ASTM E 1264.
- C. Recycled Content: Postconsumer recycled content plus one-half of preconsumer recycled content not less than 75 percent.
- D. Classification: Type IV, Form 2, Pattern E.
- E. Color: White.
- F. Light Reflectance (LR): 0.88.
- G. Ceiling Attenuation Class (CAC): 35.
- H. Noise Reduction Coefficient (NRC): 80.
- I. Edge/Joint Detail: Beveled, tegular reveal sized to fit flange of exposed suspension-system members.
- J. Thickness: 7/8 inch.
- K. Modular Size: 24 by 24 inches.
- L. Suspension System: Type MSS-2.



**2.3 ACOUSTICAL PANELS – APC-4**

- A. **Basis-of-Design Product: Subject to compliance with requirements, provide Armstrong World Industries, Inc; Invisacoustics Basics Acoustical Panels 1212WH or a comparable product by one of the following:**
  - 1. **CertainTeed Corporation.**
  - 2. **USG Corporation.**
- B. **Acoustical Panel Standard: Manufacturer's standard panels according to ASTM E 1264.**
- C. **Recycled Content: Postconsumer recycled content plus one-half of preconsumer recycled content not less than 80 percent.**
- D. **Classification: Type IV, Form 2, Pattern E.**
- E. **Color: White.**
- F. **Noise Reduction Coefficient (NRC): 0.75.**
- G. **Edge/Joint Detail: Square.**
- H. **Thickness: 3/4 inch.**
- I. **Modular Size: 24 by 48 inches.**
- J. **Suspension System: None.**
  - 1. **Fasten to furring channels with manufacturer's standard recommended screws.**

**2.4 METAL SUSPENSION SYSTEM – MSS-1 (Not Used)**

**2.5 METAL SUSPENSION SYSTEM – MSS-2**

- A. Products: Subject to compliance with requirements, provide the following or comparable product from another manufacturer:
  - 1. Armstrong World Industries, Inc; Prelude.
- B. Metal Suspension-System Standard: Manufacturer's standard, direct-hung, metal suspension system and accessories according to ASTM C 635/C 635M.
- C. **Recycled Content:** Postconsumer recycled content plus one-half of preconsumer recycled content not less than 25 percent.
- D. Wide-Face, Capped, Double-Web, Steel Suspension System: Main and cross runners roll formed from cold-rolled steel sheet; prepainted, electrolytically zinc coated, or hot-dip galvanized, G30 coating designation; with prefinished 15/16-inch-wide metal caps on flanges.
  - 1. Structural Classification: Intermediate-duty system.
  - 2. End Condition of Cross Runners: Override (stepped) type.

3. Face Design: Flat, flush.
4. Cap Material: Cold-rolled steel.
5. Cap Finish: Painted white.

2.6 ACCESSORIES

- A. Attachment Devices: Size for five times the design load indicated in ASTM C 635/C 635M, Table 1, "Direct Hung," unless otherwise indicated. Comply with seismic design requirements.
- B. Wire Hangers, Braces, and Ties: Provide wires as follows:
  1. Zinc-Coated, Carbon-Steel Wire: ASTM A641/A641M, Class 1 zinc coating, soft temper.
  2. Size: Wire diameter sufficient for its stress at three times hanger design load (ASTM C635/C635M, Table 1, "Direct Hung") will be less than yield stress of wire, but not less than 0.106-inch-diameter wire.
- C. Hold-Down Clips: Manufacturer's standard hold-down.
- D. Impact Clips: Manufacturer's standard impact-clip system designed to absorb impact forces against acoustical panels.
- E. Seismic Clips: Manufacturer's standard seismic clips designed to secure acoustical panels in place during a seismic event.

2.7 METAL EDGE MOLDINGS AND TRIM

- A. Manufacturers: Subject to compliance with requirements, provide products by same manufacturer as for suspension system and acoustical panels.
- B. Roll-Formed, Sheet-Metal Edge Moldings and Trim: Type and profile indicated or, if not indicated, manufacturer's standard moldings for edges and penetrations that comply with seismic design requirements; formed from sheet metal of same material, finish, and color as that used for exposed flanges of suspension-system runners.
  1. Provide manufacturer's standard edge moldings that fit acoustical panel edge details and suspension systems indicated and that match width and configuration of exposed runners, unless otherwise indicated.
  2. ~~For lay-in panels with reveal edge details, provide stepped edge molding that forms reveal of same depth and width as that formed between edge of panel and flange at exposed suspension member.~~
  - 2.3. For circular penetrations of ceiling, provide edge moldings fabricated to diameter required to fit penetration exactly.
- C. Extruded-Aluminum Edge Moldings and Trim: Where indicated, provide manufacturer's extruded-aluminum edge moldings and trim of profile indicated or referenced by manufacturer's designations, including splice plates, corner pieces, and attachment and other clips, complying with seismic design requirements.

1. Baked-Enamel or Powder-Coat Finish: Minimum dry film thickness of 1.5 mils. Comply with ASTM C635/C635M and coating manufacturer's written instructions for cleaning, conversion coating, and applying and baking finish.

2.8 ACOUSTICAL SEALANT

- A. Acoustical Sealant: As specified in Section 07 92 19 "Acoustical Joint Sealants."

PART 3 - EXECUTION

3.1 EXAMINATION

- A. Examine substrates, areas, and conditions, including structural framing to which acoustical panel ceilings attach or abut, with Installer present, for compliance with requirements specified in this and other Sections that affect ceiling installation and anchorage and with requirements for installation tolerances and other conditions affecting performance of acoustical panel ceilings.
- B. Examine acoustical panels before installation. Reject acoustical panels that are wet, moisture damaged, or mold damaged.
- C. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 PREPARATION

- A. Measure each ceiling area and establish layout of acoustical panels to balance border widths at opposite edges of each ceiling. Avoid using less-than-half-width panels at borders unless otherwise indicated, and comply with layout shown on reflected ceiling plans.
- B. Layout openings for penetrations centered on the penetrating items.

3.3 INSTALLATION

- A. Install acoustical panel ceilings according to ASTM C 636/C 636M, seismic design requirements, and manufacturer's written instructions.
- B. Suspend ceiling hangers from building's structural members and as follows:
  1. Install hangers plumb and free from contact with insulation or other objects within ceiling plenum that are not part of supporting structure or of ceiling suspension system.
  2. Splay hangers only where required to miss obstructions; offset resulting horizontal forces by bracing, countersplaying, or other equally effective means.
  3. Splay hangers only where required to miss obstructions; offset resulting horizontal forces by bracing, countersplaying, or other equally effective means.
  4. Where width of ducts and other construction within ceiling plenum produces hanger spacings that interfere with location of hangers at spacings required to support standard

- suspension system members, install supplemental suspension members and hangers in form of trapezes or equivalent devices.
5. Secure wire hangers to ceiling suspension members and to supports above with a minimum of three tight turns. Connect hangers directly either to structures or to inserts, eye screws, or other devices that are secure and appropriate for substrate and that will not deteriorate or otherwise fail due to age, corrosion, or elevated temperatures.
  6. Do not support ceilings directly from permanent metal forms or floor deck. Fasten hangers to cast-in-place hanger inserts, postinstalled mechanical or adhesive anchors, or power-actuated fasteners that extend through forms into concrete.
  7. When steel framing does not permit installation of hanger wires at spacing required, install carrying channels or other supplemental support for attachment of hanger wires.
  8. Do not attach hangers to steel deck tabs.
  9. Do not attach hangers to steel roof deck. Attach hangers to structural members.
  10. Space hangers not more than 48 inches o.c. along each member supported directly from hangers, unless otherwise indicated; provide hangers not more than 8 inches from ends of each member.
  11. Size supplemental suspension members and hangers to support ceiling loads within performance limits established by referenced standards and publications.
- C. Install edge moldings and trim of type indicated at perimeter of acoustical ceiling area and where necessary to conceal edges of acoustical panels.
1. Apply acoustical sealant in a continuous ribbon concealed on back of vertical legs of moldings before they are installed.
  2. Screw attach moldings to substrate at intervals not more than 16 inches o.c. and not more than 3 inches from ends, leveling with ceiling suspension system to a tolerance of 1/8 inch in 12 feet. Miter corners accurately and connect securely.
  3. Do not use exposed fasteners, including pop rivets, on moldings and trim.
- D. Install suspension system runners so they are square and securely interlocked with one another. Remove and replace dented, bent, or kinked members.
- E. Install acoustical panels with undamaged edges and fit accurately into suspension system runners and edge moldings. Scribe and cut panels at borders and penetrations to provide a neat, precise fit.
1. For square-edged panels, install panels with edges fully hidden from view by flanges of suspension system runners and moldings.
  2. For reveal-edged panels on suspension system runners, install panels with bottom of reveal in firm contact with top surface of runner flanges.
  3. Paint cut edges of panel remaining exposed after installation; match color of exposed panel surfaces using coating recommended in writing for this purpose by acoustical panel manufacturer.
  4. Install hold-down, impact, and seismic clips in areas indicated and in areas required by authorities having jurisdiction; space according to panel manufacturer's written instructions unless otherwise indicated.
- 3.4 ERECTION TOLERANCES
- A. Suspended Ceilings: Install main and cross runners level to a tolerance of 1/8 inch in 12 feet, non-cumulative.

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- B. Moldings and Trim: Install moldings and trim to substrate and level with ceiling suspension system to a tolerance of 1/8 inch in 12 feet, non-cumulative.

3.5 CLEANING

- A. Clean exposed surfaces of acoustical panel ceilings, including trim, edge moldings, and suspension system members. Comply with manufacturer's written instructions for cleaning and touchup of minor finish damage.
- B. Remove and replace ceiling components that cannot be successfully cleaned and repaired to permanently eliminate evidence of damage.

END OF SECTION 09 51 13

SECTION 09 91 23 - ~~INTERIOR~~ PAINTING

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 surface preparation and the application of paint systems on interior **and exterior** substrates.
- B. Related Requirements:
  - 1. Section 051200 "Structural Steel Framing" for shop priming structural steel.

1.3 DEFINITIONS

- A. MPI Gloss Level 1: Not more than five units at 60 degrees and 10 units at 85 degrees, according to ASTM D523.
- B. MPI Gloss Level 2: Not more than 10 units at 60 degrees and 10 to 35 units at 85 degrees, according to ASTM D523.
- C. MPI Gloss Level 3: 10 to 25 units at 60 degrees and 10 to 35 units at 85 degrees, according to ASTM D523.
- D. MPI Gloss Level 4: 20 to 35 units at 60 degrees and not less than 35 units at 85 degrees, according to ASTM D523.
- E. MPI Gloss Level 5: 35 to 70 units at 60 degrees, according to ASTM D523.
- F. MPI Gloss Level 6: 70 to 85 units at 60 degrees, according to ASTM D523.
- G. MPI Gloss Level 7: More than 85 units at 60 degrees, according to ASTM D523.

1.4 ACTION SUBMITTALS

- A. Product Data: For each type of product. Include preparation requirements and application instructions.
  - 1. Manufacturer's Information: Provide manufacturer's technical information, including label analysis and instructions for handling, storing, and applying each coating material proposed for use.

2. Indicate VOC content.
- B. Sustainable Design Submittals:
  1. Product Data: For paints and coatings, indicating VOC content.
  2. Laboratory Test Reports: For paints and coatings, indicating compliance with requirements for low-emitting materials.
- C. Samples for Initial Selection: For each type of topcoat product.
- D. Samples for Verification: For each type of paint system and in each color and gloss of topcoat.
  1. Submit Samples on rigid backing, 8 inches square.
  2. Apply coats on Samples in steps to show each coat required for system.
  3. Label each coat of each Sample.
  4. Label each Sample for location and application area.
- E. Product List: Cross-reference to paint system and locations of application areas. Use same designations indicated on Drawings and in schedules. Include color designations.

#### 1.5 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
  1. Paint: 5 percent, but not less than 1 gal. of each material and color applied.

#### 1.6 QUALITY ASSURANCE

- A. Mockups: Apply mockups of each paint system indicated and each color and finish selected to verify preliminary selections made under Sample submittals and to demonstrate aesthetic effects and set quality standards for materials and execution.
  1. Architect will select one surface to represent surfaces and conditions for application of each paint system.
    - a. Vertical and Horizontal Surfaces: Provide samples of at least 100 sq. ft.
    - b. Other Items: Architect will designate items or areas required.
  2. Final approval of color selections will be based on mockups.
    - a. If preliminary color selections are not approved, apply additional mockups of additional colors selected by Architect at no added cost to Owner.
  3. Approval of mockups does not constitute approval of deviations from the Contract Documents contained in mockups unless Architect specifically approves such deviations in writing.
  4. Subject to compliance with requirements, approved mockups may become part of the completed Work if undisturbed at time of Substantial Completion.

1.7 DELIVERY, STORAGE, AND HANDLING

- A. Store materials not in use in tightly covered containers in well-ventilated areas with ambient temperatures continuously maintained at not less than 45 deg F.
  - 1. Maintain containers in clean condition, free of foreign materials and residue.
  - 2. Remove rags and waste from storage areas daily.

1.8 FIELD CONDITIONS

- A. Apply paints only when temperature of surfaces to be painted and ambient air temperatures are between 50 and 95 deg F.
- B. Do not apply paints when relative humidity exceeds 85 percent; at temperatures less than 5 deg F above the dew point; or to damp or wet surfaces.
- C. **Do not apply paints in snow, rain, fog, or mist; when relative humidity exceeds 85 percent; at temperatures less than 5 deg F above the dew point; or to damp or wet surfaces.**

PART 2 - PRODUCTS

2.1 MANUFACTURERS

- A. Basis-of-Design Product: Subject to compliance with requirements, provide products manufactured by Sherwin-Williams Company (The), or comparable products by one of the following:
  - 1. Benjamin Moore & Co.
  - 2. PPG Paints.

2.2 PAINT, GENERAL

- A. MPI Standards: Products shall comply with MPI standards indicated and shall be listed in its "MPI Approved Products Lists."
- B. Material Compatibility:
  - 1. Materials for use within each paint system shall be compatible with one another and substrates indicated, under conditions of service and application as demonstrated by manufacturer, based on testing and field experience.
  - 2. For each coat in a paint system, products shall be recommended in writing by topcoat manufacturers for use in paint system and on substrate indicated.
- C. **VOC Content:** For field applications that are inside the weatherproofing system, paints and coatings shall comply with VOC content limits of authorities having jurisdiction and the following VOC content limits:
  - 1. Flat Paints and Coatings: 50 g/L.



2. Nonflat Paints and Coatings: 50 g/L.
3. Dry-Fog Coatings: 150 g/L.
4. Primers, Sealers, and Undercoaters: 100 g/L.
5. Rust-Preventive Coatings: 100 g/L.
6. Zinc-Rich Industrial Maintenance Primers: 100 g/L.
7. Pretreatment Wash Primers: 420 g/L.
8. Shellacs, Clear: 730 g/L.
9. Shellacs, Pigmented: 550 g/L.

- D. Low-Emitting Materials: For field applications that are inside the weatherproofing system, 90 percent of paints and coatings shall comply with the requirements of the California Department of Public Health's "Standard Method for the Testing and Evaluation of Volatile Organic Chemical Emissions from Indoor Sources Using Environmental Chambers."
- E. Colors: As indicated in the color schedule on the drawings, which includes deep tones at designated locations.

### 2.3 SOURCE QUALITY CONTROL

- A. Testing of Paint Materials: Owner reserves the right to invoke the following procedure:
1. Owner will engage the services of a qualified testing agency to sample paint materials. Contractor will be notified in advance and may be present when samples are taken. If paint materials have already been delivered to Project site, samples may be taken at Project site. Samples will be identified, sealed, and certified by testing agency.
  2. Testing agency will perform tests for compliance with product requirements.
  3. Owner may direct Contractor to stop applying paints if test results show materials being used do not comply with product requirements. Contractor shall remove noncomplying paint materials from Project site, pay for testing, and repaint surfaces painted with rejected materials. Contractor will be required to remove rejected materials from previously painted surfaces if, on repainting with complying materials, the two paints are incompatible.

## PART 3 - EXECUTION

### 3.1 EXAMINATION

- A. Examine substrates and conditions, with Applicator present, for compliance with requirements for maximum moisture content and other conditions affecting performance of the Work.
- B. Maximum Moisture Content of Substrates: When measured with an electronic moisture meter as follows:
1. Concrete: 12 percent.
  2. Fiber-Cement Board: 12 percent.
  3. Masonry (Clay and CMUs): 12 percent.
  4. Wood: 15 percent.
  5. Gypsum Board: 12 percent.

- 6. Plaster: 12 percent.
- C. Gypsum Board Substrates: Verify that finishing compound is sanded smooth.
- D. Plaster Substrates: Verify that plaster is fully cured.
- E. Verify suitability of substrates, including surface conditions and compatibility, with existing finishes and primers.
- F. Proceed with coating application only after unsatisfactory conditions have been corrected.
  - 1. Application of coating indicates acceptance of surfaces and conditions.

3.2 PREPARATION

- A. Comply with manufacturer's written instructions and recommendations in "MPI Architectural Painting Specification Manual" applicable to substrates and paint systems indicated.
- B. Remove hardware, covers, plates, and similar items already in place that are removable and are not to be painted. If removal is impractical or impossible because of size or weight of item, provide surface-applied protection before surface preparation and painting.
  - 1. After completing painting operations, use workers skilled in the trades involved to reinstall items that were removed. Remove surface-applied protection if any.
- C. Clean substrates of substances that could impair bond of paints, including dust, dirt, oil, grease, and incompatible paints and encapsulants.
  - 1. Remove incompatible primers and reprime substrate with compatible primers or apply tie coat as required to produce paint systems indicated.
- D. Concrete Substrates: Remove release agents, curing compounds, efflorescence, and chalk. Do not paint surfaces if moisture content or alkalinity of surfaces to be painted exceeds that permitted in manufacturer's written instructions.
- E. Masonry Substrates: Remove efflorescence and chalk. Do not paint surfaces if moisture content or alkalinity of surfaces or mortar joints exceeds that permitted in manufacturer's written instructions.
- F. Shop-Primed Steel Substrates: Clean field welds, bolted connections, and areas where shop paint is abraded. Paint exposed areas with the same material as used for shop priming to comply with SSPC-PA 1 for touching up shop-primed surfaces.
- G. Galvanized-Metal Substrates: Remove grease and oil residue from galvanized sheet metal by mechanical methods to produce clean, lightly etched surfaces that promote adhesion of subsequently applied paints.
- H. Aluminum Substrates: Remove loose surface oxidation.
- I. Wood Substrates:

1. Scrape and clean knots, and apply coat of knot sealer before applying primer.
  2. Sand surfaces that will be exposed to view, and dust off.
  3. Prime edges, ends, faces, undersides, and backsides of wood.
  4. After priming, fill holes and imperfections in the finish surfaces with putty or plastic wood filler. Sand smooth when dried.
- J. Cotton or Canvas Insulation Covering Substrates: Remove dust, dirt, and other foreign material that might impair bond of paints to substrates.
- K. Steel Substrates: Remove rust, loose mill scale, and shop primer, if any. Clean using methods recommended in writing by paint manufacturer.**

### 3.3 APPLICATION

- A. Apply paints according to manufacturer's written instructions and to recommendations in "MPI Manual."
1. Use applicators and techniques suited for paint and substrate indicated.
  2. Paint surfaces behind movable equipment and furniture same as similar exposed surfaces. Before final installation, paint surfaces behind permanently fixed equipment or furniture with prime coat only.
  3. Paint front and backsides of access panels, removable or hinged covers, and similar hinged items to match exposed surfaces.
  4. Do not paint over labels of independent testing agencies or equipment name, identification, performance rating, or nomenclature plates.
  5. Primers specified in painting schedules may be omitted on items that are factory primed or factory finished if acceptable to topcoat manufacturers.
- B. Tint each undercoat a lighter shade to facilitate identification of each coat if multiple coats of same material are to be applied. Tint undercoats to match color of topcoat, but provide sufficient difference in shade of undercoats to distinguish each separate coat.
- C. If undercoats or other conditions show through topcoat, apply additional coats until cured film has a uniform paint finish, color, and appearance.
- D. Apply paints to produce surface films without cloudiness, spotting, holidays, laps, brush marks, roller tracking, runs, sags, ropiness, or other surface imperfections. Cut in sharp lines and color breaks.
- E. Painting Fire Suppression, Plumbing, HVAC, Electrical, Communication, and Electronic Safety and Security Work:
1. Paint the following work where exposed in equipment rooms:
    - a. Equipment that does not have factory-applied final finishes.
    - b. Uninsulated metal piping.
    - c. Uninsulated plastic piping.
    - d. Pipe hangers and supports.
    - e. Metal conduit.
    - f. Plastic conduit.

- g. Tanks that do not have factory-applied final finishes.
  - h. Duct, equipment, and pipe insulation having cotton or canvas insulation covering or other paintable jacket material.
2. Paint the following work where exposed in occupied spaces:
- a. Equipment, including panelboards.
  - b. Uninsulated metal piping.
  - c. Uninsulated plastic piping.
  - d. Pipe hangers and supports.
  - e. Metal conduit.
  - f. Plastic conduit.
  - g. Duct, equipment, and pipe insulation having cotton or canvas insulation covering or other paintable jacket material.
  - h. Other items as directed by Architect.
3. Paint portions of internal surfaces of metal ducts, without liner, behind air inlets and outlets that are visible from occupied spaces.
- F. Paint exposed structure and floor or roof deck above in occupied spaces where these items are exposed to view.
- G. Paint portions of factory finished exterior mechanical equipment where indicated on drawings.**

### 3.4 FIELD QUALITY CONTROL

- A. Dry Film Thickness Testing: Owner may engage the services of a qualified testing and inspecting agency to inspect and test paint for dry film thickness.
- 1. Contractor shall touch up and restore painted surfaces damaged by testing.
  - 2. If test results show that dry film thickness of applied paint does not comply with paint manufacturer's written recommendations, Contractor shall pay for testing and apply additional coats as needed to provide dry film thickness that complies with paint manufacturer's written recommendations.

### 3.5 CLEANING AND PROTECTION

- A. At end of each workday, remove rubbish, empty cans, rags, and other discarded materials from Project site.
- B. After completing paint application, clean spattered surfaces. Remove spattered paints by washing, scraping, or other methods. Do not scratch or damage adjacent finished surfaces.
- C. Protect work of other trades against damage from paint application. Correct damage to work of other trades by cleaning, repairing, replacing, and refinishing, as approved by Architect, and leave in an undamaged condition.

- D. At completion of construction activities of other trades, touch up and restore damaged or defaced painted surfaces.

3.6 INTERIOR PAINTING SCHEDULE

A. Concrete Substrates, Nontraffic Surfaces:

- 1. Institutional Low-Odor/VOC Latex System:
  - a. Prime Coat: Loxon Concrete and Masonry Primer.
  - b. Prime Coat for any Bare Metal: ProIndustrial Pro-Cryl Universal Primer.
  - c. Intermediate Coat: Latex, interior, institutional low odor/VOC, matching topcoat.
  - d. Topcoat (surfaces higher than 9'-0" AFF): ProMar 200 Zero VOC, flat finish.
  - e. Topcoat (surfaces below 9'-0" AFF): ProMar 200 Zero VOC, eggshell finish.

B. Concrete Substrates, Traffic Surfaces:

- 1. Water-Based Concrete Floor Sealer System:
  - a. First Coat: Sealer, water based, for concrete floors, matching topcoat.
  - b. Topcoat: GP 3477 Epoxy Water Emulsion Sealer.

C. CMU Substrates:

- 1. Epoxy System:
  - a. Block Filler: ProIndustrial Heavy Duty Block Filler.
  - b. Intermediate Coat: Epoxy, matching topcoat.
  - c. Topcoat: ProIndustrial Pre-Catalyzed Water-Based Epoxy, eggshell finish.
- 2. Institutional Low-Odor/VOC Latex System:
  - a. Block Filler (new work only): ProIndustrial Heavy Duty Block Filler.
  - b. Prime Coat (existing work only): Loxon Concrete and Masonry Primer.
  - c. Intermediate Coat: Latex, interior, institutional low odor/VOC, matching topcoat.
  - d. Topcoat: ProMar 200 Zero VOC, eggshell finish.

D. Steel Substrates:

- 1. Institutional Low-Odor/VOC Latex System:
  - a. Prime Coat: ProIndustrial Pro-Cryl Universal Primer.
  - b. Intermediate Coat: Water-based acrylic, interior, matching topcoat.
  - c. Topcoat: Pro Industrial Acrylic Coating, B66-650 Series, semi-gloss finish.

E. Steel Substrates: Exposed Ceilings with Steel Structure.

- 1. Water-Based Dry-Fall System:
  - a. Prime Coat: ProIndustrial Pro-Cryl Universal Primer.

- b. Intermediate Coat: Dryfall, interior, low VOC, matching topcoat.
  - c. Topcoat: Low VOC Waterborne Acrylic Dryfall, Flat B42-W00081.
- F. Steel Substrates: Exposed Ceilings with Steel Structure covered by spray applied fireproofing.
- 1. Water-Based Dry-Fall System:
    - a. Prime Coat: ProIndustrial Pro-Cryl Universal Primer.
    - b. Intermediate Coat: Dryfall, interior, low VOC, matching topcoat.
    - c. Topcoat: Low VOC Waterborne Acrylic Dryfall, Flat B42-W00081.
- G. Galvanized-Metal Substrates:
- 1. Institutional Low-Odor/VOC Latex System:
    - a. Prime Coat: ProIndustrial Pro-Cryl Universal Primer.
    - b. Intermediate Coat: Water-based acrylic, interior, matching topcoat.
    - c. Topcoat: Pro Industrial Acrylic Coating, B66-650 Series, semi-gloss finish.
- H. Wood Substrates: Wood Trim, Architectural Woodwork, Doors and Windows.
- 1. Institutional Low-Odor/VOC Latex System:
    - a. Prime Coat: ProMar 200 Zero VOC Primer.
    - b. Intermediate Coat: Latex, interior, institutional low odor/VOC, matching topcoat.
    - c. Topcoat: Solo Latex, satin finish.
- I. Gypsum Board and Plaster Substrates:
- 1. Institutional Low-Odor/VOC Latex System:
    - a. Prime Coat: ProMar 200 Zero VOC Primer.
    - b. Intermediate Coat: Latex, interior, institutional low odor/VOC, matching topcoat.
    - c. Topcoat: ProMar 200 Zero VOC, eggshell finish.
  - 2. Epoxy System:
    - a. Prime Coat: ProMar 200 Zero VOC Primer.
    - b. Intermediate Coat: Epoxy, matching topcoat.
    - c. Topcoat: ProIndustrial Pre-Catalyzed Water-Based Epoxy, eggshell finish.

