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USACE / NAVFAC / AFCESA **UFGS-15910N (August 2003)**
Preparing Activity: NAVFAC **Superseding UFGS-15910N (September 2001)**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated 25 June 2004

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DIVISION 15 - MECHANICAL

SECTION 15910N

DIRECT DIGITAL CONTROL SYSTEMS

08/03

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SECTION 15910N

DIRECT DIGITAL CONTROL SYSTEMS

08/03

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NOTE: This guide specification covers the requirements for direct digital control (DDC) of heating, ventilating, and air conditioning (HVAC) systems.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents**, including their organization designation and telephone number, is on the Internet.**

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR)**.**

Use of electronic communication is encouraged.

Brackets are used in the text to indicate designer choices or locations where text must be supplied by the designer.

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NOTE: The intent of this specification is to provide a multi loop, stand-alone, and distributed digital control system as manufactured by companies in the HVAC control field. This control system provides for all HVAC control functions. Analog and digital (binary, on/off, open/close) control signals are input to microprocessor based digital controllers. The digital controllers perform the control logic and output analog and digital signals to the HVAC equipment.

This control system will have interface ports to allow connection to a terminal, portable computer, and a central site computer. The interface equipment will not provide day to day control of the HVAC system, but it will allow the operator to enable and disable equipment, change setpoints,

change operating schedules, receive trends and alarms, and allow storage, modifications and downloading of control programs. This guide specification can be used to acquire a direct digital control system that consists of:

DDC of HVAC equipment with graphic operator work station. The operator workstation can be located in the building (directly connected to a communications LAN) or at a remote site (connected to the digital controller through a LAN or modems and a telephone line).

The DDC systems should have notebook computers, hand-held terminals, or panel mounted displays and keypads for direct connection to the digital controllers.

If there are questions on the design of direct digital control systems, contact the Engineering Field Division, Naval Facilities Engineering Command Mechanical Engineering Branch, or the Naval Facilities Engineering Service Center.

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NOTE: Show the following information on project drawings:

1. Mechanical Flow Drawing: Show relative position of all individual HVAC components, controller inputs (temperature sensors, pressure sensors, equipment proofs, override buttons, etc.), controller outputs (actuators, valves, dampers, etc.), and hard wired safeties (smoke detectors and freeze protection thermostats). On the same drawing show a simple points list. For example:

Equipment
VAV Air Handling Unit

Supply Fan Status - Amperage	AI
Supply Air Temperature	AI
Return Air Temperature	AI
Duct Static Pressure	AI
Chilled Water Valve	A0
Mixed Air Damper Control	AO
Supply Fan Variable Frequency Drive Speed	AO
Supply Fan VFD Status	DI
Supply Fan Start/Stop	DO

VAV Box

Space Temperature	AI
Setpoint Adjustment	AI
VAV Box Airflow - CFM	AI
VAV Box Supply Temperature	AI
VAV Box Damper	AO
VAV Box Reheat Coil	AO
Pushbutton Override	DI

Note: Above VAV Box Supply Temperature (from box to space) greatly helps maintenance and troubleshooting.

2. Direct Digital Controller Architecture Schematic: Show general architecture of DDC system including controllers, communication LANs, workstation terminal, etc.

3. Electric Elementary/Ladder Diagrams: Show line and control circuitry, motor starters, motor loads, control device actuators, manual and automatic switches, interlocks, and control sensors.

4. Dampers: Show type of damper (opposed or parallel blade).

5. Control Valves: Show control valve nominal size, flow capacities, type of fluid, inlet pressure, maximum and minimum pressure drop at design flow, and calculated Cv.

6. Include the following required controller parameters:

a. detailed sequence of operation

b. schedules and setpoints for all control loops and HVAC equipment

c. specify "dead-band" between heating and cooling

d. differential setpoints for two position control

7. Show pressure and temperature indicator scale ranges and location. Show location of temperature wells and pressure taps.

8. Indicate smoke detection system and location of key-operated override switch, when required.

9. Indicate location of meters provided in this and other sections if monitored by the DDC system.

10. Show location of room sensors, pressure sensors and outdoor air temperature sensors.

11. Show location of hand-off-auto switches at locally mounted motor starters, control panels, and motor control centers. Wire all safety controls to protect circuitry and equipment during both manual (hand) and auto (DDC) operation.
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PART 1 GENERAL

1.1 REFERENCES

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NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest guide specification. Use of SpecsIntact automated reference checking is recommended for projects based on older guide specifications.
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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL(AMCA)

AMCA 500-D	(1998) Laboratory Methods of Testing Dampers for Rating

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C12.10	(1997) Watthour Meters
ANSI C57.13	(1993) IEEE Standard Requirements for Instrument Transformers

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

ASHRAE Gdln3	(1996) Reducing Emission of Halogenated Refrigerants in Refrigeration and Air-Conditioning Equipment and Systems

ASME INTERNATIONAL (ASME)

ASME B16.18	(2002) Cast Copper Alloy Solder Joint Pressure Fittings
ASME B16.22	(2002) Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
ASME B16.26	(1988) Cast Copper Alloy Fittings for Flared Copper Tubes
ASME B16.34	(1996) Valves Flanged, Threaded, and Welding End
ASME B16.5	(1996) Pipe Flanges and Flanged Fittings
ASME B31.1	(2001) Power Piping
ASME B40.1	(1991) Gauges - Pressure Indicating Dial Type - Elastic Element
ASME BPVC SEC VIII	(2001) Boiler and Pressure Vessel Codes: Section VIII Rules for Construction of

	Pressure Vessels, Division 1

ASTM INTERNATIONAL (ASTM)

ASTM A 126	(1995; R 2001) Gray Iron Castings for Valves, Flanges, and Pipe Fittings
ASTM B 32	(2003) Solder Metal
ASTM B 75	(2002) Seamless Copper Tube
ASTM B 88	(2002) Seamless Copper Water Tube
ASTM B 88M	(1999) Seamless Copper Water Tube (Metric)
ASTM D 1238	(2001e1) Melt Flow Rates of Thermoplastics by Extrusion Plastometer
ASTM D 1693	(2001) Environmental Stress-Cracking of Ethylene Plastics
ASTM D 635	(2003) Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
ASTM D 638	(2002a) Tensile Properties of Plastics
ASTM D 792	(2000) Density and Specific Gravity (Relative Density) of Plastics by Displacement

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE C62.41	(1991) Recommended Practice for Surge Voltages in Low-Voltage AC Power Circuits
IEEE C62.45	(2002) Surge Testing for Equipment Connected to Low-Voltage (1000v and less)AC Power Circuits

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2002) National Electrical Code
NFPA 90A	(2002) Installation of Air Conditioning and Ventilating Systems

SHEET METAL AND AIR CONDITIONING CONTRACTORS' NATIONAL ASSOCIATION (SMACNA)

SMACNA HVAC Duct Const Stds	(1995, 2nd Ed) HVAC Duct Construction Standards - Metal and Flexible
SMACNA HVACTAB	(2002, 3rd Ed) HVAC Systems - Testing, Adjusting and Balancing

UNDERWRITERS LABORATORIES (UL)

UL 1449	(1996; Rev thru Jul 2002) Transient

	Voltage Surge Suppressors
UL 506	(2000; Rev thru Feb 2004) Specialty Transformers
UL 916	(1998; Rev thru Feb 2004) Energy Management Equipment

1.2 RELATED REQUIREMENTS

Section 15050N BASIC MECHANICAL MATERIALS AND METHODS, applies to this section, with the additions and modifications specified herein.

