

ADDENDUM NO. 04

August 19, 2024

Renovation of Fall Creek Intermediate School

12011 Olio Road
Fishers, IN 46038

TO: ALL BIDDERS OF RECORD

This Addendum forms a part of and modifies the Bidding Requirements, Contract Forms, Contract Conditions, the Specifications and the Drawings dated July 12, 2024, by krM Architecture. Acknowledge receipt of the Addendum in the space provided on the Bid Form. Failure to do so may subject the Bidder to disqualification.

This Addendum consists of Pages ADD 4-1 through ADD 4-2 and attached krM Architecture Addendum No. 4 dated August 19, 2024, consisting of one page of Architectural narrative, one page of MEP narrative, new Specification Section 26 33 53 – Static Uninterruptible Power System, revised Specification Section 23 09 23 – Direct Digital Control (DDC) System for HVAC, and revised Specification Section 28 31 11 – Digital, Addressable Fire-Alarm System.

A. REMINDER: ELECTRONIC BID SUBMISSION

1. Reminder that ALL bid submission is electronic via Skillman Planroom. No in-person bids are to be submitted. Reference Specification Section 00 10 00a – Electronic Bid Submission for detailed instructions. All Bidding Contractors are encouraged to engage and develop familiarity with electronic system prior to bid time.
2. All Bidding Contractors are welcome to participate in the virtual public bid opening. All bids will be opened and read aloud via Microsoft Teams. Microsoft Teams Meeting information is included below.

Microsoft Teams [Need help?](#)

[Join the meeting now](#)

Meeting ID: 239 152 510 230

Passcode: qYERNZ

Dial in by phone

[+1 317-762-3960,,478400876#](#) United States, Indianapolis

[Find a local number](#)

Phone conference ID: 478 400 876#

For organizers: [Meeting options](#) | [Reset dial-in PIN](#)

B. SPECIFICATION SECTION 00 31 00 – BID FORM SECTION

1. Replace specification section with updated version included as part of this Addendum.

C. SPECIFICATION SECTION 01 12 00 – MULTIPLE CONTRACT SUMMARY

3.03 BID CATEGORIES

A. BID CATEGORY NO. 2 – MASONRY

Add the following clarifications:

6. Masonry Contractor is responsible for all work related to recoating existing glazed masonry units. Work is to include brushing, de-glossing, recoating, priming and painting. Reference Plan Notes 12c and 12e on Exterior Elevation Drawings for additional information.

B. BID CATEGORY NO. 3 – METAL STUDS & DRYWALL

Add the following clarifications:

16. Metal Stud and Drywall Contractor is responsible for the tile backer board at all tiling locations. Reference Specification Section 09 30 00 – Tiling for additional information, specifically paragraph 2.02 – Accessory Materials.

C. BID CATEGORY NO. 10 – PLUMBING & HVAC

Replace the following specification sections:

23 09 23 – Direct Digital Control (DDC) System for HVAC

D. BID CATEGORY NO. 11 – ELECTRICAL

Add the following specification sections:

26 33 53 – Static Uninterruptible Power System

Replace the following specification sections:

28 31 11 – Digital, Addressable Fire-Alarm System

D. SPECIFICATION SECTION 01 23 00 – ALTERNATES

1. Replace specification section with updated version included as part of this Addendum.

CONTRACTOR'S BID FOR PUBLIC WORKS FORM NO. 96

Format (Revised 2013)
(Amended for HSE)

Renovation Fall Creek Intermediate School
(Hamilton Southeastern Schools)
(Hamilton County, Indiana)

PART I

(To be completed for all bids. Please type or print)

Date (month, day, year): _____

BIDDER (Firm) _____

Address _____ P.O. Box _____

City/State/Zip _____

Telephone Number: _____ Email Address: _____

Person to contact regarding this Bid _____

Pursuant to notices given, the undersigned offers to furnish labor and/or materials necessary to complete the public works project of:

Insert Category No. (s) and Name(s)

Of public works project, **Renovation of Fall Creek Intermediate School**, in accordance with Plans and Specifications prepared by *krM Architecture, 1020 Jackson Street, Anderson, IN 46016*, as follows:

BASE BID

For the sum of _____
(Sum in words)

_____ DOLLARS (\$) _____
(Sum in figures)

The undersigned acknowledges receipt of the following Addenda:

Receipt of Addenda No. (s) _____

PROPOSAL TIME

Bidder agrees that this Bid shall remain in force for a period of sixty (60) consecutive calendar days from the due date, and Bids may be accepted or rejected during this period. Bids not accepted within said sixty (60) consecutive calendar days shall be deemed rejected.

Attended pre-bid conference YES _____ NO _____

Has visited the jobsite YES _____ NO _____

The Bidder has reviewed the Guideline Schedule in Section 01 32 00 and the intent
Of the schedule can be met. YES _____ NO _____

Bidder has included their Written Drug Testing Plan that covers all employees of the bidder who will perform work on the public work project and meets or exceeds the requirements set in IC 4-13-18-5 or IC 4-13-18-6. YES _____ NO _____

The Skillman Corporation’s diversity initiative is to create a program to encourage, assist and measure the active participation of Minority- Owned, Women-Owned, Veteran – Owned and Disabled Individual-Owned Businesses. The Program is to ensure that MWVDBEs are provided full and equal opportunity to participate in all Skillman Corporation’s Projects.

Bidder has included: DBE: YES _____% NO _____
 MBE: YES _____% NO _____
 WBE: YES _____% NO _____
 VBE: YES _____% NO _____

The undersigned further agrees to furnish a bond or certified check with this Bid for an amount specified in the Notice to Bidders. If Alternate Bids apply, submit a proposal for each in accordance with the Plans and Specifications.

If additional units of material included in the contract are needed, the cost of units must be the same as that shown in the original contract if accepted by the governmental unit. If the bid is to be awarded on a unit bases, the itemization of the units shall be shown on a separate attachment.

The contractor and his subcontractors, if any, shall not discriminate against or intimidate any employee, or applicant for employment, to be employed in the performance of this contract, with respect to any matter directly or indirectly related to employment because of race, religion, color, sex, national origin or ancestry. Breach of this covenant may be regarded as a material breach of the contract.

CERTIFICATION OF USE OF UNITED STATES STEEL PRODUCTS
(if applicable)

I, the undersigned bidder or agent as a contractor on a public works project, understand my statutory obligation to use steel products made in the United States (I.C. 5-16-8-2). I hereby certify that I and all subcontractors employed by me for this project will use U.S. steel on this project if awarded. I understand that violations hereunder may result in forfeiture of contractual payments.

ALTERNATE BIDS

A blank entry or an entry of "No Bid", "N/A", or similar entry on any Alternate will cause the bid to be rejected as non-responsive only if that Alternate is selected. If no change in the bid amount is required, indicate "No Change".

****MARK "ADD" OR "DEDUCT" FOR EACH ALTERNATE****

Alternate Bid No. 1 – North Bus Lot Exterior Site Work

Change the Base Bid the sum of _____
(sum in words)

_____ DOLLARS (\$ _____)
(sum in figures)

ADD
DEDUCT

Alternate Bid No. 2 – South Drop-Off Visitor Lot Exterior Site Work

Change the Base Bid the sum of _____
(sum in words)

_____ DOLLARS (\$ _____)
(sum in figures)

ADD
DEDUCT

Alternate Bid No. 3 – Southwest Service Drive Exterior Site Work

Change the Base Bid the sum of _____
(sum in words)

_____ DOLLARS (\$ _____)
(sum in figures)

ADD
DEDUCT

Alternate Bid No. 4 – South Drop-Off Visitor Partial Sidewalk Replacement

Change the Base Bid the sum of _____
(sum in words)

DOLLARS (\$) _____
(sum in figures) ADD
DEDUCT

Alternate Bid No. 5 – Kitchen Freezer and Cooler

Change the Base Bid the sum of _____
(sum in words)

DOLLARS (\$) _____
(sum in figures) ADD
DEDUCT

Alternate Bid No. 6 – Brick Staining

Change the Base Bid the sum of _____
(sum in words)

DOLLARS (\$) _____
(sum in figures) ADD
DEDUCT

Alternate Bid No. 7 – Exterior Columns

Change the Base Bid the sum of _____
(sum in words)

DOLLARS (\$) _____
(sum in figures) ADD
DEDUCT

Alternate Bid No. 8 – Gym Curtain

Change the Base Bid the sum of _____
(sum in words)

DOLLARS (\$) _____
(sum in figures) ADD
DEDUCT

Alternate Bid No. 9 – Metal Lockers in Academic Wings

Change the Base Bid the sum of _____
(sum in words)

_____ DOLLARS (\$) _____
(sum in figures) ADD
DEDUCT

Alternate Bid No. 10 – Provide Instrumentation and Controls by Siemens (Disego) – Installed by
local Branch

Change the Base Bid the sum of _____
(sum in words)

_____ DOLLARS (\$) _____
(sum in figures) ADD
DEDUCT

PART II

(For projects of \$150,000 or more – IC 36-1-12-4)

These statements to be submitted under oath by each bidder with and as a part of his bid. (Attach additional pages for each section as needed.)

SECTION I EXPERIENCE QUESTIONNAIRE

1. What public works projects has your organization completed for the period of one (1) year prior to the date of the current bid?

{PRIVATE }Contract Amount	Class of Work	Completion Date	Name and Address of Owner

2. What public works projects are now in process of construction by your organization?

{PRIVATE }Contract Amount	Class of Work	Completion Date	Name and Address of Owner

3. Have you ever failed to complete any work awarded to you? _____ If so, where and why?

4. List references from private firms for which you have performed work.

SECTION II PLAN AND EQUIPMENT QUESTIONNAIRE

1. Explain your plan or layout for performing proposed Work. (Examples could include a narrative of when you could begin, complete the project, number of workers, etc. and any other information which you believe would enable the governmental unit to consider your bid.)

2. Please list the names and addresses of all subcontractors (i.e. persons or firms outside your own firm who have performed part of the work) that you have used on public works projects during the past five (5) years along with a brief description of the work done by each subcontractor.

3. If you intend to sublet any portion of the work, state the name and addresses of each subcontractor, equipment to be used by the subcontractor, and whether you will required a bond. However, if you are unable to currently provide a listing, please understand a listing must be provided prior to contract approval. Until the completion of the proposed project, you are under a continuing obligation to immediately notify the governmental unit in the event that you subsequently determine that you will use a subcontractor on the proposed project.

4. What equipment do you have available to use for the proposed Project? Any equipment used by subcontractors may also be required to be listed by the governmental unit.

5. Have you into contracts or received offers for all materials which substantiate the prices used in preparing your proposal? If not, please explain the rationale used which corroborate the process listed.

SECTION III CONTRACTOR'S FINANCIAL STATEMENT

Attachment of Bidder's financial statement is mandatory. Any Bid submitted without said financial statement as required by statute shall thereby be rendered invalid. The financial statement provided hereunder to the governing body awarding the Contract must be specific enough in detail so that said governing body can make a proper determination of the Bidder's capability for completing the Project if awarded.

SECTION IV CONTRACTOR NON-COLLUSION AFFIDAVIT

The undersigned Bidder or agent, being duly sworn on oath, says that he has not, nor has any other member, representative, or agent of the firm, company, corporation or partnership represented by him, entered into any combination, collusion or agreement with any person relative to the price to be bid by anyone at such letting nor to prevent any person from bidding nor to induce anyone to refrain from bidding, and that this Bid is made without reference to any other bid and without any agreement, understanding or combination with any other person in reference to such bidding.

He further says that no person or persons, firms, or corporations has, have, or will receive directly or indirectly, any rebate, fee, gift, commission, or thing of value on account of such contract.

SECTION V OATH AND AFFIRMATION

I HEREBY AFFIRM UNDER THE PENALTIES OF PERJURY THAT THE FACTS AND INFORMATION CONTAINED IN THE FOREGOING BID FOR PUBLIC WORKS ARE TRUE AND CORRECT

Dated at _____ this _____ day of _____, 20

(Name of Organization)

By

(Title of Person Signing)

ACKNOWLEDGEMENT

STATE OF _____)
) SS:
COUNTY OF _____)

Before me, a Notary Public, personally appeared the above-named

Swore that the statements contained in the foregoing document are true and correct.

Subscribed and sworn to before me this _____ day of _____,
(Title)

Notary Public _____

My Commission Expires: _____

County of Residence: _____

END OF SECTION 00 31 00

SECTION 01 23 00 - ALTERNATES

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including amended General Conditions and other Division 1 Specification Sections, apply to work of this Section.

1.02 PURPOSE

- A. The Bids for the Alternates described herein are required in order for the Owner to obtain information necessary for the proper consideration of the Project in its entirety.

1.03 ALTERNATES

- A. Definitions: Alternates are defined as alternate products, materials, equipment, installations or systems for the Work, which may, at Owner's option and under terms established by Instructions to Bidders, be selected and recorded in the Owner-Contractor Agreement to either supplement or displace corresponding basic requirements of Contract Documents. Alternates may or may not substantially change scope and general character of the Work; and must not be confused with "allowances", "unit prices", "change orders", "substitutions", and other similar provisions.

1.04 SCHEDULE OF ALTERNATES

- A. ALTERNATE NO. 1: North Bus Lot Exterior Site Work
Scope: Site improvements at North Bus Parking Lot
Drawings: C100, C101& C201
Specifications: Geotechnical Report, 31 20 00 – Earthwork, 32 12 16 – Asphalt Paving

- B. ALTERNATE NO. 2: South Drop-Off Visitor Lot Exterior Site Work
Scope: Site improvements at South Drop-off Visitor Parking Lot
Drawings: C100, C102 & C202
Specifications: Geotechnical Report, 31 20 00 – Earthwork, 32 12 16 – Asphalt Paving, 32 13 13 – Concrete Paving

- C. ALTERNATE NO. 3: Southwest Service Drive Exterior Site Work
Scope: Site improvements at Southwest Service Drive.
Drawings: C100, C102 & C202
Specifications: Geotechnical Report, 31 20 00 – Earthwork, 32 12 16 – Asphalt
- D. ALTERNATE NO. 4: South Drop-Off Visitor Partial Sidewalk Replacement
Scope: Site improvements at Partial Sidewalk Replacements adjacent to the South Drop-off Visitor Parking Lot.
Drawings: C100, C102 & C202
Specifications: Geotechnical Report, 31 20 00 – Earthwork, 32 12 16 – Asphalt Paving, 32 13 13 – Concrete Paving
- E. ALTERNATE NO. 5: Kitchen Freezer and Cooler
Scope: Add walk-in cooler and refurbishment to existing. Include exterior kitchen sidewalk noted on Civil Drawings.
Drawings: C102, D1-5, A1-1, A1-6, A8-1, A11-6, K-Series Drawings, Architectural Floor Plans – Note #13
Specifications: 11 40 00 Food Service Equipment
- F. ALTERNATE NO. 6: Brick Staining
Scope: Stain existing masonry veneer and paint existing glazed masonry units.
Drawings: Exterior Elevations – Notes #12a - #12f, Detail 2/A4-5, Details 2, 3, 4 & 8 on A4-5.
Specifications: 04 01 05 – Masonry Staining
- G. ALTERNATE NO. 7: Exterior Columns
Scope: Remove existing brick and install tile wall and granite base at all exterior columns.
Drawings: Exterior Elevations – Notes #12g & #12h, Detail 5/A4-5, Details 1, 5, 6 & 7 on A4-5.
Specifications: 04 43 13 – Stone Masonry Veneer, 09 30 00 – Tiling
- H. ALTERNATE NO. 8: Gym Curtain
Scope: Replacement of gym divider curtain.
Drawings: D2-6, A1-1
Specifications: 11 66 23 – Gymnasium Equipment

- I. ALTERNATE NO. 9: Metal Lockers in Academic Wings
Scope: Replace all metal lockers in academic wings.
Drawings: Architectural Floor Plans – Note #9,
Specifications: 10 51 13 – Metal Lockers
- J. ALTERNATE NO. 10: Provide Instrumentation and Controls by Siemens (Disego)
– Installed by local Branch.
Base Bid: No temperature controls.
Scope: Controls for building automation.
Specifications: 23 09 23 – Direct Digital Control (DDC) System for HVAC

PART 2 - PRODUCTS, PART 3 - EXECUTION (Not Used)

END OF SECTION 01 23 00



Addendum #4
Hamilton Southeastern Schools
Fall Creek Intermediate Renovations

Date: August 19, 2024
Project: Fall Creek Intermediate School
Project #: 23055
Pages: 1 of 1 pages
Bid Dates: Thursday, August 22, 2024, at 10:00AM

General Note:

The original Specifications and Drawings dated July 12, 2024, for the project referenced above are amended as noted in this Addendum No. 4. Receipt of this Addendum and any subsequent Addenda must be acknowledged on the Bid Form. Items changed or added by this addendum are to take precedence over the items or descriptions of the work in the project manual and the drawings. Items not mentioned in this addendum are to remain as described in the original plans and specifications.

Q & A:

When going through your specs it looks like the trophy case's component are separated into different specs. Is the 900DC product line for display cases an acceptable substitution for the field assembled trophy case design that is currently shown?

Yes, we will accept submittals for a prefabricated product such as **The Tablet & Ticket Co. 900DC** product line. Prefabricated alternatives must be able to match construction style and veneer options originally specified.