### **3.7 EXTERIOR PAINTING SCHEDULE**

#### **A. Steel Substrates:**

- 1. **Institutional Water Based Acrylic System:**
  - a. **Prime Coat: DTM Bonding Primer.**
  - b. **Intermediate Coat: Match topcoat.**
  - c. **Topcoat: Bond Plex, gloss finish.**

**Addendum No. 3**

THE CITY OF PHILADELPHIA  
Office of Emergency Management

END OF SECTION 09 91 23

SECTION 230923 - DIRECT DIGITAL CONTROL (DDC) SYSTEM FOR HVAC

PART 1 - GENERAL

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.
- B. Refer to Specification Section 230800 Mechanical System Cx Requirements for Mechanical Systems Commissioning.

1.2 SUMMARY

- A. Section Includes:
  - 1. DDC system for monitoring and controlling of HVAC systems.
  - 2. Delivery of selected control devices to equipment and systems manufacturers for factory installation and to HVAC systems installers for field installation.
- B. Related Documents:
  - 1. All work of this Division shall be coordinated and provided by the Building Management System (BMS) Contractor.
  - 2. The work of this Division shall be scheduled, coordinated, and interfaced with the associated work of other trades. Reference the Division 15 Sections for details.
  - 3. The work of this Division shall be as required by the Specifications, Point Schedules and Drawings.
  - 4. If the BMS Contractor believes there are conflicts or missing information in the project documents, the Contractor shall promptly request clarification and instruction from the design team.
  - 5. Dynamic Control Systems, Inc. is the current BMS Contractor. Please contact Edward Devine at [edevine@dynamiccontrols.com](mailto:edevine@dynamiccontrols.com).
- C. **Related Sections Include the following:**
  - 1. **Division 01 Section "Sustainable Design Requirements – LEEDv4 ID+C."**

1.3 DEFINITIONS

- A. Algorithm: A logical procedure for solving a recurrent mathematical problem. A prescribed set of well-defined rules or processes for solving a problem in a finite number of steps.
- B. Analog: A continuously varying signal value, such as current, flow, pressure, or temperature.
- C. BACnet Specific Definitions:



1. BACnet: Building Automation Control Network Protocol, ASHRAE 135. A communications protocol allowing devices to communicate data over and services over a network.
  2. BACnet Interoperability Building Blocks (BIBBs): BIBB defines a small portion of BACnet functionality that is needed to perform a particular task. BIBBs are combined to build the BACnet functional requirements for a device.
  3. BACnet/IP: Defines and allows using a reserved UDP socket to transmit BACnet messages over IP networks. A BACnet/IP network is a collection of one or more IP subnetworks that share the same BACnet network number.
  4. BACnet Testing Laboratories (BTL): Organization responsible for testing products for compliance with ASHRAE 135, operated under direction of BACnet International.
  5. PICS (Protocol Implementation Conformance Statement): Written document that identifies the particular options specified by BACnet that are implemented in a device.
- D. Binary: Two-state signal where a high signal level represents ON" or "OPEN" condition and a low signal level represents "OFF" or "CLOSED" condition. "Digital" is sometimes used interchangeably with "Binary" to indicate a two-state signal.
- E. Building Management System (BMS): The total integrated system of fully operational and functional elements, including equipment, software, programming, and associated materials, to be provided by this Division BMS Contractor and to be interfaced to the associated work of other related trades.
- F. Controller: Generic term for any standalone, microprocessor-based, digital controller residing on a network, used for local or global control. Three types of controllers are indicated: Network Controller, Programmable Application Controller, and Application-Specific Controller.
- G. Control System Integrator: An entity that assists in expansion of existing enterprise system and support of additional operator interfaces to I/O being added to existing enterprise system.
- H. COV: Changes of value.
- I. DDC System Provider: Authorized representative of, and trained by, DDC system manufacturer and responsible for execution of DDC system Work indicated.
- J. Distributed Control: Processing of system data is decentralized, and control decisions are made at subsystem level. System operational programs and information are provided to remote subsystems and status is reported back. On loss of communication, subsystems shall be capable of operating in a standalone mode using the last best available data.
- K. DOCSIS: Data-Over Cable Service Interface Specifications.
- L. E/P: Voltage to pneumatic.
- M. Gateway: Bidirectional protocol translator that connects control systems that use different communication protocols.
- N. HLC: Heavy load conditions.

- O. I/O: System through which information is received and transmitted. I/O refers to analog input (AI), binary input (BI), analog output (AO) and binary output (BO). Analog signals are continuous and represent control influences such as flow, level, moisture, pressure, and temperature. Binary signals convert electronic signals to digital pulses (values) and generally represent two-position operating and alarm status. "Digital," (DI and (DO), is sometimes used interchangeably with "Binary," (BI) and (BO), respectively.
- P. I/P: Current to pneumatic.
- Q. LAN: Local area network.
- R. LNS: LonWorks Network Services.
- S. LON Specific Definitions:
  - 1. FTT-10: Echelon Transmitter-Free Topology Transceiver.
  - 2. LonMark: Association comprising suppliers and installers of LonTalk products. Association provides guidelines for implementing LonTalk protocol to ensure interoperability through a standard or consistent implementation.
  - 3. LonTalk: An open standard protocol developed by the Echelon Corporation that uses a "Neuron Chip" for communication. LonTalk is a register trademark of Echelon.
  - 4. LonWorks: Network technology developed by Echelon.
  - 5. Node: Device that communicates using CEA-709.1-C protocol and that is connected to a CEA-709.1-C network.
  - 6. Node Address: The logical address of a node on the network, consisting of a Domain number, Subnet number, and Node number. "Node number" portion of an address is a number assigned to device during installation, is unique within a subnet, and is not a factory-set unique Node ID.
  - 7. Node ID: A unique 48-bit identifier assigned at factory to each CEA-709.1-C device. Sometimes called a "Neuron ID."
  - 8. Program ID: An identifier (number) stored in a device (usually EEPROM) that identifies node manufacturer, functionality of device (application and sequence), transceiver used, and intended device usage.
  - 9. Standard Configuration Property Type (SCPT): Pronounced "skip-it." A standard format type maintained by LonMark International for configuration properties.
  - 10. Standard Network Variable Type (SNVT): Pronounced "snivet." A standard format type maintained by LonMark used to define data information transmitted and received by individual nodes. "SNVT" is used in two ways. It is an acronym for "Standard Network Variable Type" and is often used to indicate a network variable itself (i.e., it can mean "a network variable of a standard network variable type").
  - 11. Subnet: Consists of a logical grouping of up to 127 nodes, where logical grouping is defined by node addressing. Each subnet is assigned a number, which is unique within a Domain. See "Node Address."
  - 12. TP/FT-10: Free Topology Twisted Pair network defined by CEA-709.3 and is most common media type for a CEA-709.1-C control network.
  - 13. TP/XF-1250: High-speed, 1.25-Mbps, twisted-pair, doubly terminated bus network defined by "LonMark Interoperability Guidelines" typically used only to connect multiple TP/FT-10 networks.
  - 14. User-Defined Configuration Property Type (UCPT): Pronounced "U-Keep-It." A Configuration Property format type that is defined by device manufacturer.

- 15. User-Defined Network Variable Type (UNVT): Network variable format defined by device manufacturer. UNVTs create non-standard communications that other vendors' devices may not correctly interpret and may negatively impact system operation. UNVTs are not allowed.
- T. Low Voltage: As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.
- U. Mobile Device: A data-enabled phone or tablet computer capable of connecting to a cellular data network and running a native control application or accessing a web interface.
- V. Modbus TCP/IP: An open protocol for exchange of process data. Modbus protocol is another form of open protocol communications standard. Modbus consists of a messaging structure designed to establish master-slave, client-server communications between a wide range of intelligent devices. It supports traditional serial and Ethernet protocols. It is a truly open standard and is one of the most widely used protocols in the industrial manufacturing environment. There is no charge for using the protocol nor are there licensing fees.
- W. MS/TP: Master-slave/token-passing, IEE 8802-3. Datalink protocol LAN option that uses twisted-pair wire for low-speed communication.
- X. MTBF: Mean time between failures.
- Y. Network Controller: Digital controller, which supports a family of programmable application controllers and application-specific controllers, that communicates on peer-to-peer network for transmission of global data.
- Z. Network Repeater: Device that receives data packet from one network and rebroadcasts it to another network. No routing information is added to protocol.
- AA. Peer to Peer: Networking architecture that treats all network stations as equal partners.
- BB. POT: Portable operator's terminal.
- CC. PUE: Performance usage effectiveness.
- DD. RAM: Random access memory.
- EE. RF: Radio frequency.
- FF. Router: Device connecting two or more networks at network layer.
- GG. Server: Computer used to maintain system configuration, historical and programming database.
- HH. TCP/IP: Transport control protocol/Internet protocol.
- II. UPS: Uninterruptible power supply.
- JJ. USB: Universal Serial Bus.

- KK. User Datagram Protocol (UDP): This protocol assumes that the IP is used as the underlying protocol.
  - LL. VAV: Variable air volume.
  - MM. Niagara/Tridium prime building controller: This controller contains all of the central programming for the HVAC systems. Each prime building controller connects directly to the City's network. Larger buildings communicate through the prime building controller to multiple sub-controllers usually via BACnet protocol. Large building systems regularly push data to Web Supervisors for long term storage of data. Each system prime controller addresses a specific IP.
  - NN. Niagara/Tridium sub-controller: This controller interacts directly with the equipment, the prime building controller, and other sub-controllers via the BACnet.
  - OO. Niagara Web Supervisor: These are networked servers that act as:
    - 1. Long term storage of data for large buildings. They may also provide this for smaller buildings (or alternatively a virtual server can be used).
    - 2. A central push location for passwords and user configurations thus allowing one building operator to access multiple buildings with the same login and different responsibilities.
  - PP. Niagara 4 Workbench: This is a software program that allows both regular and power users to access systems, reprogram controllers, adjust usernames and passwords on the Niagara framework and do various other administrative uses.
  - QQ. Systems Integrator: Contracted vendor who will assist and oversee the integration of the controls and the control system specific protocols. Vendor will often liaise with the owner and the owner's Office of Innovation and Technology.
  - RR. WLED: White light emitting diode.
- 1.4 PREINSTALLATION MEETINGS
- A. Preinstallation Conference: Conduct conference at Project site or online.
- 1.5 ACTION SUBMITTALS
- A. Multiple Submissions:
    - 1. If multiple submissions are required to execute work within schedule, first submit a coordinated schedule clearly defining intent of multiple submissions. Include a proposed date of each submission with a detailed description of submittal content to be included in each submission.
    - 2. Clearly identify each submittal requirement indicated and in which submission the information will be provided.
    - 3. Include an updated schedule in each subsequent submission with changes highlighted to easily track the changes made to previous submitted schedule.

B. Product Data: For each type of product include the following:

1. Construction details, material descriptions, dimensions of individual components and profiles, and finishes.
2. Operating characteristics, electrical characteristics, and furnished accessories indicating process operating range, accuracy over range, control signal over range, default control signal with loss of power, calibration data specific to each unique application, electrical power requirements, and limitations of ambient operating environment, including temperature and humidity.
3. Product description with complete technical data, performance curves, and product specification sheets.
4. Installation, operation and maintenance instructions including factors effecting performance.
5. Bill of materials of indicating quantity, manufacturer, and extended model number for each unique product.
  - a. Servers.
  - b. Routers.
  - c. Protocol analyzers.
  - d. DDC controllers.
  - e. Enclosures.
  - f. Electrical power devices.
  - g. UPS units.
  - h. Accessories.
  - i. Instruments.
  - j. Control dampers and actuators.
  - k. Control valves and actuators.
6. When manufacturer's product datasheets apply to a product series rather than a specific product model, clearly indicate and highlight only applicable information.
7. Each submitted piece of product literature shall clearly cross reference specification and drawings that submittal is to cover.

C. Software Submittal:

1. Cross-referenced listing of software to be loaded on each operator workstation, server, and DDC controller.
2. Description and technical data of all software provided and cross-referenced to products in which software will be installed.
3. Operating system software, operator interface and programming software, color graphic software, DDC controller software, maintenance management software, and third-party software.
4. Include a flow diagram and an outline of each subroutine that indicates each program variable name and units of measure.
5. Listing and description of each engineering equation used with reference source.
6. Listing and description of each constant used in engineering equations and a reference source to prove origin of each constant.
7. Description of operator interface to alphanumeric and graphic programming.
8. Description of each network communication protocol.

9. Description of system database, including all data included in database, database capacity and limitations to expand database.
  10. Description of each application program and device drivers to be generated, including specific information on data acquisition and control strategies showing their relationship to system timing, speed, processing burden and system throughout.
  11. Controlled Systems: Instrumentation list with element name, type of device, manufacturer, model number, and product data. Include written description of sequence of operation including schematic diagram.
- D. Sustainable Design Submittals:
1. Product Data: For adhesives, indicating VOC content.
  2. Laboratory Test Reports: For adhesives, indicating compliance with requirements for low-emitting materials.
- E. Shop Drawings:
1. General Requirements:
    - a. Include cover drawing with Project name, location, Owner, Architect, Contractor and issue date with each Shop Drawings submission.
    - b. Include a drawing index sheet listing each drawing number and title that matches information in each title block.
    - c. Prepare Drawings using AutoCAD.
  2. Include plans, elevations, sections, and mounting details where applicable.
  3. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
  4. Detail means of vibration isolation and show attachments to rotating equipment.
  5. Plan Drawings indicating the following:
    - a. Screened backgrounds of walls, structural grid lines, HVAC equipment, ductwork and piping.
    - b. Room names and numbers with coordinated placement to avoid interference with control products indicated.
    - c. Each desktop workstation, server, gateway, router, DDC controller, control panel instrument connecting to DDC controller, and damper and valve connecting to DDC controller, if included in Project.
    - d. Exact placement of products in rooms, ducts, and piping to reflect proposed installed condition.
    - e. Network communication cable and raceway routing.
    - f. Information, drawn to scale.
    - g. Proposed routing of wiring, cabling, conduit, and tubing coordinated with building services for review before installation.
  6. Schematic drawings for each controlled HVAC system indicating the following:

- a. I/O points labeled with point names shown. Indicate instrument range, normal operating set points, and alarm set points. Indicate fail position of each damper and valve, if included in Project.
  - b. I/O listed in table format showing point name, type of device, manufacturer, model number, and cross-reference to product data sheet number.
  - c. A graphic showing location of control I/O in proper relationship to HVAC system.
  - d. Wiring diagram with each I/O point having a unique identification and indicating labels for all wiring terminals.
  - e. Unique identification of each I/O that shall be consistently used between different drawings showing same point.
  - f. Elementary wiring diagrams of controls for HVAC equipment motor circuits including interlocks, switches, relays and interface to DDC controllers.
  - g. Narrative sequence of operation.
  - h. Graphic sequence of operation, showing all inputs and output logical blocks.
7. Control panel drawings indicating the following:
- a. Panel dimensions, materials, size, and location of field cable, raceways, and tubing connections.
  - b. Interior subpanel layout, drawn to scale and showing all internal components, cabling and wiring raceways, nameplates and allocated spare space.
  - c. Front, rear, and side elevations and nameplate legend.
  - d. Unique drawing for each panel.
8. DDC system network riser diagram indicating the following:
- a. Each device connected to network with unique identification for each.
  - b. Interconnection of each different network in DDC system.
  - c. For each network, indicate communication protocol, speed and physical means of interconnecting network devices, such as copper cable type, or optical fiber cable type. Indicate raceway type and size for each.
  - d. Each network port for connection of an operator workstation or other type of operator interface with unique identification for each.
9. DDC system electrical power riser diagram indicating the following:
- a. Each point of connection to field power with requirements (volts/phase/hertz/amperes/connection type) listed for each.
  - b. Each control power supply including, as applicable, transformers, power-line conditioners, transient voltage suppression and high filter noise units, DC power supplies, and UPS units with unique identification for each.
  - c. Each product requiring power with requirements (volts/phase/hertz/amperes/connection type) listed for each.
  - d. Power wiring type and size, race type, and size for each.
10. Monitoring and control signal diagrams indicating the following:
- a. Control signal cable and wiring between controllers and I/O.
  - b. Point-to-point schematic wiring diagrams for each product.

11. Color graphics indicating the following:
  - a. Itemized list of color graphic displays to be provided.
  - b. For each display screen to be provided, a true color copy showing layout of pictures, graphics and data displayed.
  - c. Intended operator access between related hierarchical display screens.
  
- F. During the design phase of a project, be sure to provide shop drawings to individuals experienced with the installation and startup of equipment related to this type of integration.
  1. Three copies of shop drawings of the entire BAS shall be submitted and shall consist of a complete list of equipment and materials, including manufacturers catalog data sheets and installation instructions.
  2. Complete system design information including:
    - a. Data entry forms for initial parameters.
    - b. Valve, and damper schedules showing:
      - 1) Size
      - 2) Configuration
      - 3) Capacity
      - 4) Location
    - c. Wiring and piping interconnection diagrams, including panel and device power and sources.
    - d. Equipment lists (bill of materials) of all proposed devices and equipment.
    - e. Software design data including:
      - 1) Flow chart of each DDC program showing interrelationship between inputs, PID functions, all other functions, outputs, etc.
      - 2) Sequence of operation relating to all flow chart functions
    - f. Control sequences for each major building-level system
    - g. DDC installation, block diagrams, and wiring diagrams for each piece of equipment
    - h. DDC panel physical layout and schematics
    - i. The BAS contractor shall submit an architecture layout that depicts devices from the JACE to NAC down to the device level
  
- G. Sequence of Operations:
  1. A complete written Sequence of Operation shall also be included with the submittal package. The BAS Contractor shall coordinate data from other contractors supplying products and systems, as part of their package and shall provide catalog data sheets, wiring diagrams and point lists to the owner for proper coordination of work.
  
- H. Product Data:
  1. Complete list of product data including:
    - a. Data sheets of all products
    - b. Valve, damper, and well and tap schedules showing size, configuration, capacity, and location of all equipment
  
- I. Project Information:
  1. Certification of installer qualifications
  
- J. System Graphic Displays:



1. The BAS Contractor shall include web browser graphical displays through which an operator can perform real-time access and control functions. The graphical displays shall consist of all major building-level systems (air handler units, VAV boxes, chillers, boilers etc.) graphic displays, alarm displays, scheduling displays, and trending displays.
  2. BAS Contractors shall utilize the City of Philadelphia graphic templates when available. In absence of a City graphic template, owner shall provide an example of an acceptable graphic template.
  3. Submittal shall include a copy of each of the graphics developed for the Graphic User Interface including a flowchart (site map) indicating how the graphics are to be linked to one another for system navigation. The graphics are to be 90% complete at this stage with the only remaining changes to be based on review comments from the A/E design team and owner. Submittal shall also include a copy of the expected main dashboard viewlets being provided for owner configuration. Viewlets should include:
    - a. Global Scheduling for Site
    - b. Alarms
    - c. Trending and Reports
- K. OIT Coordination Sheet
1. BAS contractor shall coordinate the completion of the OIT Data Sheet (Appendix A) at the start of and throughout the delivery of the project.
- L. Upon completion of the work, provide a complete set of 'as-built' drawings and application software on compact disk. Drawings shall be provided as AutoCAD™ or Visio™ compatible files.
- M. Contract Closeout Information:
1. Operating and maintenance manuals including recommended set points and schedules and holiday scheduling instructions.
  2. Owner instruction report.
  3. Certification that Owner Training has been provided by RBOP installer.
  4. As Built Instrumentation and Control Diagrams.
  5. Plan As Builts at 1/8 inch scale showing:
    - a. Upon completion of the work, provide a complete set of 'as-built' drawings and application software on compact disk. Drawings shall be provided as AutoCAD™ or Visio™ compatible files.
    - b. Eight copies of the 'as-built' drawings shall be provided in addition to the documents on compact disk.
    - c. Division 23, 25 and 26 contractors shall provide as-builts for their portions of work.
    - d. The RBOP Contractor shall be responsible for as-builts pertaining to overall RBOP architecture and network diagrams. All as built drawings shall also be installed into the RBOP server in a dedicated directory.
    - e. Communication cable circuiting drawing with DDC panels and communication devices labeled.
    - f. Power wiring circuiting drawing showing 120-volt circuit source and low voltage transformer locations, identifications, and circuit roués to each controlled device per transformer for the DDC system.
- N. System Description:

1. Full description of DDC system architecture, network configuration, operator interfaces and peripherals, servers, controller types and applications, gateways, routers and other network devices, and power supplies.
  2. Complete listing and description of each report, log and trend for format and timing and events which initiate generation.
  3. System and product operation under each potential failure condition including, but not limited to, the following:
    - a. Loss of power.
    - b. Loss of network communication signal.
    - c. Loss of controller signals to inputs and outpoints.
    - d. Operator workstation failure.
    - e. Server failure.
    - f. Gateway failure.
    - g. Network failure
    - h. Controller failure.
    - i. Instrument failure.
    - j. Control damper and valve actuator failure.
  4. Complete bibliography of documentation and media to be delivered to Owner.
  5. Description of testing plans and procedures.
  6. Description of Owner training.
- O. Delegated-Design Submittal: For DDC system products and installation indicated as being delegated.
1. Supporting documentation showing DDC system design complies with performance requirements indicated, including calculations and other documentation necessary to prove compliance.
  2. Schedule and design calculations for control dampers and actuators.
    - a. Flow at Project design and minimum flow conditions.
    - b. Face velocity at Project design and minimum airflow conditions.
    - c. Pressure drop across damper at Project design and minimum airflow conditions.
    - d. AMCA 500-D damper installation arrangement used to calculate and schedule pressure drop, as applicable to installation.
    - e. Maximum close-off pressure.
    - f. Leakage airflow at maximum system pressure differential (fan close-off pressure).
    - g. Torque required at worst case condition for sizing actuator.
    - h. Actuator selection indicating torque provided.
    - i. Actuator signal to control damper (on, close or modulate).
    - j. Actuator position on loss of power.
    - k. Actuator position on loss of control signal.
  3. Schedule and design calculations for control valves and actuators.
    - a. Flow at Project design and minimum flow conditions.
    - b. Pressure-differential drop across valve at Project design flow condition.
    - c. Maximum system pressure-differential drop (pump close-off pressure) across valve at Project minimum flow condition.

- d. Design and minimum control valve coefficient with corresponding valve position.
  - e. Maximum close-off pressure.
  - f. Leakage flow at maximum system pressure differential.
  - g. Torque required at worst case condition for sizing actuator.
  - h. Actuator selection indicating torque provided.
  - i. Actuator signal to control damper (on, close or modulate).
  - j. Actuator position on loss of power.
  - k. Actuator position on loss of control signal.
4. Schedule and design calculations for selecting flow instruments.
- a. Instrument flow range.
  - b. Project design and minimum flow conditions with corresponding accuracy, control signal to transmitter and output signal for remote control.
  - c. Extreme points of extended flow range with corresponding accuracy, control signal to transmitter and output signal for remote control.
  - d. Pressure-differential loss across instrument at Project design flow conditions.
  - e. Where flow sensors are mated with pressure transmitters, provide information for each instrument separately and as an operating pair.

## 1.6 INFORMATIONAL SUBMITTALS

### A. Coordination Drawings:

1. Plan drawings and corresponding product installation details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
  - a. Product installation location shown in relationship to room, duct, pipe and equipment.
  - b. Structural members to which products will be attached.
  - c. Wall-mounted instruments located in finished space showing relationship to light switches, fire-alarm devices and other installed devices.
  - d. Size and location of wall access panels for products installed behind walls and requiring access.
2. Reflected ceiling plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from installers of the items involved:
  - a. Ceiling components.
  - b. Size and location of access panels for products installed above inaccessible ceiling assemblies and requiring access.
  - c. Items penetrating finished ceiling including the following:
    - 1) Lighting fixtures.
    - 2) Air outlets and inlets.
    - 3) Speakers.
    - 4) Sprinklers.
    - 5) Access panels.

- 6) Motion sensors.
- 7) Pressure sensors.
- 8) Temperature sensors and other DDC control system instruments.

B. Product Certificates:

1. Data Communications Protocol Certificates: Certifying that each proposed DDC system component complies with ASHRAE 135.
2. Data Communications Protocol Certificates: Certifying that each proposed DDC system component complies with LonWorks.

C. Product Test Reports: For each product that requires testing to be performed by manufacturer.

D. Source quality-control reports.

E. Field quality-control reports.

F. Sample Warranty: For manufacturer's warranty.

1.7 CLOSEOUT SUBMITTALS

A. Operation and Maintenance Data: For DDC system to include in emergency, operation and maintenance manuals.

1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following:
  - a. Project Record Drawings of as-built versions of submittal Shop Drawings provided in electronic PDF format.
  - b. Testing and commissioning reports and checklists of completed final versions of reports, checklists, and trend logs.
  - c. As-built versions of submittal Product Data.
  - d. Names, addresses, e-mail addresses and 24-hour telephone numbers of Installer and service representatives for DDC system and products.
  - e. Operator's manual with procedures for operating control systems including logging on and off, handling alarms, producing point reports, trending data, overriding computer control and changing set points and variables.
  - f. Programming 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.
  - g. Engineering, installation, and maintenance manuals that explain how to:
    - 1) Design and install new points, panels, and other hardware.
    - 2) Perform preventive maintenance and calibration.
    - 3) Debug hardware problems.
    - 4) Repair or replace hardware.
  - h. Documentation of all programs created using custom programming language including set points, tuning parameters, and object database.

- i. Backup copy of graphic files, programs, and database on electronic media such as DVDs.
- j. List of recommended spare parts with part numbers and suppliers.
- k. Complete original-issue documentation, installation, and maintenance information for furnished third-party hardware including computer equipment and sensors.
- l. Complete original-issue copies of furnished software, including operating systems, custom programming language, operator workstation software, and graphics software.
- m. Licenses, guarantees, and warranty documents.
- n. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.
- o. Owner training materials.