1.3 SUBCONTRACTOR SPECIAL REQUIREMENTS

Perform all work in this section in accordance with the paragraph entitled "Subcontractor Special Requirements" in Section 01310 ADMINISTRATIVE REQUIREMENTS. The paragraph specifies that all contract requirements of this section shall be accomplished directly by a first tier subcontractor. No work required shall be accomplished by a second tier subcontractor.

1.4 DEFINITIONS

1.4.1 Digital Controller

A control module which is microprocessor based, programmable by the user, has integral input/output within the module or on network connected modules, and performs stand-alone operations.

1.4.2 Direct Digital Control (DDC)

Digital controls, as defined in this specification, performing control logic. The controller directly senses building environment and makes control decisions based on user defined, controller resident programs. The controller outputs control signals that directly operate valves, dampers, and motor controllers. No conventional control devices, pneumatic or electronic, such as receiver-controllers, thermostats, and logic units are present within or interface with a direct digital control loop. Actuators are electric or pneumatic, and the controller output is converted to the appropriate type of signal.

1.4.3 DDC System

A system made up of one or more digital controllers which communicate on a network.

1.4.4 Distributed Control

The intent of distributed control is to install the controllers near their respective controlled equipment. The control system consists of stand-alone controllers, with the total number of input and output points limited to 48 or less per controller. Failure of any single controller will not cause the loss of more then 48 control points.

1.4.5 Dynamic Control

A process that optimizes energy efficiency of HVAC systems (air handling units, converters, chillers, and boilers) by increasing and decreasing setpoints or starting and stopping equipment in response to heating and cooling needs of the facility. A requirement of dynamic control is knowing the heating/cooling demand status of the process. Therefore dynamic control requires controllers connected in a communications network.

1.4.6 Firmware

Firmware is software programmed into read only memory (ROM) and erasable programmable read only memory (EPROM) chips. Software may not be changed without physically altering the chip.

1.4.7 Hand-Held Terminal

A hand-held terminal is a manufacturer specific device connected directly to a communications port on a controller, through which the controller is accessed and, in some cases, programmed.

1.4.8 Input/Output (I/O) Points

I/O points refer to analog inputs (AI), digital inputs (DI), analog outputs (AO), and digital outputs (DO) in a digital controller. Another term for digital inputs and outputs is binary inputs and outputs. Inputs are from analog sensors (temperature, pressure, humidity, flow) and digital sensors (motor status, flow switches, switch position, and pulse output devices). Outputs operate modulating and on/off control devices.

1.4.9 I/O Expansion Unit

An I/O expansion unit provides additional point capacity to a digital controller and communicates with the stand-alone digital controller on a LAN. An I/O unit is not stand-alone because the control program does not reside in the I/O unit. An I/O expander which connects directly to a stand alone controller through a multi-line microprocessor bus is restricted to reside within 3 feet of the stand alone controller and is considered part of the stand alone controller.

1.4.10 Local Area Network (LAN)

a. A communications bus that interconnects digital controllers for peer-to-peer (see "peer-to-peer" below) communications. Different levels of LANs are possible within a single DDC system. In this case, a digital controller on a higher level LAN acts as a network controller to the controllers on the lower level LAN. The network controller, then, has at least two LAN communications ports. One port supports peer-to-peer communications with other digital controllers on the higher level LAN. The other port supports communications with the digital controllers on the lower level LAN.

b. LANs permit sharing global information. This allows building and site wide control strategies such as peak demand limiting, dynamic control strategies, coordinated response to alarm conditions, and remote monitoring and programming of digital controllers.

1.4.11 Microprocessor

A microprocessor refers to the central processing unit (CPU) that contains all registers and logic circuitry that allow digital controllers to function.

1.4.12 Output Signal Conversion

Output signal conversion refers to changing one kind of control output into a proportionally related signal appropriate for direct actuation of the controlled device. An example is converting a 4 to 20 mA or 0 to 10 VDC signal to a proportional 3 to 15 psig signal to operate a pneumatic actuator.

1.4.13 Optimum Start

Optimum start is a method of starting HVAC equipment prior to scheduled occupancy in order to have the building at setpoint when occupied. Optimum start is based on the zone temperatures, zone setpoints, and outdoor temperature.

1.4.14 Peer-to-Peer

Peer-to-peer refers to controllers connected on a communications LAN that act independently, as equals, and communicate with each other to pass information.

1.4.15 PID

PID refers to proportional, integral, and derivative control; the three types of action that are used in controlling modulating equipment.

1.4.16 Resolution

Refers to the number of possible states an input value or output value can take and is a function of the digital controller I/O circuitry; the A/D converter for input and the D/A converter for output. Ten bit resolution has 1024 possible states.

1.4.17 Stand-Alone Control

Refers to the digital controller performing required climate control, and energy management functions without connection to another digital controller or computer. Requirements for stand-alone control are a time clock, a microprocessor, resident control programs, PID control, and I/O. All stand-alone controllers have a communication port and firmware for direct connection and interrogation with a laptop computer or similar hand-held device. This interrogation includes parameter changes and program downloads.

1.4.18 Terminal Control Unit (TCU)

An off-the-shelf, stand-alone digital controller equipped for communication on a lower level LAN. TCUs may deviate from stand-alone only in receiving energy management and time information from a stand alone digital controller. A TCU is commonly application specific and is used for distributed control of specific HVAC subsystems. A TCU communicates with other digital controllers. Typically, a TCU communicates on a lower level LAN. Examples where TCUs are used include small air handling units (AHUs), variable air volume (VAV) boxes, fan coil units, and heat pumps.

1.5 DDC SYSTEM DESCRIPTION

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Notes on Vendor Interoperability

The technology for sharing information between two or more proprietary controllers is not fully developed. It is not realistic to simply specify a "common architecture" or gateway that seamlessly bridges the gap of vendor specific hardware, programming, and network communications.

It is possible, however to share relevant point information between different manufacturer's controllers on a case by case basis. Several control manufactures and many manufacturers of plant equipment, speed drives, and building security systems have built in communication ports or gateways for external communications. These ports and gateways are able to communicate point information to other vendors controllers using proprietary or industry standard protocols. The designer should research new and existing controller/equipment combinations to take advantage of this option if it is readily available. Specifying custom gateways or new communication ports that don't already exist commercially is costly and will increase risk.

To increase the chance of successful interoperability, begin with a simple design scheme and specify only relevant shared point types and parameters. Also specify desired actions, vendor responsibility, operator display, and physical wiring where appropriate. Do not expect or specify that two or more systems will share all possible control information. Focus more on functionality between systems as opposed to protocols and internal architecture.

For less complex cases it is best to specify interoperability directly on the controls drawings. The following example specifies communications between a DDC network made by Vendor "A" and centrifugal chiller controls made by Vendor "B":

<u>Sample Specification</u>:

<u>Need</u>: The DDC network will exchange point parameters listed in Table (1) with the chiller controls. A parameter noted as a read point means that the value is read at 1-minute minimum intervals by any relevant network controller to accomplish specified sequence of control. A parameter noted as a write point means the value is written at 1-minute minimum intervals by the controller network to the chiller to accomplish the chiller sequence of control.

<u>Capability</u>: Point parameters read by the DDC network shall be available for analysis, trending, alarming, and other functions that are available for

other similar parameters that are native to the DDC network. Any point scaling, unit conversion, or other manipulation necessary for correct program execution shall be programmed in the controller logic or communication gateway and transparent to the end user.