Specifications Items:

Section 03 30 00 – Cast-in Place Concrete

Add to section: 2.04G Moisture Vapor Reducing Admixture (MVRA)
b. AVECS; Pro-Act MVRA, <https://avecs.build/>

Section 08 80 00 – Glazing

Add to section: 2.01/C. Laminated Glass Manufacturers:
3. Armoured One; <https://armouredone.com/>

END



Addendum #4
Hamilton Southeastern School Corporation
Fall Creek Intermediate Renovations

Date: August 19, 2024
Project: FCI – Renovations
Project #: 23055
Pages: 1 of 1
Bid Dates: **August 22, 2024**

General Note:

The original Specifications and Drawings dated August 19th, 2024 for the project referenced above are amended as noted in this Addendum No. 4. Receipt of this Addendum and any subsequent Addenda must be acknowledged on the Bid Form. Items changed or added by this addendum are to take precedence over the items or descriptions of the work in the project manual and the drawings. Items not mentioned in this addendum are to remain as described in the original plans and specifications.

Specifications Items:

1. Specification Section 263353 – Static Uninterruptible Power System
 - a. Add section completely.
2. Specification Section 283111 – Digital, Addressable Fire-Alarm System
 - a. Revised manufacturer from Siemens to Simplex in all sections.
3. Specification Section 230923 – Direct Digital Control (DDC) Systems for HVAC.
 - a. Revised 1.06 Quality Assurance Item 7 Acceptable Control Supplier:
 - i. Removed Alerton – Installed by Open Control Systems.
 - ii. Removed Johnson Controls – Installed by JCI.

Drawing Set Items:

Sheet -

1. N/A

Attachments:

1. Specification Section – 263353 – Static Uninterruptible Power System
2. Specification Section – 283111 – Digital, Addressable Fire-Alarm System
3. Specification Section – 230923 – Direct Digital Control (DDC) Systems for HVAC.

END

SECTION 23 09 23
DIRECT DIGITAL CONTROL (DDC) SYSTEM FOR HVAC

PART 1 GENERAL

1.01 SUMMARY

- A. Scope:
 - 1. The Temperature Control Contractor (TCC) shall install, furnish, program, and turn over to client a complete operating DDC system for monitoring and controlling of MEP systems as shown in the Contract Documents.
- B. Section Includes:
 - 1. DDC system for monitoring and controlling of MEP systems.
 - 2. Delivery of selected control devices to equipment and systems manufacturers for factory installation and to HVAC systems installers for field installation.
- C. Scope not included in 230923:
 - 1. Electrical Contractor (EC) to provide all wiring to all motor starters, variable frequency drives, and motor control centers.
 - 2. EC to provide 120 V/60 Hz power to all direct digital controllers (DDC) that require 120 V power.
 - 3. Sheet Metal Contractor shall install all motorized dampers, duct mounted airflow measuring stations, thermowells (for temperature & pressure sensors), flow meters, control valves, and other accessories that are furnished by the TCC.
 - 4. Mechanical Contractor shall install all temperature and pressure sensing wells and control valves furnished by the Temperature Control Contractor.

1.02 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. 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.
- F. 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.
- G. COV: Changes of value.
- H. DDC System Provider: Authorized representative of, and trained by, DDC system manufacturer and responsible for execution of DDC system Work indicated.
- I. 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.
- J. DOCSIS: Data-Over Cable Service Interface Specifications.

- K. Gateway: Bidirectional protocol translator that connects control systems that use different communication protocols.
- L. HLC: Heavy load conditions.
- M. 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.
- N. LAN: Local area network.
- O. LNS: LonWorks Network Services.
- P. 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.
- Q. 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.
- R. Modbus TCP/IP: An open protocol for exchange of process data.

- S. MS/TP: Master-slave/token-passing, IEE 8802-3. Datalink protocol LAN option that uses twisted-pair wire for low-speed communication.
- T. 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.
- U. Network Repeater: Device that receives data packet from one network and rebroadcasts it to another network. No routing information is added to protocol.
- V. PDA: Personal digital assistant.
- W. Peer to Peer: Networking architecture that treats all network stations as equal partners.
- X. RAM: Random access memory.
- Y. RF: Radio frequency.
- Z. Router: Device connecting two or more networks at network layer.
- AA. TCP/IP: Transport control protocol/Internet protocol incorporated into Microsoft Windows.
- BB. UPS: Uninterruptible power supply.
- CC. USB: Universal Serial Bus.
- DD. User Datagram Protocol (UDP): This protocol assumes that the IP is used as the underlying protocol.
- EE. VAV: Variable air volume.
- FF. WLED: White light emitting diode.

1.03 ACTION SUBMITTALS

- A. 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.
 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.
- B. Shop Drawings:
 1. Include plans, elevations, sections, and mounting details where applicable.
 2. Include details of product assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
 3. Detail means of vibration isolation and show attachments to rotating equipment.
 4. 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 operator 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. Proposed routing of wiring, cabling, conduit, and tubing, coordinated with building services for review before installation.
5. 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.
 6. 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.
 7. 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 fiber-optic 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.
 8. 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.
 9. 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.
 - c. Control signal tubing to sensors, switches and transmitters.
 - d. Process signal tubing to sensors, switches and transmitters.
- C. 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. Gateway failure.
 - f. Network failure
 - g. Controller failure.
 - h. Instrument failure.
 - i. 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.
- D. Samples:
1. For each exposed product, installed in finished space for approval of selection of aesthetic characteristics.

1.04 INFORMATIONAL SUBMITTALS

- A. Coordination Drawings: Plan drawings, reflected ceiling plan(s), and other details, drawn to scale and coordinated with each other, using input from installers of the items involved.
- B. Qualification Data:
 1. Systems Provider Qualification Data:
 - a. Resume of project manager assigned to Project.
 - b. Resumes of application engineering staff assigned to Project.
 - c. Resumes of installation and programming technicians assigned to Project.
 - d. Resumes of service technicians assigned to Project.
 - e. Brief description of past project including physical address, floor area, number of floors, building system cooling and heating capacity and building's primary function.
 - f. Description of past project DDC system, noting similarities to Project scope and complexity indicated.
 - g. Names of staff assigned to past project that will also be assigned to execute work of this Project.
 - h. Owner contact information for past project including name, phone number, and e-mail address.
 - i. Contractor contact information for past project including name, phone number, and e-mail address.
 - j. Architect and Engineer contact information for past project including name, phone number, and e-mail address.
 2. Manufacturer's qualification data.
 3. Testing agency's qualifications data.
- C. Welding certificates.
- D. Product Certificates:
 1. Data Communications Protocol Certificates: Certifying that each proposed DDC system component complies with ASHRAE 135.
- E. Product Test Reports: For each product that requires testing to be performed by manufacturer.
- F. Preconstruction Test Reports: For each separate test performed.
- G. Source quality-control reports.
- H. Field quality-control reports.
- I. Sample Warranty: For manufacturer's warranty.

1.05 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.

1.06 QUALITY ASSURANCE

- A. DDC System Manufacturer Qualifications:
 1. Nationally recognized manufacturer of DDC systems and products.
 2. DDC systems with similar requirements to those indicated for a continuous period of 5 years within time of bid.
 3. DDC systems and products that have been successfully tested and in use on at least 3 past projects.
 4. Having complete published catalog literature, installation, operation and maintenance manuals for all products intended for use.
 5. Having full-time in-house employees for the following:
 - a. Product research and development.
 - b. Product and application engineering.
 - c. Product manufacturing, testing and quality control.
 - d. Technical support for DDC system installation training, commissioning and troubleshooting of installations.
 - e. Owner operator training.
 6. TCC to provide controllers as required to communicate with Desigo system.
 7. Acceptable Control Supplier:
 - a. Siemens (Desigo) – Installed by local Branch.

- B. DDC System Provider Qualifications:
 1. Authorized representative of, and trained by, DDC system manufacturer.
 2. In-place facility located within 150 miles of Project and be capable of to respond on-site within 4 hours of notice.
 3. Staffing resources of competent and experienced full-time employees that are assigned to execute work according to schedule.
 4. Service and maintenance staff assigned to support Project during warranty period.
 5. Product parts inventory to support on-going DDC system operation for a period of not less than 5 years after Substantial Completion.
 6. 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.
- C. Testing Agency Qualifications: Member company of NETA or an NRTL.
 1. Testing Agency's Field Supervisor: Certified by NETA to supervise on-site testing.
- D. 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."
- E. Pipe and Pressure-Vessel Welding Qualifications: Qualify procedures and operators according to ASME Boiler and Pressure Vessel Code.

1.07 WARRANTY

- A. Manufacturer's Warranty: Manufacturer and Installer agree to repair or replace products that fail in materials or workmanship within specified warranty period at no cost to client.
 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 24 hours of Owner's warranty service request.
 4. Warranty Period: 3 years from date of Substantial Completion. Warranty shall cover labor, material, replacement, and repairs for work performed during warranty period.

PART 2 PRODUCTS

2.01 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.

2.02 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 & store 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 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).
- D. Future Expandability:
 - 1. DDC system size shall be expandable to an ultimate capacity of at least 125% 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.
- E. Environmental Conditions for Controllers, Gateways, 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 4.
 - b. Outdoors, Unprotected: Type 4.
 - c. Indoors, Heated with Filtered Ventilation: Type 2.
 - d. Indoors, Heated with Non-Filtered Ventilation: Type 2.
 - e. Indoors, Heated and Air Conditioned: Type 2.
 - f. Mechanical Equipment Rooms:
 - 1) Chiller and Boiler Rooms: Type 4.
 - 2) Air-Moving Equipment Rooms: Type 4.
 - g. Localized Areas Exposed to Washdown: Type 4.

- h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: Type 3.
 - i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: Type 4.
 - j. Hazardous Locations: Explosion-proof rating for condition.
- F. 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 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 4.
 - b. Outdoors, Unprotected: Type 4.
 - c. Indoors, Heated with Filtered Ventilation: Type 2.
 - d. Indoors, Heated with Non-Filtered Ventilation: Type 2.
 - e. Indoors, Heated and Air Conditioned: Type 2.
 - f. Mechanical Equipment Rooms:
 - 1) Chiller and Boiler Rooms: Type 4.
 - 2) Air-Moving Equipment Rooms: Type 4.
 - g. Localized Areas Exposed to Washdown: Type 4.
 - h. Within Duct Systems and Air-Moving Equipment Not Exposed to Possible Condensation: Type 3.
 - i. Within Duct Systems and Air-Moving Equipment Exposed to Possible Condensation: Type 4.
 - j. Hazardous Locations: Explosion-proof rating for condition.
- G. Electric Power Quality:
- 1. Power-Line Surges:
 - a. Protect 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 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.
- H. 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.
- I. UPS:
 1. DDC system products powered by UPS units shall include the following:
 - a. Desktop operator workstations.
 - b. Printers.
 - c. Servers.
 - d. Gateways.
 - e. DDC controllers.
 2. DDC system instruments and actuators powered by UPS units shall be defined in the documents.
- J. 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.

2.03 SYSTEM ARCHITECTURE

- A. System architecture shall consist of no more than 3 levels of LANs.
 1. Level one LAN shall connect network controllers and operator workstations.
 2. Level two LAN shall connect programmable application controllers to other programmable application controllers, and to network controllers.
 3. Level three LAN shall connect application-specific controllers to programmable application controllers and network controllers.
 4. Level three LAN shall connect application-specific controllers to application-specific controllers.
- B. DDC system shall consist of dedicated and/or separated LANs that are not shared with other building systems and tenant data and communication networks.
- C. System architecture shall be modular and have inherent ability to expand to not less than 3 times system size indicated with no impact to performance indicated.
- D. System architecture shall perform modifications without having to remove and replace existing network equipment.
- E. 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.
- F. 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.
- G. 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.

2.04 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. Desktop and portable operator workstation with hardwired connection through LAN port.
 2. Portable operator terminal with hardwired connection through LAN port.
 3. Portable operator workstation with wireless connection through LAN router.
 4. Remote connection using outside of system personal computer or through Web access.

5. Remote connection using portable operator workstation and internet connection.
 6. Mobile device.
- B. Access to system, regardless of operator means used, shall be transparent to operator.
- C. Desktop Workstations:
1. Connect to DDC system Level one LAN through a communications port directly on LAN or through a communications port on a DDC controller.
 2. Able to communicate with any device located on any DDC system LAN.
 3. Able to communicate, with modems, remotely with any device connected to any DDC system LAN.
 4. Communication via a modem shall not interfere with LAN activity and LAN activity shall not prevent workstation from handling incoming calls.
- D. 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.
- E. Simultaneous Operator Use: Capable of accommodating up to 10 simultaneous operators that are accessing DDC system through any one of operator interfaces indicated.

2.05 NETWORK COMMUNICATION PROTOCOL

- A. Network communication protocol(s) used throughout entire DDC system shall be open to public 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.

2.06 DESKTOP OPERATOR WORKSTATIONS

- A. Performance Requirements:
1. Performance requirements may dictate equipment exceeding minimum requirements indicated.
 2. Energy Star compliant.
- B. Computer Workstation:
1. Shall include computer, monitor(s), mouse, and keyboard.
 - a. Computer shall support all building automation operations, email, include all Microsoft Office suit programs, and pdf viewer and edit program.
 - 1) Shall be a minimum i5 processor with 16 GB RAM and 3.6 GHz processor.
 - 2) 64-bit.
 - 3) Capable of expanding ram to 32 GB.
 - 4) 1 TB hard drive.
 - 5) 4 USB ports, no optical drive required.
 - 6) Graphics card suitable for BAS requirements.
 - 7) Sound card.
 - 8) Network card and built in wireless.
 - 9) Windows 10 or newer.

2.07 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 plant equipment includes, but is not limited to, boilers, chillers, and variable-speed drives.
- 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 writeable 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.

2.08 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.
 - 3. Controllers located outdoors shall be rated for operation at 40 to 150 deg F.
- 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 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. 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.
- I. 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 12 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 12 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.
- e. Limit use of three-point floating devices to VAV terminal unit control applications, and other applications indicated on Drawings, Control algorithms shall operate actuator to one end of its stroke once every 24 hours for verification of operator tracking.

2.09 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 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.
 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.

2.10 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.
 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.

2.11 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.

2.12 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 a character point name. 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 user names.
 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. 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).
- J. 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.

- K. 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.
- L. 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.
- M. 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.

2.13 ENCLOSURES

- A. General Enclosure Requirements:
 1. House each controller and associated control accessories in a 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.
- 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 25 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.
- 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.
 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 NSF/ANSI 61 gray or manufacturer's standard.
 - b. Interior color shall be NSF/ANSI 61 gray or manufacturer's standard.
 4. Hinged door full size of front face of enclosure and supported using:
 - a. Enclosures sizes less than 36 in. tall: Multiple butt hinges.
 - b. Enclosures sizes 36 in. 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.
 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.
 6. Double-door enclosure sizes up to 36 inches tall by 60 inches wide.
 7. Construct enclosure of steel.
 8. Finish enclosure with polyester powder coating that is electrostatically applied and then baked to bond to substrate.
 - a. Exterior color shall be NSF/ANSI 61 gray or manufacturer's standard.
 - b. Interior color shall be NSF/ANSI 61 gray or 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 Tall: Two hinges.
 - b. Sizes between 24 Inches through 48 Inches Tall: Three hinges.
 - c. Sizes Larger 48 Inches Tall: Four hinges.
 10. Double-door enclosures with overlapping door design to include unobstructed full-width access.
 - a. Single-door enclosures 48 inches 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.
 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.
- F. Accessories:
1. Electric Heater:
 - a. Aluminum housing with brushed finish.
 - b. Thermostatic control with adjustable set point from zero to 100 deg F.
 - c. Capacity: 100, 200, 400, and 800 W as required by application.
 - d. Fan draws cool air from bottom of enclosure and passes air across thermostat and heating elements before being released into enclosure cavity. Heated air is discharged through the top of heater.
 2. Ventilation Fans, Filtered Intake and Exhaust Grilles:
 - a. Number and size of fans, filters and grilles as required by application.
 - b. Compact cooling fans engineered for 50,000 hours of continuous operation without lubrication or service.
 - c. Fans capable of being installed on any surface and in any position within enclosure for spot cooling or air circulation.
 - d. Thermostatic control with adjustable set point from 32 to 140 deg F.
 - e. Airflow Capacity at Zero Pressure:
 - 1) 4-Inch Fan: 100 cfm.
 - 2) 6-Inch Fan: 240 cfm.
 - 3) 10-Inch Fan: 560 cfm.
 - f. Maximum operating temperature of 158 deg F.
 - g. 4-inch fan thermally protected and provided with permanently lubricated ball-bearings.
 - h. 6- and 10-inch fans with ball-bearing construction and split capacitor motors thermally protected to avoid premature failure.
 - i. Dynamically balanced impellers molded from polycarbonate material.
 - j. Fan furnished with power cord and polarized plug for power connection.
 - k. Fan brackets, finger guards and mounting hardware provided with fans to complete installation.
 - l. Removable Intake and Exhaust Grilles: Stainless steel of size to match fan size and suitable for NEMA 250, Types 1 and 12 enclosures.
 - m. Filters for NEMA 250, Type 1 Enclosures: Washable aluminum, of a size to match intake grille.
 - n. Filters for NEMA 250, Type 12 Enclosures: Disposable, of a size to match intake grille.
 3. Bar handle with keyed cylinder lock set.

2.14 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. 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.
- 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. 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.
- 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. Equip relays with coil transient suppression to limit transients to non-damaging levels.
 7. 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.
 8. 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.
 - 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.

2.15 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 100 VA.
 3. Transformer shall have both primary and secondary fuses.
- B. 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.