1.8 MAINTENANCE MATERIAL SUBMITTALS

- A. Furnish extra materials and parts that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
- B. Include product manufacturers' recommended parts lists for proper product operation over four-year period following warranty period. Parts list shall be indicated for each year.
- C. Furnish parts, as indicated by manufacturer's recommended parts list, for product operation during two-year period following warranty period.

1.9 QUALITY ASSURANCE

- A. DDC System Provider Qualifications:
  - 1. Authorized representative of, and trained by, DDC system manufacturer.
  - 2. In-place facility located within 25 miles of Project.
  - 3. Demonstrated past experience with installation of DDC system products being installed for period within five consecutive years before time of bid.
  - 4. Demonstrated past experience on five projects of similar complexity, scope and value.
  - 5. Each person assigned to Project shall have demonstrated past experience.
  - 6. Staffing resources of competent and experienced full-time employees that are assigned to execute work according to schedule.
  - 7. Service and maintenance staff assigned to support Project during warranty period.
  - 8. Product parts inventory to support on-going DDC system operation for a period of not less than 5 years after Substantial Completion.
  - 9. DDC system manufacturer's backing to take over execution of Work if necessary, to comply with requirements indicated. Include Project-specific written letter, signed by manufacturer's corporate officer, if requested.
- B. Testing Agency Qualifications: Member company of NETA or an NRTL.
  - 1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.

C. Welding Qualifications: Qualify procedures and personnel according to the following:

1. AWS D1.1/D1.1M, "Structural Welding Code - Steel."
2. AWS D1.2/D1.2M, "Structural Welding Code - Aluminum."
3. AWS D1.3/D1.3M, "Structural Welding Code - Sheet Steel."
4. AWS D1.4/D1.4M, "Structural Welding Code - Reinforcing Steel."

#### 1.10 WARRANTY

A. Manufacturer's Warranty: Manufacturer and Installer agree to repair or replace products that fail in materials or workmanship within specified warranty period.

1. Failures shall be adjusted, repaired, or replaced at no additional cost or reduction in service to Owner.
2. Include updates or upgrades to software and firmware if necessary, to resolve deficiencies.
  - a. Install updates only after receiving Owner's written authorization.
3. Warranty service shall occur during normal business hours and commence within 16 hours of Owner's warranty service request.
4. Warranty Period: Two year(s) from date of Substantial Completion.

### PART 2 - PRODUCTS

#### 2.1 DDC SYSTEM DESCRIPTION

A. Microprocessor-based monitoring and control including analog/digital conversion and program logic. A control loop or subsystem in which digital and analog information is received and processed by a microprocessor, and digital control signals are generated based on control algorithms and transmitted to field devices to achieve a set of predefined conditions.

1. DDC system shall consist of a high-speed, peer-to-peer network of distributed DDC controllers, other network devices, operator interfaces, and software.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

#### 2.2 WEB ACCESS

A. DDC system shall be Web based or Web compatible.

1. Web-Based Access to DDC System:
  - a. DDC system software shall be based on server thin-client architecture, designed around open standards of Web technology. DDC system server shall be accessed

- using a Web browser over DDC system network, using Owner's LAN, and remotely over Internet through Owner's LAN.
  - b. Intent of thin-client architecture is to provide operators complete access to DDC system via a Web browser. No special software other than a Web browser shall be required to access graphics, point displays, and trends; to configure trends, points, and controllers; and to edit programming.
  - c. Web access shall be password protected.
2. Web-Compatible Access to DDC System:
- a. Workstation and server shall perform overall system supervision and configuration, graphical user interface, management report generation, and alarm annunciation.
  - b. DDC system shall support Web browser access to building data. Operator using a standard Web browser shall be able to access control graphics and change adjustable set points.
  - c. Web access shall be password protected.

### 2.3 PERFORMANCE REQUIREMENTS

- A. Delegated Design: Engage a qualified professional to design DDC system to satisfy requirements indicated.
1. System Performance Objectives:
- a. DDC system shall manage HVAC systems.
  - b. DDC system control shall operate HVAC systems to achieve optimum operating costs while using least possible energy and maintaining specified performance.
  - c. DDC system shall respond to power failures, HVAC equipment failures, and adverse and emergency conditions encountered through connected I/O points.
  - d. DDC system shall operate while unattended by an operator and through operator interaction.
  - e. DDC system shall record trends and transaction of events and produce report information such as performance, energy, occupancies, and equipment operation.
- B. Surface-Burning Characteristics: Products installed in ducts, equipment, and return-air paths shall comply with ASTM E 84; testing by a qualified testing agency. Identify products with appropriate markings of applicable testing agency.
- 1. Flame-Spread Index: 25 or less.
  - 2. Smoke-Developed Index: 50 or less.
- C. DDC System Speed:
1. Response Time of Connected I/O:
- a. AI point values connected to DDC system shall be updated at least every five seconds for use by DDC controllers. Points used globally shall also comply with this requirement.

- b. BI point values connected to DDC system shall be updated at least every five seconds for use by DDC controllers. Points used globally shall also comply with this requirement.
  - c. AO points connected to DDC system shall begin to respond to controller output commands within two second(s). Global commands shall also comply with this requirement.
  - d. BO point values connected to DDC system shall respond to controller output commands within two second(s). Global commands shall also comply with this requirement.
2. Display of Connected I/O:
- a. Analog point COV connected to DDC system shall be updated and displayed at least every five seconds for use by operator.
  - b. Binary point COV connected to DDC system shall be updated and displayed at least every five seconds for use by operator.
  - c. Alarms of analog and digital points connected to DDC system shall be displayed within 30 seconds of activation or change of state.
  - d. Graphic display refresh shall update within eight seconds.
  - e. Point change of values and alarms displayed from workstation to workstation when multiple operators are viewing from multiple workstations shall not exceed graphic refresh rate indicated.
- D. Network Bandwidth: Design each network of DDC system to include at least 30 percent available spare bandwidth with DDC system operating under normal and heavy load conditions indicated. Calculate bandwidth usage, and apply a safety factor to ensure that requirement is satisfied when subjected to testing under worst case conditions.
- E. DDC System Data Storage:
- 1. Include server(s) with disk drive data storage to archive not less than 24 consecutive months of historical data for all I/O points connected to system, including alarms, event histories, transaction logs, trends and other information indicated.
  - 2. When logged onto a server, operator shall be able to also interact with any DDC controller connected to DDC system as required for functional operation of DDC system.
  - 3. Server(s) shall be used for application configuration; for archiving, reporting and trending of data; for operator transaction archiving and reporting; for network information management; for alarm annunciation; and for operator interface tasks and controls application management.
  - 4. Server(s) shall use IT industry-standard database platforms such as Microsoft SQL Server and Microsoft Data Engine (MSDE).
- F. Future Expandability:
- 1. DDC system size shall be expandable to an ultimate capacity of at least two times total I/O points indicated.
  - 2. Additional DDC controllers, I/O and associated wiring shall be all that is needed to achieve ultimate capacity. Initial network infrastructure shall be designed and installed to support ultimate capacity.



3. Operator interfaces installed initially shall not require hardware and software additions and revisions for ultimate capacity.
- G. Input Point Displayed Accuracy: Input point displayed values shall meet following end-to-end overall system accuracy, including errors associated with meter, sensor, transmitter, lead wire or cable, and analog to digital conversion.
1. Energy:
    - a. Electric Power: Within 1 percent of reading.
    - b. Requirements indicated on Drawings for meters not supplied by utility.
  2. Flow:
    - a. Air: Within 5 percent of design flow rate.
    - b. Air (Terminal Units): Within 5 percent of design flow rate.
  3. Gas:
    - a. Carbon Dioxide: Within 50 ppm.
    - b. Carbon Monoxide: Within 5 ppm
    - c. Hydrogen: with 20 ppm
    - d. NOx: Within 5 ppm
  4. Moisture (Relative Humidity):
    - a. Air: Within 5 percent RH.
    - b. Space: Within 5 percent RH.
    - c. Outdoor: Within 5 percent RH.
  5. Pressure:
    - a. Air, Ducts and Equipment: 1 percent of instrument range.
  6. Speed: Within 5 percent of reading.
  7. Temperature, Dew Point:
    - a. Air: Within 1 deg F (0.5 deg C).
    - b. Space: Within 1 deg F (0.5 deg C).
    - c. Outdoor: Within 2 deg F (1 deg C).
  8. Temperature, Dry Bulb:
    - a. Air: Within 1 deg F (0.5 deg C).
    - b. Space: Within 1 deg F (0.5 deg C).
    - c. Outdoor: Within 2 deg F (1 deg C).
    - d. Temperature Difference: Within 0.25 deg F (0.15 deg C).
    - e. Other Temperatures Not Indicated: Within 1 deg F (0.5 deg C).
  9. Temperature, Wet Bulb:

- a. Air: Within 0.5 deg F (0.2 deg C).
  - b. Space: Within 0.5 deg F (0.2 deg C)
  - c. Outdoor: Within 1 deg F (0.5 deg C).
- H. Precision of I/O Reported Values: Values reported in database and displayed shall have following precision:
- 1. Current:
    - a. Milliamperes: Nearest 1/100th of a milliampere.
    - b. Amperes: Nearest 1/10th of an ampere up to 100 A; nearest ampere for 100 A and more.
  - 2. Energy:
    - a. Electric Power:
      - 1) Rate (Watts): Nearest 1/10th of a watt through 1000 W.
      - 2) Rate (Kilowatts): Nearest 1/10th of a kilowatt through 1000 kW; nearest kilowatt above 1000 kW.
      - 3) Usage (Kilowatt-Hours): Nearest kilowatt through 10,000 kW; nearest 10 kW between 10,000 and 100,000 kW; nearest 100 kW for above 100,000 kW.
    - b. Thermal, Rate:
      - 1) Heating: For Btu/h, nearest Btu/h up to 1000 Btu/h; nearest 10 Btu/h between 1000 and 10,000 Btu/h; nearest 100 Btu/h for above 10,000 Btu/h. For Mbh, round to nearest Mbh up to 1000 Mbh; nearest 10 Mbh between 1000 and 10,000 Mbh; nearest 100 Mbh above 10,000 Mbh (For watts, nearest watt up to 1000 W; for kilowatts, round to nearest kilowatt up to 1000 kW; nearest 10 kW between 1000 and 10,000 kW; nearest 100 kW for above 10,000 kW).
      - 2) Cooling: For tons, nearest ton up to 1000 tons; nearest 10 tons between 1000 and 10,000 tons; nearest 100 tons above 10,000 tons (For watts, nearest watt up to 1000 W; for kilowatts, round to nearest kilowatt up to 1000 kW; nearest 10 kW between 1000 and 10,000 kW; nearest 100 kW for above 10,000 kW).
    - c. Thermal, Usage:
      - 1) Heating: For Btu, nearest Btu up to 1000 Btu; nearest 10 Btu between 1000 and 10,000 Btu; nearest 100 Btu for above 10,000 Btu. For Mbtu, round to nearest Mbtu up to 1000 Mbtu; nearest 10 Mbtu between 1000 and 10,000 Mbtu; nearest 100 Mbtu above 10,000 Mbtu (For watt-hours, nearest watt-hour up to 1000 Wh; for kilowatt-hours, round to nearest kilowatt-hour up to 1000 kWh; nearest 10 kWh between 1000 and 10,000 kWh; nearest 100 kWh for above 10,000 kWh).
      - 2) Cooling: For ton-hours, nearest ton-hours up to 1000 ton-hours; nearest 10 ton-hours between 1000 and 10,000 ton-hours; nearest 100 tons above

10,000 tons (For watt-hours, nearest watt-hour up to 1000 Wh; for kilowatt-hours, round to nearest kilowatt-hour up to 1000 kWh; nearest 10 kWh between 1000 and 10,000 kWh; nearest 100 kWh for above 10,000 kWh).

3. Flow:
    - a. Air: Nearest 1/10th of a cfm through 100 cfm; nearest cfm between 100 and 1000 cfm; nearest 10 cfm between 1000 and 10,000 cfm; nearest 100 cfm above 10,000 cfm (Nearest 1/10th of a L/s through 100 L/s; nearest L/s between 100 and 1000 L/s; nearest 10 L/s between 1000 and 10,000 L/s; nearest 100 L/s above 10,000 L/s).
  4. Gas:
    - a. Carbon Dioxide: Within 50 ppm.
    - b. Carbon Monoxide: Within 5 ppm
    - c. Hydrogen: with 20 ppm
    - d. NOx: Within 5 ppm
  5. Moisture (Relative Humidity):
    - a. Relative Humidity (Percentage): Nearest 1 percent.
  6. Speed:
    - a. Rotation (rpm): Nearest 1 rpm.
    - b. Velocity: Nearest 1/10th fpm through 100 fpm; nearest fpm between 100 and 1000 fpm; nearest 10 fpm above 1000 fpm (Nearest 1/100th of a M/s through 10 M/s; nearest 1/10th of a M/s above 10 M/s).
  7. Position, Dampers (Percentage Open): Nearest 1 percent.
  8. Pressure:
    - a. Air, Ducts and Equipment: Nearest 1/10th in. w.c. (Nearest Pa up to 1000 Pa; nearest 10 Pa above 1000 Pa).
  9. Temperature:
    - a. Air, Ducts and Equipment: Nearest 1/10th of a degree.
    - b. Outdoor: Nearest degree.
    - c. Space: Nearest 1/10th of a degree.
  10. Voltage: Nearest 1/10 volt up to 100 V; nearest volt above 100 V.
- I. Control Stability: Control variables indicated within the following limits:
1. Flow:
    - a. Air, Ducts and Equipment, except Terminal Units: Within 2 percent of design flow rate.

2. Gas:
    - a. Carbon Dioxide: Within 50 ppm.
    - b. Carbon Monoxide: Within 5 ppm
    - c. Hydrogen: with 20 ppm
    - d. NOx: Within 5 ppm
  3. Moisture (Relative Humidity):
    - a. Air: Within 2 percent RH.
    - b. Space: Within 5 percent RH.
    - c. Outdoor: Within 5 percent RH.
  4. Pressure:
    - a. Air, Ducts and Equipment: 1 percent of instrument range.
  5. Temperature, Dew Point:
    - a. Air: Within 1 deg F (0.5 deg C).
  6. Temperature, Dry Bulb:
    - a. Air: Within 2 deg F (1 deg C).
    - b. Space: Within 2 deg F (1 deg C).
  7. Temperature, Wet Bulb:
    - a. Air: Within 1 deg F (0.5 deg C).
- J. Environmental Conditions for Controllers and Routers:
1. Products shall operate without performance degradation under ambient environmental temperature, pressure and humidity conditions encountered for installed location.
    - a. If product alone cannot comply with requirement, install product in a protective enclosure that is isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated, cooled and ventilated as required by product and application.
  2. Products shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Products not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Installed location shall dictate the following NEMA 250 enclosure requirements:
    - a. Outdoors, Protected: Type 2.
    - b. Outdoors, Unprotected: Type 4.
    - c. Indoors, Heated with Filtered Ventilation: Type 1.
    - d. Indoors, Heated with Non-Filtered Ventilation: Type 2.

- e. Indoors, Heated and Air Conditioned: Type 1.
- f. Mechanical Equipment Rooms:
  - 1) Air-Moving Equipment Rooms: Type 1.
- g. Localized Areas Exposed to Washdown: Type 4.
- h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: Type 2.
- i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: Type 4.

**K. Environmental Conditions for Instruments and Actuators:**

- 1. Instruments and actuators shall operate without performance degradation under the ambient environmental temperature, pressure, humidity, and vibration conditions specified and encountered for installed location.
  - a. If instruments and actuators alone cannot comply with requirement, install instruments and actuators in protective enclosures that are isolated and protected from conditions impacting performance. Enclosure shall be internally insulated, electrically heated, cooled and ventilated as required by instrument and application.
- 2. Instruments, actuators and accessories shall be protected with enclosures satisfying the following minimum requirements unless more stringent requirements are indicated. Instruments and actuators not available with integral enclosures complying with requirements indicated shall be housed in protective secondary enclosures. Installed location shall dictate the following NEMA 250 enclosure requirements:
  - a. Outdoors, Protected: Type 2.
  - b. Outdoors, Unprotected: Type 4.
  - c. Indoors, Heated with Filtered Ventilation: Type 1.
  - d. Indoors, Heated with Non-Filtered Ventilation: Type 2.
  - e. Indoors, Heated and Air Conditioned: Type 1.
  - f. Mechanical Equipment Rooms:
    - 1) Boiler Rooms: Type 4.
    - 2) Air-Moving Equipment Rooms: Type 1.
  - g. Localized Areas Exposed to Washdown: Type 4.
  - h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: Type 2.
  - i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: Type 4.

**L. DDC System Reliability:**

- 1. Design, install and configure DDC controllers and routers to yield a MTBF of at least 40,000 hours, based on a confidence level of at least 90 percent. MTBF value shall include any failure for any reason to any part of products indicated.

2. If required to comply with MTBF indicated, include DDC system and product redundancy to maintain DCC system, and associated systems and equipment that are being controlled, operational and under automatic control.
3. Critical systems and equipment that require a higher degree of DDC system redundancy than MTBF indicated shall be indicated on Drawings.

M. Electric Power Quality:

1. Power-Line Surges:

- a. Protect susceptible DDC system products connected to ac power circuits from power-line surges to comply with requirements of IEEE C62.41.
- b. Do not use fuses for surge protection.
- c. Test protection in the normal mode and in the common mode, using the following two waveforms:
  - 1) 10-by-1000-mic.sec. waveform with a peak voltage of 1500 V and a peak current of 60 A.
  - 2) 8-by-20-mic.sec. waveform with a peak voltage of 1000 V and a peak current of 500 A.

2. Power Conditioning:

- a. Protect susceptible DDC system products connected to ac power circuits from irregularities and noise rejection. Characteristics of power-line conditioner shall be as follows:
  - 1) At 85 percent load, output voltage shall not deviate by more than plus or minus 1 percent of nominal when input voltage fluctuates between minus 20 percent to plus 10 percent of nominal.
  - 2) During load changes from zero to full load, output voltage shall not deviate by more than plus or minus 3 percent of nominal.
  - 3) Accomplish full correction of load switching disturbances within five cycles, and 95 percent correction within two cycles of onset of disturbance.
  - 4) Total harmonic distortion shall not exceed 3-1/2 percent at full load.

3. Ground Fault: Protect products from ground fault by providing suitable grounding. Products shall not fail due to ground fault condition.

N. Backup Power Source:

1. HVAC systems and equipment served by a backup power source shall have associated DDC system products that control such systems and equipment also served from a backup power source.

O. UPS:

1. DDC system products powered by UPS units shall include the following:
  - a. Servers.
  - b. DDC controllers, except application-specific controllers.

- P. Continuity of Operation after Electric Power Interruption:
  - 1. Equipment and associated factory-installed controls, field-installed controls, electrical equipment, and power supply connected to building normal and backup power systems shall automatically return equipment and associated controls to operating state occurring immediately before loss of normal power, without need for manual intervention by operator when power is restored either through backup power source or through normal power if restored before backup power is brought online.

## 2.4 SYSTEM ARCHITECTURE

- A. System architecture shall consist of no more than two or three levels of LANs.
  - 1. Level one LAN shall connect network controllers and operator workstations.
  - 2. Level one or Level two LAN shall connect programmable application controllers to other programmable application controllers, and to network controllers.
  - 3. Level two or Level three LAN shall connect application-specific controllers to programmable application controllers and network controllers.
  - 4. Level two or Level three LAN shall connect application-specific controllers to application-specific controllers.
- B. Minimum Data Transfer and Communication Speed:
  - 1. LAN Connecting Network Controllers: 100 Mbps.
  - 2. LAN Connecting Programmable Application Controllers: 100 kbps.
  - 3. LAN Connecting Application-Specific Controllers: 19,200 bps.
- C. DDC system shall consist of dedicated LANs that are not shared with other building systems and tenant data and communication networks.
- D. System architecture shall be modular and have inherent ability to expand to not less than two times system size indicated with no impact to performance indicated.
- E. System architecture shall perform modifications without having to remove and replace existing network equipment.
- F. Number of LANs and associated communication shall be transparent to operator. All I/O points residing on any LAN shall be capable of global sharing between all system LANs.
- G. System design shall eliminate dependence on any single device for system alarm reporting and control execution. Each controller shall operate independently by performing its' own control, alarm management and historical data collection.
- H. Special Network Architecture Requirements:
  - 1. Air-Handling Systems: For control applications of an air-handling system that consists of air-handling unit(s) and VAV terminal units, include a dedicated LAN of application-specific controllers serving VAV terminal units connected directly to controller that is

controlling air-handling system air-handling unit(s). Basically, create a DDC system LAN that aligns with air-handling system being controlled.

## 2.5 DDC SYSTEM OPERATOR INTERFACES

- A. Operator Means of System Access: Operator shall be able to access entire DDC system through any of multiple means, including, but not limited to, the following:
  - 1. Portable operator terminal with hardwired connection through LAN port.
  - 2. PDA with wireless connection through LAN router.
  - 3. Remote connection using outside of system personal computer or PDA through Web access.
- B. Access to system, regardless of operator means used, shall be transparent to operator.
- C. Network Ports: For hardwired connection of desktop or portable operator workstation. Network port shall be easily accessible, properly protected, clearly labeled, and installed at the following locations:
  - 1. Each mechanical equipment room.
- D. POT:
  - 1. Connect DDC controller through a communications port local to controller.
  - 2. Able to communicate with any DDC system controller that is directly connected or connected to DDC system.
- E. Personal Digital Assistant:
  - 1. Connect to system through a wireless router connected to LAN.
  - 2. Able to communicate with any DDC controller connected to DDC system.
- F. Critical Alarm Reporting:
  - 1. Operator-selected critical alarms shall be sent by DDC system to notify operator of critical alarms that require immediate attention.
  - 2. DDC system shall send alarm notification to multiple recipients that are assigned for each alarm.
  - 3. DDC system shall notify recipients by any or all means, including e-mail, text message and prerecorded phone message to mobile and landline phone numbers.
- G. Simultaneous Operator Use: Capable of accommodating up to five simultaneous operators that are accessing DDC system through any one of operator interfaces indicated.

## 2.6 NETWORKS

- A. Acceptable networks for connecting workstations, mobile devices, and network controllers include the following:



1. ATA 878.1, ARCNET.
2. CEA-709.1-C.
3. IP.
4. IEEE 8802-3, Ethernet.

B. Acceptable networks for connecting programmable application controllers include the following:

1. ATA 878.1, ARCNET.
2. CEA-709.1-C.
3. IP.
4. IEEE 8802-3, Ethernet.

C. Acceptable networks for connecting application-specific controllers include the following:

1. ATA 878.1, ARCNET.
2. CEA-709.1-C.
3. EIA-485A.
4. IP.
5. IEEE 8802-3, Ethernet.

## 2.7 NETWORK COMMUNICATION PROTOCOL

A. Network communication protocol(s) used throughout entire DDC system shall be open to Owner and available to other companies for use in making future modifications to DDC system.

B. ASHRAE 135 Protocol:

1. ASHRAE 135 communication protocol shall be sole and native protocol used throughout entire DDC system.
2. DDC system shall not require use of gateways except to integrate HVAC equipment and other building systems and equipment, not required to use ASHRAE 135 communication protocol.
3. If used, gateways shall connect to DDC system using ASHRAE 135 communication protocol and Project object properties and read/write services indicated by interoperability schedule.
4. Operator workstations, controllers and other network devices shall be tested and listed by BACnet Testing Laboratories.

C. Industry Standard Protocols:

1. DDC system shall use any one or a combination of the following industry standard protocols for network communication while complying with other DDC system requirements indicated:
  - a. ASHRAE 135.
  - b. Modbus Application Protocol Specification V1.1b.

2. Operator workstations and network controllers shall communicate through ASHRAE 135 protocol.
3. Portions of DDC system networks using ASHRAE 135 communication protocol shall be an open implementation of network devices complying with ASHRAE 135. Network devices shall be tested and listed by BACnet Testing Laboratories.
4. Portions of DDC system networks using CEA-709.1-C communication protocol shall be an open implementation of LonWorks technology using CEA-709.1-C communication protocol and using LonMark SNVTs as defined in LonMark SNVT list exclusively for DDC system.
5. Portions of DDC system networks using Modbus Application Protocol Specification V1.1b communication protocol shall be an open implementation of network devices and technology complying with Modbus Application Protocol Specification V1.1b.
6. Gateways shall be used to connect networks and network devices using different protocols.

## 2.8 PORTABLE OPERATOR TERMINAL

- A. Description: Handheld device with integral keypad or touch screen operator interface.
- B. Display: Multiple lines of text display for use in operator interaction with DDC system.
- C. Cable: Flexible cable, at least 36 inches long, with a plug-in jack for connection to DDC controllers, network ports or instruments with an integral LAN port. As an alternative to hardwired connection, POT shall be accessible to DDC controllers through a wireless network connection.
- D. POT shall be powered through network connection.
- E. Connection of POT to DDC system shall not interrupt or interfere with normal network operation in any way, prevent alarms from being transmitted, or preclude central initiated commands and system modification.
- F. POT shall give operator the ability to do the following:
  1. Display and monitor BI point status.
  2. Change BO point set point (on or off, open or closed).
  3. Display and monitor analog point values.
  4. Change analog control set points.
  5. Command a setting of AO point.
  6. Display and monitor I/O point in alarm.
  7. Add a new or delete an existing I/O point.
  8. Enable and disable I/O points, initiators, and programs.
  9. Display and change time and date.
  10. Display and change time schedules.
  11. Display and change run-time counters and run-time limits.
  12. Display and change time and event initiation.
  13. Display and change control application and DDC parameters.
  14. Display and change programmable offset values.

15. Access DDC controller initialization routines and diagnostics.

## 2.9 SERVERS

### A. Performance Requirements:

1. Performance requirements may dictate equipment exceeding minimum requirements indicated.
2. Energy Star compliant.
3. Redundant Array of Independent Disks: one configuration.
4. Drive Bays: Eight at 2.5 inches (65 mm) or eight at 3.5 inches (90 mm).
5. Hard-Drive Storage: two drives.
6. Network Interface: Dual port Ethernet.
7. DVD +RW Drive.
8. Color, flat-screen display.
9. Keyboard and mouse.
10. Next-day on-site warranty for three-year period following Substantial Completion.