<u>Method</u>: Exchange of information noted in Table (1) shall be over a single communication cable between communication ports on the chiller and DDC network. A gateway or translator device is allowable between communication ports if necessary. The gateway and communication cable must meet all relevant criteria in the project specification.

<u>Presentation</u>: All read and write point information listed in Table (1) shall be presented at their relevant locations in real time engineering units at the operator workstation.

<u>Table (1) Shared Information Between Chiller and Building DDC</u>

Point/Parameter	Units	Write to Chiller	Read by DDC
Chiller Enable	On/Off	X	
Chilled Water Supply Temperature Set Point	deg. F	X	
Chilled Water Supply Temperature	deg. F		X
Chilled Water Return Temperature	deg. F		X
Entering Condenser Water Temperature	deg. F		X
Phase A Motor Current	Amps		X
Accumulated Run Time	Hours		X

****

a. [Remove existing and] [provide new] [and] [modify existing] DDC systems including associated equipment and accessories. Manufacturer's products, including design, materials, fabrication, assembly, erection, examination, inspection, and testing shall be in accordance with ASME B31.1 and NFPA 70, except as modified herein or indicated otherwise.

b. Provide the DDC systems to maintain stable temperature control and all other conditions as indicated. The end-to-end accuracy of the system, including temperature sensor error, wiring error, A/D conversion, and display, shall be 1 degree F or less.

[c. The existing DDC system was manufactured by [_____].]

[d. Provide a DDC system with a new workstation and workstation software. If working with an existing DDC system of the same manufacturer, upgrade the existing workstation software with the manufacturers' latest software version.]

1.5.1 Design Requirements

1.5.1.1 Control System Schematic

Provide control system schematic that includes the following:

a. Location of each input and output device

b. Flow diagram of each HVAC component, for instance flow through coils, fans, dampers

c. Name or symbol for each component such as V-1, DM-2, and T-1 for a valve, damper motor, and temperature sensor, respectively

d. Setpoints

e. Sensor range

f. Actuator range

g. Valve and damper schedules and normal position

h. Switch points on input switches

i. Written sequence of operation for each schematic

j. Schedule identifying each sensor and controlled device with the following information:

(1) LAN and Software point name with send and receive address if applicable

(2) Point type (AO, AI, DO, DI)

(3) Point range

(4) Digital controller number for each point

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NOTE: If DDC system consists of two levels of local area network (LAN), identify controllers on the sub LAN by a two number code. The first number will be that of the controller on the higher level LAN that acts as the lower level LAN network controller. The second number will be the number of the lower level controller. If controllers reside in multiple buildings, add building number to the LAN identifier.

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1.5.1.2 Electrical Equipment Ladder Diagrams

Submit diagrams showing electrical equipment interlocks, including voltages and currents.

1.5.1.3 Component Wiring Diagrams

Submit a wiring diagram for each type of input device and each type of output device. Diagram shall show how the device is wired and powered; showing typical connections at the digital controller and each power supply, as well as at the device itself. Show for all field connected devices, including, but not limited to, control relays, motor starters, electric or electronic actuators, and temperature, pressure, flow, proof, and humidity sensors and transmitters.

1.5.1.4 Terminal Strip Diagrams

Submit a diagram of each terminal strip, including digital controller terminal strips, terminal strip location, termination numbers and associated point names.

1.5.1.5 Communication Architecture Schematic

Submit a schematic showing communication networks used for all DDC system controllers, workstations, and field interface devices.

1.6 SUBMITTALS

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NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not complex and can be reviewed through the Contractor's Quality Control system. Only add a "G" if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy projects.

Submittal items not designated with a "G" are considered as being for information only for Army projects and for Contractor Quality Control approval for Navy projects.

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Government approval is required for submittals with a "G" designation;

submittals not having a "G" designation are [for Contractor Quality Control approval.][for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

List of Drawings; G

List of Symbols and Abbreviations Used on Drawings; G

List of I/O Points; G

Equipment Components List; G

AC Power Table; G

SD-02 Shop Drawings

Control system schematic; G

Ladder diagrams; G

Component wiring diagrams; G

Terminal strip diagrams; G

Communication architecture schematic; G

SD-03 Product Data

DDC hardware; G

DDC capabilities; G

VARIABLE FREQUENCY MOTOR DRIVES; G

Workstation software; G

Input devices; G

Output devices; G

Surge and Transient Protection; G

Notebook computer; G

Hand-Held terminal; G

Smoke detectors; G

Pneumatic tubing; G

Air Compressors; G

Refrigerated Air Dryer; G

SD-06 Test Reports

****
NOTE: Include the bracketed option for Code CI 52, Construction Engineering Branch review for LANTNAVFACENGCOM projects. Ensure that appropriate information for this special approval procedure is specified in the Section 01330, "Submittal Procedures" to coordinate the special requirements. For other projects, submittal review shall be performed by the designer of record.
****

[Submit, for review and approval, to Code CI 52, Construction Engineering Branch, Atlantic Division, Naval Facilities Engineering Command, the SD-06, "Test Reports", listed below. Field test plan and performance verification test plan shall be submitted to and approved by Code CI 52 prior to commencing the respective test, that is, the field test and the performance verification test. All other submittals in this section require Government approval and shall be sent to the designer of record for review and approval.]

Field Test Plan; G

Performance Verification Test Plan; G

Field Tests; G

Performance Verification Tests; G

SD-07 Certificates

Contractors Qualifications; G

Training; G

SD-10 Operation and Maintenance Data

Controls and HVAC System Operators Manual; G

DDC Manufacturer's Hardware and Software Manuals; G

SD-11 Closeout Submittals

Training Course Documentation; G

Service organizations; G

Contractor certification; G

1.7 Operating environment

Protect components from humidity and temperature variations, dust, and other contaminants, within limits published by the manufacturer.

1.8 QUALITY ASSURANCE

1.8.1 Standard Products

a. Material and equipment shall be standard products of manufacturer regularly engaged in the manufacturing of such product, using similar materials, design and workmanship. The standard products shall have been in commercial or industrial use for 2 years prior to bid opening. The 2-year use shall include applications of similarly sized equipment and materials used under similar circumstances and sold on the commercial market through advertisements, manufacturers' catalogs, or brochures.

b. Products are supported by a local service organization.

****
NOTE: Delete items below that are not used
****

1.8.1.1 DDC Hardware

a. I/O type and characteristics

b. Resident programs

c. Communications ports

d. Protected memory

e. Operating temperature limits

1.8.1.2 DDC Capabilities

a. Communications; baud rates, communication ports, hierarchy

b. Trending capabilities

c. Alarming capabilities; capable of alarm generation as defined in this specification

d. Messaging capabilities

e. Self diagnostic capabilities

e. PID control capabilities

1.8.1.3 Workstation Software

a. Mouse and keyboard operation

b. Communications

c. DDC Program download capability

d. Dynamic point update

e. Program modification

f. Database modification

g. Graphics and graphics modification

h. Penetration of graphics

1.8.1.4 Input Devices

a. Transmitters

b. Temperature sensors

c. Humidity sensors

d. Pressure sensors

e. Flow or motor proof

f. Sensor wells

1.8.1.5 Output Devices

a. Dampers

b. Valves

c. Actuators

d. Control relays

e. Solenoid air valves

f. Electronic to pneumatic transducer

1.8.1.6 Surge and Transient Protection

a. Power line

b. Communications lines

c. Controller I/O

1.8.2 Nameplates and Tags

a. Nameplates and tags bearing device unique identifiers shall be engraved or stamped. Permanently attach nameplates to HVAC control panel doors and back plates.

b. For each field mounted piece of equipment attach a plastic or metal tag with equipment name and point identifier.