2.16 UNINTERRUPTABLE POWER SUPPLY (UPS) UNITS

- A. 250 through 1000 VA:
 1. UPS units shall provide continuous, regulated output power without using their batteries during brown-out, surge, and spike conditions.
 2. Load served shall not exceed 75 percent of UPS rated capacity, including power factor of connected loads.
 - a. Larger-capacity units shall be provided for systems with larger connected loads.
 - b. UPS shall provide 5 minutes of battery power.
 3. Performance:
 - a. Input Voltage: Single phase, 120- or 230-V ac, compatible with field power source.
 - b. Load Power Factor Range (Crest Factor): 0.65 to 1.0.
 - c. Output Voltage: 101- to 132-V ac, while input voltage varies between 89 and 152-V ac.
 - d. On Battery Output Voltage: Sine wave.
 - e. Inverter overload capacity shall be minimum 150 percent for 30 seconds.
 - f. Recharge time shall be a maximum of six hours to 90 percent capacity after full discharge to cutoff.
 - g. Transfer Time: 6 ms.
 - h. Surge Voltage Withstand Capacity: IEEE C62.41, Categories A and B; 6 kV/200 and 500 A; 100-kHz ringwave.
 4. UPS shall be automatic during fault or overload conditions.
 5. Unit with integral line-interactive, power condition topology to eliminate all power contaminants.
 6. Include front panel with power switch and visual indication of power, battery, fault and temperature.
 7. Unit shall include an audible alarm of faults and front panel silence feature.
 8. Unit with four NEMA WD 1, NEMA WD 6 Configuration 5-15R receptacles.
 9. UPS shall include dry contacts (digital output points) for low battery condition and battery-on (primary utility power failure) and connect the points to the DDC system.
 10. Batteries shall be sealed lead-acid type and be maintenance free. Battery replacement shall be front accessible by user without dropping load.
 11. Include tower models installed in ventilated cabinets to the particular installation location.
- B. 1000 through 3000 VA:

1. UPS units shall provide continuous, regulated output power without using their batteries during brown-out, surge, and spike conditions.
2. Load served shall not exceed 75 percent of UPS rated capacity, including power factor of connected loads.
 - a. Larger-capacity units, or multiple units, shall be provided for systems with larger connected loads.
 - b. UPS shall provide 5 minutes of battery power.
3. Performance:
 - a. Input Voltage: Single phase, 120-V ac, plus 20 to minus 30 percent.
 - b. Power Factor: Minimum 0.97 at full load.
 - c. Output Voltage: Single phase, 120-V ac, within 3 percent, steady state with rated output current of 10.0 A, 30.0-A peak.
 - d. Inverter overload capacity shall be minimum 150 percent for 30seconds.
 - e. Recharge time shall be a maximum of eight hours to 90 percent capacity.
4. UPS bypass shall be automatic during fault or overload conditions.
5. UPS shall include dry contacts (digital output points) for low battery condition and battery-on (primary utility power failure) and connect the points to the DDC system.
6. Batteries shall be sealed lead-acid type and be maintenance free.
7. Include tower models installed in ventilated cabinets or rack models installed on matching racks, as applicable to the particular installation location and space availability/configuration.

2.17 CONTROL WIRE AND CABLE

- A. Wire: Single conductor control wiring above 24 V.
 1. Wire size shall be at least No. 14 AWG or sized per length of run.
 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 or sized per length of run.
 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 or sized per length of run.
 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. 100BASE-TX, 1000BASE-T, or 1000BASE-TX.
 - b. TIA/EIA 586, Category 6.
 - c. Minimum No. 22 AWG solid or sized per length of run.
 - d. Shielded Twisted Pair (STP).
 - e. Thermoplastic insulated conductors, enclosed in a thermoplastic outer jacket, Class CMP as plenum rated.

2.18 RACEWAYS FOR CONTROL WIRING, CABLING, 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. EMT: Comply with NEMA ANSI C80.3 and UL 797.
 3. 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.

2.19 CONTROL POWER WIRING AND RACEWAYS

- A. Installation minimum requirements:
 1. Mechanical spaces, services spaces, and areas without ceiling: All wiring including cables in EMT.
 2. Space sensors and alarms: All wiring cables in EMT within wall construction.
 3. Ducted ceiling return: Approved non-plenum cable.
 4. Non-ducted return ceiling plenum: Approved plenum rated cable.
 5. Non-accessible ceilings: EMT or code compliant equal solid conduit.
 6. Inside air handling units: All wiring including cables in EMT or code compliant solid conduit.
 7. Note the use of cable is limited to low voltage service with less than 24 volt only.
 8. Do not lay cables on ceiling grids.
 9. Conduit junctions and terminations shall utilize compression fittings.
- B. All control wiring that is stated to be routed in EMT shall be separate from any power wiring.

2.20 FIELD EQUIPMENT

- A. Space Sensors:
 1. See space sensor schedule on drawings.
 2. Set-point adjustment to be a maximum plus and minus 5 degrees from the null setpoint programmed through the DDC system.
 3. Space sensors may be (RTD) 1,000 Ohm platinum with an accuracy of ± 0.5 deg F or 10,000 OHM thermistor with accuracy of ± 0.5 deg. F for all spaces.
 4. Space sensor shall be manufacture's standard color.
 5. Provide insulating bases for all sensors located on exterior walls and on exterior column wraps. Foam seal cavity and junction box prior to installing insulating base.
 6. Space sensors with occupant set-point adjustment shall be adjustable from the operator's workstation as to the deadband of adjustability allowed to the occupants.
- B. Temperature Sensors:
 1. Duct sensors for critical spaces shall utilize averaging elements, 1000 OHM platinum Resistance Temperature Detectors (RTD) having an accuracy of ± 0.5 deg F.
 2. Duct sensors for non-critical spaces may utilize 10,000 OHM or 20,000 OHM thermistor having an accuracy of ± 1.0 deg F. 1000 OHM RTDs are also acceptable for non-critical applications.
 3. Immersion sensors to be furnished with companion wells separable stainless steel. Well pressure rating shall be consistent with and extend the system pressure it will be immersed in. Wells shall withstand pipe design flow velocities.
- C. Low limit thermostats:

1. Low limit safety thermostats shall be manually reset, line voltage with maximum 23'-0" flexible sensing elements responsible to lowest temperature along entire length. Furnish minimum two (2) wired in series on the discharge side of the first hydronic coils (i.e., a 4-section coil requires eight low limit thermostats wired in series). Contractor to note that the operating head of such instruments shall be shielded from conditions whereby it could be activated by low temperature.
2. All flexible averaging sensors shall be attached by wire ties to a suspended wire or insulated cable to prevent sensor contact with metal or other unit components.
3. Install flexible sensors across all coils at a maximum of 6" from the bottom of the bottom coil and a minimum of 7" diameter to turn the sensor. Install the detector with a maximum free distance of 12" between each pass.
4. Staggered coils (if applicable) shall utilize multiple sensors. Each sensor shall cover one section of the staggered coil. Sensing elements shall be a minimum of 17' long.
5. All flexible sensors shall be protected at point of penetration of unit via a section of poly tubing to prevent contact of the sensor and the unit.
6. Mount detector within 6" of the face of the coil unless noted otherwise. For staggered coil banks, this requirement applies for each half of the bank
7. TCC to note that when any low limit controls are above an elevation 7'-0" above floor level or otherwise inaccessible, they shall employ automatic reset and shall be wired to an auxiliary control panel of a 5'-0" elevation. The control panel with piano hinged door shall utilize a latching reset relay for each individual low limit control which ensures that the fan is de-energized even as the low limit resets automatically. The panel face shall utilize a red alarm pilot light that remains lit until the 10 second time delay reset relay momentary contact switch is activated. An LED inside the panel shall indicate which of low limits has signaled the alarm.

D. Electronic Actuators:

1. Manufactured, brand labeled or distributed by Belimo or Johnson Controls, Inc. or Siemens.
2. Size for torque required for damper seal at load conditions.
3. Coupling: V-bolt dual nut clamp with a V-shaped, toothed cradle.
4. Mounting: Actuators shall be direct shaft mount type. Actuators shall be capable of being mechanically and electrically paralleled to increase torque if required.
5. Overload protected electronically throughout rotation.
6. Fail safe operation: Mechanical, spring return mechanism.
7. Power requirements (spring return): 24 VAC.
8. Proportional actuators shall be fully programmable through an EEPROM without the use of actuator mounted switches.
9. Temperature rating: -22 deg. F to +122 deg. F.
10. Housing: Minimum requirement NEMA Type 2/IP54 mounted in any orientation. NEMA 4/4X (IP67) required for outdoor applications.
11. Agency listings: ISO 9001 or UL.
12. The manufacturer shall warrant all components for a period of 5 years from the date of production with the first two years unconditional.
13. All damper actuators used on equipment introducing outdoor air shall be furnished with mechanical spring return mechanism as indicated in "fail safe operation" above.
14. All actuators shall have external adjustable stops to limit the travel in either direction and a gear release to allow manual positioning.
15. Actuators shall be provided with position feedback signal (2-10 VDC or 4-20 mA) where indicated on control drawings. Feedback signal shall be independent of the input signal and shall provide true position indication.

E. Dampers:

1. All automatic dampers furnished by this Contractor for modulating control shall be of the proportioning type with opposed or parallel blades depending on the application or as shown on the drawings. Dampers for two position action shall be of the opposed blade type for all applications except those located immediately at the inlet of fans and as noted

- otherwise on the drawings. Dampers for generator radiator fan exhaust shall be opposed blade type.
2. All dampers for outdoor air service and exhaust air service to be equivalent to TAMCO Series 9000 aluminum and have the following features:
 - a. Frames shall be 4" deep X 1" and no less than .080" in thickness, mill finish extruded aluminum 6063-T5 with mounting flanges on both sides of the frame. Frame to be assembled using plated steel mounting fasteners.
 - b. Entire frame shall be thermally broken by means of two polyurethane resin pockets complete with thermal cuts.
 - c. Blades shall be extruded aluminum 6063-T5, mill finish air foil profiles, internally insulated with expanded polyurethane foam and shall be thermally broken.
 - d. Blade and frame seals shall be of extruded silicone and shall be secured in an integral slot within the aluminum extrusions. Blade and frame seals are to be mechanically fastened to eliminate shrinkage and movement over the life of the damper. Adhesive or clip on type blade seals shall not be approved. Jamb seals shall be silicone.
 - e. Maintenance free bearings are to be composed of an inner bearing fixed to a 7/16" aluminum hexagon blade pivot pin, rotating within a polycarbonate outer bearing inserted into the frame. There shall be no metal-to-metal or metal-to-plastic contact.
 - f. Adjustable 7/16" hexagonal drive rod, U-bolt fastener and hexagonal retaining nuts shall be corrosion resistant, zinc plated steel to provide positive connection to blades and linkage.
 - g. Linkage hardware shall be installed in the frame side. All linkage crank arm and rod hardware parts shall be constructed of mill finished aluminum, complete with corrosion resistant, zinc plated trunnions and cup point trunnion screws for a slip-proof grip.
 - h. Dampers are to be designed for operation in temperatures ranging between -40 deg. F (-40 deg. C) and 212 deg. F (100 deg. C).
 - i. Dampers shall be rated Leakage Class 1A at 1 in. w.g. (0.25 kPa) static pressure differential. Standard air leakage data shall be certified under the AMCA Certified Ratings Program.
 - j. Dampers shall be made to size required without blanking off free area.
 - k. Dampers shall be available as "flanged to duct" mounting type.
 - l. Installation of dampers must be in accordance with manufacturer's installation guidelines provided with each damper shipment.
 - m. Intermediate or tubular steel structural support is required to resist applied pressure loads for dampers that consist of two or more sections in both height and width. (See manufacturer's installation guidelines).
 3. Dampers for all other applications to be equal to TAMCO Series 1500 Ultra Low Leakage Air Foil Aluminum and have the following features:
 - a. Frames shall be 4" deep X 1" and no less than .080" in thickness, mill finish extruded aluminum 6063-T5 with mounting flanges on both sides of the frame. Frame to be assembled using plated steel mounting fasteners.
 - b. Entire frame shall be thermally broken by means of two polyurethane resin pockets complete with thermal cuts.
 - c. Blades shall be extruded aluminum 6063-T5, mill finish air foil profiles, internally insulated with expanded polyurethane foam and shall be thermally broken.
 - d. Blade and frame seals shall be of extruded silicone and shall be secured in an integral slot within the aluminum extrusions. Blade and frame seals are to be mechanically fastened to eliminate shrinkage and movement over the life of the damper. Adhesive or clip on type blade seals shall not be approved.
 - e. Maintenance free bearings are to be composed of an inner bearing fixed to a 7/16" aluminum hexagon blade pivot pin, rotating within a polycarbonate outer bearing inserted into the frame. There shall be no metal-to-metal or metal-to-plastic contact.
 - f. Adjustable 7/16" hexagonal drive rod, U-bolt fastener and hexagonal retaining nuts shall be corrosion resistant, zinc plated steel to provide positive connection to blades and linkage.

- g. Linkage hardware shall be installed in the frame side. All linkage crank arm and rod hardware parts shall be constructed of mill finished aluminum, complete with corrosion resistant, zinc plated trunnions and cup point trunnion screws for a slip-proof grip.
 - h. Dampers are to be designed for operation in temperatures ranging between -40 deg. F (-40 deg. C) and 212 deg. F (100 deg. C).
 - i. Dampers shall be rated Leakage Class 1A at 1 in. w.g. (0.25 kPa) static pressure differential. Standard air leakage data shall be certified under the AMCA Certified Ratings Program.
 - j. Dampers shall be made to size required without blanking off free area.
 - k. Dampers shall be available with either opposed blade action or parallel blade action.
 - l. Dampers shall be available as "flanged to duct" mounting type.
 - m. Installation of dampers must be in accordance with manufacturer's installation guidelines provided with each damper shipment.
 - n. Intermediate or tubular steel structural support is required to resist applied pressure loads for dampers that consist of two or more sections in both height and width. (See manufacturer's installation guidelines).
4. Automatic dampers (modulating) shall be designed for face velocity that varies from 1,200 fpm to 2,000 fpm in most cases as approved by the design engineer. Dampers to be selected by the supplier with blade shaft lengths that prevent torsion that will create a leakage of more than 2 percent of the rated leakage capacity. Beyond that point, the dampers shall be broken into multiple sections. Field supplied mullions are required on large dampers exceeding 200 square feet.
 5. Individual damper section actuators are preferred unless access to actuators is difficult and then jack shafting is acceptable. TCC to note that drive shafts between dampers of different air paths (i.e., outdoor air and return air or return air and exhaust air) is not acceptable. Jack shafting between sections is permitted when such shafting is designed to accommodate and eliminate the effects of torsion.
 6. TCC to note that free access to all actuators is the responsibility of the TCC.
 7. Each damper shall be equipped with an individual damper operator of the size and style required for the service intended.
 8. Actuators to be designed for modulating control with spring return to the fail "safe" position. Actuators to be low voltage with 100% surplus torque (submittals to incorporate calculations to prove 100 percent closure under 4.0" wg status pressure differential for modulating service and 2.0" wg for two position application).
 9. Terminal box/AFCV damper actuators to be low voltage, non-spring return and incremental control with 200 percent torque. All control actuators to utilize auto zero program to insure total accuracy of damper actuator. The feature to be activated during periods of low or no occupancy.
- F. Insertion Turbine Flow Meters for Closed Loop Condenser Water:
1. Provide dual turbine flow meter complete with all installation hardware necessary to enable insertion and removal of the meter without system shutdown. The flow meter shall be hand insertable up to 400 psi. The flow meter shall have two contra-rotating axial turbines, with electronic impedance-based sensing and an averaging circuit to reduce measurement errors due to swirl and flow profile distortion.
 2. The flow meter shall be installed in accordance with the manufacturer's installation guide including meter orientation and straight pipe recommendations.
 3. Wetted metal components shall be nickel-plated brass for applications operating below 250 degrees F, 316L SS construction for DW applications, HTHW applications operating over 250 degrees F, and for any application in non-metallic pipe. The maximum operating temperature shall be 280 degrees F, 300 F peak.
 4. Each flow meter shall be individually wet-calibrated against a primary volumetric standard that is accurate to within 0.1% and traceable to NIST. The manufacturer's certificate of calibration shall be provided with each flow meter.

5. Accuracy shall be within $\pm 0.5\%$ of rate at the calibrated velocity, within $\pm 1\%$ of rate over a 10:1 turndown (3.0 to 30 ft/s) and within $\pm 2\%$ of rate over a 50:1 turndown (from 0.4 to 20 ft/s).
 6. The flow meter shall include integral analog output(s), 4-20 mA, 0-10V, or 0-5V, and a high resolution frequency output for use with peripheral devices (remote display or BTU Meter). FB-1210 for Bi-directional applications shall include an isolated contact closure output for direction.
 7. The flow meter shall be covered by the manufacturer's three-year warranty.
 8. Turbine meter shall be ONICON Incorporated Model F-1210 Dual Turbine, or equivalent as approved by the Engineer.
- G. Energy BTU Measurement System:
1. The entire energy BTU measurement system shall be built and calibrated by a single manufacturer and shall consist of a flow meter, two temperature sensors, a BTU meter, temperature thermowells, and all required mechanical installation hardware. The BTU meter and associated sensors and flow meter shall be installed in accordance with the manufacturer's installation guide.
 2. The BTU meter shall provide the following points both at the integral LCD and as outputs to the building control system: Energy total, Energy rate, flow rate, supply temperature and return temperature. Output signals shall be either serial network (protocol conforming to BACnet[®] MS/TP, JCI-N2, MODBUS RTU, MODBUS TCP, or Siemens-P1) and/or via individual analog and pulse outputs.
 3. Each BTU meter shall be factory programmed and tagged for its specific application, and shall be re-programmable using the front panel keypad (no special interface device or computer required).
 4. Temperature sensors shall be loop-powered current based (mA) sensors and shall be bath-calibrated and matched (NIST traceable) for the specific temperature range for each application. The calculated differential temperature used in the energy calculation shall be accurate to within $\pm 0.15^\circ\text{F}$ (including the error from individual temperature sensors, sensor matching, input offsets, and calculations).
 5. A certificate of NIST traceable calibration shall be provided with each system.
 6. Flow meter shall be in accordance with paragraph A, B, C, or D, refer to meter schedule for specific flow meter type.
 7. All equipment shall be covered by the manufacturer's three-year warranty.
 8. Energy BTU measurement system shall be ONICON Incorporated System-10 BTU Meter, or equivalent as approved by the Engineer.
- H. Differential Pressure Transmitter:
1. Liquid: Furnish field mounted differential pressure transmitters as indicated on plans for measuring differential pressure and transmitting an isolated 4 to 20 mA DC output linear differential pressure signal.
 - a. The unit shall be accurate to $\pm 0.20\%$ of calibrated span. It shall withstand static pressures of 1000 psig with negligible change in output. The flanges shall be made of stainless steel with stainless steel wetted sensing components, wetted parts all stainless steel and a silicone fill fluid. A brass or stainless 3 valve bypass manifold and bracket mounting kit shall be utilized for easier on-site equalization and calibration. Unit shall be protected against radio frequency interference and shall have a water-tight (NEMA Type 4) electrical enclosure with 1/2" NPT conduit connection. An LCD display is not required.
 - 1) The Type A transmitter shall be a standard process grade loop powered transmitter as manufactured by:
 - a) Rosemount Model 3051C.
 - b) Foxboro Model IDP10.
 - c) Yokogawa Model EJA110A.
 2. Air: Furnish field mounted differential pressure transmitters using a 4-20 mA (or 0-10 VDC) output linear with measured differential pressure. Accuracy shall be $\pm 0.8\%$ of calibrated

span. Response time shall be 250 milliseconds. Transmitter shall be in a standard grade transmitter manufactured by Ashcroft or Setra.