### B. Servers shall include the following:

1. Full-feature backup server (server and backup minimum requirement).
2. Software licenses.
3. CAT-5e or CAT-6 cable installation between server(s) and network.

### C. Web Server:

1. If required to be separate, include Web server hardware and software to match, except backup server is not required.
2. Firewalls between server Web and networks.
3. Password protection for access to server from Web server.
4. CAT-5e or CAT 6 cable installation between the server(s) and building Ethernet network.

### D. Power each server through a dedicated UPS unit.

- 1.

## 2.10 SYSTEM SOFTWARE

### A. System Software Minimum Requirements:

1. Real-time multitasking and multiuser 32-bit operating system that allows concurrent multiple operator workstations operating and concurrent execution of multiple real-time programs and custom program development.
2. Operating system shall be capable of operating DOS and Microsoft Windows applications.
3. Database management software shall manage all data on an integrated and non-redundant basis. Additions and deletions to database shall be without detriment to existing data. Include cross linkages so no data required by a program can be deleted by an operator until that data have been deleted from respective programs.

4. Network communications software shall manage and control multiple network communications to provide exchange of global information and execution of global programs.
5. Operator interface software shall include day-to-day operator transaction processing, alarm and report handling, operator privilege level and data segregation control, custom programming, and online data modification capability.
6. Scheduling software shall schedule centrally based time and event, temporary, and exception day programs.

B. Operator Interface Software:

1. Minimize operator training through use of English language pronouncing and English language point identification.
2. Minimize use of a typewriter-style keyboard through use of a pointing device similar to a mouse.
3. Operator sign-off shall be a manual operation or, if no keyboard or mouse activity takes place, an automatic sign-off.
4. Automatic sign-off period shall be programmable from one to 60 minutes in one-minute increments on a per operator basis.
5. Operator sign-on and sign-off activity shall be recorded and sent to printer.
6. Security Access:
  - a. Operator access to DDC system shall be under password control.
  - b. An alphanumeric password shall be field assignable to each operator.
  - c. Operators shall be able to access DDC system by entry of proper password.
  - d. Operator password shall be same regardless of which computer or other interface means is used.
  - e. Additions or changes made to passwords shall be updated automatically.
  - f. Each operator shall be assigned an access level to restrict access to data and functions the operator is capable of performing.
  - g. Software shall have at least five access levels.
  - h. Each menu item shall be assigned an access level so that a one-for-one correspondence between operator assigned access level(s) and menu item access level(s) is required to gain access to menu item.
  - i. Display menu items to operator with those capable of access highlighted. Menu and operator access level assignments shall be online programmable and under password control.
7. Data Segregation:
  - a. Include data segregation for control of specific data routed to a workstation, to an operator or to a specific output device, such as a printer.
  - b. Include at least 32 segregation groups.
  - c. Segregation groups shall be selectable such as "fire points," "fire points on second floor," "space temperature points," "HVAC points," and so on.
  - d. Points shall be assignable to multiple segregation groups. Display and output of data to printer or monitor shall occur where there is a match of operator or peripheral segregation group assignment and point segregations.

- e. Alarms shall be displayed and printed at each peripheral to which segregation allows, but only those operators assigned to peripheral and having proper authorization level will be allowed to acknowledge alarms.
  - f. Operators and peripherals shall be assignable to multiple segregation groups and all assignments are to be online programmable and under password control.
8. Operators shall be able to perform commands including, but not limited to, the following:
- a. Start or stop selected equipment.
  - b. Adjust set points.
  - c. Add, modify, and delete time programming.
  - d. Enable and disable process execution.
  - e. Lock and unlock alarm reporting for each point.
  - f. Enable and disable totalization for each point.
  - g. Enable and disable trending for each point.
  - h. Override control loop set points.
  - i. Enter temporary override schedules.
  - j. Define holiday schedules.
  - k. Change time and date.
  - l. Enter and modify analog alarm limits.
  - m. Enter and modify analog warning limits.
  - n. View limits.
  - o. Enable and disable demand limiting.
  - p. Enable and disable duty cycle.
  - q. Display logic programming for each control sequence.
9. Reporting:
- a. Generated automatically and manually.
  - b. Sent to displays, printers and disk files.
  - c. Types of Reporting:
    - 1) General listing of points.
    - 2) List points currently in alarm.
    - 3) List of off-line points.
    - 4) List points currently in override status.
    - 5) List of disabled points.
    - 6) List points currently locked out.
    - 7) List of items defined in a "Follow-Up" file.
    - 8) List weekly schedules.
    - 9) List holiday programming.
    - 10) List of limits and deadbands.
10. Summaries: For specific points, for a logical point group, for an operator selected group(s), or for entire system without restriction due to hardware configuration.

C. Graphic Interface Software:

- 1. Include a full interactive graphical selection means of accessing and displaying system data to operator. Include at least five levels with the penetration path operator assignable

- (for example, site, building, floor, air-handling unit, and supply temperature loop). Native language descriptors assigned to menu items are to be operator defined and modifiable under password control.
2. Include a hierarchical-linked dynamic graphic operator interface for accessing and displaying system data and commanding and modifying equipment operation. Interface shall use a pointing device with pull-down or penetrating menus, color and animation to facilitate operator understanding of system.
  3. Include at least 10 levels of graphic penetration with the hierarchy operator assignable.
  4. Descriptors for graphics, points, alarms and such shall be modified through operator's workstation under password control.
  5. Graphic displays shall be online user definable and modifiable using the hardware and software provided.
  6. Data to be displayed within a graphic shall be assignable regardless of physical hardware address, communication or point type.
  7. Graphics are to be online programmable and under password control.
  8. Points may be assignable to multiple graphics where necessary to facilitate operator understanding of system operation.
  9. Graphics shall also contain software points.
  10. Penetration within a graphic hierarchy shall display each graphic name as graphics are selected to facilitate operator understanding.
  11. Back-trace feature shall permit operator to move upward in the hierarchy using a pointing device. Back trace shall show all previous penetration levels. Include operator with option of showing each graphic full screen size with back trace as horizontal header or by showing a "stack" of graphics, each with a back trace.
  12. Display operator accessed data on the monitor.
  13. Operator shall select further penetration using pointing device to click on a site, building, floor, area, equipment, and so on. Defined and linked graphic below that selection shall then be displayed.
  14. Include operator with means to directly access graphics without going through penetration path.
  15. Dynamic data shall be assignable to graphics.
  16. Display points (physical and software) with dynamic data provided by DDC system with appropriate text descriptors, status or value, and engineering unit.
  17. Use color, rotation, or other highly visible means, to denote status and alarm states. Color shall be variable for each class of points, as chosen by operator.
  18. Points shall be dynamic with operator adjustable update rates on a per point basis from one second to over a minute.
  19. For operators with appropriate privilege, points shall be commanded directly from display using pointing device.
    - a. For an analog command point such as set point, current conditions and limits shall be displayed and operator can position new set point using pointing device.
    - b. For a digital command point such as valve position, valve shall show its current state such as open or closed and operator could select alternative position using pointing device.
    - c. Keyboard equivalent shall be available for those operators with that preference.
  20. Operator shall be able to split or resize viewing screen into quadrants to show one graphic on one quadrant of screen and other graphics or spreadsheet, bar chart, word processing, curve plot and other information on other quadrants on screen. This feature

shall allow real-time monitoring of one part of system while displaying other parts of system or data to better facilitate overall system operation.

21. Help Features:
    - a. On-line context-sensitive help utility to facilitate operator training and understanding.
    - b. Bridge to further explanation of selected keywords. Document shall contain text and graphics to clarify system operation.
      - 1) If help feature does not have ability to bridge on keywords for more information, a complete set of user manuals shall be provided in an indexed word-processing program, which shall run concurrently with operating system software.
    - c. Available for Every Menu Item:
      - 1) Index items for each system menu item.
  22. Graphic generation software shall allow operator to add, modify, or delete system graphic displays.
    - a. Include libraries of symbols depicting HVAC symbols such as fans, coils, filters, dampers, valves pumps, and electrical symbols.
    - b. Graphic development package shall use a pointing device in conjunction with a drawing program to allow operator to perform the following:
      - 1) Define background screens.
      - 2) Define connecting lines and curves.
      - 3) Locate, orient and size descriptive text.
      - 4) Define and display colors for all elements.
      - 5) Establish correlation between symbols or text and associated system points or other displays.
- D. Project-Specific Graphics: Graphics documentation including, but not limited to, the following:
1. Site plan showing each building, and additional site elements, which are being controlled or monitored by DDC system.
  2. Plan for each building floor, including interstitial floors, and each roof level of each building, showing the following:
    - a. Room layouts with room identification and name.
    - b. Locations and identification of all monitored and controlled HVAC equipment and other equipment being monitored and controlled by DDC system.
    - c. Location and identification of each hardware point being controlled or monitored by DDC system.
  3. Control schematic for each of following, including a graphic system schematic representation with point identification, set point and dynamic value indication.
  4. Graphic display for each piece of equipment connected to DDC system through a data communications link. Include dynamic indication of all points associated with equipment.

5. DDC system network riser diagram that shows schematic layout for entire system including all networks and all controllers, and other network devices.

E. Customizing Software:

1. Software to modify and tailor DDC system to specific and unique requirements of equipment installed, to programs implemented and to staffing and operational practices planned.
2. Online modification of DDC system configuration, program parameters, and database using menu selection and keyboard entry of data into preformatted display templates.
3. As a minimum, include the following modification capability:
  - a. Operator assignment shall include designation of operator passwords, access levels, point segregation and auto sign-off.
  - b. Peripheral assignment capability shall include assignment of segregation groups and operators to consoles and printers, designation of backup workstations and printers, designation of workstation header points and enabling and disabling of print-out of operator changes.
  - c. System configuration and diagnostic capability shall include communications and peripheral port assignments, DDC controller assignments to network, DDC controller enable and disable, assignment of command trace to points and application programs and initiation of diagnostics.
  - d. System text addition and change capability shall include English or native language descriptors for points, segregation groups and access levels and action messages for alarms, run time and trouble condition.
  - e. Time and schedule change capability shall include time and date set, time and occupancy schedules, exception and holiday schedules and daylight savings time schedules.
  - f. Point related change capability shall include the following:
    - 1) System and point enable and disable.
    - 2) Run-time enable and disable.
    - 3) Assignment of points to segregation groups, calibration tables, lockout, and run time and to a fixed I/O value.
    - 4) Assignment of alarm and warning limits.
  - g. Application program change capability shall include the following:
    - 1) Enable and disable of software programs.
    - 2) Programming changes.
    - 3) Assignment of comfort limits, global points, time and event initiators, time and event schedules and enable and disable time and event programs.
4. Software shall allow operator to add points, or groups of points, to DDC system and to link them to energy optimization and management programs. Additions and modifications shall be online programmable using operator workstation, downloaded to other network devices and entered into their databases. After verification of point additions and associated program operation, database shall be uploaded and recorded on hard drive and disk for archived record.



5. Include high-level language programming software capability for implementation of custom DDC programs. Software shall include a compiler, linker, and up- and down-load capability.
  6. Include a library of DDC algorithms, intrinsic control operators, arithmetic, logic and relational operators for implementation of control sequences. Also include, as a minimum, the following:
    - a. Proportional control (P).
    - b. Proportional plus integral (PI).
    - c. Proportional plus integral plus derivative (PID).
    - d. Adaptive and intelligent self-learning control.
      - 1) Algorithm shall monitor loop response to output corrections and adjust loop response characteristics according to time constant changes imposed.
      - 2) Algorithm shall operate in a continuous self-learning manner and shall retain in memory a stored record of system dynamics so that on system shut down and restart, learning process starts from where it left off.
  7. Fully implemented intrinsic control operators including sequence, reversing, ratio, time delay, time of day, highest select AO, lowest select AO, analog controlled digital output, analog control AO, and digitally controlled AO.
  8. Logic operators such as "And," "Or," "Not," and others that are part of a standard set available with a high-level language.
  9. Arithmetic operators such as "Add," "Subtract," "Multiply," "Divide," and others that are part of a standard set available with a high-level language.
  10. Relational operators such as "Equal To," "Not Equal To," "Less Than," "Greater Than," and others that are part of a standard set available with a high-level language.
- F. Alarm Handling Software:
1. Include alarm handling software to report all alarm conditions monitored and transmitted through DDC controllers and other network devices.
  2. Include first in, first out handling of alarms according to alarm priority ranking, with most critical alarms first, and with buffer storage in case of simultaneous and multiple alarms.
  3. Alarm handling shall be active at all times to ensure that alarms are processed even if an operator is not currently signed on to DDC system.
  4. Alarms display shall include the following:
    - a. Indication of alarm condition such as "Abnormal Off," "Hi Alarm," and "Low Alarm."
    - b. "Analog Value" or "Status" group and point identification with native language point descriptor such as "Space Temperature, Building 110, 2nd Floor, Room 212."
    - c. Discrete per point alarm action message, such as "Call Maintenance Dept. Ext-5561."
    - d. Include extended message capability to allow assignment and printing of extended action messages. Capability shall be operator programmable and assignable on a per point basis.

5. Alarms shall be directed to appropriate operator workstations, printers, and individual operators by privilege level and segregation assignments.
6. Send e-mail alarm messages to designated operators.
7. Send e-mail, page, text and voice messages to designated operators for critical alarms.
8. Alarms shall be categorized and processed by class.

a. Class 1:

- 1) Associated with fire, security and other extremely critical equipment monitoring functions; have alarm, trouble, return to normal, and acknowledge conditions printed and displayed.
- 2) Unacknowledged alarms to be placed in unacknowledged alarm buffer.
- 3) All conditions shall cause an audible sound and shall require individual acknowledgment to silence audible sound.

b. Class 2:

- 1) Critical, but not life-safety related, and processed same as Class 1 alarms, except do not require individual acknowledgment.
- 2) Acknowledgement may be through a multiple alarm acknowledgment.

c. Class 3:

- 1) General alarms; printed, displayed and placed in unacknowledged alarm buffer queues.
- 2) Each new alarm received shall cause an audible sound. Audible sound shall be silenced by "acknowledging" alarm or by pressing a "silence" key.
- 3) Acknowledgement of queued alarms shall be either on an individual basis or through a multiple alarm acknowledgement.
- 4) Alarms returning to normal condition shall be printed and not cause an audible sound or require acknowledgment.

d. Class 4:

- 1) Routine maintenance or other types of warning alarms.
- 2) Alarms to be printed only, with no display, no audible sound and no acknowledgment required.

9. Include an unacknowledged alarm indicator on display to alert operator that there are unacknowledged alarms in system. Operator shall be able to acknowledge alarms on an individual basis or through a multiple alarm acknowledge key, depending on alarm class.
10. To ensure that no alarm records are lost, it shall be possible to assign a backup printer to accept alarms in case of failure of primary printer.

G. Reports and Logs:

1. Include reporting software package that allows operator to select, modify, or create reports using DDC system I/O point data available.
2. Each report shall be definable as to data content, format, interval and date.

3. Report data shall be sampled and stored on DDC controller, within storage limits of DDC controller, and then uploaded to archive on server for historical reporting.
  4. Operator shall be able to obtain real-time logs of all I/O points by type or status, such as alarm, point lockout, or normal.
  5. Reports and logs shall be stored on server hard drives in a format that is readily accessible by other standard software applications, including spreadsheets and word processing.
  6. Reports and logs shall be readily printed and set to be printed either on operator command or at a specific time each day.
- H. Standard Reports: Standard DDC system reports shall be provided and operator shall be able to customize reports later.
1. All I/O: With current status and values.
  2. Alarm: All current alarms, except those in alarm lockout.
  3. Disabled I/O: All I/O points that are disabled.
  4. Alarm Lockout I/O: All I/O points in alarm lockout, whether manual or automatic.
  5. Alarm Lockout I/O in Alarm: All I/O in alarm lockout that are currently in alarm.
  6. Logs:
    - a. Alarm history.
    - b. System messages.
    - c. System events.
    - d. Trends.
- I. Custom Reports: Operator shall be able to easily define any system data into a daily, weekly, monthly, or annual report. Reports shall be time and date stamped and shall contain a report title.
- J. Tenant Override Reports: Prepare Project-specific reports.
1. Weekly report showing daily total time in hours that each tenant has requested after-hours HVAC.
  2. Monthly report showing daily total time in hours that each tenant has requested after-hours HVAC.
  3. Annual summary report that shows after-hours HVAC usage on a monthly basis.
- ~~K. Utility Reports: Prepare Project specific reports.~~
- ~~1. Electric Report:
    - a. Include weekly report showing daily electrical consumption and peak electrical demand with time and date stamp for each meter.
    - b. Include monthly report showing the daily electrical consumption and peak electrical demand with time and date stamp for each meter.
    - c. Include annual report showing the monthly electrical consumption and peak electrical demand with time and date stamp for each meter.
    - d. For each weekly, monthly and annual report, include sum total of submeters combined by load type, such as lighting, receptacles and HVAC equipment showing daily electrical consumption and peak electrical demand.~~

- e. — For each weekly, monthly and annual report, include sum total of all submeters in building showing electrical consumption and peak electrical demand.
2. — Natural Gas Report:
- a. — Include weekly report showing daily natural gas consumption and peak natural gas demand with time and date stamp for each meter.
  - b. — Include monthly report showing the daily natural gas consumption and peak natural gas demand with time and date stamp for each meter.
  - c. — Include annual report showing the monthly natural gas consumption and peak natural gas demand with time and date stamp for each meter.
  - d. — For each weekly, monthly and annual report, include sum total of submeters combined by load type, such as boilers and service water heaters showing daily natural gas consumption and peak natural gas demand.
  - e. — For each weekly, monthly and annual report, include sum total of all submeters in building showing natural gas consumption and peak natural gas demand.
3. — Service Water Report:
- a. — Include weekly report showing daily service water consumption and peak service water demand with time and date stamp for each meter.
  - b. — Include monthly report showing the daily service water consumption and peak service water demand with time and date stamp for each meter.
  - c. — Include annual report showing the monthly service water consumption and peak service water demand with time and date stamp for each meter.
  - d. — For each weekly, monthly and annual report, include sum total of submeters combined by load type, such as cooling tower makeup and irrigation showing daily service water consumption and peak service water demand.
  - e. — For each weekly, monthly and annual report, include sum total of all submeters in building showing service water consumption and peak service water demand.
- L. — Energy Reports: Prepare Project specific daily, weekly, monthly annual and since installed energy reports.
- 1. — Prepare report for each purchased energy utility, indicating the following:
    - a. — Time period being reported with beginning and end date, and time indicated.
    - b. — Consumption in units of measure commonly used to report specific utility consumption over time.
    - c. — Gross area served by utility.
    - d. — Consumption per unit area served using utility specific unit of measure.
    - e. — Cost per utility unit.
    - f. — Utility cost per unit area.
    - g. — Convert all utilities to a common energy consumption unit of measure and report for each utility.
    - h. — Consumption per unit area using common unit of measure.
  - 2. — Prepare report for each renewable energy source, indicating the following:
    - a. — Time period being reported with beginning and end date, and time indicated.

- b. — ~~Harvested energy in units of measure commonly used to report specific harvested energy consumption over time.~~
  - c. — ~~Gross area served by renewable energy source.~~
  - d. — ~~Harvested energy per unit area served using specific unit of measure.~~
  - e. — ~~Cost per purchased utility unit displaced by renewable energy.~~
  - f. — ~~Cost savings attributed to harvested energy source.~~
  - g. — ~~Cost savings per unit area attributed to harvested energy.~~
  - h. — ~~Convert all renewable energy sources to a common energy consumption unit of measure and report for each.~~
  - i. — ~~Harvested energy per unit area using common unit of measure.~~
3. — ~~Prepare purchased energy utility report for each submetered area that indicates the following:~~
- a. — ~~Time period being reported with beginning and end date, and time indicated.~~
  - b. — ~~Gross area served.~~
  - c. — ~~Energy consumption by energy utility type.~~
  - d. — ~~Energy consumption per unit area by energy utility type.~~
  - e. — ~~Total energy consumption of all utilities in common units of measure.~~
  - f. — ~~Total energy consumption of all utilities in common units of measure per unit area.~~
  - g. — ~~Unit energy cost by energy utility type.~~
  - h. — ~~Energy cost by energy utility type.~~
  - i. — ~~Energy cost per unit area by energy utility type.~~
  - j. — ~~Total cost of all energy utilities.~~
  - k. — ~~Total cost of all energy utilities per unit area.~~
4. — ~~Prepare Project total purchased energy utility report that combines all purchased energy utilities and all areas served. Project total energy report shall indicate the following:~~
- a. — ~~Time period being reported with beginning and end date, and time indicated.~~
  - b. — ~~Gross area served.~~
  - c. — ~~Energy consumption by energy utility type.~~
  - d. — ~~Energy consumption per unit area by energy utility type.~~
  - e. — ~~Total energy consumption of all utilities in common units of measure.~~
  - f. — ~~Total energy consumption of all utilities in common units of measure per unit area.~~
  - g. — ~~Unit energy cost by energy utility type.~~
  - h. — ~~Energy cost by energy utility type.~~
  - i. — ~~Energy cost per unit area by energy utility type.~~
  - j. — ~~Total cost of all energy utilities.~~
  - k. — ~~Total cost of all energy utilities per unit area.~~
- M. — ~~Weather Reports:~~
1. — ~~Include daily report showing the following:~~
- a. — ~~Daily minimum, maximum, and average outdoor dry bulb temperature.~~
  - b. — ~~Daily minimum, maximum, and average outdoor wet bulb temperature.~~
  - c. — ~~Daily minimum, maximum, and average outdoor dew point temperature.~~
  - d. — ~~Number of heating degree days for each day calculated from a base temperature of 55 deg F (13 deg C).~~

- e. — Number of cooling degree days for each day calculated from a base temperature of 65 deg F (18 deg C).
  - f. — Daily minimum, maximum, and average outdoor carbon dioxide level.
  - g. — Daily minimum, maximum, and average relative humidity.
  - h. — Daily minimum, maximum, and average barometric pressure.
  - i. — Daily minimum, maximum, and average wind speed and direction.
2. — Include weekly report showing the following:
- a. — Daily minimum, maximum, and average outdoor dry bulb temperature.
  - b. — Daily minimum, maximum, and average outdoor wet bulb temperature.
  - c. — Daily minimum, maximum, and average outdoor dew point temperature.
  - d. — Number of heating degree days for each day calculated from a base temperature of 55 deg F (13 deg C).
  - e. — Number of cooling degree days for each day calculated from a base temperature of 65 deg F (18 deg C).
  - f. — Weekly minimum, maximum, and average outdoor carbon dioxide level.
  - g. — Daily minimum, maximum, and average relative humidity.
  - h. — Daily minimum, maximum, and average barometric pressure.
  - i. — Daily minimum, maximum, and average wind speed and direction.
3. — Include monthly report showing the following:
- a. — Daily minimum, maximum, and average outdoor dry bulb temperature.
  - b. — Daily minimum, maximum, and average outdoor wet bulb temperature.
  - c. — Daily minimum, maximum, and average outdoor dew point temperature.
  - d. — Number of heating degree days for each day calculated from a base temperature of 55 deg F (13 deg C).
  - e. — Number of cooling degree days for each day calculated from a base temperature of 65 deg F (18 deg C).
  - f. — Monthly minimum, maximum, and average outdoor carbon dioxide level.
  - g. — Daily minimum, maximum, and average relative humidity.
  - h. — Daily minimum, maximum, and average barometric pressure.
  - i. — Daily minimum, maximum, and average wind speed and direction.
4. — Include annual (12-month) report showing the following:
- a. — Monthly minimum, maximum, and average outdoor dry bulb temperature.
  - b. — Monthly minimum, maximum, and average outdoor wet bulb temperature.
  - c. — Monthly minimum, maximum, and average outdoor dew point temperature.
  - d. — Number of heating degree days for each day calculated from a base temperature of 55 deg F (13 deg C).
  - e. — Number of cooling degree days for each day calculated from a base temperature of 65 deg F (18 deg C).
  - f. — Annual minimum, maximum, and average outdoor carbon dioxide level.
  - g. — Monthly minimum, maximum, and average relative humidity.
  - h. — Daily minimum, maximum, and average barometric pressure.
  - i. — Daily minimum, maximum, and average wind speed and direction.

N. Standard Trends:

1. Trend all I/O point present values, set points, and other parameters indicated for trending.
  2. Trends shall be associated into groups, and a trend report shall be set up for each group.
  3. Trends shall be stored within DDC controller and uploaded to hard drives automatically on reaching 75 of DDC controller buffer limit, or by operator request, or by archiving time schedule.
  4. Preset trend intervals for each I/O point after review with Owner.
  5. Trend intervals shall be operator selectable from 10 seconds up to 60 minutes. Minimum number of consecutive trend values stored at one time shall be 100 per variable.
  6. When drive storage memory is full, most recent data shall overwrite oldest data.
  7. Archived and real-time trend data shall be available for viewing numerically and graphically by operators.
- O. Custom Trends: Operator shall be able to define a custom trend log for any I/O point in DDC system.
1. Each trend shall include interval, start time, and stop time.
  2. Data shall be sampled and stored on DDC controller, within storage limits of DDC controller, and then uploaded to archive on server hard drives.
  3. Data shall be retrievable for use in spreadsheets and standard database programs.
- P. Programming Software:
1. Include programming software to execute sequences of operation indicated.
  2. Include programming routines in simple and easy to follow logic with detailed text comments describing what the logic does and how it corresponds to sequence of operation.
  3. Programming software shall be any of the following:
    - a. Graphic Based: Programming shall use a library of function blocks made from preprogrammed code designed for DDC control systems.
      - 1) Function blocks shall be assembled with interconnection lines that represent to control sequence in a flowchart.
      - 2) Programming tools shall be viewable in real time to show present values and logical results of each function block.
    - b. Menu Based: Programming shall be done by entering parameters, definitions, conditions, requirements and constraints.
    - c. Line by Line and Text Based: Programming shall declare variable types such as local, global, real, integer, and so on, at the beginning of the program. Use descriptive comments frequently to describe programming code.
  4. Include means for detecting programming errors and testing software control strategies with a simulation tool before implementing in actual control. Simulation tool may be inherent with programming software or as a separate product.
- Q. Database Management Software:

1. Where a separate SQL database is used for information storage, DDC system shall include database management software that separates database monitoring and managing functions by supporting multiple separate windows.
2. Database secure access shall be accomplished using standard SQL authentication including ability to access data for use outside of DDC system applications.
3. Database management function shall include summarized information on trend, alarm, event, and audit for the following database management actions:
  - a. Backup.
  - b. Purge.
  - c. Restore.
4. Database management software shall support the following:
  - a. Statistics: Display database server information and trend, alarm, event, and audit information on database.
  - b. Maintenance: Include method of purging records from trend, alarm, event and audit databases by supporting separate screens for creating a backup before purging, selecting database, and allowing for retention of a selected number of day's data.
  - c. Backup: Include means to create a database backup file and select a storage location.
  - d. Restore: Include a restricted means of restoring a database by requiring operator to have proper security level.
5. Database management software shall include information of current database activity, including the following:
  - a. Ready.
  - b. Purging record from a database.
  - c. Action failed.
  - d. Refreshing statistics.
  - e. Restoring database.
  - f. Shrinking a database.
  - g. Backing up a database.
  - h. Resetting Internet information services.
  - i. Starting network device manager.
  - j. Shutting down the network device manager.
  - k. Action successful.
6. Database management software monitoring functions shall continuously read database information once operator has logged on.
7. Include operator notification through on-screen pop-up display and e-mail message when database value has exceeded a warning or alarm limit.
8. Monitoring settings window shall have the following sections:
  - a. Allow operator to set and review scan intervals and start times.
  - b. E-mail: Allow operator to create and review e-mail and phone text messages to be delivered when a warning or an alarm is generated.