1.8.3 Verification of Dimensions

The contractor shall verify all dimensions in the field, and shall advise the Contracting Officer of any discrepancy before performing work.

1.8.4 Drawings

Because of the small scale of the drawings, it is not possible to indicate all offsets, fittings, and accessories that may be required. The Contractor shall carefully investigate the mechanical, electrical, and finish conditions that could affect the work, and shall furnish all work necessary to meet such conditions.

1.8.4.1 List of Drawings

Provide a list of drawings.

1.8.4.2 List of Symbols and Abbreviations Used on Drawings

Provide an index of symbols and abbreviations used on the drawings.

1.8.4.3 List of I/O Points

For each input and output physically connected to a digital controller provide, on a controller by controller basis, provide the following:

a. Point description: for example: mixed air temperature, supply fan start/stop, etc.

b. Point type: AO, AI, DO, or DI.

c. Point range

d. Sensor range associated with point range:

e. Software name(s) associated with point, if any.

f. Point connection terminal number

1.8.4.4 Equipment Components List

Submit a listing of controllers and connected devices shown on control system schematic. List the following:

a. Control system schematic name

b. Description

c. Manufacturer of controller

d. Controller's name

e. Equipment part numbers

f. Cv for valves

g. For actuators:

(1) Motive force (such as pneumatic, or electric)

(2) Normal position

(3) Nominal operating range (such as 3 to 7 psi, 4 to 8 mA)

1.8.4.5 AC Power Table

Submit a table listing each controller and the circuit breaker number, panel box number, and physical location of each controller's source of AC power.

1.8.5 Contractors Qualifications

a. The Contractor or subcontractor performing the work shall have completed at least three DDC systems installations of a similar design and have successfully operated a similar sequence of operation for at least three years.

1.8.6 Pressure Tank Certification

Provide certification stating pressure tanks are constructed and labeled in accordance with ASME BPVC SEC VIII for a minimum of 125 psig working pressure.

1.8.7 Training Course Documentation

Training course documentation including a manual for each trainee plus two additional copies and one copy of audiovisual training aids, if used. Documentation shall include an agenda, defined objectives for each lesson and detailed description of the subject matter of each lesson.

1.8.8 Service Organizations

Qualified service organization list including the names and telephone numbers of organizations qualified to service the HVAC control systems.

1.8.9 Contractor Certification

Provide certification that installation of the control system is complete and meets the technical requirements of this section.

1.8.10 Controls and HVAC System Operators Manual

Provide two copies of a Control and HVAC Systems Operators Manual. Provide in a 3 ring binder with a minimum of the following 7 sections. Use tabs to divide each section.

a. Description of HVAC Systems: Provide a description of the HVAC system components and control system. Include sequence of operation and a complete points list.

b. Controls Drawings: Provide drawings as specified in submittal paragraph.

c. Control Program Listings: Provide listing of all control programs, including terminal equipment controller setup pages if used.

d. Current Operating Parameters: Provide printouts of input and output setup information, (database setups). This section provides information such as point addresses, slopes and offsets for all points, database of points, etc.

e. Design Information: Include relevant design data and calculations.

f. Control Equipment Technical Data Sheets: Provide technical data sheets for all controller hardware and accessories.

g. Backup of Control Program: Provide backup copies of the control program and ACAD control drawings on CD-ROM [100MB Zip Disks].

1.8.11 DDC Manufacturer's Hardware and Software Manuals

Provide the following manuals.

a. Installation and Technical Manuals for all digital controller hardware.

[b. Installation and Technical Manuals for workstation.]

c. Operator Manuals for all digital controllers.

[d. Operator Manuals for all workstation software.]

e. Programming Manuals for all digital controllers.

[f. Programming Manuals for workstation software.]

1.8.12 Modification of References

The advisory provision in ASME B31.1 and NFPA 70 are mandatory. Substitute the word "shall" for "should" wherever it appears and interpret all references to the "authority having jurisdiction" and "owner" to mean the Contracting Officer.

PART 2 PRODUCTS

2.1 DDC SYSTEM

a. Provide a DDC system as a distributed control system. The system shall have stand-alone digital controllers, a communications Network [, and a separate workstation computer with workstation software].

b. Provide an operator programmable system to perform closed-loop, modulating control of building equipment. Connect all digital controllers through the communication network to share common data and report to workstation computers. Provide workstation DDC software capable of programming and monitoring the digital controllers. The control system shall be capable of downloading programs between the workstation and digital controllers.

c. Provide the quantity of digital controllers indicated on the drawings to perform required climate control, energy management, and alarm functions. The quantity of controllers shall be no less than the number shown on drawings. All material used shall be currently in production.

2.1.1 Direct Digital Controllers

DDC hardware shall be UL 916 rated.

2.1.1.1 Distributed Control

Apply digital controllers in a distributed control manner.

2.1.1.2 I/O Point Limitation

Total number of I/O hardware points, including those communicated over a

LAN, used by a single stand-alone digital controller, including I/O expansion units shall not exceed 48.

2.1.1.3 Environmental Operating Limits

Provide digital controllers that operate in environmental conditions between 32 and 120 degrees F.

2.1.1.4 Stand-Alone Control

Provide stand-alone digital controllers.

2.1.1.5 Internal Clock

Provide a clock with each stand-alone controller. Each controller shall have its clock backed up by a battery or capacitor with sufficient capacity to maintain clock operation for a minimum of 72 hours during power outage.

2.1.1.6 Memory

a. Provide sufficient memory for each controller to support required control, communication, trends, alarms, and messages

b. Memory Protection: Programs residing in memory shall be protected either by using EEPROM, flash memory, or by an uninterruptible power source (battery or uninterruptible power supply (UPS)). The backup power source shall have sufficient capacity to maintain volatile memory during an AC power failure. Where the uninterruptible power source is rechargeable (a rechargeable battery), provide sufficient back-up capacity for a minimum of seventy-two hours. The rechargeable power source shall be constantly charged while the controller is operating under normal line power. Where a non-rechargeable power source is used, provide sufficient capacity for a minimum of two years accumulated power failure. Batteries shall be replaceable without soldering.

2.1.1.7 Inputs

Provide input function integral to the direct digital controller. Provide input type(s) as required by the DDC design. For each type of input used on high-level controllers, provide at least one similar spare input point per controller.

a. Analog Inputs: Allowable input types are 100 ohm (or higher) platinum RTDs, thermistors, 4 to 20 mA, and 0-10 VDC. Thermistor and direct RTD inputs must have appropriate conversion curves stored in controller software or firmware. Analog to digital (A/D) conversion shall have 10-bit minimum resolution.

b. Digital Inputs: Digital inputs shall sense open/close, on/off, or other two state indications.

2.1.1.8 Outputs

Provide output function integral to the direct digital controller. Provide output type(s) as required by the DDC design. For each type of output used on high-level controllers, provide at least one similar spare output point per controller.

a. Analog Outputs: Provide controllers with 10 bit minimum output resolution. Output shall be 4 to 20 mA, 0 to 10 VDC, or 0 to 20 psig. Each pneumatic output shall have feedback for monitoring of the actual pneumatic signal.

b. Digital Outputs: Provide contacts rated at a minimum of 1 ampere at 24 volts.