- I. Airflow Measuring Stations:
 1. All air flow measuring stations to be furnished under this contract as shown on control schematics and as scheduled.
 - a. Approved manufacturers are Tek-Air Systems, Air Monitor, Paragon, Ebtron, Farr, and Airflow Wing.
 2. Duct-mounted stations shall be installed by the Sheet Metal Contractor while fan inlet station installation responsibility shall be by this Contractor.
 3. Sizing and physical location of stations shall be the responsibility of this Contractor. TCC to ensure that sufficient distance is available both upstream and downstream such that turbulence is not a factor in the velocity pressure measurement. Sizing shall insure that the minimum velocity across the station affords accuracy of measurement and the design engineer shall be notified within 30 days of contract award if any modifications are required to the field ductwork.
 4. TCC to ensure that a proper access door upstream of the station is provided in the ductwork such that the inlet face of the unit may be cleaned as necessary.
 5. Duct-mounted air flow measuring stations:
 - a. Furnish and install air flow measuring stations constructed of 16 gage sheet metal casing and a copper velocity pressure traverse section.
 - b. The velocity pressure traverse section shall consist of air straightening tubes, total pressure sensors and static pressure sensors, all interconnected to form a traverse by copper manifolds which shall equalize and integrate each type sensor measurement into one (1) total pressure and one (1) static pressure metering port. There shall be one static pressure sensor for each total pressure sensor.
 - c. A minimum of one static and one total pressure sensor shall be used for every 16 square feet in cross section. For larger ducts, a minimum of one static and one total pressure sensor shall be used for every 36" of duct cross sectional area up to a maximum as recommended by ASHRAE guide for traverse measurement.
 - d. Identification: Each air flow measuring station shall have a nameplate with the following information:
 - 1) Unit size.
 - 2) Unit designation.
 - 3) Design air quantity.
 - 4) Direction of air flow.
 - 5) Design air velocity.
 6. Fan inlet air flow sensing (non-intrusive piezometer type):
 - a. Accuracy: Within 2% throughout the velocity range of 600 fpm and over, when installed in accordance with published recommendations
 - b. Temperature: 350 deg F continuous operation; 400 deg F intermittent operation
 - c. Humidity: 0-100% continuous operation
 - d. Corrosion resistance: Good salt air and mild acid resistance, excellent solvent and aromatic hydrocarbon resistance
 - e. Material: 6063-T5 anodized aluminum, galvanized mounting brackets
- J. Thermal Dispersion Air Flow Measurement:
 1. Air volume measurement system to consist of multiple sensors designed to average velocity using thermal dispersion principles. System to be designed to be totally independent of temperature, density, and humidity. Tek-Air or Ebtron.
 2. The quantity of sensing tubes shall conform to manufacturer's requirements for spacing based on the specified accuracy and the actual inlet and outlet conditions.
 3. Unit to be accurate to 1.5% between 50 fpm and 6000 fpm. Output to be 4-20 mA.
- K. VAV/CAV Terminal Unit Control Components (DDC Control):

Component	Furnished By	Installed By	Wired By
Disconnect Switch	Manufacturer	Manufacturer	Manufacturer
Transformer	TCC	Manufacturer	Manufacturer
Damper Actuator	TCC	Manufacturer	Manufacturer
Flow Controller	TCC	Manufacturer	Manufacturer
Flow Sensing	Manufacturer	Manufacturer	Manufacturer
Misc Accessories	TCC	TCC	TCC

L. Gas Instruments:

1. Dual Carbon Monoxide (CO) & Nitrogen Dioxide (No2) Sensor and Controller.
 - a. Comply with UL 61010-1.
 - b. Wall mounted.
 - c. 24 VAC power.
 - d. BACnet MS/TP protocol.
 - e. Programmable fan and alarm relays.
 - f. Integrated display with LED indicators for status and adjustable parameters for warning and alarm setpoints.
 - g. Audible alarm.
 - h. 2 analog outputs.
 - i. Field replaceable sensing elements with a 7-year minimum life expectancy on each element.
 - j. Standard water/dust tight, corrosion resistant drip proof enclosure.
 - k. Carbon Monoxide accuracy to be plus or minus 5% between 0-100 ppm and cover up to 7500 SF.
 - l. Nitrogen Dioxide accuracy to be plus or minus 5% between 0-10 ppm and cover up to 7500 SF.
 - m. Include standard 7-year warranty on sensor electronics and 2-year warranty on replaceable elements.
 - n. Similar or equivalent to Senva TG Series.
2. Carbon Monoxide (CO) Sensor and Controller.
 - a. Comply with UL 61010-1.
 - b. Wall mounted.
 - c. 24 VAC power.
 - d. BACnet MS/TP protocol.
 - e. Programmable fan and alarm relays.
 - f. Integrated display with LED indicators for status and adjustable parameters for warning and alarm setpoints.
 - g. Audible alarm.
 - h. 2 analog outputs.
 - i. Field replaceable sensing elements with a 7-year minimum life expectancy on each element.
 - j. Standard water/dust tight, corrosion resistant drip proof enclosure.
 - k. Carbon Monoxide accuracy to be plus or minus 5% between 0-100 ppm and cover up to 7500 SF.
 - l. Include standard 7-year warranty on sensor electronics and 2-year warranty on replaceable elements.
 - m. Similar or equivalent to Senva TG Series.
 - n. Application
 - 1) Locate in any mechanical room with condensing boilers.

M. Control Valves:

1. Source Limitations: Obtain valves from single manufacturer.
2. Selection Criteria:
 - a. Control valves shall be suitable for operation at following conditions:
 - 1) Refer to specification section 232113 – Hydronic Piping for system pressures.
 - b. Fail positions unless otherwise indicated:

- 1) Condenser Water: Open.
- c. In water systems, select modulating control valves for a design Cv based on a pressure drop of:
 - 1) 1 psig for two-position unless otherwise indicated.
 - 2) 5 psig for two way modulating unless otherwise indicated.
 - 3) 5 psig for three way modulating unless otherwise indicated.
- d. Actuators:
 - 1) Actuators for Steam Control Valves: Shutoff against 1.5 times design pressure.

2.21 BALL-STYLE CONTROL VALVES

- A. Ball Valves with Single Port and Characterized Disk:
 - 1. Pressure Rating for NPS 1 and Smaller: Nominal 600 WOG.
 - 2. Pressure Rating for NPS 1-1/2 through NPS 2: Nominal 400 WOG.
 - 3. Close-off Pressure: 200 psig.
 - 4. Process Temperature Range: Zero to 212 deg F.
 - 5. Body and Tail Piece: Cast bronze ASTM B 61, ASTM B 62, ASTM B 584, or forged brass with nickel plating.
 - 6. End Connections: Threaded (NPT) ends.
 - 7. Ball: 300 series stainless steel.
 - 8. Stem and Stem Extension:
 - a. Material to match ball.
 - b. Blowout-proof design.
 - c. Sleeve or other approved means to allow valve to be opened and closed without damaging the insulation or the vapor barrier seal.
 - 9. Ball Seats: Reinforced PTFE.
 - 10. Stem Seal: Reinforced PTFE packing ring with a threaded packing ring follower to retain the packing ring under design pressure with the linkage removed. Alternative means, such as EPDM O-rings, are acceptable if an equivalent cycle endurance can be demonstrated by testing.
 - 11. Flow Characteristic: Equal percentage.
- B. Ball Valves with Two Ports and Characterized Disk:
 - 1. Pressure Rating for NPS 1 and Smaller: Nominal 600 WOG.
 - 2. Pressure Rating for NPS 1-1/2 through NPS 2: Nominal 400 WOG.
 - 3. Close-off Pressure: 200 psig.
 - 4. Process Temperature Range: Zero to 212 deg F.
 - 5. Body and Tail Piece: Cast bronze ASTM B 61, ASTM B 62, ASTM B 584, or forged brass with nickel plating.
 - 6. End Connections: Threaded (NPT) ends.
 - 7. Ball: 300 series stainless steel.
 - 8. Stem and Stem Extension:
 - a. Material to match ball.
 - b. Blowout-proof design.
 - c. Sleeve or other approved means to allow valve to be opened and closed without damaging the insulation or the vapor barrier seal.
 - 9. Ball Seats: Reinforced PTFE.
 - 10. Stem Seal: Reinforced PTFE packing ring with a threaded packing ring follower to retain the packing ring under design pressure with the linkage removed. Alternative means, such as EPDM O-rings, are acceptable if an equivalent cycle endurance can be demonstrated by testing.
 - 11. Flow Characteristics for A-Port: Equal percentage.
 - 12. Flow Characteristics for B-Port: Modified for constant common port flow.

2.22 GLOBE-STYLE CONTROL VALVES

- A. General Globe-Style Valve Requirements:
 - 1. Globe-style control valve body dimensions shall comply with ISA 75.08.01.
 - 2. Construct the valves to be serviceable from the top.

3. For cage guided valves, trim shall be field interchangeable for different valve flow characteristics, such as equal percentage, linear, and quick opening.
 4. Reduced trim for one nominal size smaller shall be available for industrial valves NPS 1 and larger.
 5. Replaceable seats and plugs.
 6. Furnish each control valve with a corrosion-resistant nameplate indicating the following:
 - a. Manufacturer's name, model number, and serial number.
 - b. Body and trim size.
 - c. Arrow indicating direction of flow.
- B. Two-Way Globe Valves NPS 2 and Smaller:
1. Globe Style: Single port.
 2. Body: Cast bronze or forged brass with ASME B16.5, Class 250 rating.
 3. End Connections: Threaded.
 4. Bonnet: Screwed.
 5. Packing: PTFE V-ring.
 6. Plug: Top guided.
 7. Plug, Seat, and Stem: stainless steel.
 8. Process Temperature Range: 35 to 248 deg F.
 9. Ambient Operating Temperature: 35 to 150 deg F.
 10. Leakage: FCI 70-2, Class IV.
 11. Rangeability: 25 to 1.
 12. Equal percentage flow characteristic.
- C. Three-Way Globe Valves NPS 2 and Smaller:
1. Globe Style: Mix flow pattern.
 2. Body: Cast bronze or forged brass with ASME B16.5, Class 250 rating.
 3. End Connections: Threaded.
 4. Bonnet: Screwed.
 5. Packing: PTFE V-ring.
 6. Plug: Top guided.
 7. Plug, Seat, and Stem: stainless steel.
 8. Process Temperature Range: 35 to 248 deg F.
 9. Ambient Operating Temperature: 35 to 150 deg F.
 10. Leakage: FCI 70-2, Class IV.
 11. Rangeability: 25 to 1.
 12. Linear flow characteristic.
- D. Two-Way Globe Valves NPS 2-1/2 to NPS 6:
1. Globe Style: Single port.
 2. Body: Cast iron complying with ASME B61.1, Class 125.
 3. End Connections: Flanged, suitable for mating to ASME B16.5, Class 150 flanges.
 4. Bonnet: Bolted.
 5. Packing: PTFE cone-ring.
 6. Plug: Top or bottom guided.
 7. Plug, Seat, and Stem: Brass or stainless steel.
 8. Process Temperature Rating: 35 to 281 deg F.
 9. Leakage: 0.1 percent of maximum flow.
 10. Rangeability: Varies with valve size between 6 and 10 to 1.
 11. Modified linear flow characteristic.

2.23 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.

2.24 IDENTIFICATION

- A. Instrument Air Pipe and Tubing:
 - 1. Engraved tag shall bear the following information:
 - a. Service (Example): "Instrument Air."
 - b. Pressure Range (Example): 0 to 30 psig.
 - 2. Letter size shall be a minimum of 0.25 inch high.
 - 3. Tag shall consist of white lettering on blue background.
 - 4. Tag shall be engraved phenolic consisting of three layers of rigid laminate. Top and bottom layers are color-coded blue with contrasting white center exposed by engraving through outer layer.
 - 5. Include tag with a brass grommet, chain and S-hook.
- B. 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. Operator Workstations: Minimum of 0.5 inch high.
 - b. Printers: Minimum of 0.5 inch high.
 - c. DDC Controllers: Minimum of 0.5 inch high.
 - d. Gateways: Minimum of 0.5 inch high.
 - e. Repeaters: Minimum of 0.5 inch high.
 - f. Enclosures: Minimum of 0.5 inch high.
 - g. Electrical Power Devices: Minimum of 0.25 inch high.
 - h. UPS units: Minimum of 0.5 inch high.
 - i. Accessories: Minimum of 0.25 inch high.
 - j. Instruments: Minimum of 0.25 inch high.
 - k. Control Damper and Valve Actuators: Minimum of 0.25 inch 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.
- C. Valve Tags:
 - 1. Brass tags and brass chains attached to valve.
 - 2. Tags shall be at least 1.5 inches diameter.
 - 3. Include tag with unique valve identification indicating control influence such as flow, level, pressure, or temperature; followed by location of valve, and followed by three-digit sequential number. For example: TV-1.001.
 - 4. Valves with Project-specific identification tags having unique identification numbers following requirements indicated and provided by original manufacturer do not require an additional tag.
- D. 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."

- E. 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 beyond white border.

2.25 SOURCE QUALITY CONTROL

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

PART 3 EXECUTION

3.01 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.

3.02 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. Air-terminal units specified in Section 233600 "Air Terminal Units."
 - b. Boilers specified in Section 235216 "Condensing Boilers."
 - c. Chillers specified in Section 236416 "Centrifugal Water Chillers."
 - d. Cooling towers specified in Section 236514.14 "Cooling Towers."
 - e. Air-handling units specified in Section 237313 "Modular Indoor Central-Station Air-Handling Units."
 - f. Ductless Splits in Section 238126 "Split-System Air-Conditioners."
 - g. Refrigerator and Freezer/Coolers – see KEC plans.
 - h. Switchboards specified in Section 262300 "Low-Voltage Switchgear."
 - i. Motor-control centers specified in Section 262419 "Motor-Control Centers."
 - j. Variable-frequency controllers specified in Section 262923 "Variable-Frequency Motor Controllers."
 - k. Generator sets specified in Section 263213 "Engine Generators."
 - l. UPS specified in Section 263353 "Static Uninterruptible Power Supply."
 - m. Refrigerant monitoring.
- 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. Automated water treatment systems specified in Section 232500 "HVAC Water Treatment."

- b. Power monitoring specified in Section 260913 "Electrical Power Monitoring and Control."
- c. Lighting controls specified in Section 260943.23 "Relay-Based Lighting Controls."
- d. Fire-alarm system specified in Section 283111 "Digital, Addressable Fire Alarm System."
- e. Access controls specified in Section 281300 "Access Control."

3.03 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 when subjected to a force.
- 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.
- K. Corrosive Environments:
 - 1. Avoid or limit use of materials in corrosive airstreams and environments, including, but not limited to, the following:
 - a. Laboratory exhaust-air streams.
 - b. Process exhaust-air streams.
 - 2. When conduit is in contact with a corrosive airstream and environment, use Type 316 stainless-steel conduit and fittings or conduit and fittings that are coated with a corrosive-resistant coating that is suitable for environment. Comply with requirements for installation of raceways and boxes specified in Section 260533 "Raceways and Boxes for Electrical Systems."
 - 3. Where instruments are located in a corrosive airstream and are not corrosive resistant from manufacturer, field install products in NEMA 250, Type 4X enclosure constructed of Type 316L stainless steel.

3.04 OPERATOR WORKSTATION INSTALLATION

- A. Desktop Operator Workstations Installation:
 - 1. Install operator workstation(s) at location(s) directed by Owner.
 - 2. Install multiple-receptacle power strip with cord for use in connecting multiple workstation components to a single duplex electrical power receptacle.