- c. Warning: Allow operator to define warning limit parameters, set reminder frequency and link e-mail message.
  - d. Alarm: Allow operator to define alarm limit parameters, set reminder frequency and link e-mail message.
  - e. Database Login: Protect system from unauthorized database manipulation by creating a read access and a write access for each of trend, alarm, event and audit databases as well as operator proper security access to restore a database.
9. Monitoring settings taskbar shall include the following informational icons:
- a. Normal: Indicates by color and size, or other easily identifiable means that all databases are within their limits.
  - b. Warning: Indicates by color and size, or other easily identifiable means that one or more databases have exceeded their warning limit.
  - c. Alarm: Indicates by color and size, or other easily identifiable means that one or more databases have exceeded their alarm limit.

#### 2.11 ASHRAE 135 GATEWAYS

- A. Include BACnet communication ports, whenever available as an equipment OEM standard option, for integration via a single communication cable. BACnet-controlled equipment includes, but is not limited to, VRF System and DOAS Unit.
- B. Include gateways to connect BACnet to legacy systems, existing non-BACnet devices, and existing non-BACnet DDC-controlled equipment, only when specifically requested and approved by Owner.
- C. Include with each gateway an interoperability schedule showing each point or event on legacy side that BACnet "client" will read, and each parameter that BACnet network will write to. Describe this interoperability of BACnet services, or BIBBs, defined in ASHRAE 135, Annex K.
- D. Gateway Minimum Requirements:
  - 1. Read and view all readable object properties on non-BACnet network to BACnet network and vice versa where applicable.
  - 2. Write to all writable object properties on non-BACnet network from BACnet network and vice versa where applicable.
  - 3. Include single-pass (only one protocol to BACnet without intermediary protocols) translation from non-BACnet protocol to BACnet and vice versa.
  - 4. Comply with requirements of Data Sharing Read Property, Data Sharing Write Property, Device Management Dynamic Device Binding-B, and Device Management Communication Control BIBBs according to ASHRAE 135.
  - 5. Hardware, software, software licenses, and configuration tools for operator-to-gateway communications.
  - 6. Backup programming and parameters on CD media and the ability to modify, download, backup, and restore gateway configuration.

2.12 ASHRAE 135 PROTOCOL ANALYZER

- A. Analyzer and required cables and fittings for connection to ASHRAE 135 network.
- B. Analyzer shall include the following minimum capabilities:
  - 1. Capture and store to a file data traffic on all network levels.
  - 2. Measure bandwidth usage.
  - 3. Filtering options with ability to ignore select traffic.

2.13 WIRELESS ROUTERS FOR OPERATOR INTERFACE

- A. Single-Band Wireless Routers:
  - 1. Description: High-speed router with integral Ethernet ports.
  - 2. Technology: IEEE 802.11n; 2.4-GHz speed band.
  - 3. Speed: Up to 300 Mbps.
  - 4. Compatibility: IEEE 802.11n/g/b/a wireless devices.
  - 5. Ethernet Ports: Four, gigabit (1000 Mbps).
  - 6. Wireless Security: Wi-Fi Protected Access (WPA) and WPA2 according to IEEE 802.11i.
- B. Dual-Band Wireless Routers:
  - 1. Description: High-speed, dual-band router with integral Ethernet ports and USB port.
  - 2. Technology: IEEE 802.11n; 2.4- and 5-GHz speed bands.
  - 3. Speed: Up to 300 Mbps on 2.4-GHz band and up to 450 Mbps on 5-GHz band.
  - 4. Compatibility: IEEE 802.11n/g/b/a wireless devices.
  - 5. Ethernet Ports: Four, gigabit (1000 Mbps).
  - 6. USB Port: One, USB 2.0 or 3.0.
  - 7. Wireless Security: Wi-Fi Protected Access (WPA) and WPA2 according to IEEE 802.11i.

2.14 DDC CONTROLLERS

- A. DDC system shall consist of a combination of network controllers, programmable application controllers and application-specific controllers to satisfy performance requirements indicated.
- B. DDC controllers shall perform monitoring, control, energy optimization and other requirements indicated.
- C. DDC controllers shall use a multitasking, multiuser, real-time digital control microprocessor with a distributed network database and intelligence.
- D. Each DDC controller shall be capable of full and complete operation as a completely independent unit and as a part of a DDC system wide distributed network.
- E. Environment Requirements:
  - 1. Controller hardware shall be suitable for the anticipated ambient conditions.

2. Controllers located in conditioned space shall be rated for operation at 32 to 120 deg F (Zero to 50 deg C).
  3. Controllers located outdoors shall be rated for operation at 40 to 150 deg F (40 to 65 deg C).
- F. Power and Noise Immunity:
1. Controller shall operate at 90 to 110 percent of nominal voltage rating and shall perform an orderly shutdown below 80 percent of nominal voltage.
  2. Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios with up to 5 W of power located within 36 inches (900 mm) of enclosure.
- G. DDC Controller Spare Processing Capacity:
1. Include spare processing memory for each controller. RAM, PROM, or EEPROM will implement requirements indicated with the following spare memory:
    - a. Network Controllers: 50 percent.
    - b. Programmable Application Controllers: Not less than 60 percent.
    - c. Application-Specific Controllers: Not less than 70 percent.
  2. Memory shall support DDC controller's operating system and database and shall include the following:
    - a. Monitoring and control.
    - b. Energy management, operation and optimization applications.
    - c. Alarm management.
    - d. Historical trend data of all connected I/O points.
    - e. Maintenance applications.
    - f. Operator interfaces.
    - g. Monitoring of manual overrides.
- H. DDC Controller Spare I/O Point Capacity: Include spare I/O point capacity for each controller as follows:
1. Network Controllers:
    - a. ~~10 percent of each AI, AO, BI, and BO point connected to controller.~~
    - b. Minimum Spare I/O Points per Controller:
      - 1) AIs: ~~Two~~. **One**
      - 2) AOs: ~~Two~~. **One**
      - 3) BIs: ~~Three~~. **One**
      - 4) BOs: ~~Three~~. **One**
  2. Programmable Application Controllers:
    - a. ~~10 percent of each AI, AO, BI, and BO point connected to controller.~~
    - a. Minimum Spare I/O Points per Controller:

- 1) AIs: ~~Two~~ **One**
- 2) AOs: ~~Two~~ **One**
- 3) BIs: ~~Three~~ **One**
- 4) BOs: ~~Three~~ **One**

3. Application-Specific Controllers:

~~b. 10 percent of each AI, AO, BI, and BO point connected to controller.~~

a. Minimum Spare I/O Points per Controller:

- 1) AIs: ~~Two~~ **One**
- 2) AOs: ~~Two~~ **One**
- 3) BIs: ~~Three~~ **One**
- 4) BOs: ~~Three~~ **One**

I. Maintenance and Support: Include the following features to facilitate maintenance and support:

1. Mount microprocessor components on circuit cards for ease of removal and replacement.
2. Means to quickly and easily disconnect controller from network.
3. Means to quickly and easily access connect to field test equipment.
4. Visual indication that controller electric power is on, of communication fault or trouble, and that controller is receiving and sending signals to network.

J. Input and Output Point Interface:

1. Hardwired input and output points shall connect to network, programmable application and application-specific controllers.
2. Input and output points shall be protected so shorting of point to itself, to another point, or to ground will not damage controller.
3. Input and output points shall be protected from voltage up to 24 V of any duration so that contact will not damage controller.
4. AIs:
  - a. AIs shall include monitoring of low-voltage (zero- to 10-V dc), current (4 to 20 mA) and resistance signals from thermistor and RTD sensors.
  - b. AIs shall be compatible with, and field configurable to, sensor and transmitters installed.
  - c. Controller AIs shall perform analog-to-digital (A-to-D) conversion with a minimum resolution of 8 bits or better to comply with accuracy requirements indicated.
  - d. Signal conditioning including transient rejection shall be provided for each AI.
  - e. Capable of being individually calibrated for zero and span.
  - f. Incorporate common-mode noise rejection of at least 50 dB from zero to 100 Hz for differential inputs, and normal-mode noise rejection of at least 20 dB at 60 Hz from a source impedance of 10000 ohms.

5. AOs:

- a. Controller AOs shall perform analog-to-digital (A-to-D) conversion with a minimum resolution of 8 bits or better to comply with accuracy requirements indicated.
  - b. Output signals shall have a range of 4 to 20 mA dc or zero- to 10-V dc as required to include proper control of output device.
  - c. Capable of being individually calibrated for zero and span.
  - d. AOs shall not exhibit a drift of greater than 0.4 percent of range per year.
6. BIs:
- a. Controller BIs shall accept contact closures and shall ignore transients of less than 5-ms duration.
  - b. Isolation and protection against an applied steady-state voltage of up to 180-V ac peak.
  - c. BIs shall include a wetting current of at least 12 mA to be compatible with commonly available control devices and shall be protected against effects of contact bounce and noise.
  - d. BIs shall sense "dry contact" closure without external power (other than that provided by the controller) being applied.
  - e. Pulse accumulation input points shall comply with all requirements of BIs and accept up to 10 pulses per second for pulse accumulation. Buffer shall be provided to totalize pulses. Pulse accumulator shall accept rates of at least 20 pulses per second. The totalized value shall be reset to zero on operator's command.
7. BOs:
- a. Controller BOs shall include relay contact closures or triac outputs for momentary and maintained operation of output devices.
    - 1) Relay contact closures shall have a minimum duration of 0.1 second. Relays shall include at least 180 V of isolation. Electromagnetic interference suppression shall be provided on all output lines to limit transients to non-damaging levels. Minimum contact rating shall be 1 A at 24-V ac.
    - 2) Triac outputs shall include at least 180 V of isolation. Minimum contact rating shall be 1 A at 24-V ac.
  - b. BOs shall include for two-state operation or a pulsed low-voltage signal for pulse-width modulation control.
  - c. BOs shall be selectable for either normally open or normally closed operation.
  - d. Include tristate outputs (two coordinated BOs) for control of three-point floating-type electronic actuators without feedback.

## 2.15 NETWORK CONTROLLERS

### A. General Network Controller Requirements:

- 1. Include adequate number of controllers to achieve performance indicated.
- 2. System shall consist of one or more independent, standalone, microprocessor-based network controllers to manage global strategies indicated.

3. Controller shall have enough memory to support its operating system, database, and programming requirements.
4. Data shall be shared between networked controllers and other network devices.
5. Operating system of controller shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.
6. Controllers that perform scheduling shall have a real-time clock.
7. Controller shall continually check status of its processor and memory circuits. If an abnormal operation is detected, controller shall assume a predetermined failure mode and generate an alarm notification.
8. Controllers shall be fully programmable.

B. Communication:

1. Network controllers shall communicate with other devices on DDC system Level one network.
2. Network controller also shall perform routing if connected to a network of programmable application and application-specific controllers.

C. Operator Interface:

1. Controller shall be equipped with a service communications port for connection to a portable operator's workstation or PDA.
2. Local Keypad and Display:
  - a. Equip controller with local keypad and digital display for interrogating and editing data.
  - b. Use of keypad and display shall require security password.

D. Serviceability:

1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
3. Controller shall maintain BIOS and programming information in event of a power loss for at least 72 hours.

2.16 PROGRAMMABLE APPLICATION CONTROLLERS

A. General Programmable Application Controller Requirements:

1. Include adequate number of controllers to achieve performance indicated.
2. Controller shall have enough memory to support its operating system, database, and programming requirements.
3. Data shall be shared between networked controllers and other network devices.
4. Operating system of controller shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and allow for central monitoring and alarms.

5. Controllers that perform scheduling shall have a real-time clock.
6. Controller shall continually check status of its processor and memory circuits. If an abnormal operation is detected, controller shall assume a predetermined failure mode and generate an alarm notification.
7. Controllers shall be fully programmable.

B. Communication:

1. Programmable application controllers shall communicate with other devices on network.

C. Operator Interface:

1. Controller shall be equipped with a service communications port for connection to a portable operator's workstation or PDA>
2. Local Keypad and Display:
  - a. Equip controller with local keypad and digital display for interrogating and editing data.
  - b. Use of keypad and display shall require security password.

D. Serviceability:

1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
3. Controller shall maintain BIOS and programming information in event of a power loss for at least 72 hours.

2.17 APPLICATION-SPECIFIC CONTROLLERS

A. Description: Microprocessor-based controllers, which through hardware or firmware design are dedicated to control a specific piece of equipment. Controllers are not fully user-programmable but are configurable and customizable for operation of equipment they are designed to control.

1. Capable of standalone operation and shall continue to include control functions without being connected to network.
2. Data shall be shared between networked controllers and other network devices.

B. Communication: Application-specific controllers shall communicate with other application-specific controller and devices on network, and to programmable application and network controllers.

C. Operator Interface: Controller shall be equipped with a service communications port for connection to a portable operator's workstation. Connection shall extend to port on space temperature sensor that is connected to controller.

D. Serviceability:

1. Controller shall be equipped with diagnostic LEDs or other form of local visual indication of power, communication, and processor.
2. Wiring and cable connections shall be made to field-removable, modular terminal strips or to a termination card connected by a ribbon cable.
3. Controller shall use nonvolatile memory and maintain all BIOS and programming information in event of power loss.

2.18 CONTROLLER SOFTWARE

A. General Controller Software Requirements:

1. Software applications shall reside and operate in controllers. Editing of applications shall occur at operator workstations.
2. I/O points shall be identified by up to 30-character point name and up to 16-character point descriptor. Same names shall be used at operator workstations.
3. Control functions shall be executed within controllers using DDC algorithms.
4. Controllers shall be configured to use stored default values to ensure fail-safe operation. Default values shall be used when there is a failure of a connected input instrument or loss of communication of a global point value.

B. Security:

1. Operator access shall be secured using individual security passwords and usernames.
2. Passwords shall restrict operator to points, applications, and system functions as assigned by system manager.
3. Operator log-on and log-off attempts shall be recorded.
4. System shall protect itself from unauthorized use by automatically logging off after last keystroke. The delay time shall be operator-definable.

C. Scheduling: Include capability to schedule each point or group of points in system. Each schedule shall consist of the following:

1. Weekly Schedule:

- a. Include separate schedules for each day of week.
- b. Each schedule should include the capability for start, stop, optimal start, optimal stop, and night economizer.
- c. Each schedule may consist of up to 10 events.
- d. When a group of objects are scheduled together, include capability to adjust start and stop times for each member.

2. Exception Schedules:

- a. Include ability for operator to designate any day of the year as an exception schedule.
- b. Exception schedules may be defined up to a year in advance. Once an exception schedule is executed, it will be discarded and replaced by regular schedule for that day of week.



3. Holiday Schedules:
  - a. Include capability for operator to define up to 99 special or holiday schedules.
  - b. Schedules may be placed on scheduling calendar and will be repeated each year.
  - c. Operator shall be able to define length of each holiday period.
  
- D. System Coordination:
  1. Include standard application for proper coordination of equipment.
  2. Application shall include operator with a method of grouping together equipment based on function and location.
  3. Group may then be used for scheduling and other applications.
  
- E. Binary Alarms:
  1. Each binary point shall be set to alarm based on operator-specified state.
  2. Include capability to automatically and manually disable alarming.
  
- F. Analog Alarms:
  1. Each analog object shall have both high and low alarm limits.
  2. Alarming shall be able to be automatically and manually disabled.
  
- G. Alarm Reporting:
  1. Operator shall be able to determine action to be taken in event of an alarm.
  2. Alarms shall be routed to appropriate operator workstations based on time and other conditions.
  3. Alarm shall be able to start programs, print, be logged in event log, generate custom messages, and display graphics.
  
- H. Remote Communication:
  1. System shall have ability to dial out in the event of an alarm.
  
- I. Electric Power Demand Limiting:
  1. Demand-limiting program shall monitor building or other operator-defined electric power consumption from signals connected to electric power meter or from a watt transducer or current transformer.
  2. Demand-limiting program shall predict probable power demand such that action can be taken to prevent exceeding demand limit. When demand prediction exceeds demand limit, action will be taken to reduce loads in a predetermined manner. When demand prediction indicates demand limit will not be exceeded, action will be taken to restore loads in a predetermined manner.
  3. Demand reduction shall be accomplished by the following means:
    - a. Reset air-handling unit supply temperature set points.
    - b. Reset space temperature set points.
    - c. De-energize equipment based on priority.

4. Demand-limiting parameters, frequency of calculations, time intervals, and other relevant variables shall be based on the means by which electric power service provider computes demand charges.
5. Include demand-limiting prediction and control for any individual meter monitored by system or for total of any combination of meters.
6. Include means operator to make the following changes online:
  - a. Addition and deletion of loads controlled.
  - b. Changes in demand intervals.
  - c. Changes in demand limit for meter(s).
  - d. Maximum shutoff time for equipment.
  - e. Minimum shutoff time for equipment.
  - f. Select rotational or sequential shedding and restoring.
  - g. Shed and restore priority.
7. Include the following information and reports, to be available on an hourly, daily, weekly, monthly and annual basis:
  - a. Total electric consumption.
  - b. Peak demand.
  - c. Date and time of peak demand.
  - d. Daily peak demand.
- J. Maintenance Management: System shall monitor equipment status and generate maintenance messages based on operator-designated run-time, starts, and calendar date limits.
- K. Sequencing: Include application software based on sequences of operation indicated to properly sequence chillers, boilers, and other applicable HVAC equipment.
- L. Control Loops:
  1. Support any of the following control loops, as applicable to control required:
    - a. Two-position (on/off, open/close, slow/fast) control.
    - b. Proportional control.
    - c. Proportional plus integral (PI) control.
    - d. Proportional plus integral plus derivative (PID) control.
      - 1) Include PID algorithms with direct or reverse action and anti-windup.
      - 2) Algorithm shall calculate a time-varying analog value used to position an output or stage a series of outputs.
      - 3) Controlled variable, set point, and PID gains shall be operator-selectable.
    - e. Adaptive (automatic tuning).
- M. Staggered Start: Application shall prevent all controlled equipment from simultaneously restarting after a power outage. Order which equipment (or groups of equipment) is started, along with the time delay between starts, shall be operator-selectable.
- N. Energy Calculations:

1. Include software to allow instantaneous power or flow rates to be accumulated and converted to energy usage data.
2. Include an algorithm that calculates a sliding-window average (rolling average). Algorithm shall be flexible to allow window intervals to be operator specified (such as 15, 30, or 60 minutes).
3. Include an algorithm that calculates a fixed-window average. A digital input signal shall define start of window period (such as signal from utility meter) to synchronize fixed-window average with that used by utility.

O. Anti-Short Cycling:

1. BO points shall be protected from short cycling.
2. Feature shall allow minimum on-time and off-time to be selected.

P. On and Off Control with Differential:

1. Include an algorithm that allows a BO to be cycled based on a controlled variable and set point.
2. Algorithm shall be direct- or reverse-acting and incorporate an adjustable differential.

Q. Run-Time Totalization:

1. Include software to totalize run-times for all BI and BO points.
2. A high run-time alarm shall be assigned, if required, by operator.

## 2.19 ENCLOSURES

A. General Enclosure Requirements:

1. House each controller and associated control accessories in a single enclosure. Enclosure shall serve as central tie-in point for control devices such as switches, transmitters, transducers, power supplies and transformers.
2. Do not house more than one controller in a single enclosure.
3. Include enclosure door with key locking mechanism. Key locks alike for all enclosures and include one pair of keys per enclosure.
4. Equip doors of enclosures housing controllers and components with analog or digital displays with windows to allow visual observation of displays without opening enclosure door.
5. Individual wall-mounted single-door enclosures shall not exceed 36 inches wide and 48 inches high.
6. Individual wall-mounted double-door enclosures shall not exceed 60 inches wide and 36 inches high.
7. Include wall-mounted enclosures with brackets suitable for mounting enclosures to wall or freestanding support stand as indicated.
8. Supply each enclosure with a complete set of as-built schematics, tubing, and wiring diagrams and product literature located in a pocket on inside of door. For enclosures with windows, include pocket on bottom of enclosure.

B. Internal Arrangement:

1. Internal layout of enclosure shall group and protect pneumatic, electric, and electronic components associated with a controller, but not an integral part of controller.
2. Arrange layout to group similar products together.
3. Include a barrier between line-voltage and low-voltage electrical and electronic products.
4. Factory or shop install products, tubing, cabling and wiring complying with requirements and standards indicated.
5. Terminate field cable and wire using heavy-duty terminal blocks.
6. Include spare terminals, equal to not less than 10 percent of used terminals.
7. Include spade lugs for stranded cable and wire.
8. Install a maximum of two wires on each side of a terminal.
9. Include enclosure field power supply with a toggle-type switch located at entrance inside enclosure to disconnect power.
10. Include enclosure with a line-voltage nominal 20-A GFCI duplex receptacle for service and testing tools. Wire receptacle on hot side of enclosure disconnect switch and include with a 5-A circuit breaker.
11. Mount products within enclosure on removable internal panel(s).
12. Include products mounted in enclosures with engraved, laminated phenolic nameplates (black letters on a white background). The nameplates shall have at least 1/4-inch-high lettering.
13. Route tubing cable and wire located inside enclosure within a raceway with a continuous removable cover.
14. Label each end of cable, wire and tubing in enclosure following an approved identification system that extends from field I/O connection and all intermediate connections throughout length to controller connection.
15. Size enclosure internal panel to include at least 25 percent spare area on face of panel.

C. Environmental Requirements:

1. Evaluate temperature and humidity requirements of each product to be installed within each enclosure.
2. Calculate enclosure internal operating temperature considering heat dissipation of all products installed within enclosure and ambient effects (solar, conduction and wind) on enclosure.
3. Where required by application, include temperature-controlled electrical heat to maintain inside of enclosure above minimum operating temperature of product with most stringent requirement.
4. Where required by application, include temperature-controlled ventilation fans with filtered louver(s) to maintain inside of enclosure below maximum operating temperature of product with most stringent requirement.
5. Include temperature-controlled cooling within the enclosure for applications where ventilation fans cannot maintain inside temperature of enclosure below maximum operating temperature of product with most stringent requirement.
6. Where required by application, include humidity-controlled electric dehumidifier or cooling to maintain inside of enclosure below maximum relative humidity of product with most stringent requirement and to prevent surface condensation within enclosure.

D. Wall-Mounted, NEMA 250, Type 1:

1. Enclosure shall be NRTL listed according to UL 50 or UL 50E.
2. Construct enclosure of steel, not less than:

- a. Enclosure size less than 24 in. (600 mm): 0.053 in. (1.35 mm) or 0.067 in. (1.7 mm) thick.
  - b. Enclosure size 24 in. (600 mm) and larger: 0.067 in. (1.7 mm) or 0.093 in. (2.36 mm) thick.
3. Finish enclosure inside and out with polyester powder coating that is electrostatically applied and then baked to bond to substrate.
    - a. Exterior color shall be selected by Architect.
    - b. Interior color shall be manufacturer's standard.
  4. Hinged door full size of front face of enclosure and supported using:
    - a. Enclosures sizes less than 36 in. (900 mm) tall: Multiple butt hinges.
    - b. Enclosures sizes 36 in. (900 mm) tall and larger: Continuous piano hinges.
  5. Removable internal panel with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.
    - a. Size less than 24 in. (600 mm): Solid or perforated] steel, 0.053 in. (1.35 mm) thick.
    - b. Size 24 in. (600 mm) and larger: Solid aluminum, 0.10 in. (3 mm) or steel, 0.093 in. (2.36 mm) thick.
  6. Internal panel mounting hardware, grounding hardware and sealing washers.
  7. Grounding stud on enclosure body.
  8. Thermoplastic pocket on inside of door for record Drawings and Product Data.
- E. Wall Mounted NEMA 250, Types 4 and 12:
1. Enclosure shall be NRTL listed according to UL 508A.
  2. Seam and joints are continuously welded and ground smooth.
  3. Where recessed enclosures are indicated, include enclosures with face flange for flush mounting.
  4. Externally formed body flange around perimeter of enclosure face for continuous perimeter seamless gasket door seal.
  5. Single-door enclosure sizes up to 60 inches tall by 36 inches wide (1500 mm tall by 900 mm wide).
  6. Double-door enclosure sizes up to 36 inches tall by 60 inches wide (900 mm tall by 1500 mm wide).
  7. Construct enclosure of steel, not less than the following:
    - c. Enclosure size less than 24 in. (600 mm): 0.053 in. (1.35 mm) or 0.067 in. (1.7 mm) thick.
    - a. Size 24 Inches (600 mm) and Larger: 0.067 inch (1.7 mm) thick.
  8. Finish enclosure with polyester powder coating that is electrostatically applied and then baked to bond to substrate.
    - a. Exterior color shall be as selected by Architect.
    - b. Interior color shall be manufacturer's standard.