2.1.1.9 PID Control

Provide controllers with proportional integral, and derivative control capability. Terminal controllers (TCV) are not required to have the derivative component.

2.1.1.10 Digital Controller Networking Capabilities

The upper level digital controllers shall be capable of networking with other similar upper level controllers. Upper level controllers shall also be capable of communicating over a network between buildings.

2.1.1.11 Communications Ports

a. Controller-to-Controller LAN Communications Ports: Controllers in the building DDC system shall be connected in a communications network. Controllers shall have controller to controller communication ports to both peer controllers (upper level controllers) and terminal controllers (lower level controllers). Network may consist of more than one level of local area network and one level may have multiple drops. Communications network shall permit sharing information between controllers, allowing execution of dynamic control strategies, and coordinated response to alarm conditions. Minimum baud rate for the lowest level LAN is 9600 Baud. Minimum baud rate for the highest level LAN shall be 9600 Baud. Minimum baud rate for a DDC system consisting of a single LAN is 9600 Baud.

b. On-Site Interface Ports: Provide a RS-232, RS-485, or RJ-11 communications port for each digital controller that allows direct connection of a computer or hand held terminal and through which the controller may be fully accessed. Controller access shall not be limited to access through another controller. On-site interface communication ports shall be in addition to the communications port(s) supporting controller to controller communications. Communication rate is 9600 Baud minimum. Every controller on the highest level LAN shall have a communications port supporting direct connection of a computer; a hand held terminal port is not sufficient. By connecting a computer to this port, every controller in the direct digital control system shall be accessible and programmable.. The following operations shall be available: downloading and uploading control programs, modifying programs and program data base, and retrieving or accepting trend reports, status reports, messages, and alarms.

c. Remote Work Station Interface Port: Provide one additional direct connect computer port in each DDC system for permanent connection of a remote operator's work station, unless the workstation is a node on the LAN. All operations possible by directly connecting a computer to a controller at the highest level LAN shall be available through this port.

d. Telecommunications Interface Port: Provide one additional telecommunications port in each DDC system permitting remote communications via telephone. All operations possible by directly connecting a computer to a controller at the highest level LAN shall be available through the telecommunications port. A telecommunications port provided on a digital controller shall be in addition to the port required for directly connecting a computer to the controller. Telecommunication baud rate is 28000 minimum.

2.1.1.12 Modem

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NOTE: When a modem is not required for communication between the workstation and the DDC system, delete this paragraph. Add a modem if a laptop computer is specified with a desktop workstation.

****

Provide two modems per DDC system to communicate between the digital control system and the computer workstation. Minimum modem baud rate is 56 Kbaud with v.90 communication standard.

****

NOTE: Indicate control devices that must be in enclosures with more stringent requirements than that covered by NEMA 1.

****

2.1.1.13 Digital Controller Cabinet

Each indoor digital controller cabinet shall protect the controller from dust and rated NEMA 1, unless specified otherwise. Each outdoor digital controller cabinet shall protect the controller from all outside conditions and rated NEMA 4. Cabinets for high level controllers shall be hinged door, lockable, and have offset removable metal back plate.

2.1.1.14 Main Power Switch

Each controller on the highest level LAN or each control cabinet shall have a main external power switch for isolation of the controller from AC power. The switch shall be located in the DDC cabinet.

2.1.2 Terminal Control Units

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NOTE: TCUs are digital controllers, as defined in Definitions, for Terminal Control Units. TCUs generally communicate on a lower level LAN. Designer should specify location of the TCU on the drawings. Examples of terminal control unit applications include VAV boxes, fan coil units, and heat pumps.

****

a. The same company as the digital controllers shall manufacture TCUs.

b. TCUs shall automatically start-up on return of power after a failure, and previous operating parameters shall exist or shall be automatically downloaded from a digital controller on a higher level LAN.

c. TCUs do not require an internal clock if they get time information from a higher level digital controller.

2.1.3 DDC Software

2.1.3.1 Sequence of Control

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NOTE: The sequence of control shall be written to include all conventional control operations (e.g. temperature and pressure control loops), time event operations, energy management functions (night setback, reset schedules, and optimum start routines), push button overrides, demand limiting, safeties, and emergency conditions. The preferred location for specifying and documenting the sequence of control is directly on the project drawings.

****

Provide, in the digital controllers, software to execute the sequence of control. Provide one registered copy of all software used to program control sequences in all direct digital controllers and LAN controllers on the computer workstation. Provide any access keys which restrict programming language software functions or the ability to compile or prepare programming for download to controllers. Provide final copy of each program used in the system in both compiled and editable formats. Where specially programmed factory configured smart controllers are used in the system, provide minimum factory programming tools and specialized controller programs ready for download to replacement controllers. At minimum, controllers must be capable of performing programming functions outlined in the following "Parameter Modification" section.

2.1.3.2 Parameter Modification

Provide software to modify control parameters. Parameter modification for all controllers (high level and low level application specific) is through the main workstation computer [and with laptop computer or keypad terminal directly at each controller]. Modifications accomplished without having to make changes directly in line-by-line programming. When the control program is of the line-by-line type, database parameters in the following list that take real number values require assignment of variable names so parameters can be changed without modifying programming. Alternatively, block programming languages shall provide for modification of these database parameters in fill-in-the-blank screens. Parameters of like type, including those in different high level and low level controllers, may be grouped together for a single, global change. For example, an operator may group all second floor space temperature setpoints into a group and raise the setpoint by two degrees with a single command. The following parameters shall be modifiable in this way:

a. Setpoints

b. Dead band limits and spans

c. Reset schedules

d. Switch over points

e. PID gains and time between control output changes

f. Time

g. Timed local override time

h. Occupancy schedules

i. Holidays

j. Alarm points, alarm limits, and alarm messages

k. Point definition database

l. Point enable, disable, and override

m. Trend points, trend intervals, trend reports

n. Analog input default values

o. Passwords

p. Communications parameters including network and telephone communications setups

2.1.3.3 Differential

Where setpoint is in response to some analog input such as temperature, pressure, or humidity, include a setpoint differential to prevent short cycling of control devices.

2.1.3.4 Motor and Flow Status Delay

Provide an adjustable delay between when a motor is commanded on or off and when the control program looks to the motor or flow status input for confirmation of successful command execution.

2.1.3.5 Run time Accumulation

Provide resettable run time accumulation for each controlled digital output.

2.1.3.6 Timed Local Override

Provide user definable adjustable run time for each push of a momentary contact timed local override. Pushes shall be cumulative with each push designating the same length of time. Provide a user definable limit on the number of contact closures summed, such as 6, before the contact closures are ignored. Timed local overrides are disabled during occupancy periods.

2.1.3.7 Time Programs

Provide programs to automatically adjust for leap years, daylight savings time, and operator time adjustments.

2.1.3.8 Scheduling

a. Individual controlled equipment shall be schedulable with schedule based on time of day, day of week, and day of year. Equipment may be associated into groups. Each group may be associated with a different schedule. Changing the schedule of a group shall change the schedule of all equipment in the group. Groups may be modified, created and deleted by the operator.

b. Provide capability to view and modify schedules in a seven-day week format. When control program does not automatically compute holidays, provide capability to enter holiday schedules one full year at a time.

2.1.3.9 Point Override

I/O and virtual points shall accept software overrides to any possible value.