3. Install software on workstation(s) and verify software functions properly.
 4. Develop Project-specific graphics, trends, reports, logs and historical database.
 5. Power workstation through a UPS unit. Locate UPS adjacent to workstation.
- B. Portable Operator Workstations Installation:
1. Turn over portable operator workstations to Owner at Substantial Completion.
 2. Install software on workstation(s) and verify software functions properly.
- C. Color Graphics Application:
1. Use system schematics indicated as starting point to create graphics.
 2. Develop Project-specific library of symbols for representing system equipment and products.
 3. Incorporate digital images of Project-completed installation into graphics where beneficial to enhance effect.
 4. Submit sketch of graphic layout with description of all text for each graphic for Owner's review before creating graphic using graphics software.
 5. Seek Owner input in graphics development once using graphics software.
 6. Final editing shall be done on-site with Owner's review and feedback.
 7. Refine graphics as necessary for Owner acceptance.
 8. On receiving Owner acceptance, print a hard copy for inclusion in operation and maintenance manual. Prepare a scanned copy PDF file of each graphic and include with softcopy of DDC system operation and maintenance manual.

3.05 GATEWAY INSTALLATION

- A. Install gateways if required for DDC system communication interface requirements indicated.
 1. Install gateway(s) required to suit indicated requirements.
- B. Test gateway to verify that communication interface functions properly.

3.06 ROUTER INSTALLATION

- A. Install routers if required for DDC system communication interface requirements indicated.
 1. Install router(s) required to suit indicated requirements.
- B. Test router to verify that communication interface functions properly.

3.07 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 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 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.

3.08 ENCLOSURES INSTALLATION

- A. Install the following items in enclosures, to comply with indicated requirements:
 1. Gateways.
 2. Routers.

3. Controllers.
 4. Electrical power devices.
 5. UPS units.
 6. Relays.
 7. Accessories.
 8. Instruments.
 9. Actuators
- B. Attach wall-mounted enclosures to wall using the following types of steel struts:
1. For NEMA 250, Type 1 Enclosures: Use galvanized-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 of like size.
- D. Install floor-mounted enclosures located in mechanical equipment rooms on concrete housekeeping pads. Attach enclosure legs using galvanized steel anchors.
- E. 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.

3.09 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.

3.10 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. Operator workstation.
 2. Printer.
 3. Gateway.
 4. Router.
 5. DDC controller.
 6. Enclosure.
 7. Electrical power device.
 8. UPS unit.
 9. 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.

3.11 NETWORK INSTALLATION

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

3.12 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 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.

3.13 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 and cable trays except in accessible ceiling spaces and in gypsum board partitions where unenclosed wiring method may be used. 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, 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 separation where conduits run axially above or below ducts and pipes.
 - 4. Limit above-grade conduit runs to 100 feet 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 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.
 - 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 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 long not less than 12 inches 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.
- 2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 12 inches.
- 3) Electrical Equipment Rating More Than 5 kVA: A minimum of 24 inches.
- 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.
 - 2) Electrical Equipment Rating between 2 and 5 kVA: A minimum of 6 inches.
 - 3) Electrical Equipment Rating More Than 5 kVA: A minimum of 12 inches.
- 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.
 - 3) Electrical Equipment Rating More Than 5 kVA: A minimum of 6 inches.
- e. Separation between Cables and Electrical Motors and Transformers, 5 kVA or 5 HP and Larger: A minimum of 48 inches.
- f. Separation between Cables and Fluorescent Fixtures: A minimum of 5 inches.

3.14 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 with the assistance of a factory-authorized service representative:
 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.
 3. Testing of Pneumatic and Air-Signal Tubing:
 - a. Test for leaks and obstructions.
 - b. Disconnect each pipe and tubing line before a test is performed, and blowout dust, dirt, trash, condensate and other foreign materials with compressed air. Use commercially pure compressed air or nitrogen as distributed in gas cylinders. Air from an oil-free compressor with an air dryer is an acceptable alternative for the test.
 - c. After foreign matter is expelled and line is free from obstructions, plug far end of tubing run.
 - d. Connect a pressure source to near end of run with a needle valve between air supply and tubing run.
 - e. Connect a pressure gage accurate to within 0.5 percent of test between the shutoff needle valve and tubing run under test.
 - f. For system pressures above 30 psig, apply a pressure of 1.5 times operating pressure. Record pressure in tubing run every 10 minutes for one hour. Allowable drop in pressure in one-hour period shall not exceed 1 psig.
 - g. For system pressures 30 psig and below, apply a pressure of 2.0 times operating pressure to piping and tubing run. Record pressure in tubing run every 5 minutes for one hour. Allowable drop in pressure in one-hour period shall not exceed 0.5 psig.
- 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.

3.15 DDC SYSTEM I/O CHECKOUT PROCEDURES

- A. Check installed products before continuity tests, leak 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. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material and support.
- E. For pneumatic products, verify that air supply for each product is properly installed.
- F. 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.
- G. Control Valve Checkout:
 1. For pneumatic valves, verify that pressure gages are provided in each air line to valve actuator and positioner.
 2. Verify that control valves are installed correctly for flow direction.
 3. Verify that valve body attachment is properly secured and sealed.
 4. Verify that valve actuator and linkage attachment is secure.
 5. Verify that actuator wiring is complete, enclosed and connected to correct power source.
 6. Verify that valve ball, disc or plug travel is unobstructed.
 7. 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.
- H. 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 instruments with tubing connections, verify that tubing attachment is secure and isolation valves have been provided.
 7. For flow instruments, verify that recommended upstream and downstream distances have been maintained.
 8. For temperature instruments:
 - a. Verify sensing element type and proper material.
 - b. Verify length and insertion.

3.16 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. Stroke control dampers with pilot positioners. Adjust damper and positioner following manufacturer's recommended procedure, so damper is 100 percent closed, 50 percent closed and 100 percent open at proper air pressure.
 - 3. Check and document open and close cycle times for applications with a cycle time less than 30 seconds.
 - 4. 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. Stroke control valves with pilot positioners. Adjust valve and positioner following manufacturer's recommended procedure, so valve is 100 percent closed, 50 percent closed and 100 percent open at proper air pressures.
 - 3. Check and document open and close cycle times for applications with a cycle time less than 30 seconds.
 - 4. 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.

3.17 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.

3.18 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.

3.19 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.

3.20 FINAL REVIEW

- A. Submit written request to Architect and 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 Architect and 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 Each 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 each 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. Modifications are made with messages and write services initiated by an operator using workstation graphics, or by completing a field in a menu with instructional text.
- 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.

3.21 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.

3.22 MAINTENANCE SERVICE

- A. Maintenance Service: Beginning at Substantial Completion, maintenance service shall include 12-month full maintenance by DDC system manufacturer's authorized service representative. Include quarterly 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.

3.23 SOFTWARE SERVICE AGREEMENT

- A. Technical Support: Beginning at Substantial Completion, service agreement shall include software support for one year(s).
- B. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within one year 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.

3.24 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.
 3. Minimum Training Requirements:
 - a. Provide not less than 24 hours of training total.
 - b. Stagger training over multiple training classes to accommodate Owner's requirements. All training shall occur before end of warranty period.
 - c. Total days of training shall be broken into not more than five separate training classes. Coordinate with owner.
- C. Training Schedule:
1. Schedule training with Owner 20 business days before expected Substantial Completion.
 2. Schedule training to provide Owner with at least 15 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. 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.
- F. 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.
- G. 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.
- H. 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.
- I. 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.
- J. 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.
- K. 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.
- L. 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.
- M. 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

SECTION 26 33 53
STATIC UNINTERRUPTIBLE POWER SYSTEM

PART 1 GENERAL

1.01 SUMMARY

- A. These specifications describe requirements for an Uninterruptible Power System (UPS) optimized for maximum efficiency. The UPS shall automatically maintain AC power to the critical load within specified tolerances and without interruption during failure or deterioration of the normal power source.
- B. The manufacturer shall design and furnish all materials and equipment to be fully compatible with electrical, environmental and space conditions at the site. The UPS shall include all equipment to properly interface the AC power source to the intended load and shall be designed for unattended operation.

1.02 STANDARDS

- A. The UPS and all associated equipment and components shall be manufactured in accordance with the following applicable standards:
 - 1. The UPS shall be UL listed per UL Standard 1778, Fifth Edition, Uninterruptible Power Supplies, and shall be CSA certified.
 - 2. The UPS shall be provided with a Short Circuit Withstand Rating (SCWR) label denoting the maximum source fault short circuit current that is applicable to the unit. The withstand rating shall be independently verified by a nationally recognized, third-party lab.
 - 3. The UPS shall withstand input surges to both the rectifier and bypass when configured as either a single-input or dual-input unit without damage as per the criteria in EN62040-2 (4kV). The manufacturer shall provide evidence of compliance upon request.
 - 4. The UPS shall comply with FCC Rules and Regulations, Part 15, Subpart J, Class A. This compliance is legally required to prevent interference with adjacent equipment. The UPS shall have a label stating FCC compliance. The manufacturer shall provide evidence and test data of compliance upon request.
 - 5. The UPS shall be compatible with the wiring practices, materials and coding in accordance with the requirements of the National Electrical Code, OSHA and applicable local codes and standards. Provisions shall be made in the cabinets to permit installation of input, output and external control cabling using raceway or conduit for top and bottom access to input, output, bypass and DC connections. Connection cabinets shall provide for wiring gutter and wire bend radius as defined by the NEC and UL.
 - 6. The UPS classification shall be VFI-SS-111 per the criteria in IEC EN62040-3.
 - 7. The UPS shall comply with the Energy Star program requirements for Uninterruptible Power Supplies (UPSs) – eligibility criteria, version 2.0.
 - 8. The UPS and matching Battery Cabinets shall be seismically certified in accordance with the 2015 International Building Code (IBC), 2016 California Building Code (CBC), and American Society of Civil Engineers (ASCE) Minimum Design Loads, with seismic performance of $S_{ds}=1.93$, $I_p=1.5$ and $z/h=1.0$. Optional seismic brackets shall be available from the UPS manufacturer for use in compliance with this certification.

1.03 SYSTEM DESCRIPTION

- A. Design Requirements
 - 1. The UPS shall be sized to provide a minimum of 40kW output (unity load power factor rating)
 - 2. The UPS output capacity shall have the option to enable scalability at the time of ordering and shall be upgradeable by Vertiv Services.
 - 3. The UPS shall have the option to configure the system for N+1 internal redundancy at the time of order.
 - 4. The UPS shall be able to supply all required power to full rated output kVA loads with power factor from 0.5 lagging to 0.9 leading. The UPS shall also work from unity power factor to 0.5 leading power factors subject to derating.
 - 5. Load voltage and bypass line voltage shall be 208VAC, three-phase, four-wire plus ground. Input voltage shall be 208VAC, three-phase, four-wire plus ground. The AC input source and bypass input source shall each be a solidly grounded wye service.
 - 6. The battery shall support the UPS at 100% rated kW load for at least 20-30 minutes at 77°F

- (25°C) at startup.
7. The UPS shall have an active power factor-corrected IGBT converter/rectifier, capable of maintaining input power factor and input current total harmonic distortion (THDi) within specifications without an additional input filter.
 8. The UPS shall be of transformer-free design, requiring no internal transformer in the main power path for the basic operation of the module. Optional transformers in cabinets or otherwise external to the basic UPS module shall be permissible to provide isolation and/or voltage transformation.
- B. Modes of Operation
1. The UPS shall operate as an on-line reverse transfer system in the following modes:
 - a. Normal: The critical AC load shall be continuously powered by the UPS inverter. The rectifier/charger shall derive power from the utility AC source and supply DC power to the DC-DC converter, which in turn shall supply the inverter while simultaneously float charging the battery.
 - b. ECO Mode: The critical AC load shall be continuously powered by the bypass with the inverter available to power the load if the bypass source voltage or frequency exceeds adjustable parameters of power quality.
 - c. Battery: Upon failure of utility AC power, the critical load shall be powered by the inverter, which, without any switching, shall obtain its power from the battery plant via the DC-DC converter. There shall be no interruption in power to the critical load upon failure or restoration of the utility AC source.
 - d. Recharge: Upon restoration of the utility AC source, the rectifier shall supply power to the output inverter and to the DC-DC converter, which shall simultaneously recharge the batteries. This shall be an automatic function and shall cause no interruption to the critical load.
 - e. Bypass: If the UPS must be taken out of service, the static transfer switch shall transfer the load to the bypass source. The transfer process shall cause no interruption in power to the critical load.
 - f. Maintenance Bypass: An external wrap-around maintenance bypass shall be used to ensure full isolation of the unit for the service of internal components while providing safety from arc flash and in compliance with OSHA requirements.
 - g. Off-Battery: If the battery only is taken out of service, it shall be disconnected from the DC-DC converter by means of an external disconnect circuit breaker (in the case of external batteries). The UPS shall continue to function and meet all the specified steady-state performance criteria, except for the power outage backup time capability. If multiple battery strings are used, each string shall be capable of being electrically isolated for safety during maintenance.
- C. Performance Requirements
1. The solid-state power components, magnetics, electronic devices and overcurrent protection devices shall operate within the manufacturer's recommended temperature when the UPS is operating at 100% critical load and maintain battery charging under either of the following conditions:
 - a. Any altitude within the specified operating range up to 4922 ft. (1500m) elevation
 - b. Any ambient temperature within the specified operating range of 32°F to 104°F (0°C to 40°C)
- D. Input
1. Voltage: Input/output voltage specifications of the UPS shall be
 2. Rectifier AC Input: 208V, three-phase, four-wire-plus-ground
 3. Bypass AC Input: 208V, three-phase, four-wire-plus-ground
 4. AC Output: 208V, three-phase, four-wire-plus-ground
 5. Voltage Range: +20%, -15% at full load; -40% at half load
 6. Frequency Range: 40 - 70Hz
 7. Maximum Inrush Current: UPS inrush current not to exceed 1.5 times rated input current
 8. Input Current Walk-In: The UPS shall contain a controlled module walk-in to minimize inrush current upon auto-restart. The module walk-in is programmable for a 1 to 5 second delay.

9. Power Factor: Minimum 0.99 at full load with nominal input voltage
10. Current Distortion: Less than or equal to 5% input current THDi at full load input current in double-conversion mode (nominal input voltage, <1% input voltage THDv, and <1% input voltage imbalance)
11. Surge Protection: Sustains input surges of 6kV without damage per criteria listed in IEEE C62.41, Category A, Level 3 and Category B, Level 3 and per IEC/EN/AS 61000-4-2, 3, 4, 5, 6 Category 2
12. Short Circuit Current Rating: Units shall carry as standard 65kA Short Circuit Withstand Rating. All ratings shall be certified and a label shall be applied to the unit clearly identifying this rating as required by the National Electrical Code.

E. AC Output

1. Load Rating: 100% of load rating at 104°F (40°C) for any load from 0.5 lagging to 0.9 leading
2. Voltage Regulation
 - a. ±1% RMS average for a balanced, three-phase load
 - b. ±5% for 100% unbalanced load for line-to-line imbalances
3. Voltage Adjustment Range: ±5% for line drop compensation adjustable by factory service personnel.
4. Voltage Distortion: 1% total harmonic distortion (THD) maximum into a 100% linear load, 3% THD maximum into a 100% non-linear load with crest factor ratio of 3:1
5. Frequency Regulation: 50 or 60Hz, ±0.05% free running
6. Bypass Frequency Synchronization Range: ±0.5, 1.0, 2.0, 3.0 Hz, adjustable by factory service personnel, ±2.0 Hz default setting
7. Frequency Slew Rate: 0.1 to 3 Hz/sec, 0.6 Hz/sec default setting
8. System Efficiency (defined as output kW/input kW at rated lagging load power factor; and up to values listed below:

kVA Rating	Maximum Efficiency
40	95.3%

9. Phase Imbalance
 - a. Balanced loads: 120° ±1°
 - b. 100% unbalanced loads: 120° ±1.5°
10. Voltage Transients (average of all three phases)
 - a. 0-100% or 100-0%
 - b. Response: Meets ITIC and CBEMA Curve Requirements
 - c. Complies with IEC/EN 62040-3: 2010 Figure 2 Curve 1, Class 1
 - d. Transient Voltage Deviation, RMS 10%
 - e. Recovers within 60ms
11. Overload at Full Output Voltage with ±1% voltage regulation
 - a. 100% continuously
 - b. 105% - 110% of full load for 60 minutes (40°C) ambient
 - c. 110% - 125% of full load for 10 minutes (40°C) ambient
 - d. 125% - 150% of full load for 60 seconds (40°C) ambient
 - e. >150% of full load for a minimum of 200 milliseconds (40°C) ambient

F. Grounding

1. The UPS chassis shall have an equipment ground terminal.

1.04 ENVIRONMENTAL CONDITIONS

- A. The UPS shall be able to withstand the following environmental conditions without damage or degradation of operating characteristics:
 1. Operating Ambient Temperature
 - a. UPS: 32°F to 104°F (0°C to 40°C) without derating
 - b. Battery: 77°F (25°C), ±5°F (±3°C)
 2. Storage/Transport Ambient Temperature
 - a. -4°F to 158°F (-20°C to 70°C)

3. Relative Humidity
 - a. 0 to 95%, non-condensing
4. Altitude
 - a. Operating: To 4922 ft. (1500m) above Mean Sea Level without derating (compliant with IEC/EN 62040-3 at altitudes exceeding 1500m) Consult factory for derating above 4922 ft. (1500m) elevation.
 - b. Storage/Transport: To 50,000 ft. (15,000m) above Mean Sea Level
5. Audible Noise Level
 - a. 57.8 dBA measured 1 meter from all sides (40 kVA frame)
 - b. 63 dBA measured 1 meter from all sides (100 kVA frame)
 - c. 64 dBA measured 1 meter from all sides (200 kVA frame)

1.05 SUBMITTALS

- A. Proposal Submittals
 1. Submittals with the proposal shall include:
 - a. Descriptions of equipment to be furnished, including deviations from these specifications.
 - b. Document stating compliance with FCC requirements.
 - c. Document stating listing to UL, including edition used for listing.
 - d. Document showing compliance with required SCCR and labeling.
 - e. System configuration with single-line diagrams.
 - f. Detailed layouts of customer power and control connections.
 - g. Functional relationship of equipment, including weights, dimensions and heat dissipation.
 - h. Information to allow distribution system coordination.
 - i. Size and weight of shipping units to be handled by contractor.
- B. Order Submittals
 1. Submittals supplied at time of order shall include:
 - a. All the documentation presented with the proposal, per above section.
 - b. Detailed installation drawings including all terminal locations.
 - c. Interconnect wiring diagrams showing conduit wiring with terminal numbers for each wire.
- C. UPS Delivery Submittals
 1. Submittals upon UPS delivery shall include:
 - a. A complete set of submittal drawings.
 - b. Two (2) sets of instruction manuals. Manuals shall include a functional description of the equipment, safety precautions, instructions, step-by-step operating procedures and routine maintenance guidelines, including illustrations.