9. Corner-formed door, full size of enclosure face, supported using multiple concealed hinges with easily removable hinge pins.
  - a. Sizes through 24 Inches (600 mm) Tall: Two hinges.
  - b. Sizes between 24 Inches (600 mm) through 48 Inches (1200 mm) Tall: Three hinges.
  - c. Sizes Larger 48 Inches (1200 mm) Tall: Four hinges.
10. Double-door enclosures with overlapping door design to include unobstructed full-width access.
  - a. Single-door enclosures 48 inches (1200 mm) and taller, and all double-door enclosures, with three-point (top, middle and bottom) latch system.
11. Removable internal panel with a white polyester powder coating that is electrostatically applied and then baked to bond to substrate.
  - d. Size less than 24 in. (600 mm): Solid or perforated] steel, 0.053 in. (1.35 mm) thick.
  - a. Size 24 in. (600 mm) and larger: Solid aluminum, 0.10 in. (3 mm) or steel, 0.093 in. (2.36 mm) thick.
12. Internal panel mounting studs with hardware, grounding hardware, and sealing washers.
13. Grounding stud on enclosure body.
14. Thermoplastic pocket on inside of door for record Drawings and Product Data.

## 2.20 RELAYS

### A. General-Purpose Relays:

1. Relays shall be heavy duty and rated for at least 10 A at 250-V ac and 60 Hz.
2. Relays shall be either double pole double throw (DPDT) or three-pole double throw, depending on the control application.
3. Use a plug-in-style relay with an eight-pin octal plug for DPDT relays and an 11-pin octal plug for three-pole double-throw relays.
4. Construct the contacts of either silver cadmium oxide or gold.
5. Enclose the relay in a clear transparent polycarbonate dust-tight cover.
6. Relays shall have LED indication and a manual reset and push-to-test button.
7. Performance:
  - a. Mechanical Life: At least 10 million cycles.
  - b. Electrical Life: At least 100,000 cycles at rated load.
  - c. Pickup Time: 15 ms or less.
  - d. Dropout Time: 10 ms or less.
  - e. Pull-in Voltage: 85 percent of rated voltage.
  - f. Dropout Voltage: 50 percent of nominal rated voltage.
  - g. Power Consumption: 2 VA.
  - h. Ambient Operating Temperatures: Minus 40 to 115 deg F (Minus 40 to 46 deg C).
8. Equip relays with coil transient suppression to limit transients to non-damaging levels.

9. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
10. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

**B. Multifunction Time-Delay Relays:**

1. Relays shall be continuous duty and rated for at least 10 A at 240-V ac and 60 Hz.
2. Relays shall be DPDT relay with up to eight programmable functions to provide on/off delay, interval and recycle timing functions.
3. Use a plug-in-style relay with either an 8- or 11-pin octal plug.
4. Construct the contacts of either silver cadmium oxide or gold.
5. Enclose the relay in a dust-tight cover.
6. Include knob and dial scale for setting delay time.
7. Performance:
  - a. Mechanical Life: At least 10 million cycles.
  - b. Electrical Life: At least 100,000 cycles at rated load.
  - c. Timing Ranges: Multiple ranges from 0.1 seconds to 100 minutes.
  - d. Repeatability: Within 2 percent.
  - e. Recycle Time: 45 ms.
  - f. Minimum Pulse Width Control: 50 ms.
  - g. Power Consumption: 5 VA or less at 120-V ac.
  - h. Ambient Operating Temperatures: Minus 40 to 115 deg F (Minus 40 to 46 deg C).
8. Equip relays with coil transient suppression to limit transients to non-damaging levels.
9. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
10. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

**C. Latching Relays:**

1. Relays shall be continuous duty and rated for at least 10 A at 250-V ac and 60 Hz.
2. Relays shall be either DPDT or three-pole double throw, depending on the control application.
3. Use a plug-in-style relay with a multibladed plug.
4. Construct the contacts of either silver cadmium oxide or gold.
5. Enclose the relay in a clear transparent polycarbonate dust-tight cover.
6. Performance:
  - a. Mechanical Life: At least 10 million cycles.
  - b. Electrical Life: At least 100,000 cycles at rated load.
  - c. Pickup Time: 15 ms or less.
  - d. Dropout Time: 10 ms or less.
  - e. Pull-in Voltage: 85 percent of rated voltage.
  - f. Dropout Voltage: 50 percent of nominal rated voltage.
  - g. Power Consumption: 2 VA.
  - h. Ambient Operating Temperatures: Minus 40 to 115 deg F (Minus 40 to 46 deg C).
7. Equip relays with coil transient suppression to limit transients to non-damaging levels.

8. Plug each relay into an industry-standard, 35-mm DIN rail socket. Plug all relays located in control panels into sockets that are mounted on a DIN rail.
9. Relay socket shall have screw terminals. Mold into the socket the coincident screw terminal numbers and associated octal pin numbers.

D. Current Sensing Relay:

1. Monitors ac current.
2. Independent adjustable controls for pickup and dropout current.
3. Energized when supply voltage is present and current is above pickup setting.
4. De-energizes when monitored current is below dropout current.
5. Dropout current is adjustable from 50 to 95 percent of pickup current.
6. Include a current transformer, if required for application.
7. House current sensing relay and current transformer in its own enclosure. Use NEMA 250, Type 12 enclosure for indoors and NEMA 250, Type 4 for outdoors.

E. Combination On-Off Status Sensor and On-Off Relay:

1. Description:
  - a. On-off control and status indication in a single device.
  - b. LED status indication of activated relay and current trigger.
  - c. Closed-Open-Auto override switch located on the load side of the relay.
2. Performance:
  - a. Ambient Temperature: Minus 30 to 140 deg F (Minus 34 to 60 deg C).
  - b. Voltage Rating: Single-phase loads rated for 300-V ac. Three-phase loads rated for 600-V ac.
3. Status Indication:
  - a. Current Sensor: Integral sensing for single-phase loads up to 20 A and external solid or split sensing ring for three-phase loads up to 150 A.
  - b. Current Sensor Range: As required by application.
  - c. Current Set Point: Fixed or adjustable as required by application.
  - d. Current Sensor Output:
    - 1) Solid-state, single-pole double-throw contact rated for 30-V ac and dc and for 0.4 A.
    - 2) Solid-state, single-pole double-throw contact rated for 120-V ac and 1.0 A.
    - 3) Analog, zero- to 5- or 10-V dc.
    - 4) Analog, 4 to 20 mA, loop powered.
4. Relay: Single-pole double-throw, continuous-duty coil; rated for 10-million mechanical cycles.
5. Enclosure: NEMA 250, Type 1 enclosure.



2.21 ELECTRICAL POWER DEVICES

A. Transformers:

1. Transformer shall be sized for the total connected load, plus an additional 25 percent of connected load.
2. Transformer shall be at least 40 VA.
3. Transformer shall have both primary and secondary fuses.

B. Power-Line Conditioner:

1. General Power-Line Conditioner Requirements:

- a. Design to ensure maximum reliability, serviceability and performance.
- b. Overall function of the power-line conditioner is to receive raw, polluted electrical power and purify it for use by electronic equipment. The power-line conditioner shall provide isolated, regulated, transient and noise-free sinusoidal power to loads served.

2. Standards: NRTL listed per UL 1012.

3. Performance:

- a. Single phase, continuous, 100 percent duty rated KVA/KW capacity. Design to supply power for linear or nonlinear, high crest factor, resistive and reactive loads.
- b. Automatically regulate output voltage to within 2 percent or better with input voltage fluctuations of plus 10 to minus 20 percent of nominal when system is loaded 100 percent. Use Variable Range Regulation to obtain improved line voltage regulation when operating under less than full load conditions.
  - 1) At 75 Percent Load: Output voltage automatically regulated to within 3 percent with input voltage fluctuations of plus 10 to minus 35 percent of nominal.
  - 2) At 50 Percent Load: Output voltage automatically regulated to within 3 percent with input voltage fluctuations of plus 10 to minus 40 percent of nominal.
  - 3) At 25 Percent Load: Output voltage automatically regulated to within 3 percent with input voltage fluctuations of plus 10 to minus 45 percent of nominal.
- c. With input voltage distortion of up to 40 percent, limit the output voltage sine wave to a maximum harmonic content of 5 percent.
- d. Automatically regulate output voltage to within 2.5 percent when load (resistive) changes from zero percent to 100 percent to zero percent.
- e. Output voltage returns to 95 percent of nominal level within two cycles and to 100 percent within three cycles when the output is taken from no load to full resistive load or vice-versa. Recovery from partial resistive load changes is corrected in a shorter period of time.
- f. K Factor: 30, designed to operate with nonlinear, non-sinusoidal, high crest factor loads without overheating.
- g. Input power factor within 0.95 approaching unity with load power factor as poor as 0.6.

- h. Attenuate load-generated odd current harmonics 23 dB at the input.
  - i. Electrically isolate the primary from the secondary. Meet isolation criteria as defined in NFPA 70, Article 250-5D.
  - j. Lighting and Surge Protection: Compares to UL 1449 rating of 330 V when subjected to Category B3 (6000 V/3000 A) combination waveform as established by IEEE C62.41.
  - k. Common-mode noise attenuation of 140 dB.
  - l. Transverse-mode noise attenuation of 120 dB.
  - m. With loss of input power for up to 16.6 ms, the output sine wave remains at usable ac voltage levels.
  - n. Reliability of 200,000 hours' MTBF.
  - o. At full load, when measured at 1-m distance, audible noise is not to exceed 54 dB.
  - p. Approximately 92 percent efficient at full load.
4. Transformer Construction:
- a. Ferro resonant, dry type, convection cooled, 600V class. Transformer windings of Class H (220 deg C) insulated copper.
  - b. Use a Class H installation system throughout with operating temperatures not to exceed 150 deg C over a 40-deg C ambient temperature.
  - c. Configure transformer primary for multi-input voltage. Include input terminals for source conductors and ground.
  - d. Manufacture transformer core using M-6 grade, grain-oriented, stress-relieved transformer steel.
  - e. Configure transformer secondary in a 240/120-V split with a 208-V tap or straight 120 V, depending on power output size.
  - f. Electrically isolate the transformer secondary windings from the primary windings. Bond neutral conductor to cabinet enclosure and output neutral terminal.
  - g. Include interface terminals for output power hot, neutral and ground conductors.
  - h. Label leads, wires and terminals to correspond with circuit wiring diagram.
  - i. Vacuum impregnate transformer with epoxy resin.
5. Cabinet Construction:
- a. Design for panel or floor mounting.
  - b. NEMA 250, Type 1, general-purpose, indoor enclosure.
  - c. Manufacture the cabinet from heavy gauge steel complying with UL 50.
  - d. Include a textured baked-on paint finish.
- C. Transient Voltage Suppression and High-Frequency Noise Filter Unit:
- 1. The maximum continuous operating voltage shall be at least 125 percent.
  - 2. The operating frequency range shall be 47 to 63 Hz.
  - 3. Protection modes according to NEMA LS-1.
  - 4. The rated single-pulse surge current capacity, for each mode of protection, shall be no less than the following:
    - a. Line to Neutral: 45,000 A.
    - b. Neutral to Ground: 45,000 A.
    - c. Line to Ground: 45,000 A.
    - d. Per Phase: 90,000 A.

5. Clamping voltages shall be in compliance with test and evaluation procedures defined in NEMA LS-1. Maximum clamping voltage shall be as follows:
  - a. Line to Neutral: 360 V.
  - b. Line to Ground: 360 V.
  - c. Neutral to Ground: 360 V.
6. Electromagnetic interference and RF interference noise rejection or attenuation values shall comply with test and evaluation procedures defined in NEMA LS-1.
  - a. Line to Neutral:
    - 1) 100 kHz: 42 dB.
    - 2) 1 MHz: 25 dB.
    - 3) 10 MHz: 21 dB.
    - 4) 100 MHz: 36 dB.
  - b. Line to Ground:
    - 1) 100 kHz: 16 dB.
    - 2) 1 MHz: 55 dB.
    - 3) 10 MHz: 81 dB.
    - 4) 100 MHz: 80 dB.
7. Unit shall have LED status indicator that extinguishes to indicate a failure.
8. Unit shall be listed by an NRTL as a transient voltage surge suppressor per UL 1449, and as an electromagnetic interference filter per UL 1283.
9. Unit shall not generate any appreciable magnetic field.
10. Unit shall not generate an audible noise.

**D. DC Power Supply:**

1. Plug-in style suitable for mating with a standard eight-pin octal socket. Include the power supply with a mating mounting socket.
2. Enclose circuitry in a housing.
3. Include both line and load regulation to ensure a stable output. To protect both the power supply and the load, power supply shall have an automatic current limiting circuit.
4. Performance:
  - a. Output voltage nominally 25-V dc within 5 percent.
  - b. Output current up to 100 mA.
  - c. Input voltage nominally 120-V ac, 60 Hz.
  - d. Load regulation within 0.5 percent from zero- to 100-mA load.
  - e. Line regulation within 0.5 percent at a 100-mA load for a 10 percent line change.
  - f. Stability within 0.1 percent of rated volts for 24 hours after a 20-minute warmup.

**2.22 CONTROL WIRE AND CABLE**

- A. Wire: Single conductor control wiring above 24 V.

1. Wire size shall be at least No. 18 AWG.
  2. Conductor shall be 7/24 soft annealed copper strand with 2- to 2.5-inch lay.
  3. Conductor insulation shall be 600 V, Type THWN or Type THHN, and 90 deg C according to UL 83.
  4. Conductor colors shall be black (hot), white (neutral), and green (ground).
  5. Furnish wire on spools.
- B. Single Twisted Shielded Instrumentation Cable above 24 V:
1. Wire size shall be a minimum No. 18 AWG.
  2. Conductors shall be a twisted, 7/24 soft annealed copper strand with a 2- to 2.5-inch lay.
  3. Conductor insulation shall have a Type THHN/THWN or Type TFN rating.
  4. Shielding shall be 100 percent type, 0.35/0.5-mil aluminum/Mylar tape, helically applied with 25 percent overlap, and aluminum side in with tinned copper drain wire.
  5. Outer jacket insulation shall have a 600-V, 90-deg C rating and shall be Type TC cable.
  6. For twisted pair, conductor colors shall be black and white. For twisted triad, conductor colors shall be black, red and white.
  7. Furnish wire on spools.
- C. Single Twisted Shielded Instrumentation Cable 24 V and Less:
1. Wire size shall be a minimum No. 18 AWG.
  2. Conductors shall be a twisted, 7/24 soft annealed copper stranding with a 2- to 2.5-inch lay.
  3. Conductor insulation shall have a nominal 15-mil thickness, constructed from flame-retardant PVC.
  4. Shielding shall be 100 percent type, 1.35-mil aluminum/polymer tape, helically applied with 25 percent overlap, and aluminum side in with tinned copper drain wire.
  5. Outer jacket insulation shall have a 300-V, 105-deg C rating and shall be Type PLTC cable.
  6. For twisted pair, conductor colors shall be black and white. For twisted triad, conductor colors shall be black, red and white.
  7. Furnish wire on spools.
- D. LAN and Communication Cable: Comply with DDC system manufacturer requirements for network being installed.
1. Cable shall be plenum rated.
  2. Cable shall comply with NFPA 70.
  3. Cable shall have a unique color that is different from other cables used on Project.
  4. Copper Cable for Ethernet Network:
    - a. 1000BASE-T or 1000BASE-TX.
    - b. TIA/EIA 586, Category 5e or Category 6.
    - c. Minimum No. 24 AWG solid.
    - d. Shielded Twisted Pair (STP) or Unshielded Twisted Pair (UTP).
    - e. Thermoplastic insulated conductors, enclosed in a thermoplastic outer jacket, Class CMP as plenum rated.

2.23 RACEWAYS FOR CONTROL WIRING, CABLEING AND TUBING

A. Metal Conduits, Tubing, and Fittings:

1. Listing and Labeling: Metal conduits, tubing, and fittings shall be listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.
2. GRC: Comply with NEMA ANSI C80.1 and UL 6.
3. ARC: Comply with NEMA ANSI C80.5 and UL 6A.
4. IMC: Comply with NEMA ANSI C80.6 and UL 1242.
5. PVC-Coated Steel Conduit: PVC-coated rigid steel conduit or IMC.
  - a. Comply with NEMA RN 1.
  - b. Coating Thickness: 0.040 inch (1 mm), minimum.
6. EMT: Comply with NEMA ANSI C80.3 and UL 797.
7. FMC: Comply with UL 1; zinc-coated steel or aluminum.
8. LFMC: Flexible steel conduit with PVC jacket and complying with UL 360.
9. Fittings for Metal Conduit: Comply with NEMA ANSI FB 1 and UL 514B.
  - a. Conduit Fittings for Hazardous (Classified) Locations: Comply with UL 1203 and NFPA 70.
  - b. Fittings for EMT:
    - 1) Material: Steel or die cast.
    - 2) Type: Setscrew or compression.
  - c. Expansion Fittings: PVC or steel to match conduit type, complying with UL 651, rated for environmental conditions where installed, and including flexible external bonding jumper.
  - d. Coating for Fittings for PVC-Coated Conduit: Minimum thickness of 0.040 inch (1 mm), with overlapping sleeves protecting threaded joints.
10. Joint Compound for IMC, GRC, or ARC: Approved, as defined in NFPA 70, by authorities having jurisdiction for use in conduit assemblies, and compounded for use to lubricate and protect threaded conduit joints from corrosion and to enhance their conductivity.

2.24 OPTICAL FIBER CABLE AND CONNECTORS

A. Cables:

1. Performance Requirements:
  - a. Fiber: Multimode graded index. Core/cladding size shall be either 62.5/125 or 100/140 micrometers.
  - b. Numerical Aperture:
    - 1) 62.5/125 Micrometer Fiber: 0.275 plus or minus 0.015.
    - 2) 100/140 Micrometer Fiber: 0.29 plus or minus 0.015.

- c. Maximum Attenuation:
    - 1) 850 nm: 6.0 dB/km.
    - 2) 1300 nm: 5.0 dB/km.
  - d. Minimum Bandwidth Dispersion: 300 MHz-km at 850 nm.
  - e. Core/Cladding Index Difference: 0.3 percent plus or minus 0.05 percent, measured using refractive rear field measurement procedure.
  - f. Color-code finished fibers for easy identification.
  - g. Splice Loss: Fibers shall be spliced together to form a longer fiber using a commercially available fiber splicing machine recommended by cable manufacturer. Maximum loss per fiber splice shall be 0.20 dB.
  - h. Connection: Fibers shall be connected using fiber-optic connectors. Nominal connector loss shall not be greater than 1 dB.
  - i. Fiber-optic cable shall be suitable for use with 100Base-FX or 100Base-SX standard (as applicable) as defined in IEEE 802.3.
2. Mechanical and Environmental Requirements:
- a. Tensile Strength: Fiber cable shall withstand a minimum tensile strength of 2700 N with maximum elongation of less than 0.5 percent.
  - b. Bending Radius: Minimum static bending radius for cable shall be 10 times outside diameter for non-armored cables and 20 times outside diameter for armored cables. Non-armored cables shall withstand being flexed at minimum static bending radius plus or minus 90 degrees for at least 20 cycles at 20 to 40 cycles per minute at 20 deg C. Armored cables shall withstand being flexed at minimum static bending radius plus or minus 90 degrees for at least 10 cycles at 20 to 40 cycles per minute at 20 deg C.
  - c. Vibration: Cable shall withstand a vibration test with vibration amplitude of 5 mm and frequency of 10 cycles per second for at least five hours.
  - d. Twist: Cable shall withstand twisting of 360 degrees over a length of 2 m for at least 10 cycles at 10 cycles per minute.
  - e. Temperature: Cable shall withstand the following temperatures:
    - 1) Installation: Minus 30 to 70 deg C.
    - 2) Operation: Minus 40 to 70 deg C.
    - 3) Storage/Shipping: Minus 40 to 70 deg C.
  - f. Lifetime: Average lifetime of a 2-km, 12-fiber cable shall be at least 20 years when installed in a natural ambient environment. End of useful life shall be reached if failing to comply with requirements indicated or a spontaneous catastrophic fiber failure.
  - g. Crush Resistance: Cable shall withstand a compressive force of 705 N/cm for armored cables and 600 N/cm for non-armored cables. There shall be no attenuation increase after force is removed.
3. Cable Structure:

- a. Number of Fibers: Supply the required number of fibers in each cable for DDC system indicated, plus not less than 50 percent spare. Cable structure shall have fibers grouped for easy handling.
  - b. Strength Members: Include cable with strength members to satisfy mechanical and environmental conditions indicated.
  - c. Cable Core: Core shall consist of stranded buffer tubes around a central member of appropriate geometric size and shall be filled and bound to maintain core integrity. A fibrous strength member may be stranded around core to provide necessary strength for cable.
  - d. Cable Jacket: Protect cable by an extruded-polyethylene jacket.
  - e. Cable Armor: For cables requiring extra mechanical protection, one or two layers of galvanized corrugated steel tape coated by an anticorrosive compound shall be either helically or longitudinally applied over standard outer jacket. Apply a second outer jacket of polyethylene over coated steel tape. Thickness of sheaths and jackets are not specified as long as mechanical and environmental conditions are satisfied.
  - f. Cable Installation: Cables shall be suitable for a semiprotected outdoor installation.
4. Packaging and Shipping:
- a. Seal both ends of each length of cable.
  - b. Test individual fibers in each cable before shipping to verify compliance with Specifications.
- B. Connectors:
1. Performance Requirements:
    - a. Type: Fiber-optic connectors shall be either Type ST or Type SMA. Use either connector type exclusively. No substitutions are allowed.
    - b. Insertion Loss: Connector shall have an insertion loss of not greater than 1 dB.
    - c. Coupling Tolerance: Connector shall withstand at least 500 couplings with insertion loss within 0.25-dB tolerance limit.
    - d. Mechanical Requirements:
      - 1) Connector shall enclose outermost coating of single fiber cable and be able to be mated or unmated without using a tool.
      - 2) Mount connector rigidly in a metal frame.
      - 3) Connector shall allow a semiskilled person to properly install connector to a single fiber easily in a field environment with simple tools.
- C. Splice Organizer Cabinet:
1. Minimum Capacity: Each splice organizer shall accommodate number of connectors required for DDC system indicated, plus 100 percent spare.
  2. Mounting: Wall mount the splice organizer cabinet.
- D. Raceways:
1. Mechanical and Performance Requirements:

- a. Construction: Nonmetallic, flexible raceway system manufactured specifically for routing fiber-optic cables.
- b. Suitable for use in return-air plenums, air-handling rooms, above ceilings and under access floors.
- c. Exhibit low smoke generation and flame-spread characteristics, and have high-temperature service tolerance.
- d. Size raceway according to NFPA 70 requirements for communications cables.
- e. Tensile Strength at Yield: 10,800 psi.
- f. Elongation at Break: 25 percent.

E. Cable Identification:

1. Labeling product shall be self-laminating cable marker.
2. Cable labeling shall include numeric designation, source, destination, and cable type.

2.25 ACCESSORIES

A. Damper Blade Limit Switches:

1. Sense positive open and/or closed position of the damper blades.
2. NEMA 250, Type 13, oil-tight construction.
3. Arrange for the mounting application.
4. Additional waterproof enclosure when required by its environment.
5. Arrange to prevent "over-center" operation.

B. Instrument Enclosures:

1. Include instrument enclosure for secondary protection to comply with requirements indicated in "Performance Requirements" Article.
2. NRTL listed and labeled to UL 50.
3. Sized to include at least 25 percent spare area on subpanel.
4. Instrument(s) mounted within enclosure on internal subpanel(s).
5. Enclosure face with engraved, laminated phenolic nameplate for each instrument within enclosure.
6. Enclosures housing pneumatic instruments shall include main pressure gage and a branch pressure gage for each pneumatic device, installed inside.
7. Enclosures housing multiple instruments shall route tubing and wiring within enclosure in a raceway having a continuous removable cover.
8. Enclosures larger than 12 inches shall have a hinged full-size face cover.
9. Equip enclosure with lock and common key.

2.26 IDENTIFICATION

A. Control Equipment, Instruments, and Control Devices:

1. Engraved tag bearing unique identification.
  - a. Include instruments with unique identification identified by equipment being controlled or monitored, followed by point identification.



2. Letter size shall be as follows:
  - a. Servers: Minimum of 0.5 inch (13 mm) high.
  - b. DDC Controllers: Minimum of 0.5 inch (13 mm) high.
  - c. Enclosures: Minimum of 0.5 inch (13 mm) high.
  - d. Electrical Power Devices: Minimum of 0.5 inch (13 mm) high.
  - e. UPS units: Minimum of 0.5 inch (13 mm) high.
  - f. Accessories: Minimum of 0.25 inch (6 mm) high.
  - g. Instruments: Minimum of 0.25 inch (6 mm) high.
  - h. Control Damper and Valve Actuators: Minimum of 0.25 inch (6 mm) high.
3. Tag shall consist of white lettering on black background.
4. Tag shall be engraved phenolic consisting of three layers of rigid laminate. Top and bottom layers are color-coded black with contrasting white center exposed by engraving through outer layer.
5. Tag shall be fastened with drive pins.
6. Instruments, control devices and actuators with Project-specific identification tags having unique identification numbers following requirements indicated and provided by original manufacturer do not require an additional tag.

**B. Raceway and Boxes:**

1. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
2. Paint cover plates on junction boxes and conduit same color as the tape banding for conduits. After painting, label cover plate "HVAC Controls," using an engraved phenolic tag.
3. For raceways housing pneumatic tubing, add a phenolic tag labeled "HVAC Instrument Air Tubing."
4. For raceways housing air signal tubing, add a phenolic tag labeled "HVAC Air Signal Tubing."

**C. Equipment Warning Labels:**

1. Acrylic label with pressure-sensitive adhesive back and peel-off protective jacket.
2. Lettering size shall be at least 14-point type with white lettering on red background.
3. Warning label shall read "CAUTION-Equipment operated under remote automatic control and may start or stop at any time without warning. Switch electric power disconnecting means to OFF position before servicing."
4. Lettering shall be enclosed in a white line border. Edge of label shall extend at least 0.25 inch (6 mm) beyond white border.

**2.27 SOURCE QUALITY CONTROL**

- A. Testing Agency:** Engage a qualified testing agency to evaluate the following according to industry standards for each product, and to verify DDC system reliability specified in performance requirements:

1. DDC controllers.
2. Routers.

3. Operator workstations.
- B. Product(s) and material(s) will be considered defective if they do not pass tests and inspections.
- C. Prepare test and inspection reports.