2.1.3.10 Alarming

I/O points and software points shall be alarmable. Alarms may be enabled and disabled for every point. Alarm limits shall be adjustable on analog points. Controllers connected to an external communications device such as a printer, terminal, or computer, shall download alarm and alarm message when alarm occurs. When a computer workstation is connected to a DDC system with a LAN or modem, operator selected alarm conditions will initiate a call and report to the computer [or an alphanumeric pager]. Otherwise alarms will be stored and automatically downloaded when a communications link occurs. The following conditions shall generate alarms:

a. Motor is commanded on or off but motor status input indicates no change

b. Temperature, humidity, or pressure strays outside selectable limits

c. An analog input takes a value indicating sensor failure

d. A module is not communicating on the LAN

e. A power outage occurs

2.1.3.11 Messages

Messages shall be operator defined and assigned to alarm or status conditions. Messages shall be displayed on the workstation or printer when these conditions occur.

2.1.3.12 Trending

DDC system shall have the capability to trend all I/O and virtual points. Points may be associated into groups. A trend report may be set up for each group. The period between logging consecutive trend values shall range from one minute to 60 minutes at a minimum The minimum number of consecutive trend values stored at one time shall be 30 per variable. When trend memory is full, the most recent data shall overwrite the oldest data. Trend data shall be capable of being uploaded to computer. Trend data shall be available on a real time basis; trend data shall appear numerically and graphically on a connected computer's screen as the data is processed from the DDC system. Trend reports shall be capable of uploading to computer for storage.

2.1.3.13 Status Display

Current status of I/O and virtual points shall be displayed on command. Points shall be associated into functional groups, such as all the I/O and virtual points associated with control of a single air handling unit, and displayed as a group, so the status of a single mechanical system can be readily checked. A group shall be selectable from a menu of groups having meaningful names; such as AHU-4, Second Floor, Chiller System, and other such names.

2.1.3.14 Diagnostics

Each controller shall perform self-diagnostic routines and provide messages to an operator when errors are detected. The DDC system shall be capable of recognizing a non-responsive module on a LAN. The remaining, responsive modules on a LAN shall not operate in a degraded mode.

2.1.3.15 Power Loss

During a power outage, each controller shall assume a disabled status and outputs shall go to a user definable state. Upon restoration of power, DDC system shall perform an orderly restart, with sequencing of outputs.

2.1.3.16 Program Transfer

Provide software for download of control programs and database from a computer to controllers and upload of same to computer from controllers. Every digital controller in the DDC system shall be capable of being downloaded and uploaded to through a single controller on the highest level LAN.

2.1.3.17 Password Protection

Provide at least three levels of password protection to the DDC system permitting different levels of access to the system. The lowest level allows monitoring only. The highest level allows full control of all functions, including setting new passwords.

****
NOTE: Delete all paragraphs referencing the workstation when no workstation is specified.
****

2.1.3.18 Energy Data Recording

Provide a resettable signal accumulation for each meter at the main building digital controller.

a. Calculate hot water thermal energy in W BTU/HR using hot water supply temperature and flow and hot water return temperature signals.

b. Calculate chilled water thermal energy in W BTU/HR using chilled water supply temperature and flow and chilled water return temperature signals.

c. Record electrical energy in KWH BTU/HR. [and electrical demand in KW BTU].

d. Record steam in kg/hr lbs/hr [and annunciate high pressure steam pressure in kPa psi].

e. Record natural gas in L 100 cubic feet.

2.1.4 Workstation

a. Provide a central workstation computer with installed software to provide an interface for monitoring, troubleshooting, and making adjustments to the program or operating parameters of all DDC controllers, including TCUs. The workstation shall also be capable of programming all controllers, including TCUs.

b. DDC system shall routinely operate continuously without connection to the workstation. Information at the workstation is not required for day to day operations of the direct digital controllers.

2.1.4.1 Hardware

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NOTE: Update these criteria as technology dictates.
****

The DDC system manufacturer shall recommend all workstation computer equipment and peripherals. The workstation shall be configured to operate according to the DDC system manufacturer's specifications. Workstation hardware shall be configured to allow operation of software, uploading and downloading of programs, and creation of graphics. At a minimum the workstation hardware shall consist of:

a. Computer; computer shall use Microsoft Windows 98, 2000, or NT, and shall not have less than Intel Pentium III processor, running at 600 megahertz speed, 18 giga-byte hard disc, 128 megabyte RAM, 1 serial and 1 parallel port, 2 USB ports, 17 inch monitor with 740 x 1024 and 0.28 dpi minimum resolution, 101 character keyboard, a 1.4 megabyte 3 1/2 inch floppy drive, 48X internal CD ROM drive,[internal 100MB Zip drive with 2 Zip disks][16X internal read, writer, rewrite CD-Rom Drive with software].

b. Mouse

c. Modem; 56 Kbaud, v.90 standard

d. Printer; printer shall be laser output with one spare cartridge.

e. 120-volt terminal strip UL 1449 6-outlet with surge protection.

2.1.4.2 Software

Workstation software shall be configured to operate according to the DDC system manufacturer's specifications. Software shall be installed in the workstation computer and permit monitoring and troubleshooting of the DDC system. Workstation software permits modification of controller parameters and control for all controllers, both high level and low level application specific. Operations shall be menu selected. Menu selections shall be made with a mouse.

a. Menu System: Menu system shall allow an operator to select a particular function or access a particular screen through successive menu penetration.

b. Controller Parameter Modification: The workstation software shall be an interface for performance specified in paragraph entitled "Parameter Modification" and available through direct connection of a computer to a digital controller. Parameter modification shall require only that an operator "fill in the blank" for a parameter on a screen requesting the information in plain language. Parameter modifications shall download to the appropriate controllers at operator request.

c. Program modification: For systems using a line-by-line programming language, provide an off-line text editor, similar to a BASIC program editor, permitting modification of controller resident control programs. For systems using block programming languages provide a capability for linking blocks together to create new programs or modify existing programs. Program modifications shall download to appropriate controllers at operator request.

2.1.4.3 Graphic-Based Software

The workstation shall use graphic-based software to provide a user-friendly interface to the DDC system. Graphic-based software shall provide graphical representation of the building, the buildings mechanical systems, and the DDC system. The current value and point name of every I/O point shall be shown on at least one graphic and in its appropriate physical location relative to building and mechanical systems.

a. Graphics shall closely follow the style of the control drawings in representing mechanical systems, sensors, controlled devices, and point names.

b. Graphic Title: Graphics shall have an identifying title visible when the graphic is viewed.

c. Dynamic Update: When the workstation is on-line with the control system, point data shall update dynamically on the graphic images.

d. Graphic Penetration: Provide graphic penetration when the capability exists. For systems without graphic penetration, provide menu penetration for selection of individual graphics to give the same hierarchical affect provided by graphic penetration.

e. Graphic Types: Graphic-based software shall have graphics of the building exterior, building section, floor plans, and mechanical systems. Provide the following graphics:

(1) Building Exterior Graphic: Show exterior architecture, major landmarks, and building number.

(2) Building Section Graphic: Show floors in section graphic with appropriate floor name on each floor.

(3) Floor Plan Graphics: Provide a single graphic for each floor, unless the graphic will contain more information than can

reasonably be shown on a single graphic. Each heating or cooling zone within a floor plan shall have a zone name and its current temperature displayed within the zone outline. Show each controlled variable in the zone. Provide visual warning for each point in alarm.