1.06 WARRANTY

- A. UPS Warranty
 1. The UPS manufacturer shall warrant the unit against defects in workmanship and materials for 12 months after initial startup or 18 months after the shipping date, whichever comes first.
- B. Warranty – End User
 1. Warranties associated with items not manufactured by the UPS supplier but included as part of the system shall be passed through to the end user.

1.07 QUALITY ASSURANCE

- A. Manufacturer's Qualifications
 1. A minimum of 20 years' experience in the design, manufacture and testing of solid-state UPS systems shall be required.
 2. The quality system for the engineering and manufacturing facility shall be certified to conform to Quality System Standard ISO 9001 for the design and manufacture of power protection systems for computers and other sensitive electronics.
- B. Factory Testing
 1. Before shipment, the manufacturer shall fully and completely test the UPS unit to ensure compliance with the specification.

2. The UPS unit shall be tested at the system-specified capacity. Testing shall be done using load banks at part-load and the full kW rating of the unit.
3. Operational discharge and recharge tests to ensure guaranteed rated performance.
4. System operations such as startup, shutdown and transfers shall be demonstrated.
5. A certified copy of the test results shall be available for each system as indicated on the order.

1.08 APPROVED MANUFACTURER

- A. The UPS shall be a Vertiv Liebert EXM UPS system.

PART 2 PRODUCT

2.01 FABRICATION

- A. Materials
 1. All materials of the UPS shall be new, of current manufacture, high grade and shall not have been in prior service except as required during factory testing. All active electronic devices shall be solid-state. All power semiconductors shall be sealed. Control logic and fuses shall be physically isolated from power train components to ensure operator safety and protection from heat. All circuit boards shall be conformal coated. All bus bars shall be copper and plated.
- B. UPS Internal Wiring
 1. Wiring practices, materials and coding shall be in accordance with the requirements of the National Electrical Code, OSHA and applicable local codes and standards. All bolted connections of busbars, lugs and cables shall be in accordance with requirements of the National Electrical Code and other applicable standards. All electrical power connections shall be torqued to the required value and marked with a visual indicator.
- C. Field Wiring
 1. All field wiring power connections shall be tin-plated copper busbars for connection integrity. Busbars shall have adequate space to allow two-hole, long-barrel, compression type lugs forming a permanent connection between field wiring and field-installed lugs.
 2. Provisions shall be made in the cabinets to permit installation of input, output and external control cabling using raceway or conduit. Provision shall be made for top and bottom access to input, output, bypass and DC connections. In conformance with the NEC, connection cabinets shall provide for adequate wire bend radius.
- D. Construction and Mounting
 1. The UPS shall be in NEMA Type 1 enclosures (IEC 60529 IP20), designed for floor mounting. The UPS shall be structurally adequate and have provisions for hoisting, jacking and forklift handling. Maximum cabinet height shall be 78.7 in. (2000mm).
 2. The UPS shall be NEMA Type 1-compliant, with front doors open to enable safe change of air filters without the need for shutdown.
- E. Cooling
 1. Adequate ventilation shall be provided to ensure that all components are operated well within temperature ratings.
 2. Temperature sensors shall be provided to monitor the UPS's internal temperature. Upon detection of temperatures in excess of the manufacturer's recommendations, the sensors shall cause audible alarms to be sounded and visual alarms to be displayed on the UPS control panel. Air filters shall be located at the point of air inlet and shall be changeable. No service clearance or ventilation shall be required in the rear of the system.

2.02 EQUIPMENT

- A. UPS System
 1. The UPS system shall consist of an IGBT power factor-corrected rectifier, DC-DC converter and three-phase, transformer-free inverter, bypass static transfer switch, bypass synchronizing circuitry, protective devices and accessories as specified. The specified system shall also include a battery disconnect breaker and battery system.
- B. Surge Protection
 1. The UPS shall have built-in protection against surges, sags and overcurrent from the AC source. The protection shall meet the requirements of ANSI C62.41 A3 and B3 including:
 - a. 6kV, 100kHz ring wave, line-to-line, line-to-neutral, line-to-ground and neutral-to-

- ground
 - b. 6kV, combined wave, line-to-line, line-to-neutral, line-to-ground and neutral-to-ground
- C. Output Protection
 1. The UPS shall be protected against sudden changes in output load and short circuits at the output terminals. The UPS shall have built-in protection against permanent damage to itself and the connected load for all predictable types of malfunctions. Fast-acting, current-limiting devices shall be used to protect against cascading failure of solid-state devices. Internal UPS malfunctions shall cause the module to trip off-line with minimum damage to the module and provide maximum information to maintenance personnel regarding the reason for tripping off-line. The load shall be automatically transferred to the bypass line uninterrupted for an internal UPS malfunction. The status of protective devices shall be indicated on a graphic display screen on the front of the unit.

2.03 COMPONENTS

- A. Rectifier
 1. The term rectifier shall denote the solid-state equipment and controls necessary to convert alternating current to regulated direct current to supply the inverter and charge the battery. The DC output of the rectifier shall meet the input requirements of the inverter without the battery being connected.
 - a. Input Current Harmonic Distortion: The rectifier shall actively control and reduce input current distortion over the full operating range of the UPS without the need for an additional passive input filter. Input current THD shall be less than 5% at rated load and nominal voltage in double-conversion mode.
 - b. Dynamic Current Input Limit Reduction: The rectifier, in conjunction with the other UPS controls and circuitry, shall adjust the current demanded for battery charging as a function of UPS wattage load and input voltage level.
- B. DC-DC Converter
 1. The term DC-DC converter shall denote the equipment and controls to regulate the output of the rectifier to the levels appropriate for charging the battery and to boost the battery voltage to the level required to operate the inverter. The DC-DC converter shall be solid-state, capable of providing rated output power and, for increased performance, shall be a pulse width-modulated design and shall utilize insulated gate bipolar transistors (IGBTs). The DC-DC converter shall control charging of the battery. The AC ripple voltage of the charger DC shall not exceed 1% RMS of the float voltage.
 - a. Battery Equalize Charge: A manually initiated equalize charge feature shall be provided to apply an equalize voltage to the battery. The duration of equalize charge time shall be adjustable from 8 to 30 hours. A method shall be available to deactivate this feature for valve regulated battery systems.
 - b. Stop Battery Charging Function: Battery charging may be stopped by a shunt trip of the battery cabinet breaker when overtemperature is sensed in the battery cabinet, on generator or when environmental contact is closed.
 - c. Overvoltage Protection: There shall be DC overvoltage protection so that if the DC voltage rises to the pre-set limit, the UPS shall shut down automatically and initiate an uninterrupted load transfer to bypass or shall disconnect the battery via the DC breaker(s) in the battery string.
 - d. Temperature-Compensated Charging: The UPS shall adjust the battery charging voltage based on the battery temperature reported from external battery temperature sensors. When multiple sensors are used, the voltage shall be based on the average temperature measured. Excessive difference in the temperature measurements shall be reported and the charging voltage adjusted to protect the batteries from excessive current.
 - e. Battery Load Testing: The UPS shall be capable of performing battery load testing under operator supervision. To accomplish this, the rectifier shall reduce charging voltage to force the batteries to carry the load for a short time. If the curve of battery voltage drop indicates diminished battery capacity, the UPS shall display an alarm message. If the voltage drop indicates battery failure, the UPS shall terminate the test

immediately and annunciate the appropriate alarms.

C. Inverter

1. The term inverter shall denote the equipment and controls to convert direct current from the rectifier or battery via the DC-DC converter to precise alternating current to power the load. The inverter shall be solid-state, capable of providing rated output power and, for increased performance, the inverter shall be a pulse-width-modulated design and shall utilize insulated gate bipolar transistors (IGBTs). To further enhance reliable performance and efficiency, the inverter shall not require an inverter output series static switch/isolator for the purposes of overload or fault isolation or transfers to bypass.
 - a. Overload Capability: The inverter shall be able to withstand an overload across its output terminals while supplying full rated voltage of up to 150% for 60 seconds. The inverter shall be capable of at least 200% current for short-circuit conditions including phase-to-phase, phase-to-ground and three-phase faults. After the fault is removed, the UPS shall return to normal operation without damage. If the short circuit is sustained, the load shall be transferred to the bypass source and the inverter shall disconnect automatically from the critical load bus.
 - b. Output Frequency: The output frequency of the inverter shall be controlled by an oscillator. The oscillator shall hold the inverter output frequency to $\pm 0.05\%$ for steady state and transient conditions. The inverter shall track the bypass continuously, providing the bypass source maintains a frequency within the user- selected synchronization range. If the bypass source fails to remain within the selected range, the inverter shall revert to the internal oscillator.
 - c. Phase-to-Phase Balance: The inverter shall provide a phase-to-phase voltage displacement of no worse than $\pm 1.5\%$ with a 100% unbalanced load.
 - d. Inverter Fault Sensing and Isolation: The UPS shall be provided with a means to detect a malfunctioning inverter and isolate it from the critical load bus to prevent disturbance of the critical load voltage beyond the specified limits.
 - e. Battery Protection: The inverter shall be provided with monitoring and control circuits to protect the battery system from damage due to excessive discharge. Inverter shutdown shall be initiated when the battery voltage has reached the end of discharge voltage. The battery end-of-discharge voltage shall be calculated and automatically adjusted for partial load conditions to allow extended operation without damaging the battery. Automatic shutdown based on discharge time shall not be acceptable.

D. Inverter Bypass Operation

1. When maintenance is required or when the inverter cannot maintain voltage to the load due to sustained overload or malfunction, a bypass circuit shall be provided to isolate the inverter output from the load and provide a path for power directly from an alternate AC (bypass) source. The UPS control system shall constantly monitor the availability of the inverter bypass circuit to perform a transfer. The inverter bypass circuit shall consist of a continuous duty bypass static switch and an overcurrent protection device to isolate the static bypass switch from the bypass utility source. The bypass static switch shall denote the solid-state device incorporating SCRs (silicon controlled rectifiers) that can automatically and instantaneously connect the alternate AC source to the load.
 - a. Static Bypass Switch Rating: The static bypass switch shall be rated for continuous duty operation at full rated load for highest reliability without the use of mechanical devices, such as those used with a momentary rated device.
 - b. Manual Load Transfers: A manual load transfer between the inverter output and the alternate AC source shall be initiated from the control panel. Manually initiated transfers shall be make-before-break, utilizing the inverter and the bypass static switch.
 - c. Automatic Load Transfers: An automatic load transfer between the inverter output and the alternate AC source shall be initiated if an overload condition is sustained for a period in excess of the inverter output capability or due to a malfunction that would affect the output voltage. Transfers caused by overloads shall initiate an automatic retransfer of the load to the inverter only after the load has returned to a level within the rating of the inverter source and the alarm has been acknowledged.

- d. Back-Feed Protection: As required by UL1778 and CSA, the static transfer switch shall not back-feed UPS power to the bypass distribution system while the UPS is operating on battery during a bypass power outage. The purpose of this requirement is to prevent the risk of electrical shock on the distribution system when the normal source of power is disconnected or has failed. If a shorted SCR is detected, the static transfer switch shall be isolated by an internal circuit breaker in the matching maintenance bypass cabinet or by an external circuit breaker in the customer's feeder panel and an alarm message shall be annunciated at the UPS control panel. The load shall remain on conditioned and protected power after detection of a shorted SCR and isolation of the bypass static switch.
 - e. Active ECO-Mode: When selected, this mode of operation shall transfer the load to the bypass source and maintain it there as long as the bypass source frequency, slew rate and voltage are within the adjusted operating parameters. While in this mode, the inverter shall remain operating to be able to instantaneously assume the load without interrupting the output voltage. Should the bypass source go outside the adjusted limits, the bypass static switch shall turn Off, isolating the load from the bypass while the inverter assumes the full critical load. The load shall be transferred from the bypass source to the inverter while maintaining the output voltage within the ITIC and CBEMA curves.
- E. Display and Controls
1. UPS Control Panel: The UPS shall be provided with a microprocessor-based control panel for operator interface (may also be referred to as User Interface, or UI) to configure and monitor the UPS. The control panel shall be located on the front of the unit where it can be operated without opening the hinged front door. A backlit, menu-driven, full- graphics, color touchscreen liquid crystal display shall be used to enter setpoints for the battery test (duration and end voltage), display system information, metering information, a one-line diagram of the UPS and battery, active events, event history, startup instructions and transfer and shutdown screens. No mechanical push buttons shall be used.
 2. Logic: UPS system logic and control programming shall reside in a microprocessor-based control system with nonvolatile flash memory. Rectifier, inverter and system control logic shall utilize high-speed digital signal processors (DSPs). CANbus shall be used to communicate between the logic and the User Interface as well as the options. Switches, contacts and relays shall be used only to signal the logic system as to the status of mechanical devices or to signal user control inputs. Customer external signals shall be isolated from the UPS logic by relays or optical isolation.
 3. Metered Values: A microprocessor shall control the display and memory functions of the monitoring system. All three phases of three-phase parameters shall be displayed simultaneously. All voltage and current parameters shall be monitored using true RMS measurements for accuracy to $\pm 3\%$ of voltage, $\pm 5\%$ AC current. The following parameters shall be displayed:
 - a. Input voltage, line-to-line
 - b. Input current per phase
 - c. Input frequency
 - d. Input apparent power (kVA)
 - e. Battery voltage
 - f. Battery charging/discharging current
 - g. Output voltage, line-to-line
 - h. Output frequency
 - i. Bypass input voltage, line-to-line
 - j. Bypass input frequency
 - k. Load current
 - l. Load real power (kW), total and percentage
 - m. Load apparent power (kVA), total and percentage
 - n. Load percentage of capacity
 - o. Battery temperature, each battery string

- p. Battery state of charge
- 4. Power Flow Indications: A power flow diagram shall graphically depict whether the load is being supplied from the inverter, bypass or battery and shall provide, on the same screen, the status of the following components:
 - a. AC Input Circuit Breaker (optional)
 - b. Battery Circuit Breaker, each breaker connection of complete battery complement, complete disconnection and partial connection (one or more, but not all breakers open.)
 - c. Maintenance Bypass Status
- 5. Main Display Screen—The following UPS status messages shall be displayed:
 - a. Rectifier (Off / Soft Start / Main Input On / Battery Input On)
 - b. Input Supply (Normal Mode / Battery Mode / All Off)
 - c. Battery Self Test (True / False)
 - d. Input Disconnect (Open / Closed)
 - e. EPO (True / False)
 - f. Charger (On / Off)
 - g. Output Disconnect (Open / Closed)
 - h. Maint. Disconnect (Open / Closed)
 - i. Bypass Disconnect (Open / Closed)
 - j. Inverter (Off / Soft Start / On)
 - k. Bypass (Normal / Unable To Trace / Abnormal)
 - l. Output Supply (All Off / Bypass Mode / Inverter Mode / Output Disable)
 - m. Inverter On (Enable / Disable)
- 6. HMI Control Buttons: Buttons shall be provided to start and stop the inverter. A pop-up message requesting confirmation shall be displayed whenever a command is initiated that would change the status of the UPS. Other buttons shall be provided to reset faults and silence the alarm buzzer.
- 7. Event Log: This menu item shall display the list of events that have occurred recently while the UPS was in operation. The Event Log shall store up to 2048 events, with the oldest events being overwritten first if the log's capacity is reached.
- 8. Battery Status Indicator: A battery status indicator shall display DC alarm conditions, temperature, battery state of charge, the present battery voltage, total discharge time, status of last battery test and battery time remaining during discharge.
- 9. The UPS shall provide the operator with controls to perform the following functions:
 - a. Configure and manage manual battery test
 - b. Modify test duration and minimum voltage
 - c. Start battery test
 - d. Monitor test status and progression
 - e. Stop battery test
 - f. Battery test status
- 10. Alarms—The following alarm messages shall be displayed:
 - a. Mains Voltage Abnormal
 - b. Mains Undervoltage
 - c. Mains Freq. Abnormal
 - d. Charger Fault
 - e. Battery Reversed
 - f. No Battery
 - g. Parallel Comm. Fail
 - h. Bypass Unable to Track
 - i. Bypass Abnormal
 - j. Inverter Asynchronous
 - k. Fan Fault
 - l. Control Power Fail
 - m. Unit Overload
 - n. System Overload

- o. Bypass Phase Reversed
 - p. Transfer Time-Out
 - q. Load Sharing Fault
 - r. Bypass Over Current.
11. Controls—System-level control functions shall be:
 - a. Start Inverter (and transfer to inverter)
 - b. Stop Inverter (after transferring to bypass)
 - c. Startup Screen
 - d. Battery Test Setpoint Adjustment
 - e. Configure Manual Battery Test
 - f. Initiate Manual Battery Test
 - g. System Settings (Time, Date, Language, LCD Brightness, Password, Audio Level)
 - h. Alarm Silence Command
 - i. Fault Reset Command
 - j. ECO mode
 12. Manual Procedures: Load Transfers: HMI buttons (START INVERTER, STOP INVERTER) shall provide the means for the user to transfer the load to bypass and back on UPS.
- F. Self-Diagnostics
1. Event Log File - The control system shall maintain a log of the event conditions that have occurred during system operation. Each log shall contain the event name, event time/date stamp and a set/clear indicator.
- G. Remote Monitoring and Integration Capabilities
1. Vertiv™ LIFE™ Services: The UPS manufacturer shall provide as an option LIFE™ services, which provides 24x7 continuous monitoring of events and parametric data, event and data analysis reports and dispatch of factory-trained field service personnel. The UPS shall be able to initiate periodic and critical event-driven communication with a remote service center to transfer event and parametric data for analysis and action. The remote service center shall be staffed with factory-trained service personnel who are capable of receiving, analyzing and interpreting the communicated events and data. The remote service center personnel shall also be capable of dispatching factory-trained field service personnel to the location of the UPS.
 2. Communication Cards: The UPS can be equipped with up to three optional communication card(s) including:
 - a. Optional Vertiv™ Liebert® IntelliSlot IS-UNITY-DP card providing Web-based UPS monitoring and management capabilities, Liebert® LIFE™ Services delivery and two of the following third-party open protocols:
 - b. SNMP protocols (v1, v2, v3) with IPv4 or IPv6
 - c. Modbus RTU or Modbus TCP
 - d. BACnet MSTP or BACnet IP
 - e. Note: Modbus RTU and BACnet MSTP cannot both be enabled simultaneously.
 - f. Up to 10 external environmental sensors can be monitored
 - g. Temperature
 - 1) Humidity
 - 2) Leak Detection
 - 3) Contact Inputs
 - h. Optional Vertiv™ Liebert® SiteScan™ Interface card to interface with Liebert® SiteScan™ Web software.
 - i. Optional Vertiv™ Liebert® IntelliSlot Unity SNMP card providing Web-based UPS monitoring and management capabilities for SNMP protocols (v1, v2, v3) with IPv4 or IPv6
 - j. Liebert® IntelliSlot Unity, Vertiv™ LIFE™ card included to enable Vertiv™ LIFE™ Services when the optional Liebert® IntelliSlot Unity card is not purchased.
 3. Output Alarm Contacts: Dry contact outputs shall be provided for Summary Alarm, Bypass Active, Low Battery and AC Input Failure.