**PART 3 - EXECUTION**

**3.1 EXAMINATION**

- A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.
  1. Verify compatibility with and suitability of substrates.
- B. Examine roughing-in for products to verify actual locations of connections before installation.
  1. Examine roughing-in for instruments installed in piping to verify actual locations of connections before installation.
  2. Examine roughing-in for instruments installed in duct systems to verify actual locations of connections before installation.
- C. Examine walls, floors, roofs, and ceilings for suitable conditions where product will be installed.
- D. Prepare written report, endorsed by Installer, listing conditions detrimental to performance of the Work.
- E. Proceed with installation only after unsatisfactory conditions have been corrected.

**3.2 DDC SYSTEM INTERFACE WITH OTHER SYSTEMS AND EQUIPMENT**

- A. Communication Interface to Equipment with Integral Controls:
  1. DDC system shall have communication interface with equipment having integral controls and having a communication interface for remote monitoring or control.
  2. Equipment to Be Connected:
    - a. Roof-top units specified in Section 237413 "Packaged, Outdoor, Central-Station Air-Handling Units."
    - b. Switchboards specified in Section 262300 "Low-Voltage Switchgear."
    - c. Motor-control centers specified in Section 262419 "Motor-Control Centers."
    - d. Variable-frequency controllers specified in Section 262923 "Variable-Frequency Motor Controllers."
- B. Communication Interface to Other Building Systems:

1. DDC system shall have a communication interface with systems having a communication interface.
2. Systems to Be Connected:
  - a. Power monitoring specified in Section 260913 "Electrical Power Monitoring and Control."
  - b. Lighting controls specified in Section 260926 "Lighting Control Panelboards."
  - c. Lighting controls specified in Section 260943.16 "Addressable-Luminaire Lighting Controls."
  - d. Lighting controls specified in Section 260943.23 "Relay-Based Lighting Controls."
  - e. Fire-alarm system specified in Section 283111 "Digital, Addressable Fire Alarm System."
  - f. Fire-alarm system specified in Section 283112 "Zoned (DC Loop) Fire-Alarm System."
  - g. Access controls specified in Section 281300 "Access Control."
  - h. Intrusion detection specified in Section 281600 "Intrusion Detection."

### 3.3 CONTROL DEVICES FOR INSTALLATION BY INSTALLERS

- A. Deliver selected control devices, specified in indicated HVAC instrumentation and control device Sections, to identified equipment and systems manufacturers for factory installation and to identified installers for field installation.
- B. Deliver the following to duct fabricator and Installer for installation in ductwork. Include installation instructions to Installer and supervise installation for compliance with requirements.
  1. DDC control dampers, which are specified in Section 230923.12 "DDC Control Dampers."
  2. Airflow sensors and switches, which are specified in Section 230923.14 "Flow Instruments."
- C. Deliver the following to plumbing and HVAC piping installers for installation in piping. Include installation instructions to Installer and supervise installation for compliance with requirements.
  1. DDC control valves, which are specified in Section 230923.11 "Control Valves."
  2. Pipe-mounted flow meters, which are specified in Section 230923.14 "Flow Instruments."
  3. Pipe-mounted sensors, switches and transmitters. Flow meters are specified in Section 230923.14 "Flow Instruments." Liquid temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
  4. Pressure sensors, switches, and transmitters are specified in Section 230923.23 "Pressure Instruments." Liquid temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
  5. Pipe- and tank-mounted thermowells. Liquid thermowells are specified in Section 230923.27 "Temperature Instruments."

3.4 CONTROL DEVICES FOR EQUIPMENT MANUFACTURER FACTORY INSTALLATION

- A. Deliver the following to air-handling unit manufacturer for factory installation. Include installation instructions to air-handling unit manufacturer.
  - 1. Programmable application or application-specific controller.
  - 2. Unit-mounted DDC control dampers and actuators, which are specified in Section 230923.12 "Control Dampers."
  - 3. Unit-mounted airflow sensors, switches and transmitters, which are specified in Section 230923.14 "Flow Instruments."
  - 4. Unit-mounted pressure sensors, switches and transmitters, which are specified in Section 230923.23 "Pressure Instruments."
  - 5. Unit-mounted temperature sensors, switches and transmitters. Air-temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
  - 6. Relays.
  
- B. Deliver the following to terminal unit manufacturer for factory installation. Include installation instructions to terminal unit manufacturer.
  - 1. Programmable application or application-specific controller.
  - 2. Electric damper actuator. Dampers actuators are specified in Section 230923.12 "Control Dampers."
  - 3. Unit-mounted flow and pressure sensors, transmitters and transducers. Flow sensors, transmitters, and transducers are specified in Section 230923.14 "Flow Instruments." Pressure sensors, switches, and transmitters are specified in Section 230923.23 "Pressure Instruments."
  - 4. Unit-mounted temperature sensors. Air-temperature sensors, switches, and transmitters are specified in Section 230923.27 "Temperature Instruments."
  - 5. Relays.

3.5 GENERAL INSTALLATION REQUIREMENTS

- A. Install products to satisfy more stringent of all requirements indicated.
- B. Install products level, plumb, parallel, and perpendicular with building construction.
- C. Support products, tubing, piping wiring and raceways. Brace products to prevent lateral movement and sway or a break in attachment.
- D. If codes and referenced standards are more stringent than requirements indicated, comply with requirements in codes and referenced standards.
- E. Fabricate openings and install sleeves in ceilings, floors, roof, and walls required by installation of products. Before proceeding with drilling, punching, and cutting, check for concealed work to avoid damage. Patch, flash, grout, seal, and refinish openings to match adjacent condition.
- F. Firestop penetrations made in fire-rated assemblies. Comply with requirements in Section 078413 "Penetration Firestopping."

- G. Seal penetrations made in acoustically rated assemblies. Comply with requirements in Section 079200 "Joint Sealants."
- H. Welding Requirements:
  - 1. Restrict welding and burning to supports and bracing.
  - 2. No equipment shall be cut or welded without approval. Welding or cutting will not be approved if there is risk of damage to adjacent Work.
  - 3. Welding, where approved, shall be by inert-gas electric arc process and shall be performed by qualified welders according to applicable welding codes.
  - 4. If requested on-site, show satisfactory evidence of welder certificates indicating ability to perform welding work intended.
- I. Fastening Hardware:
  - 1. Stillson wrenches, pliers, and other tools that damage surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening fasteners.
  - 2. Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
  - 3. Lubricate threads of bolts, nuts and screws with graphite and oil before assembly.
- J. If product locations are not indicated, install products in locations that are accessible and that will permit service and maintenance from floor, equipment platforms, or catwalks without removal of permanently installed furniture and equipment.

### 3.6 POT INSTALLATION

- A. Install one portable operator terminal(s).
- B. Turn over POTs to Owner at Substantial Completion.
- C. Install software on each POT and verify that software functions properly.

### 3.7 SERVER INSTALLATION

- A. Install one server at location directed by Owner.
- B. Install number of servers required to suit requirements indicated. Review Project requirements and indicate layout of proposed location in Shop Drawings.
- C. Install software indicated on server(s) and verify that software functions properly.
- D. Develop Project-specific graphics, trends, reports, logs, and historical database.
- E. Power servers through dedicated UPS unit. Locate UPS adjacent to server.

3.8 ROUTER INSTALLATION

- A. Install routers if required for DDC system communication interface requirements.
- B. Test router to verify that communication interface functions properly.

3.9 CONTROLLER INSTALLATION

- A. Install controllers in enclosures to comply with indicated requirements.
- B. Connect controllers to field power supply.
- C. Install controller with latest version of applicable software and configure to execute requirements indicated.
- D. Test and adjust controllers to verify operation of connected I/O to achieve performance indicated requirements while executing sequences of operation.
- E. Installation of Network Controllers:
  - 1. Quantity and location of network controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
  - 2. Install controllers in a protected location that is easily accessible by operators.
  - 3. Top of controller shall be within 72 inches (1800 mm) of finished floor.
- F. Installation of Programmable Application Controllers:
  - 1. Quantity and location of programmable application controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
  - 2. Install controllers in a protected location that is easily accessible by operators.
  - 3. Top of controller shall be within 72 inches (1800 mm) of finished floor.
- G. Application-Specific Controllers:
  - 1. Quantity and location of application-specific controllers shall be determined by DDC system manufacturer to satisfy requirements indicated.
  - 2. For controllers not mounted directly on equipment being controlled, install controllers in a protected location that is easily accessible by operators.

3.10 INSTALLATION OF WIRELESS ROUTERS FOR OPERATOR INTERFACE

- A. Install wireless routers to achieve optimum performance and best possible coverage.
- B. Mount wireless routers in a protected location that is within 60 inches (1500 mm) of floor and easily accessible by operators.
- C. Connect wireless routers to field power supply and to UPS units if network controllers are powered through UPS units.

- D. Install wireless router with latest version of applicable software and configure wireless router with WPA2 security and password protection. Create access password with not less than 12 characters consisting of letters and numbers and at least one special character. Document password in operations and maintenance manuals for reference by operators.
- E. Test and adjust wireless routers for proper operation with portable workstation and other wireless devices intended for use by operators.

3.11 ENCLOSURES INSTALLATION

- A. Install the following items in enclosures, to comply with indicated requirements:
  - 1. Routers.
  - 2. Controllers.
  - 3. Electrical power devices.
  - 4. UPS units.
  - 5. Relays.
  - 6. Accessories.
  - 7. Instruments.
  - 8. Actuators
- B. Attach wall-mounted enclosures to wall using the following types of steel struts:
  - 1. For NEMA 250, Type 1 Enclosures: Use corrosion-resistant-coated steel strut and hardware.
  - 2. For NEMA 250, Type 4 Enclosures and Enclosures Located Outdoors: Use stainless-steel strut and hardware.
  - 3. Install plastic caps on exposed cut edges of strut.
- C. Align top of adjacent enclosures.
- D. Install continuous and fully accessible wireways to connect conduit, wire, and cable to multiple adjacent enclosures. Wireway used for application shall have protection equal to NEMA 250 rating of connected enclosures.

3.12 ELECTRIC POWER CONNECTIONS

- A. Connect electrical power to DDC system products requiring electrical power connections.
- B. Design of electrical power to products not indicated with electric power is delegated to DDC system provider and installing trade. Work shall comply with NFPA 70 and other requirements indicated.
- C. Comply with requirements in Section 262816 "Enclosed Switches and Circuit Breakers" for electrical power circuit breakers.
- D. Comply with requirements in Section 260519 "Low-Voltage Electrical Power Conductors and Cables" for electrical power conductors and cables.

- E. Comply with requirements in Section 260533 "Raceways and Boxes for Electrical Systems" for electrical power raceways and boxes.

3.13 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Comply with requirements in Section 260553 "Identification for Electrical Systems" for identification products and installation.
- B. Install engraved phenolic nameplate with unique identification on face for each of the following:
  - 1. Server.
  - 2. Router.
  - 3. Protocol analyzer.
  - 4. DDC controller.
  - 5. Enclosure.
  - 6. Electrical power device.
  - 7. UPS unit.
  - 8. Accessory.
- C. Install engraved phenolic nameplate with unique instrument identification on face of each instrument connected to a DDC controller.
- D. Install engraved phenolic nameplate with identification on face of each control damper and valve actuator connected to a DDC controller.
- E. Where product is installed above accessible tile ceiling, also install matching engraved phenolic nameplate with identification on face of ceiling grid located directly below.
- F. Where product is installed above an inaccessible ceiling, also install engraved phenolic nameplate with identification on face of access door directly below.
- G. Warning Labels:
  - 1. Shall be permanently attached to equipment that can be automatically started by DDC control system.
  - 2. Shall be located in highly visible location near power service entry points.

3.14 NETWORK INSTALLATION

- A. Install fiber-optic cable when connecting between the following network devices and when located in different buildings on campus.
  - 1. Network controllers.
- B. Install copper or fiber-optic cable when connecting between the following network devices located in same building:
  - 1. Network controllers.



- C. Install copper cable when connecting between the following:
  - 1. Network controllers or programmable application controllers.
  - 2. Routers.
  - 3. Routers and network controllers or programmable application controllers.
  - 4. Network controllers and programmable application controllers.
  - 5. Programmable application controllers.
  - 6. Programmable application controllers and application-specific controllers.
  - 7. Application-specific controllers.
  
- D. Install network cable in continuous raceway.
  - 1. Where indicated on Drawings, cable trays may be used for copper cable in lieu of conduit.

3.15 NETWORK NAMING AND NUMBERING

- A. Coordinate with Owner and provide unique naming and addressing for networks and devices.
  
- B. ASHRAE 135 Networks:
  - 1. MAC Address:
    - a. Every network device shall have an assigned and documented MAC address unique to its network.
    - b. Ethernet Networks: Document MAC address assigned at its creation.
    - c. ARCNET or MS/TP networks: Assign from 00 to 64.
  
  - 2. Network Numbering:
    - a. Assign unique numbers to each new network.
    - b. Provide ability for changing network number through device switches or operator interface.
    - c. DDC system, with all possible connected LANs, can contain up to 65,534 unique networks.
  
  - 3. Device Object Identifier Property Number:
    - a. Assign unique device object identifier property numbers or device instances for each device network.
    - b. Provide for future modification of device instance number by device switches or operator interface.
    - c. LAN shall support up to 4,194,302 unique devices.
  
  - 4. Device Object Name Property Text:
    - a. Device object name property field shall support 32 minimum printable characters.
    - b. Assign unique device "Object Name" property names with plain-English descriptive names for each device.

- 1) Example 1: Device object name for device controlling boiler plant at Building 1000 would be "HW System B1000."
  - 2) Example 2: Device object name for a VAV terminal unit controller could be "VAV unit 102".
5. Object Name Property Text for Other Than Device Objects:
- a. Object name property field shall support 32 minimum printable characters.
  - b. Assign object name properties with plain-English names descriptive of application.
    - 1) Example 1: "Zone 1 Temperature."
    - 2) Example 2 "Fan Start and Stop."
6. Object Identifier Property Number for Other Than Device Objects:
- a. Assign object identifier property numbers according to [Drawings] [or] [tables] indicated.
  - b. If not indicated, object identifier property numbers may be assigned at Installer's discretion but must be approved by Owner in advance, be documented and be unique for like object types within device.
- 3.16 CONTROL WIRE, CABLE AND RACEWAYS INSTALLATION
- A. Comply with NECA 1.
  - B. Comply with TIA 568-C.1.
  - C. Wiring Method: Install cables in raceways. Conceal raceway and cables except in unfinished spaces.
    1. Install plenum cable in environmental air spaces, including plenum ceilings.
    2. Comply with requirements for cable trays specified in Section 260536 "Cable Trays for Electrical Systems."
    3. Comply with requirements for raceways and boxes specified in Section 260533 "Raceways and Boxes for Electrical Systems."
  - D. Wiring Method: Conceal conductors and cables in accessible ceilings, walls, and floors where possible.
  - E. Field Wiring within Enclosures: Bundle, lace, and train conductors to terminal points with no excess and without exceeding manufacturer's limitations on bending radii. Install lacing bars and distribution spools.
  - F. Conduit Installation:
    1. Install conduit expansion joints where conduit runs exceed 200 feet (60 m), and conduit crosses building expansion joints.
    2. Coordinate conduit routing with other trades to avoid conflicts with ducts, pipes and equipment and service clearance.

3. Maintain at least 3-inch (75-mm) separation where conduits run axially above or below ducts and pipes.
4. Limit above-grade conduit runs to 100 feet (30 m) without pull or junction box.
5. Do not install raceways or electrical items on any "explosion-relief" walls, or rotating equipment.
6. Do not fasten conduits onto the bottom side of a metal deck roof.
7. Flexible conduit is permitted only where flexibility and vibration control is required.
8. Limit flexible conduit to 3 feet (1 m) long.
9. Conduit shall be continuous from outlet to outlet, from outlet to enclosures, pull and junction boxes, and shall be secured to boxes in such manner that each system shall be electrically continuous throughout.
10. Direct bury conduits underground or install in concrete-encased duct bank where indicated.
  - a. Use rigid, nonmetallic, Schedule 80 PVC.
  - b. Provide a burial depth according to NFPA 70, but not less than 24 inches (600 mm).
11. Secure threaded conduit entering an instrument enclosure, cabinet, box, and trough, with a locknut on outside and inside, such that conduit system is electrically continuous throughout. Provide a metal bushing on inside with insulated throats. Locknuts shall be the type designed to bite into the metal or, on inside of enclosure, shall have a grounding wedge lug under locknut.
12. Conduit box-type connectors for conduit entering enclosures shall have an insulated throat.
13. Connect conduit entering enclosures in wet locations with box-type connectors or with watertight sealing locknuts or other fittings.
14. Offset conduits where entering surface-mounted equipment.
15. Seal conduit runs used by sealing fittings to prevent the circulation of air for the following:
  - a. Conduit extending from interior to exterior of building.
  - b. Conduit extending into pressurized duct and equipment.
  - c. Conduit extending into pressurized zones that are automatically controlled to maintain different pressure set points.

G. Wire and Cable Installation:

1. Cables serving a common system may be grouped in a common raceway. Install control wiring and cable in separate raceway from power wiring. Do not group conductors from different systems or different voltages.
2. Install cables with protective sheathing that is waterproof and capable of withstanding continuous temperatures of 90 deg C with no measurable effect on physical and electrical properties of cable.
  - a. Provide shielding to prevent interference and distortion from adjacent cables and equipment.
3. Install lacing bars to restrain cables, to prevent straining connections, and to prevent bending cables to smaller radii than minimums recommended by manufacturer.

4. Bundle, lace, and train conductors to terminal points without exceeding manufacturer's limitations on bending radii, but not less than radii specified in BICSI ITSIMM, "Cabling Termination Practices" Chapter. Install lacing bars and distribution spools.
5. UTP Cable Installation:
  - a. Comply with TIA 568-C.2.
  - b. Do not untwist UTP cables more than 1/2 inch (12 mm) from the point of termination, to maintain cable geometry.
6. Installation of Cable Routed Exposed under Raised Floors:
  - a. Install plenum-rated cable only.
  - b. Install cabling after the flooring system has been installed in raised floor areas.
  - c. Coil cable 6 feet (1.8 m) long not less than 12 inches (300 mm) in diameter below each feed point.
7. Identify each wire on each end and at each terminal with a number-coded identification tag. Each wire shall have a unique tag.
8. Provide strain relief.
9. Terminate wiring in a junction box.
  - a. Clamp cable over jacket in junction box.
  - b. Individual conductors in the stripped section of the cable shall be slack between the clamping point and terminal block.
10. Terminate field wiring and cable not directly connected to instruments and control devices having integral wiring terminals using terminal blocks.
11. Install signal transmission components according to IEEE C2, REA Form 511a, NFPA 70, and as indicated.
12. Keep runs short. Allow extra length for connecting to terminal boards. Do not bend flexible coaxial cables in a radius less than 10 times the cable OD. Use sleeves or grommets to protect cables from vibration at points where they pass around sharp corners and through penetrations.
13. Ground wire shall be copper and grounding methods shall comply with IEEE C2. Demonstrate ground resistance.
14. Wire and cable shall be continuous from terminal to terminal without splices.
15. Use insulated spade lugs for wire and cable connection to screw terminals.
16. Use shielded cable to transmitters.
17. Use shielded cable to temperature sensors.
18. Perform continuity and meager testing on wire and cable after installation.
19. Do not install bruised, kinked, scored, deformed, or abraded wire and cable. Remove and discard wire and cable if damaged during installation, and replace it with new cable.
20. Cold-Weather Installation: Bring cable to room temperature before dereeling. Heat lamps shall not be used for heating.
21. Pulling Cable: Comply with BICSI ITSIM, Ch. 4, "Pulling Cable." Monitor cable pull tensions.
22. Protection from Electro-Magnetic Interference (EMI): Provide installation free of (EMI). As a minimum, comply with the following requirements:

- a. Comply with BICSI TDMM and TIA 569-C for separating unshielded cable from potential EMI sources, including electrical power lines and equipment.
- b. Separation between open cables or cables in nonmetallic raceways and unshielded power conductors and electrical equipment shall be as follows:
  - 1) Electrical Equipment Rating Less Than 2 kVA: A minimum of 5 inches (127 mm).
  - 2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 12 inches (300 mm).
  - 3) Electrical Equipment Rating More Than 5 kVA: A minimum of 24 inches (610 mm).
- c. Separation between cables in grounded metallic raceways and unshielded power lines or electrical equipment shall be as follows:
  - 1) Electrical Equipment Rating Less Than 2 kVA: A minimum of 2-1/2 inches (64 mm).
  - 2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 6 inches (150 mm).
  - 3) Electrical Equipment Rating More Than 5 kVA: A minimum of 12 inches (300 mm).
- d. Separation between cables in grounded metallic raceways and power lines and electrical equipment located in grounded metallic conduits or enclosures shall be as follows:
  - 1) Electrical Equipment Rating Less Than 2 kVA: No requirement.
  - 2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 3 inches (76 mm).
  - 3) Electrical Equipment Rating More Than 5 kVA: A minimum of 6 inches (150 mm).
- e. Separation between Cables and Electrical Motors and Transformers, 5 kVA or 5 HP and Larger: A minimum of 48 inches (1200 mm).
- f. Separation between Cables and Fluorescent Fixtures: A minimum of 5 inches (127 mm).

3.17 FIBER-OPTIC CABLE SYSTEM INSTALLATION

- A. Comply with TIA 568-C.3, except where requirements indicated are more stringent.
- B. Raceway Installation:
  - 1. Install continuous raceway for routing fiber-optic cables.
  - 2. Install raceways continuously between pull boxes and junction boxes. Raceways shall enter and be secured to enclosures.
  - 3. Make bends in raceway using large-radius preformed ells. Field bending shall be according to NFPA 70 minimum radii requirements. Use only equipment specifically designed for material and size involved.

4. Install no more than the equivalent of two 90-degree bends in any pathway run. Support within 12 inches (300 mm) of changes in direction. Use long radius elbows for all fiber-optic cables.
5. Entire raceway shall be complete and raceway interior cleaned before installation of fiber-optic cables.
6. Securely fasten raceway to building structure using clamps and clips designed for purpose.
7. Install nylon or polyethylene pulling line in raceways. Clearly label as "pulling line," indicating source and destination.

C. Fiber-Optic Cable Installation:

1. Route cables as efficiently as possible, minimizing amount of cable required.
2. Continuously lubricate cables during pulling-in process.
3. Do not exceed maximum pulling tensions provided by cable manufacturer. Monitor cable pulling tension with a mechanical tension meter.
4. Arrange cables passing through pull boxes to obtain maximum clearance among cables within box.
5. As cables emerge from intermediate point pull boxes, coil cable in a figure eight pattern with loops not less than 24 inches (600 mm) in diameter.
6. Terminate fiber-optic cables in a fiber-optic splice organizer cabinet, unless connected equipment can accept fiber-optic cables directly. Terminate cables with connectors.
7. Install and connect appropriate opto-electronic equipment and fiber jumper cables between opto-electronic equipment and fiber-optic cable system to DDC system fiber-optic cable system. Verify interface compatibility.

D. Cable and Raceway Identification:

1. Label cables at both ends. Labels shall be typed, not handwritten.
2. Mark raceways at each pull box indicating the type and number of cables within.

3.18 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Manufacturer's Field Service: Engage a factory-authorized service representative to test and inspect components, assemblies, and installations, including connections.

C. Perform the following tests and inspections:

1. Perform each visual and mechanical inspection and electrical test stated in NETA Acceptance Testing Specification. Certify compliance with test parameters.
2. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

D. Testing:

1. Perform preinstallation, in-progress, and final tests, supplemented by additional tests, as necessary.

2. Preinstallation Cable Verification: Verify integrity and serviceability for new cable lengths before installation. This assurance may be provided by using vendor verification documents, testing, or other methods. As a minimum, furnish evidence of verification for cable attenuation and bandwidth parameters.
3. In-Progress Testing: Perform standard tests for correct pair identification and termination during installation to ensure proper installation and cable placement. Perform tests in addition to those specified if there is any reason to question condition of material furnished and installed. Testing accomplished is to be documented by agency conducting tests. Submit test results for Project record.
4. Final Testing: Perform final test of installed system to demonstrate acceptability as installed. Testing shall be performed according to a test plan supplied by DDC system manufacturer. Defective Work or material shall be corrected and retested. As a minimum, final testing for cable system, including spare cable, shall verify conformance of attenuation, length, and bandwidth parameters with performance indicated.
5. Test Equipment: Use a fiber-optic time domain reflectometer for testing of length and optical connectivity.
6. Test Results: Record test results and submit copy of test results for Project record.

3.19 DDC SYSTEM I/O CHECKOUT PROCEDURES

- A. Check installed products before continuity tests and calibration.
- B. Check instruments for proper location and accessibility.
- C. Check instruments for proper installation on direction of flow, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.
- D. Control Damper Checkout:
  1. Verify that control dampers are installed correctly for flow direction.
  2. Verify that proper blade alignment, either parallel or opposed, has been provided.
  3. Verify that damper frame attachment is properly secured and sealed.
  4. Verify that damper actuator and linkage attachment is secure.
  5. Verify that actuator wiring is complete, enclosed and connected to correct power source.
  6. Verify that damper blade travel is unobstructed.
- E. Control Valve Checkout:
  1. Verify that control valves are installed correctly for flow direction.
  2. Verify that valve body attachment is properly secured and sealed.
  3. Verify that valve actuator and linkage attachment is secure.
  4. Verify that actuator wiring is complete, enclosed and connected to correct power source.
  5. Verify that valve ball, disc or plug travel is unobstructed.
  6. After piping systems have been tested and put into service, but before insulating and balancing, inspect each valve for leaks. Adjust or replace packing to stop leaks. Replace the valve if leaks persist.
- F. Instrument Checkout:

1. Verify that instrument is correctly installed for location, orientation, direction and operating clearances.
2. Verify that attachment is properly secured and sealed.
3. Verify that conduit connections are properly secured and sealed.
4. Verify that wiring is properly labeled with unique identification, correct type and size and is securely attached to proper terminals.
5. Inspect instrument tag against approved submittal.
6. For flow instruments, verify that recommended upstream and downstream distances have been maintained.
7. For temperature instruments:
  - a. Verify sensing element type and proper material.
  - b. Verify length and insertion.