(4) Mechanical System Graphics: Provide two-dimensional drawings to symbolize mechanical equipment; do not use line drawings. Show controlled or sensed mechanical equipment. Each graphic shall consist of a single mechanical system; examples are a graphic for an air handling unit, a graphic for a VAV box, a graphic for a heating water system, and a graphic for a chiller system. Place sensors and controlled devices associated with mechanical equipment in their appropriate locations. Place point name and point value adjacent to sensor or controlled device. Provide visual warning of each point in alarm. Point values shall update dynamically on the graphic.

f. Graphic Editing: Full capacity as provided by a draw software package shall be included for operator editing of graphics. Graphics may be created, deleted, modified, and text added. Provide capability to store graphic symbols in a symbol directory and import these symbols into graphics. A minimum of 256 colors shall be available.

g. Dynamic Point Editing: Provide full editing capability for deleting, adding, and modifying dynamic points on graphics.

h. Trending: Trend data shall be displayed graphically, with control variable and process variable plotted as functions of time on the same chart. Graphic display of trend data shall be internal to the workstation software and not resulting from download of trend data into a third-party spreadsheet program such as Excel, unless such transfer is automatic and transparent to the operator, and the third-party software is included with the workstation software package. At the operator's discretion, trend data shall be plotted real time.

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NOTE: The notebook computer is designed to allow HVAC mechanics to monitor all points, modify setpoints and operating parameters. If a notebook computer is not required, consider specifying manufacturer's hand held interface device or LCD display with keypad.

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2.1.5 Maintenance Personnel Interface Tools

Provide a notebook computer for field communication with the digital controllers. In addition to changing setpoints, and making operational changes, field personnel shall be able to[upload, modify, and] download programs with the notebook computer.

2.1.5.1 Notebook Computer

a. Provide notebook computer, necessary software, carrying case, and direct connection cable to communicate with all digital controllers [and smart thermostats] when directly connected.

b. Provide notebook computer with the following features as a minimum:

(1) Pentium III 600 MHz with active matrix color screen

(2) Internal hard disk; minimum 6 Giga bytes

(3) Internal battery operation; for a minimum of 3 hours of operation.

(4) RAM; minimum 64 Megabytes

(5) 48X CD ROM and 3.5 inch 1.44 MB floppy drive

(6) Serial interface port to communicate with the digital controller. Parallel port to communicate with a printer.

(7) Software: Digital control manufacturer's graphic DDC software, and all other required programs installed. Windows 98, 2000, or NT operating system installed. Include all documentation and original media.

2.2 SENSORS AND INPUT HARDWARE

2.2.1 Field Installed Temperature Sensors

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NOTE: Selection of the type of temperature sensors is dependent on the local activity. The designer shall coordinate standardization of temperature sensors with existing DDC projects, or local activity requirements. No more than two types of temperature sensors should be used in one project.

****

2.2.1.1 Thermistors

Precision thermistors may be used in temperature sensing applications below 200 degrees F. Sensor accuracy over the application range shall be 0.36 degree F or less between the range of 32 to 150 degrees F. Stability error of the thermistor over five years shall not exceed 0.25 degree F cumulative. Sensor element and leads shall be encapsulated. Bead thermistors are not allowed. A/D conversion resolution error shall be kept to 0.1 degree F. Total error for a thermistor circuit shall not exceed 0.5 degree F, which includes sensor error and digital controller A/D conversion resolution error. Provide 18 gage twisted and shielded cable for thermistors.

2.2.1.2 Resistance Temperature Detectors (RTDs)

Provide RTD sensors with 1000 ohm, or higher, platinum elements that are compatible with the digital controllers. Sensors shall be encapsulated in epoxy, series 300 stainless steel, anodized aluminum, or copper. Temperature sensor accuracy shall be 0.1 percent (1 ohm) of expected ohms (1000 ohms) at 32 degrees F. Temperature sensor stability error over five years shall not exceed 0.25 degree F cumulative. Direct connection of RTDs to digital controllers, without transmitters, is preferred provided controller supports direct connection of RTDs. When RTDs are connected directly to the controller, keep lead resistance error to 0.25 degree F or less. Total error for a RTD circuit shall not exceed 0.5 degree F, which includes sensor error, lead resistance error or 4 to 20 mA or 0 to 10 VDC transmitter error, and A/D conversion resolution error.

2.2.1.3 Temperature Sensor Details

a. Room Type: Conceal element behind protective cover matched to the room interior. Room temperature sensors connected directly to application specific controllers shall have integral pushbutton, system override digital input button, and a setpoint adjustment lever. Provide a connection to allow interrogation of the digital controller.

b. Duct Averaging Type: Continuous averaging RTDs for ductwork applications shall be one foot in length for each 4 square feet of ductwork cross-sectional area with a minimum length of 6 feet. Probe type duct sensors of one foot length minimum are acceptable in ducts 12 feet square and less.

c. Immersion Type: Three inches total immersion for use with sensor wells, unless otherwise indicated.

d. Sensor Wells: Stainless steel [brass] material. Provide heat-sensitive transfer agent between exterior sensor surface and interior well surface.

e. Outside Air Type: Provide element on the buildings north side with sunshade to minimize solar effects. Mount element at least 3 inches from building outside wall. Sunshade shall not inhibit the flow of ambient air across the sensing element. Shade shall protect sensing element from snow, ice, and rain.

****
NOTE: In most cases transmitters are not needed for temperature. An RTD sensor without transmitter is accurate for most applications and may be calibrated within controller software.
****

2.2.2 Transmitters

Transmitters shall have 4 to 20 mA or 0 to 10 VDC output linearly scaled to the temperature, pressure, humidity, or flow range sensed. Transmitter shall be matched to the sensor, factory calibrated, and sealed. Total error shall not exceed 0.1 percent at any point across the measured span. Supply voltage shall be 24 volts AC or DC. Transmitters shall have non-interactive offset and span adjustments. For temperature sensing, transmitter stability shall not exceed 0.05 degrees C a year.

2.2.2.1 Spans and Ranges

Transmitter spans or ranges shall meet the following:

a. Temperature:

(1) 50 degrees F span: Room, chilled water, cooling coil discharge air, return air sensors

(2) 100 degrees F span: Outside air, hot water, heating coil

discharge air, mixed air sensors

(3) 200 degrees F span: High temperature hot water, heating hot water, chilled/hot water system sensors.

b. Pressure:

(1) -0.5 to 0.5 [-0.25 to 0.25] inches water differential range: static pressure control of rooms

(2) 0 to 5 inches water differential range: Duct static pressure

(3) 0 to 60 psig [0 to 100 psig] [0 to 200 psig] differential: Water differential pressure

c. Relative Humidity:

(1) 10 to 90 percent minimum relative humidity range

2.2.3 Relative Humidity Transmitters

Provide integral humidity transducer and transmitter. Output of relative humidity instrument shall be a 4 to 20 mA or 0 to 10 VDC signal proportional to full range of relative humidity input. Accuracy shall be 2 percent of full scale, long-term stability shall be less than one percent drift per year. Sensing element shall be polymer type.

2.2.4 Pressure Transmitters

Provide integral pressure transducer and transmitter. Output of pressure instrument shall be a 4 to 20 mA signal proportional to the pressure span. Accuracy shall be 1.0 percent. Linearity shall be 0.1 percent.

2.2.5 Current Transducers

Provide current transducers to monitor amperage of motors. Select current transducer for normal measured amperage to be near 50 percent of full-scale range. Current transducers shall have an accuracy of one percent and 4 to 20 mA or 0 to 10 VDC output signal.

****

NOTE: Choose between CO2 sensors and air quality sensors, or use both. CO2 sensors provide information to ensure adequate ventilation. Air quality sensors are very useful to monitor areas that are vulnerable to organic contaminates like car exhaust and industrial solvents.