4. Customer Input Contacts: The UPS shall have four discrete input contacts available for the input and display of customer-provided alarm points or to initiate a pre-assigned UPS operation. Each input can be signaled by an isolated, external, normally open contact.
 5. When an assembly is selected as a pre-assigned UPS operation, the following actions shall be initiated:
 - a. On Generator—Provides selectable choices to enable or disable battery charging and enable or disable ECO Mode operation while on generator.
 - b. Transfer to Bypass—Manual command to transfer from inverter operation to static bypass operation.
 - c. Fast Power Off—Emergency Module Off (EPO) command to stop UPS operation.
 - d. Acknowledge Fault—Acknowledge a UPS alarm condition and present faults will be reset.
 - e. Bypass/Inverter Off—Emergency Power Off (EPO) command to stop UPS operation.
 - f. External Maintenance Bypass Breaker (MBB) status (open or closed)
- H. Battery Disconnect Breaker
1. The battery cabinet shall have a properly rated circuit breaker (600VDC) to isolate it from the Vertiv™ Liebert® EXM UPS. This breaker shall be in a separate NEMA-1 enclosure or in a matching battery cabinet. When this breaker is open, there shall be no battery voltage in the UPS enclosure. The UPS shall be automatically disconnected from the battery by a shunt trip of the battery cabinet breaker when signaled by other control functions.
- I. Maintenance Bypass Cabinet
1. The UPS system shall incorporate a matching cabinet to house a wraparound maintenance bypass with the following features:
 - a. 3 breakers for complete electrical isolation of the UPS with system voltage of 208/120VAC, 4W+Gnd input/output only, no integral output distribution
 - b. Kirk Key Interlock interface with Solenoid Key Release Unit (SKRU)
- J. Valve-regulated, Lead-acid Battery
1. The UPS system shall be provided with a valve-regulated, lead acid battery plant.
 2. The battery shall be fully charged per the manufacturer's instructions during startup and shall demonstrate the specified operating time.
- K. Matching Battery Cabinet
1. The battery cabinet shall consist of sealed, valve-regulated batteries, a circuit breaker for isolating the battery from the UPS and a control interface to the UPS module.
 2. The circuit breaker shall be sized to allow discharge at the maximum published rating of the battery. The interface to the UPS module shall provide status and thermal data to allow the UPS to regulate the charging voltage and inhibit the conditions associated with battery thermal runaway. If the temperature measurement in a battery cabinet indicates that thermal runaway is occurring, then the UPS controls shall isolate the cabinet from the charger by tripping the battery breaker in that cabinet while leaving the other battery cabinets connected to allow UPS operation during a loss of power to the rectifier.
 3. The battery cabinet shall be rated NEMA 1, matching the UPS style and design.
 - a. Battery Cabinets Connected Directly to the UPS: The manufacturer shall provide all power and control parts necessary to connect the UPS to the battery cabinets.
 - b. Battery Cabinets Separated from the UPS: The manufacturer shall provide all power and control parts necessary to interconnect the battery cabinets. The installer shall provide all cabling necessary to interconnect the UPS and the battery cabinets.
 - c. Both overhead and under-floor site installed cabling shall be accommodated. Cable installation shall not require removal of batteries or any other battery cabinet assemblies.
 - d. The battery system shall be sized to support a 40 kW load for 22 minutes, 30 kW for 33 minutes, and 14 kW for 78 minutes. The battery system shall provide 100% initial capacity upon delivery.
 - e. The battery shall be lead-calcium, sealed, valve-regulated type with a three (3) - year full warranty and a seven (7) -year pro rata warranty under full float operation. The battery design shall utilize absorbent glass mat (AGM) technology to immobilize the

electrolyte.

L. Battery Monitoring System

1. The battery system shall be provided with an Vertiv™ Liebert ® Alber™ comprehensive battery monitoring system. The system shall provide predictive on-line test, analysis and remote monitoring using patented DC resistance measurements.
2. The system shall include automatic monitoring, alarming, recording and displaying of these battery parameters.
 - a. Individual jar voltage (high and low alarm)
 - b. Individual jar DC resistance (high and low alarm) accomplished by applying a momentary load at user defined intervals
 - c. Individual inter-tier and disconnect switch resistance measurements (high alarm) performed at user-defined intervals
 - d. Total overall battery voltage per string (high and low alarm)
 - e. Two ambient temperatures per string for temperature trending (high and low alarm)
 - f. Real time system discharge logging of the overall voltage, individual jar voltage (low alarm), discharge current (high alarm) and temperatures
 - g. Ripple current per string
 - h. String current (high alarm)
 - i. Optional float current per string (high and low alarm)
3. The system shall provide reports for evaluation of the battery condition. Reports shall include:
 - a. Alarm condition reporting – tabular, fax or e-mail
 - b. Jar out-of-limits summary report – tabular
 - c. Individual jar voltages over time – graph or tabular
 - d. Individual jar resistance values over time – graph or tabular
 - e. Total battery voltage over time – graph or tabular
 - f. Ambient temperature over time – graph or tabular
 - g. Discharge report: total battery voltage decay vs. time – graph or tabular
 - h. Discharge report: jar voltage decay vs. time – graph or tabular
 - i. Discharge hit summary report – tabular
 - j. Discharge hit interval summary report – tabular
 - k. General summary report of battery and monitor status of all systems to the battery or string level based on user-set thresholds
 - l. Detail summary reports of battery and monitor status of all systems with a line graph trend of any parameter that violated a threshold
 - m. Executive report showing overall system health.
4. Data from universal battery diagnostic system shall be viewed through an Ethernet port with one of the following protocols: SNMP, TCP/IP/Modbus, SMS or HTTP. An optional RS-485 port shall be available for Modbus communication.

PART 3 EXECUTION

3.01 INSTALLATION

- A. Examine areas and conditions, with Installer present, for compliance with requirements for conditions affecting performance of the UPS.
- B. Comply with NECA 1.
- C. Wiring Method: Install cables in raceways except within cabinets.
- D. 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.
- E. Equipment Mounting: Install UPS on concrete base. Comply with requirements for concrete base specified in Section 03 30 00 "Cast-in-Place Concrete".
 1. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of concrete base 6 inches from the outer edge of the base.
 2. For supported equipment, install epoxy-coated anchor bolts that extend through concrete

- base and anchor into structural concrete floor.
- 3. Place and secure anchorage devices. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
- 4. Install anchor bolts to elevations required for proper attachment to supported equipment.
- F. Maintain minimum clearances and workspace at equipment according to manufacturer's written instructions and NFPA 70.
- G. Connections: Interconnect system components. Make connections to supply and load circuits according to manufacturer's wiring diagrams unless otherwise indicated. Apply oxide inhibitor on battery terminals.
- H. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 26 05 53 "Identification for Electrical Systems".
 - 1. Identify each battery cell individually.
- 3.02 GROUNDING**
- A. Comply with requirements in Section 26 05 26 "Grounding and Bonding for Electrical Systems".
- 3.03 BATTERY EQUALIZATION**
- A. Equalize charging of battery cells according to manufacturer's written instructions. Record individual-cell voltages.
- 3.04 FIELD QUALITY CONTROL**
- A. The following inspections and test procedures shall be performed by factory-trained field service personnel during the UPS startup.
 - 1. Visual Inspection
 - a. Inspect equipment for signs of damage.
 - b. Verify installation per drawings supplied with installation manuals or submittal package.
 - c. Inspect cabinets for foreign objects.
 - d. Verify that neutral and ground conductors are properly sized and configured per Vertiv requirements as noted in Vertiv drawings supplied with installation manuals or submittal package.
 - e. Inspect each battery jar for proper polarity.
 - f. Verify that all printed circuit boards are configured properly.
 - 2. Mechanical Inspection
 - a. Check all control wiring connections for tightness.
 - b. Check all power wiring connections for tightness.
 - c. Check all terminal screws, nuts and/or spade lugs for tightness.
 - 3. Electrical Inspection
 - a. Check all fuses for continuity.
 - b. Confirm input and bypass voltage and phase rotation are correct.
 - c. Verify control transformer connections are correct for voltages being used.
 - d. Ensure connection and voltage of the battery string(s).
- 3.05 UNIT STARTUP**
- A. Energize control power.
- B. Perform control/logic checks and adjust to meet Vertiv specification.
- C. Verify DC float and equalize voltage levels.
- D. Verify DC voltage clamp and overvoltage shutdown levels.
- E. Verify battery discharge, low battery warning and low battery shutdown levels.
- F. Verify fuse monitor alarms and system shutdown.
- G. Verify inverter voltages and regulation circuits.
- H. Verify inverter/bypass sync circuits and set overlap time.
- I. Perform manual transfers and returns.
- J. Simulate utility outage at no load.
- K. Verify proper recharge.
- 3.06 MANUFACTURER'S FIELD SERVICE**
- A. Service Personnel: The UPS manufacturer shall directly employ a nationwide service organization, consisting of factory-trained field service personnel dedicated to the startup and

maintenance of UPS and power equipment.

1. The manufacturer shall provide a national dispatch center to coordinate field service personnel schedules. One toll-free number shall reach a qualified support person 24 hours a day, 7 days a week and 365 days a year. If emergency service is required, on-site response time shall be 4 hours or less within 150 miles of a Vertiv Services center.
 2. Two local customer engineers shall be assigned to the site with a regional office as a backup. Escalation procedures shall be in place to notify Power Technical Support if a site is not functioning within 24 hours.
- B. Automated Site Monitoring: The UPS manufacturer shall provide as an option an automated site monitoring service. This service shall be staffed by a qualified support person 24 hours a day, 7 days a week and 365 days a year. At the detection of an alarm within the UPS, the controls shall initiate communication with the monitoring service. The monitoring service shall be capable of interpreting the communicated alarms to allow dispatch of a service engineer.
- C. Replacement Parts Stocking: Parts shall be available through an extensive network to ensure round-the-clock parts availability throughout the country.
1. Spare parts shall be stocked by local field service personnel with backup available from national parts centers and the manufacturing location. A Customer Support Parts Coordinator shall be on call 24 hours a day, 7 days a week, 365 days a year for immediate parts availability.
- D. Maintenance Contracts: A complete offering of preventive and full-service maintenance contracts for both the UPS system and battery system shall be available.
- 3.07 DEMONSTRATION**
- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain the UPS.

END OF SECTION

SECTION 28 31 11
DIGITAL, ADDRESSABLE FIRE-ALARM SYSTEM

PART 1 GENERAL

1.01 SUMMARY

- A. Section Includes:
 - 1. Fire-alarm control unit.
 - 2. Manual fire-alarm boxes.
 - 3. System smoke detectors.
 - 4. Nonsystem smoke detectors.
 - 5. Heat detectors.
 - 6. Notification appliances.
 - 7. Magnetic door holders.
 - 8. Remote annunciator.
 - 9. Addressable interface device.
 - 10. Digital alarm communicator transmitter.
- B. Related Requirements:
 - 1. Section 280513 "Conductors and Cables for Electronic Safety and Security" for cables and conductors for fire-alarm systems.

1.02 ACTION SUBMITTALS

- A. Product Data: For each type of product, including furnished options and accessories.
- B. Shop Drawings: For fire-alarm system.
 - 1. Comply with recommendations and requirements in the "Documentation" section of the "Fundamentals" chapter in NFPA 72.
 - 2. Include plans, elevations, sections, details, and attachments to other work.
 - 3. Include details of equipment assemblies. Indicate dimensions, weights, loads, required clearances, method of field assembly, components, and locations. Indicate conductor sizes, indicate termination locations and requirements, and distinguish between factory and field wiring.
 - 4. Detail assembly and support requirements.
 - 5. Include voltage drop calculations for notification-appliance circuits.
 - 6. Include battery-size calculations.
 - 7. Include input/output matrix.
 - 8. Include statement from manufacturer that all equipment and components have been tested as a system and meet all requirements in this Specification and in NFPA 72.
 - 9. Include performance parameters and installation details for each detector.
 - 10. Verify that each duct detector is listed for complete range of air velocity, temperature, and humidity possible when air-handling system is operating.
 - 11. Include plans, sections, and elevations of heating, ventilating, and air-conditioning ducts, drawn to scale; coordinate location of duct smoke detectors and access to them.
 - a. Show critical dimensions that relate to placement and support of sampling tubes, detector housing, and remote status and alarm indicators.
 - b. Show field wiring required for HVAC unit shutdown on alarm.
 - c. Locate detectors according to manufacturer's written recommendations.
 - 12. Include floor plans to indicate final outlet locations showing address of each addressable device. Show size and route of cable and conduits and point-to-point wiring diagrams.
- C. General Submittal Requirements:
 - 1. Submittals shall be approved by authorities having jurisdiction prior to submitting them to Architect.
 - 2. Shop Drawings shall be prepared by persons with the following qualifications:
 - a. Trained and certified by manufacturer in fire-alarm system design.
 - b. NICET-certified, fire-alarm technician; Level IV minimum.
- D. Delegated-Design Submittal: For notification appliances and smoke and heat detectors, in addition to submittals listed above, indicate compliance with performance requirements and

design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

1. Drawings showing the location of each notification appliance and smoke and heat detector, ratings of each, and installation details as needed to comply with listing conditions of the device.
2. Design Calculations: Calculate requirements for selecting the spacing and sensitivity of detection, complying with NFPA 72. Calculate spacing and intensities for strobe signals and sound-pressure levels for audible appliances.
3. Indicate audible appliances required to produce square wave signal per NFPA 72.

1.03 INFORMATIONAL SUBMITTALS

- A. Qualification Data: For Installer.
- B. Field quality-control reports.
- C. Sample warranty.

1.04 CLOSEOUT SUBMITTALS

- A. Operation and Maintenance Data: For fire-alarm systems and components to include in emergency, operation, and maintenance manuals.
 1. In addition to items specified in Section 017823 "Operation and Maintenance Data," include the following and deliver copies to authorities having jurisdiction:
 - a. Comply with the "Records" section of the "Inspection, Testing and Maintenance" chapter in NFPA 72.
 - b. Provide "Fire Alarm and Emergency Communications System Record of Completion Documents" according to the "Completion Documents" Article in the "Documentation" section of the "Fundamentals" chapter in NFPA 72.
 - c. Complete wiring diagrams showing connections between all devices and equipment.
 - d. Riser diagram.
 - e. Record copy of site-specific software.
 - f. Provide "Inspection and Testing Form" according to the "Inspection, Testing and Maintenance" chapter in NFPA 72, and include the following:
 - 1) Equipment tested.
 - 2) Frequency of testing of installed components.
 - 3) Frequency of inspection of installed components.
 - 4) Requirements and recommendations related to results of maintenance.
 - 5) Manufacturer's user training manuals.
 - g. Manufacturer's required maintenance related to system warranty requirements.
 - h. Abbreviated operating instructions for mounting at fire-alarm control unit and each annunciator unit.
- B. Software and Firmware Operational Documentation:
 1. Software operating and upgrade manuals.
 2. Program Software Backup: On magnetic media or compact disk, complete with data files.
 3. Device address list.
 4. Printout of software application and graphic screens.

1.05 QUALITY ASSURANCE

- A. Installer Qualifications: Personnel shall be trained and certified by manufacturer for installation of units required for this Project.
- B. Installer Qualifications: Installation shall be by personnel certified by NICET as fire-alarm Level III technician.
- C. NFPA Certification: Obtain certification according to NFPA 72 by a UL-listed alarm company.