3.20 DDC SYSTEM I/O ADJUSTMENT, CALIBRATION AND TESTING:

- A. Calibrate each instrument installed that is not factory calibrated and provided with calibration documentation.
- B. Provide a written description of proposed field procedures and equipment for calibrating each type of instrument. Submit procedures before calibration and adjustment.
- C. For each analog instrument, make a three-point test of calibration for both linearity and accuracy.
- D. Equipment and procedures used for calibration shall comply with instrument manufacturer's written instructions.
- E. Provide diagnostic and test equipment for calibration and adjustment.
- F. Field instruments and equipment used to test and calibrate installed instruments shall have accuracy at least twice the instrument accuracy being calibrated. An installed instrument with an accuracy of 1 percent shall be checked by an instrument with an accuracy of 0.5 percent.
- G. Calibrate each instrument according to instrument instruction manual supplied by manufacturer.
- H. If after calibration indicated performance cannot be achieved, replace out-of-tolerance instruments.
- I. Comply with field testing requirements and procedures indicated by ASHRAE's Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements, and to supplement requirements indicated.
- J. Analog Signals:
  1. Check analog voltage signals using a precision voltage meter at zero, 50, and 100 percent.
  2. Check analog current signals using a precision current meter at zero, 50, and 100 percent.



3. Check resistance signals for temperature sensors at zero, 50, and 100 percent of operating span using a precision-resistant source.

K. Digital Signals:

1. Check digital signals using a jumper wire.
2. Check digital signals using an ohmmeter to test for contact making or breaking.

L. Control Dampers:

1. Stroke and adjust control dampers following manufacturer's recommended procedure, from 100 percent open to 100 percent closed and back to 100 percent open.
2. Check and document open and close cycle times for applications with a cycle time less than 30 seconds.
3. For control dampers equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

M. Control Valves:

1. Stroke and adjust control valves following manufacturer's recommended procedure, from 100 percent open to 100 percent closed and back to 100 percent open.
2. Check and document open and close cycle times for applications with a cycle time less than 30 seconds.
3. For control valves equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.

N. Meters: Check sensors at zero, 50, and 100 percent of Project design values.

O. Sensors: Check sensors at zero, 50, and 100 percent of Project design values.

P. Switches: Calibrate switches to make or break contact at set points indicated.

Q. Transmitters:

1. Check and calibrate transmitters at zero, 50, and 100 percent of Project design values.
2. Calibrate resistance temperature transmitters at zero, 50, and 100 percent of span using a precision-resistant source.

3.21 DDC SYSTEM CONTROLLER CHECKOUT

A. Verify power supply.

1. Verify voltage, phase and hertz.
2. Verify that protection from power surges is installed and functioning.
3. Verify that ground fault protection is installed.
4. If applicable, verify if connected to UPS unit.
5. If applicable, verify if connected to a backup power source.
6. If applicable, verify that power conditioning units, transient voltage suppression and high-frequency noise filter units are installed.

- B. Verify that wire and cabling is properly secured to terminals and labeled with unique identification.
- C. Verify that spare I/O capacity is provided.

3.22 DDC CONTROLLER I/O CONTROL LOOP TESTS

- A. Testing:
  - 1. Test every I/O point connected to DDC controller to verify that safety and operating control set points are as indicated and as required to operate controlled system safely and at optimum performance.
  - 2. Test every I/O point throughout its full operating range.
  - 3. Test every control loop to verify operation is stable and accurate.
  - 4. Adjust control loop proportional, integral and derivative settings to achieve optimum performance while complying with performance requirements indicated. Document testing of each control loop's precision and stability via trend logs.
  - 5. Test and adjust every control loop for proper operation according to sequence of operation.
  - 6. Test software and hardware interlocks for proper operation. Correct deficiencies.
  - 7. Operate each analog point at the following:
    - a. Upper quarter of range.
    - b. Lower quarter of range.
    - c. At midpoint of range.
  - 8. Exercise each binary point.
  - 9. For every I/O point in DDC system, read and record each value at operator workstation, at DDC controller and at field instrument simultaneously. Value displayed at operator workstation, at DDC controller and at field instrument shall match.
  - 10. Prepare and submit a report documenting results for each I/O point in DDC system and include in each I/O point a description of corrective measures and adjustments made to achieve desired results.

3.23 DDC SYSTEM VALIDATION TESTS

- A. Perform validation tests before requesting final review of system. Before beginning testing, first submit Pretest Checklist and Test Plan.
- B. After approval of Test Plan, execute all tests and procedures indicated in plan.
- C. After testing is complete, submit completed test checklist.
- D. Pretest Checklist: Submit the following list with items checked off once verified:
  - 1. Detailed explanation for any items that are not completed or verified.
  - 2. Required mechanical installation work is successfully completed and HVAC equipment is working correctly.

3. HVAC equipment motors operate below full-load amperage ratings.
4. Required DDC system components, wiring, and accessories are installed.
5. Installed DDC system architecture matches approved Drawings.
6. Control electric power circuits operate at proper voltage and are free from faults.
7. Required surge protection is installed.
8. DDC system network communications function properly, including uploading and downloading programming changes.
9. Using BACnet protocol analyzer, verify that communications are error free.
10. Each controller's programming is backed up.
11. Equipment, products, tubing, wiring cable and conduits are properly labeled.
12. All I/O points are programmed into controllers.
13. Testing, adjusting and balancing work affecting controls is complete.
14. Dampers and actuators zero and span adjustments are set properly.
15. Each control damper and actuator goes to failed position on loss of power.
16. Valves and actuators zero and span adjustments are set properly.
17. Each control valve and actuator goes to failed position on loss of power.
18. Meter, sensor and transmitter readings are accurate and calibrated.
19. Control loops are tuned for smooth and stable operation.
20. View trend data where applicable.
21. Each controller works properly in standalone mode.
22. Safety controls and devices function properly.
23. Interfaces with fire-alarm system function properly.
24. Electrical interlocks function properly.
25. Operator workstations and other interfaces are delivered, all system and database software is installed, and graphic are created.
26. Record Drawings are completed.

E. Test Plan:

1. Prepare and submit a validation test plan including test procedures for performance validation tests.
2. Test plan shall address all specified functions of DDC system and sequences of operation.
3. Explain detailed actions and expected results to demonstrate compliance with requirements indicated.
4. Explain method for simulating necessary conditions of operation used to demonstrate performance.
5. Include a test checklist to be used to check and initial that each test has been successfully completed.
6. Submit test plan documentation 10 business days before start of tests.

F. Validation Test:

1. Verify operating performance of each I/O point in DDC system.
  - a. Verify analog I/O points at operating value.
  - b. Make adjustments to out-of-tolerance I/O points.
    - 1) Identify I/O points for future reference.
    - 2) Simulate abnormal conditions to demonstrate proper function of safety devices.

- 3) Replace instruments and controllers that cannot maintain performance indicated after adjustments.
  2. Simulate conditions to demonstrate proper sequence of control.
  3. Readjust settings to design values and observe ability of DDC system to establish desired conditions.
  4. After 24 Hours following Initial Validation Test:
    - a. Re-check I/O points that required corrections during initial test.
    - b. Identify I/O points that still require additional correction and make corrections necessary to achieve desired results.
  5. After 24 Hours of Second Validation Test:
    - a. Re-check I/O points that required corrections during second test.
    - b. Continue validation testing until I/O point is normal on two consecutive tests.
  6. Completely check out, calibrate, and test all connected hardware and software to ensure that DDC system performs according to requirements indicated.
  7. After validation testing is complete, prepare and submit a report indicating all I/O points that required correction and how many validation re-tests it took to pass. Identify adjustments made for each test and indicate instruments that were replaced.
- G. DDC System Response Time Test:
1. Simulate HLC.
    - a. Heavy load shall be an occurrence of 50 percent of total connected binary COV, one-half of which represent an "alarm" condition, and 50 percent of total connected analog COV, one-half of which represent an "alarm" condition, that are initiated simultaneously on a one-time basis.
  2. Initiate 10 successive occurrences of HLC and measure response time to typical alarms and status changes.
  3. Measure with a timer having at least 0.1-second resolution and 0.01 percent accuracy.
  4. Purpose of test is to demonstrate DDC system, as follows:
    - a. Reaction to COV and alarm conditions during HLC.
    - b. Ability to update DDC system database during HLC.
  5. Passing test is contingent on the following:
    - a. Alarm reporting at printer beginning no more than two seconds after the initiation (time zero) of HLC.
    - b. All alarms, both binary and analog, are reported and printed; none are lost.
    - c. Compliance with response times specified.
  6. Prepare and submit a report documenting HLC tested and results of test including time stamp and print out of all alarms.

H. DDC System Network Bandwidth Test:

1. Test network bandwidth usage on all DDC system networks to demonstrate bandwidth usage under DDC system normal operating conditions and under simulated HLC.
2. To pass, none of DDC system networks shall use more than 70 percent of available bandwidth under normal and HLC operation.

3.24 DDC SYSTEM WIRELESS NETWORK VERIFICATION

- A. DDC system Installer shall design wireless DDC system networks to comply with performance requirements indicated.
- B. Installer shall verify wireless network performance through field testing and shall document results in a field test report.
- C. Testing and verification of all wireless devices shall include, but not be limited to, the following:
  1. Speed.
  2. Online status.
  3. Signal strength.

3.25 FINAL REVIEW

- A. Submit written request to Construction Manager when DDC system is ready for final review. Written request shall state the following:
  1. DDC system has been thoroughly inspected for compliance with contract documents and found to be in full compliance.
  2. DDC system has been calibrated, adjusted and tested and found to comply with requirements of operational stability, accuracy, speed and other performance requirements indicated.
  3. DDC system monitoring and control of HVAC systems results in operation according to sequences of operation indicated.
  4. DDC system is complete and ready for final review.
- B. Review by Construction Manager shall be made after receipt of written request. A field report shall be issued to document observations and deficiencies.
- C. Take prompt action to remedy deficiencies indicated in field report and submit a second written request when all deficiencies have been corrected. Repeat process until no deficiencies are reported.
- D. Should more than two reviews be required, DDC system manufacturer and Installer shall compensate entity performing review for total costs, labor and expenses, associated with third and subsequent reviews. Estimated cost of each review shall be submitted and approved by DDC system manufacturer and Installer before making the review.

- E. Prepare and submit closeout submittals when no deficiencies are reported.
- F. A part of DDC system final review shall include a demonstration to parties participating in final review.
  - 1. Provide staff familiar with DDC system installed to demonstrate operation of DDC system during final review.
  - 2. Provide testing equipment to demonstrate accuracy and other performance requirements of DDC system that is requested by reviewers during final review.
  - 3. Demonstration shall include, but not be limited to, the following:
    - a. Accuracy and calibration of 10 I/O points randomly selected by reviewers. If review finds that some I/O points are not properly calibrated and not satisfying performance requirements indicated, additional I/O points may be selected by reviewers until total I/O points being reviewed that satisfy requirements equals quantity indicated.
    - b. HVAC equipment and system hardwired and software safeties and life-safety functions are operating according to sequence of operation. Up to 10 I/O points shall be randomly selected by reviewers. Additional I/O points may be selected by reviewers to discover problems with operation.
    - c. Correct sequence of operation after electrical power interruption and resumption after electrical power is restored for randomly selected HVAC systems.
    - d. Operation of randomly selected dampers and valves in normal-on, normal-off and failed positions.
    - e. Reporting of alarm conditions for randomly selected alarms, including different classes of alarms, to ensure that alarms are properly received by operators and operator workstations.
    - f. Trends, summaries, logs and reports set-up for Project.
    - g. For up to three HVAC systems randomly selected by reviewers, use graph trends to show that sequence of operation is executed in correct manner and that HVAC systems operate properly through complete sequence of operation including different modes of operations indicated. Show that control loops are stable and operating at set points and respond to changes in set point of 20 percent or more.
    - h. Software's ability to communicate with controllers, operator workstations, uploading and downloading of control programs.
    - i. Software's ability to edit control programs off-line.
    - j. Data entry to show Project-specific customizing capability including parameter changes.
    - k. Step through penetration tree, display all graphics, demonstrate dynamic update, and direct access to graphics.
    - l. Execution of digital and analog commands in graphic mode.
    - m. Spreadsheet and curve plot software and its integration with database.
    - n. Online user guide and help functions.
    - o. Multitasking by showing different operations occurring simultaneously on four quadrants of split screen.
    - p. System speed of response compared to requirements indicated.
    - q. For Each Network and Programmable Application Controller:
      - 1) Memory: Programmed data, parameters, trend and alarm history collected during normal operation is not lost during power failure.

- 2) Operator Interface: Ability to connect directly to each type of digital controller with a portable operator workstation and PDA. Show that maintenance personnel interface tools perform as indicated in manufacturer's technical literature.
  - 3) Standalone Ability: Demonstrate that controllers provide stable and reliable standalone operation using default values or other method for values normally read over network.
  - 4) Electric Power: Ability to disconnect any controller safely from its power source.
  - 5) Wiring Labels: Match control drawings.
  - 6) Network Communication: Ability to locate a controller's location on network and communication architecture matches Shop Drawings.
  - 7) Nameplates and Tags: Accurate and permanently attached to control panel doors, instrument, actuators and devices.
- r. For Operator Workstation:
- 1) I/O points lists agree with naming conventions.
  - 2) Graphics are complete.
  - 3) UPS unit, if applicable, operates.
- s. Communications and Interoperability: Demonstrate proper interoperability of data sharing, alarm and event management, trending, scheduling, and device and network management. Use ASHRAE 135 protocol analyzer to help identify devices, view network traffic, and verify interoperability. Requirements must be met even if only one manufacturer's equipment is installed.
- 1) Data Presentation: On operator workstation, demonstrate graphic display capabilities.
  - 2) Reading of Any Property: Demonstrate ability to read and display any used readable object property of any device on network.
  - 3) Set Point and Parameter Modifications: Show ability to modify set points and tuning parameters indicated.
  - 4) Peer-to-Peer Data Exchange: Network devices are installed and configured to perform without need for operator intervention to implement Project sequence of operation and to share global data.
  - 5) Alarm and Event Management: Alarms and events are installed and prioritized according to Owner. Demonstrate that time delays and other logic are set up to avoid nuisance tripping. Show that operators with sufficient privileges are permitted.
  - 6) Schedule Lists: Schedules are configured for start and stop, mode change, occupant overrides, and night setback as defined in sequence of operations.
  - 7) Schedule Display and Modification: Ability to display any schedule with start and stop times for calendar year. Show that all calendar entries and schedules are modifiable from any connected operator workstation by an operator with sufficient privilege.
  - 8) Archival Storage of Data: Data archiving is handled by operator workstation and server and local trend archiving and display is accomplished.
  - 9) Modification of Trend Log Object Parameters: Operator with sufficient privilege can change logged data points, sampling rate, and trend duration.

10) Device and Network Management:

- a) Display of network device status.
- b) Display of BACnet Object Information.
- c) Silencing devices transmitting erroneous data.
- d) Time synchronization.
- e) Remote device re-initialization.
- f) Backup and restore network device programming and master database(s).
- g) Configuration management of routers.

3.26 ADJUSTING

- A. Occupancy Adjustments: When requested within 12 months from date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to Project during other-than-normal occupancy hours for this purpose.

3.27 MAINTENANCE SERVICE

- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include 12 months' full maintenance by DDC system manufacturer's authorized service representative. Include monthly preventive maintenance, repair or replacement of worn or defective components, cleaning, calibration and adjusting as required for proper operation. Parts and supplies shall be manufacturer's authorized replacement parts and supplies.

3.28 SOFTWARE SERVICE AGREEMENT

- A. Technical Support: Beginning at Substantial Completion, service agreement shall include software support for two year(s).
- B. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within two year(s) from date of Substantial Completion. Upgrading software shall include operating system and new or revised licenses for using software.
  - 1. Upgrade Notice: At least 30 days to allow Owner to schedule and access system and to upgrade computer equipment if necessary.

3.29 DEMONSTRATION

- A. Engage a factory-authorized service representative with complete knowledge of Project-specific system installed to train Owner's maintenance personnel to adjust, operate, and maintain DDC system.
- B. Extent of Training:



1. Base extent of training on scope and complexity of DDC system indicated and training requirements indicated. Provide extent of training required to satisfy requirements indicated even if more than minimum training requirements are indicated.
  2. Inform Owner of anticipated training requirements if more than minimum training requirements are indicated.
- C. Training Schedule:
1. Schedule training with Owner 20 business days before expected Substantial Completion.
  2. Schedule training to provide Owner with at least 20 business days of notice in advance of training.
  3. Training shall occur within normal business hours at a mutually agreed on time. Unless otherwise agreed to, training shall occur Monday through Friday, except on U.S. Federal holidays, with two morning sessions and two afternoon sessions. Each morning session and afternoon session shall be split in half with 15-minute break between sessions. Morning and afternoon sessions shall be separated by 60-minute lunch period. Training, including breaks and excluding lunch period, shall not exceed eight hours per day.
  4. Provide staggered training schedule as requested by Owner.
- D. Training Attendee List and Sign-in Sheet:
1. Request from Owner in advance of training a proposed attendee list with name, phone number and e-mail address.
  2. Provide a preprinted sign-in sheet for each training session with proposed attendees listed and no fewer than six blank spaces to add additional attendees.
  3. Preprinted sign-in sheet shall include training session number, date and time, instructor name, phone number and e-mail address, and brief description of content to be covered during session. List attendees with columns for name, phone number, e-mail address and a column for attendee signature or initials.
  4. Circulate sign-in sheet at beginning of each session and solicit attendees to sign or initial in applicable location.
  5. At end of each training day, send Owner an e-mail with an attachment of scanned copy (PDF) of circulated sign-in sheet for each session.
- E. Training Attendee Headcount:
1. Plan in advance of training for Owner supplied number of attendees.
  2. Make allowance for Owner to add up to two attendee(s) at time of training.
  3. Headcount may vary depending on training content covered in session. Attendee access may be restricted to some training content for purposes of maintaining system security.
- F. Training Attendee Prior Knowledge: For guidance in planning required training and instruction, assume attendees have the following:
1. High school education and degree.
  2. Basic user knowledge of computers and office applications.
  3. Basic knowledge of HVAC systems.
  4. Basic knowledge of DDC systems.
  5. Basic knowledge of DDC system and products installed.

G. Attendee Training Manuals:

1. Provide each attendee with a color hard copy of all training materials and visual presentations.
2. Hard-copy materials shall be organized in a three-ring binder with table of contents and individual divider tabs marked for each logical grouping of subject matter. Organize material to provide space for attendees to take handwritten notes within training manuals.
3. In addition to hard-copy materials included in training manual, provide each binder with a sleeve or pocket that includes a DVD or flash drive with PDF copy of all hard-copy materials.

H. Instructor Requirements:

1. One or multiple qualified instructors, as required, to provide training.
2. Instructors shall have not less than five years of providing instructional training on not less than five past projects with similar DDC system scope and complexity to DDC system installed.

I. Organization of Training Sessions:

1. Organize training sessions into logical groupings of technical content and to reflect different levels of operators having access to system. Plan training sessions to accommodate the following three levels of operators:
  - a. Daily operators.
  - b. Advanced operators.
  - c. System managers and administrators.
2. Plan and organize training sessions to group training content to protect DDC system security. Some attendees may be restricted to some training sessions that cover restricted content for purposes of maintaining DDC system security.

J. Training Outline:

1. Submit training outline for Owner review at least 10 business day before scheduling training.
2. Outline shall include a detailed agenda for each training day that is broken down into each of four training sessions that day, training objectives for each training session and synopses for each lesson planned.

K. On-Site Training:

1. Owner will provide conditioned classroom or workspace with ample desks or tables, chairs, power and data connectivity for instructor and each attendee.
2. Instructor shall provide training materials, projector and other audiovisual equipment used in training.
3. Provide as much of training located on-site as deemed feasible and practical by Owner.
4. On-site training shall include regular walk-through tours, as required, to observe each unique product type installed with hands-on review of operation, calibration and service requirements.

5. Operator workstation provided with DDC system shall be used in training. If operator workstation is not indicated, provide a temporary workstation to convey training content.

L. Off-Site Training:

1. Provide conditioned training rooms and workspace with ample tables desks or tables, chairs, power and data connectivity for each attendee.
2. Provide capability to remotely access to Project DDC system for use in training.
3. Provide a workstation for use by each attendee.

M. Training Content for Daily Operators:

1. Basic operation of system.
2. Understanding DDC system architecture and configuration.
3. Understanding each unique product type installed including performance and service requirements for each.
4. Understanding operation of each system and equipment controlled by DDC system including sequences of operation, each unique control algorithm and each unique optimization routine.
5. Operating operator workstations, printers and other peripherals.
6. Logging on and off system.
7. Accessing graphics, reports and alarms.
8. Adjusting and changing set points and time schedules.
9. Recognizing DDC system malfunctions.
10. Understanding content of operation and maintenance manuals including control drawings.
11. Understanding physical location and placement of DDC controllers and I/O hardware.
12. Accessing data from DDC controllers.
13. Operating portable operator workstations.
14. Review of DDC testing results to establish basic understanding of DDC system operating performance and HVAC system limitations as of Substantial Completion.
15. Running each specified report and log.
16. Displaying and demonstrating each data entry to show Project-specific customizing capability. Demonstrating parameter changes.
17. Stepping through graphics penetration tree, displaying all graphics, demonstrating dynamic updating, and direct access to graphics.
18. Executing digital and analog commands in graphic mode.
19. Demonstrating control loop precision and stability via trend logs of I/O for not less than 10 percent of I/O installed.
20. Demonstrating DDC system performance through trend logs and command tracing.
21. Demonstrating scan, update, and alarm responsiveness.
22. Demonstrating spreadsheet and curve plot software, and its integration with database.
23. Demonstrating on-line user guide, and help function and mail facility.
24. Demonstrating multitasking by showing dynamic curve plot, and graphic construction operating simultaneously via split screen.
25. Demonstrating the following for HVAC systems and equipment controlled by DDC system:

- a. Operation of HVAC equipment in normal-off, -on and failed conditions while observing individual equipment, dampers and valves for correct position under each condition.
- b. For HVAC equipment with factory-installed software, show that integration into DDC system is able to communicate with DDC controllers or gateways, as applicable.
- c. Using graphed trends, show that sequence of operation is executed in correct manner, and HVAC systems operate properly through complete sequence of operation including seasonal change, occupied and unoccupied modes, warm-up and cool-down cycles and other modes of operation indicated.
- d. Hardware interlocks and safeties function properly and DDC system performs correct sequence of operation after electrical power interruption and resumption after power is restored.
- e. Reporting of alarm conditions for each alarm, and confirm that alarms are received at assigned locations, including operator workstations.
- f. Each control loop responds to set point adjustment and stabilizes within time period indicated.
- g. Sharing of previously graphed trends of all control loops to demonstrate that each control loop is stable and set points are being maintained.

N. Training Content for Advanced Operators:

1. Making and changing workstation graphics.
2. Creating, deleting and modifying alarms including annunciation and routing.
3. Creating, deleting and modifying point trend logs including graphing and printing on an ad-hoc basis and operator-defined time intervals.
4. Creating, deleting and modifying reports.
5. Creating, deleting and modifying points.
6. Creating, deleting and modifying programming including ability to edit control programs off-line.
7. Creating, deleting and modifying system graphics and other types of displays.
8. Adding DDC controllers and other network communication devices such as gateways and routers.
9. Adding operator workstations.
10. Performing DDC system checkout and diagnostic procedures.
11. Performing DDC controllers operation and maintenance procedures.
12. Performing operator workstation operation and maintenance procedures.
13. Configuring DDC system hardware including controllers, workstations, communication devices and I/O points.
14. Maintaining, calibrating, troubleshooting, diagnosing and repairing hardware.
15. Adjusting, calibrating and replacing DDC system components.

O. Training Content for System Managers and Administrators:

1. DDC system software maintenance and backups.
2. Uploading, downloading and off-line archiving of all DDC system software and databases.
3. Interface with Project-specific, third-party operator software.
4. Understanding password and security procedures.
5. Adding new operators and making modifications to existing operators.

6. Operator password assignments and modification.
7. Operator authority assignment and modification.
8. Workstation data segregation and modification

P. Training requirements per the City of Philadelphia:

1. All training shall be coordinated with the Owner and with the Systems Integrator (if applicable)
2. Basic Operator Training:
  - a. One day (8 hours total) conduct training courses for designated personnel in the maintenance, service, and operation of the RBOp system and other systems as specified in the contract, including specified hardware and software. The training shall be oriented to those specific systems provided under this contract. The BAS Contractor is responsible for providing audiovisual equipment, manuals, instructors and other training material and supplies. The Systems Integrator shall review all training manuals, assist the BAS Contractors in conducting the training and coordinate training with the Owner.
3. Materials
  - a. Training manuals shall include an agenda, defined objectives for each lesson, and a detailed description of the subject matter for each lesson. Where the Contractor presents portions of the course material by audiovisuals, copies of those audiovisuals shall be delivered to the Owner. Upon completion of this course, each student, using appropriate documentation, should be able to start the system, operate the system, recover the system after a failure, perform routine maintenance and describe the specific hardware architecture and operation of the system.
4. System Training and Coordination
  - a. If available, the BAS Contractor, Owner and Systems Integrator, shall provide 8 hours of training on the sequence of operations that includes Server level integration i.e. integration of lighting, card access, , etc. and other topics as requested by the Owner, or as listed in the FMCS section of the contractor.
5. Systems Follow-Up Training:
  - a. The BAS Contractor shall provide 12 hours of warranty follow up training, in no less than 4 hour increments, to be scheduled at the request of the owner during the one-year warranty period. These sessions address questions and advanced topics as requested by the owner.

Q. Video of Training Sessions:

1. Provide a digital video and audio recording of each training session. Create a separate recording file for each session.
2. Stamp each recording file with training session number, session name and date.
3. Provide Owner with two copies of digital files on DVDs or flash drives for later reference and for use in future training.
4. Owner retains right to make additional copies for intended training purposes without having to pay royalties.

END OF SECTION 230923

R.

**3.30 CONSTRUCTION WASTE MANAGEMENT (LEED)**

- A. The contractor, subcontractors, and their personnel shall follow the procedures and practices for waste separation, collection, and transport as defined in the contractor's "Waste Management Plan" as required by Division 01 Section "Construction Waste Management."

END OF SECTION 230923

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