1.06 WARRANTY

- A. Special Warranty: Manufacturer agrees to repair or replace fire-alarm system equipment and components that fail in materials or workmanship within specified warranty period.
 1. Warranty Extent: All equipment and components not covered in the Maintenance Service Agreement.
 2. Warranty Period: Five years from date of Substantial Completion.

PART 2 PRODUCTS

2.01 SYSTEM DESCRIPTION

- A. Noncoded, UL-certified addressable system, with multiplexed signal transmission and voice evacuation.
- B. Automatic sensitivity control of certain smoke detectors.
- C. All components provided shall be listed for use with the selected system.
- D. 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.

2.02 SYSTEMS OPERATIONAL DESCRIPTION

- A. Fire-alarm signal initiation shall be by one or more of the following devices and systems:
 - 1. Manual stations.
 - 2. Heat detectors.
 - 3. Smoke detectors.
 - 4. Duct smoke detectors.
 - 5. Carbon monoxide detectors.
 - 6. Automatic sprinkler system water flow.
 - 7. Fire-extinguishing system operation.
 - 8. Fire standpipe system.
 - 9. Dry system pressure flow switch.
- B. Fire-alarm signal shall initiate the following actions:
 - 1. Continuously operate alarm notification appliances.
 - 2. Identify alarm and specific initiating device at fire-alarm control unit and remote annunciators.
 - 3. Transmit an alarm signal to the remote alarm receiving station.
 - 4. Unlock electric door locks in designated egress paths.
 - 5. Release fire and smoke doors held open by magnetic door holders.
 - 6. Switch heating, ventilating, and air-conditioning equipment controls to fire-alarm mode.
 - 7. Close smoke dampers in air ducts of designated air-conditioning duct systems as applicable.
 - 8. Activate preaction systems as applicable.
 - 9. Activate emergency shutoffs for gas and fuel supplies.
 - 10. Record events in the system memory.
- C. Supervisory signal initiation shall be by one or more of the following devices and actions:
 - 1. Valve supervisory switch.
 - 2. High- or low-air-pressure switch of a dry-pipe or preaction sprinkler system.
 - 3. Loss of communication with any panel on the network.
- D. System trouble signal initiation shall be by one or more of the following devices and actions:
 - 1. Open circuits, shorts, and grounds in designated circuits.
 - 2. Opening, tampering with, or removing alarm-initiating and supervisory signal-initiating devices.
 - 3. Loss of communication with any addressable sensor, input module, relay, control module, or remote annunciator.
 - 4. Loss of primary power at fire-alarm control unit.
 - 5. Ground or a single break in internal circuits of fire-alarm control unit.
 - 6. Abnormal ac voltage at fire-alarm control unit.
 - 7. Break in standby battery circuitry.
 - 8. Failure of battery charging.
 - 9. Abnormal position of any switch at fire-alarm control unit or annunciator.
- E. System Supervisory Signal Actions:
 - 1. Initiate notification appliances.
 - 2. Identify specific device initiating the event at fire-alarm control unit and remote annunciators.
 - 3. After a time delay of 200 seconds, transmit a trouble or supervisory signal to the remote alarm receiving station.

2.03 PERFORMANCE REQUIREMENTS

2.04 FIRE-ALARM CONTROL UNIT

- A. Provide products by the following:
 - 1. Simplex
- B. General Requirements for Fire-Alarm Control Unit:
 - 1. Field-programmable, microprocessor-based, modular, power-limited design with electronic modules, complying with UL 864.
 - 2. Addressable Initiation Device Circuits: The FACP shall indicate which communication zones have been silenced and shall provide selective silencing of alarm notification appliance by building communication zone.
 - 3. Addressable Control Circuits for Operation of Notification Appliances and Mechanical Equipment: The FACP shall be listed for releasing service.
 - 4. Emergency voice communication.
- C. Alphanumeric Display and System Controls: Arranged for interface between human operator at fire-alarm control unit and addressable system components including annunciation and supervision. Display alarm, supervisory, and component status messages and the programming and control menu.
 - 1. Annunciator and Display: Liquid-crystal type, 80 characters, minimum.
 - 2. Keypad: Arranged to permit entry and execution of programming, display, and control commands.
- D. Initiating-Device, Notification-Appliance, and Signaling-Line Circuits:
 - 1. Pathway Class Designations: NFPA 72, Class B.
 - 2. Pathway Survivability: Level 1.
- E. Notification-Appliance Circuit:
 - 1. Audible appliances shall sound in a three-pulse temporal pattern, as defined in NFPA 72.
 - 2. Visual alarm appliances shall flash in synchronization where multiple appliances are in the same field of view, as defined in NFPA 72.
- F. Door Controls: Door hold-open devices that are controlled by smoke detectors at doors in smoke-barrier walls shall be connected to fire-alarm system.
- G. Remote Smoke-Detector Sensitivity Adjustment: Controls shall select specific addressable smoke detectors for adjustment, display their current status and sensitivity settings, and change those settings. Allow controls to be used to program repetitive, time-scheduled, and automated changes in sensitivity of specific detector groups. Record sensitivity adjustments and sensitivity-adjustment schedule changes in system memory.
- H. Transmission to Remote Alarm Receiving Station: Automatically transmit alarm, supervisory, and trouble signals to a remote alarm station.
- I. Primary Power: 24-V dc obtained from 120-V ac service and a power-supply module. Initiating devices, notification appliances, signaling lines, trouble signals, supervisory and digital alarm communicator transmitters shall be powered by 24-V dc source.
 - 1. Alarm current draw of entire fire-alarm system shall not exceed 80 percent of the power-supply module rating.
- J. Secondary Power: 24-V dc supply system with batteries, automatic battery charger, and automatic transfer switch.

2.05 MANUAL FIRE-ALARM BOXES

- A. Provide products by the following:
 - 1. Simplex
- B. General Requirements for Manual Fire-Alarm Boxes: Comply with UL 38.
 - 1. Single-action mechanism, pull-lever type; with integral addressable module arranged to communicate manual-station status (normal, alarm, or trouble) to fire-alarm control unit.
 - 2. Station Reset: Key- or wrench-operated switch.

2.06 SYSTEM SMOKE DETECTORS

- A. Provide products by the following:
 - 1. Simplex
- B. General Requirements for System Smoke Detectors:

1. Comply with UL 268; operating at 24-V dc, nominal.
 2. Detectors shall be two-wire type.
 3. Base Mounting: Detector and associated electronic components shall be mounted in a twist-lock module that connects to a fixed base. Provide terminals in the fixed base for connection to building wiring.
 4. Self-Restoring: Detectors do not require resetting or readjustment after actuation to restore them to normal operation.
 5. Integral Visual-Indicating Light: LED type, indicating detector has operated and power-on status.
- C. Photoelectric Smoke Detectors:
1. Detector address shall be accessible from fire-alarm control unit and shall be able to identify the detector's location within the system and its sensitivity setting.
 2. An operator at fire-alarm control unit, having the designated access level, shall be able to manually access the following for each detector:
 - a. Primary status.
 - b. Device type.
 - c. Present average value.
 - d. Present sensitivity selected.
 - e. Sensor range (normal, dirty, etc.).
 - f. Sensor range (normal, dirty, etc.).
- D. Duct Smoke Detectors: Photoelectric type complying with UL 268A.
1. Detector address shall be accessible from fire-alarm control unit and shall be able to identify the detector's location within the system and its sensitivity setting.
 2. An operator at fire-alarm control unit, having the designated access level, shall be able to manually access the following for each detector:
 - a. Primary status.
 - b. Device type.
 - c. Present average value.
 - d. Present sensitivity selected.
 - e. Sensor range (normal, dirty, etc.).
 3. Weatherproof Duct Housing Enclosure: NEMA 250, Type 4X; NRTL listed for use with the supplied detector for smoke detection in HVAC system ducts.
 4. Each sensor shall have multiple levels of detection sensitivity.
 5. Sampling Tubes: Design and dimensions as recommended by manufacturer for specific duct size, air velocity, and installation conditions where applied.
 6. Relay Fan Shutdown: Fully programmable relay rated to interrupt fan motor-control circuit.

2.07 CARBON MONOXIDE DETECTORS

- A. General: Carbon monoxide detector listed for connection to fire-alarm system.
1. Mounting: Adapter plate for outlet box mounting.
 2. Testable by introducing test carbon monoxide into the sensing cell.
 3. Detector shall provide alarm contacts and trouble contacts.
 4. Detector shall send trouble alarm when nearing end-of-life, power supply problems, or internal faults.
 5. Comply with UL 2075.
 6. Locate, mount, and wire according to manufacturer's written instructions.
 7. Provide means for addressable connection to fire-alarm system.
 8. Test button simulates an alarm condition.

2.08 NOTIFICATION APPLIANCES

- A. Provide products by the following:
1. Simplex
- B. General Requirements for Notification Appliances: Connected to notification-appliance signal circuits, zoned as indicated, equipped for mounting as indicated, and with screw terminals for system connections.

1. Combination Devices: Factory-integrated audible and visible devices in a single-mounting assembly, equipped for mounting as indicated, and with screw terminals for system connections.
- C. Chimes: Vibrating type.
- D. Audible Notification Appliances: Speaker type. Comply with UL 1480.
- E. Visible Notification Appliances: Xenon strobe lights complying with UL 1971, with clear or nominal white polycarbonate lens mounted on an aluminum faceplate. The word "FIRE" is engraved in minimum 1-inch-high letters on the lens.
 1. Mounting: Wall mounted unless otherwise indicated.
 2. Flashing shall be in a temporal pattern, synchronized with other units.
 3. Strobe Leads: Factory connected to screw terminals.
 4. Mounting Faceplate: Factory finished, white.

2.09 REMOTE ANNUNCIATOR

- A. Description: Annunciator functions shall match those of fire-alarm control unit for alarm, supervisory, and trouble indications. Manual switching functions shall match those of fire-alarm control unit, including acknowledging, silencing, resetting, and testing.
 1. Mounting: Flush cabinet, NEMA 250, Type 1.
 - a. Contractor to confirm flush mount compatibility with existing wall installation.
- B. Display Type and Functional Performance: Alphanumeric display and LED indicating lights shall match those of fire-alarm control unit. Provide controls to acknowledge, silence, reset, and test functions for alarm, supervisory, and trouble signals.

2.10 ADDRESSABLE INTERFACE DEVICE

- A. General:
 1. Include address-setting means on the module.
 2. Store an internal identifying code for control panel use to identify the module type.
 3. Listed for controlling HVAC fan motor controllers.
- B. Monitor Module: Microelectronic module providing a system address for alarm-initiating devices for wired applications with normally open contacts.
- C. Control Module:
 1. Operate notification devices.
 2. Operate solenoids for use in sprinkler service.

2.11 DIGITAL ALARM COMMUNICATOR TRANSMITTER

- A. Digital alarm communicator transmitter shall be acceptable to the remote central station and shall comply with UL 632.
- B. Functional Performance: Unit shall receive an alarm, supervisory, or trouble signal from fire-alarm control unit and automatically capture two telephone line(s) and dial a preset number for a remote central station. When contact is made with central station(s), signals shall be transmitted. If service on either line is interrupted for longer than 45 seconds, transmitter shall initiate a local trouble signal and transmit the signal indicating loss of telephone line to the remote alarm receiving station over the remaining line. Transmitter shall automatically report telephone service restoration to the central station. If service is lost on both telephone lines, transmitter shall initiate the local trouble signal.
 1. Communication types.
 - a. VOIP
 - b. Cellular
- C. Local functions and display at the digital alarm communicator transmitter shall include the following:
 1. Verification that both telephone lines are available.
 2. Programming device.
 3. LED display.
 4. Manual test report function and manual transmission clear indication.
 5. Communications failure with the central station or fire-alarm control unit.
- D. Digital data transmission shall include the following:
 1. Address of the alarm-initiating device.

2. Address of the supervisory signal.
 3. Address of the trouble-initiating device.
 4. Loss of ac supply.
 5. Loss of power.
 6. Low battery.
 7. Abnormal test signal.
 8. Communication bus failure.
- E. Secondary Power: Integral rechargeable battery and automatic charger.
- F. Self-Test: Conducted automatically every 24 hours with report transmitted to central station.

PART 3 EXECUTION

3.01 EQUIPMENT INSTALLATION

- A. Comply with NFPA 72, NFPA 101, and requirements of authorities having jurisdiction for installation and testing of fire-alarm equipment. Install all electrical wiring to comply with requirements in NFPA 70 including, but not limited to, Article 760, "Fire Alarm Systems."
- B. Connecting to Existing Equipment: Verify that existing fire-alarm system is operational before making changes or connections.
- C. Equipment Mounting: Install fire-alarm control unit on finished floor.
- D. Install wall-mounted equipment, with tops of cabinets not more than 78 inches above the finished floor.
- E. Manual Fire-Alarm Boxes:
 1. Install manual fire-alarm box in the normal path of egress within 60 inches of the exit doorway.
 2. Mount manual fire-alarm box on a background of a contrasting color.
 3. The operable part of manual fire-alarm box shall be between 42 inches and 48 inches above floor level. All devices shall be mounted at the same height unless otherwise indicated.
- F. Smoke- or Heat-Detector Spacing: Comply with NFPA 72.
- G. Duct Smoke Detectors: Comply with NFPA 72 and NFPA 90A. Install sampling tubes so they extend the full width of duct. Tubes more than 36 inches long shall be supported at both ends.
- H. Elevator Shafts: Coordinate temperature rating and location with sprinkler rating and location. Do not install smoke detectors in sprinklered elevator shafts.
- I. Single-Station Smoke Detectors: Where more than one smoke alarm is installed within a dwelling or suite, they shall be connected so that the operation of any smoke alarm causes the alarm in all smoke alarms to sound.
- J. Remote Status and Alarm Indicators: Install in a visible location near each smoke detector, sprinkler water-flow switch, and valve-tamper switch that is not readily visible from normal viewing position.
- K. Audible Alarm-Indicating Devices: Install not less than 6 inches below the ceiling. Install speakers on flush-mounted back boxes with the device-operating mechanism concealed behind a grille. Install all devices at the same height unless otherwise indicated.
- L. Visible Alarm-Indicating Devices: Install adjacent to each alarm bell or alarm horn and at least 6 inches below the ceiling. Install all devices at the same height unless otherwise indicated.
- M. Device Location-Indicating Lights: Locate in public space near the device they monitor.

3.02 PATHWAYS

- A. Pathways shall be installed in EMT.
- B. Exposed EMT shall be painted red enamel.

3.03 CONNECTIONS

- A. Make addressable connections with a supervised interface device to the following devices and systems. Install the interface device less than 36 inches from the device controlled. Make an addressable confirmation connection when such feedback is available at the device or system being controlled.
 1. Smoke dampers in air ducts of designated HVAC duct systems.
 2. Electronically locked doors and access gates.

3. Alarm-initiating connection to activate emergency shutoffs for gas and fuel supplies.
4. Supervisory connections at valve supervisory switches.
5. Supervisory connections at low-air-pressure switch of each dry-pipe sprinkler system.
6. Supervisory connections at fire-extinguisher locations.

3.04 IDENTIFICATION

- A. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification specified in Section 260553 "Identification for Electrical Systems."
- B. Install framed instructions in a location visible from fire-alarm control unit.

3.05 GROUNDING

- A. Ground fire-alarm control unit and associated circuits; comply with IEEE 1100. Install a ground wire from main service ground to fire-alarm control unit.
- B. Ground shielded cables at the control panel location only. Insulate shield at device location.

3.06 FIELD QUALITY CONTROL

- A. Field tests shall be witnessed by authorities having jurisdiction.
- B. Perform the following tests and inspections:
 1. Visual Inspection: Conduct visual inspection prior to testing.
 - a. Inspection shall be based on completed record Drawings and system documentation that is required by NFPA 72 in its "Completion Documents, Preparation" table in the "Documentation" section of the "Fundamentals" chapter.
 - b. Comply with the "Visual Inspection Frequencies" table in the "Inspection" section of the "Inspection, Testing and Maintenance" chapter in NFPA 72; retain the "Initial/Reacceptance" column and list only the installed components.
 2. System Testing: Comply with the "Test Methods" table in the "Testing" section of the "Inspection, Testing and Maintenance" chapter in NFPA 72.
 3. Test audible appliances for the public operating mode according to manufacturer's written instructions. Perform the test using a portable sound-level meter complying with Type 2 requirements in ANSI S1.4.
 4. Test audible appliances for the private operating mode according to manufacturer's written instructions.
 5. Test visible appliances for the public operating mode according to manufacturer's written instructions.
 6. Factory-authorized service representative shall prepare the "Fire Alarm System Record of Completion" in the "Documentation" section of the "Fundamentals" chapter in NFPA 72 and the "Inspection and Testing Form" in the "Records" section of the "Inspection, Testing and Maintenance" chapter in NFPA 72.
- C. Reacceptance Testing: Perform reacceptance testing to verify the proper operation of added or replaced devices and appliances.
- D. Fire-alarm system will be considered defective if it does not pass tests and inspections.
- E. Prepare test and inspection reports.
- F. Maintenance Test and Inspection: Perform tests and inspections listed for weekly, monthly, quarterly, and semiannual periods. Use forms developed for initial tests and inspections.
- G. Annual Test and Inspection: One year after date of Substantial Completion, test fire-alarm system complying with visual and testing inspection requirements in NFPA 72. Use forms developed for initial tests and inspections.

3.07 SOFTWARE SERVICE AGREEMENT

- A. Comply with UL 864.
- B. Technical Support: Beginning at Substantial Completion, service agreement shall include software support for two years.
- C. Upgrade Service: At Substantial Completion, update software to latest version. Install and program software upgrades that become available within two years 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 access to system and to upgrade computer equipment if necessary.

3.08 DEMONSTRATION

- A. Train Owner's maintenance personnel to adjust, operate, and maintain fire-alarm system.

END OF SECTION