****

2.2.6 Air Quality Sensors

2.2.6.1 CO2 Sensor

Provide CO2 sensors with integral transducers where shown. Output signal shall be 4 to 20 mA or 0 to 10 VDC. Accuracy shall be $\pm$5 percent of full scale.

2.2.6.2 Air Quality Sensor

Provide full spectrum air quality sensors with filters utilizing hot wire element based on the Taguchi principle. The sensor monitors a wide range of gaseous organic materials which are common components of indoor air contaminants. These gaseous materials include paints and solvents, cooking and cigarette smoke, and car exhaust. The Sensor must compensate for temperature and humidity, have span and calibration potentiometers, operate on 24 VDC power with output of 0-10 VDC and operating between 32 to 140 degrees F and 5 to 95 percent RH. Provide isolation power supply for each sensor.

2.2.7 Input Switches

2.2.7.1 Timed Local Override

Provide momentary contact push button override with override time set in controller software. Provide to override DDC time of day program and activate occupancy program for assigned units. Upon expiration of override time, the control system shall return to time-of-day program. Time interval for the length of operation shall be software adjustable and shall expire unless reset.

2.2.7.2 Hand-Off-Auto Switch

Provide hand-off-auto switch with name plate to manually switch between off, DDC (auto) and manual (hand) control. Size and wire hand-off-auto switch to switch control (120 VAC or less), not line, circuitry. Wire all safety controls to protect circuit and equipment during both hand and auto operation.

2.2.7.3 Insertion Freeze Protection Switch

Electric switch shall be capillary type. Provide special purpose insertion thermostats with flexible elements a minimum of 20 feet in length for coil face areas up to 40 square feet. Switch contacts shall be rated for motor starter circuit voltage being interrupted. Switch shall be equipped with auxiliary set of contacts for input of switch status to digital controller. Provide additional elements or longer elements for larger coils at the rate of 1-foot of element per 4 square feet of coil. Serpentine capillaries perpendicular to the air flow to uniformly sense the entire airflow. A freezing condition at 18-inch increments along the sensing element shall activate the thermostatic switch. Switch shall require manual reset after activation.

2.2.7.4 Non-Modulating, Electric, Humidistat Switch

Provide a set point adjustable, wall mounted humidistat. Contacts shall be Single Pole Double Throw(SPDT) for low voltage (24volt) applications. Adjustable set-point range shall be 20%-80% relative humidity. Sensing element shall be bulk polymer or thin film polymer with an accuracy of plus or minus 2 percent over the entire range. Sensing element shall be non-saturating and shall be capable of withstanding a saturated condition without permanently affecting calibration or sustaining damage. Humidistat cover shall consist of locking metal or heavy-duty plastic.

2.2.8 Electronic Airflow Measurement Stations and Transmitters

a. Station - Each station shall contain an array of velocity sensing elements and straightening vanes inside a flanged sheet metal casing. The velocity sensing elements shall be of the RTD or thermistor type. The sensing elements shall be distributed across the duct cross section in the quantity and pattern set forth for measurements and instruments of ASHRAE Gdln3 and SMACNA HVACTAB for the traversing of ducted air flows. The resistance to airflow through the airflow measurement station shall not exceed 0.08 inch water gage at an airflow of 2,000 fpm. Station construction shall be suitable for operation at airflow of up to 5,000 fpm over a temperature range of 40 to 120 degrees F, and accuracy shall be plus or minus 3 percent over a range of 125 to 2,500 fpm scaled to air volume.

b. Each transmitter shall produce a linear, temperature compensated 4 to 20 mA or 0 to 10 VDC output corresponding to the actual air flow. The transmitter shall be a 2-wire, loop powered device. The output error of the transmitter shall not exceed 0.5 percent of the calibrated measurement.

2.2.9 Energy Metering

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NOTE: The requirement for metering shall be based on NAVFAC Maintenance Manual: Utilities Metering (MO-221) Criteria.
****

2.2.9.1 Electric Meters

****
NOTE: Select the appropriate paragraph. Use the first paragraph when additional requirements for electric meters are covered in another specification section and insert appropriate Section number and title in the blanks below using format per UFC 1-300-02. Use the second paragraph when electric meters are not covered in an additional specification section.
****

[Provide kilowatt-hour (kWh) meter as specified in [_____], for building as indicated. [Provide contacts for kilowatt (kW) pulse accumulation].] [Provide kilowatt-hour (kWh) meter for building as indicated. Integrate electric meter signal into DDC system; meter signal output must be compatible with DDC input. DDC shall measure both instantaneous and accumulated electrical usage.

a. Meter: ANSI C12.10. Provide watt-hour meter and socket corresponding to the ratios of the current transformers and transformer secondary voltage. Meters shall be selected for [ ] -volt, three-phase, [three] [four] -wire [wye] [delta] system, three-element type with three current transformers. Meters shall be complete with a box mounted socket having automatic circuit closing bypass. Provide watt-hour meter with not less than four pointer-type kWh registers, provisions for pulse initiation, and a universal Class 2 indicating maximum kW demand register, sweep pointer indicating type, with a [15] [30] [60] -minute interval. Meter accuracy shall be within plus or minus one percent. The correct multiplier shall be provided on face of meter.

b. Current Transformers: ANSI C57.13. Provide three current transformers with 600-volt insulation, rated for metering with voltage, BIL, momentary, and burden ratings coordinated with the ratings of the associated meters. Provide a butyl molded donut or window type transformers mounted on a bracket to allow secondary cables to connect to the transformer bushings. Identify the wiring of the current transformer secondary feeders to permit field current measurements to be taken with hook-on ammeters.]

****

NOTE: Locate steam meters in piping in accordance with ASME, Fluid Meters; Their theory and applications, Sixth Edition, 1971.

****

2.2.9.2 Steam Meters

[Requirements for steam meters is specified in Section 02554, "Exterior Aboveground Steam Distribution". Integrate steam meter consumption signal into the DDC system.] Provide vortex steam meters as shown on drawings. Steam meters, on pressure lines below 100 psig, or where pressures may fluctuate, shall be pressure compensated. All steam meters shall have a minimum turndown ratio of 10 to 1. Meter signal output must be compatible with DDC input. DDC shall measure both instantaneous and accumulated steam flow.

2.3 OUTPUT HARDWARE

2.3.1 Dampers

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NOTE: Use parallel blade dampers for mixing boxes and when two-position control is required. Use opposed blade dampers when modulating dampers on air outlets of small cooling tower; use parallel blade dampers for face and bypass control. Show the dampers on the contract drawings. Indicate parallel blade or opposed blade dampers as appropriate for each application.

****

Damper shall conform to SMACNA HVAC Duct Const Stds.

a. A single damper section shall have blades no longer than 1220 mm 48 inches and shall be no higher than 1830 mm 72 inches. Maximum damper blade width shall be 203 mm 8 inches. Larger sized damper shall be made from a combination of sections.

b. Dampers shall be steel, or other materials where shown. Flat blades shall be made rigid by folding the edges. Blades shall be provided with compressible seals at points of contact. The channel frames of the dampers shall be provided with jamb seals to minimize air leakage. Dampers shall not leak in excess of 102 L/s per square meter 20 cfm per square foot at 996 Pa 4 inches water gage static pressure when closed. Seals shall be suitable for an operating temperature range of minus 40 degrees C to 93 degrees C 40 degrees F to 200 degrees F. Dampers shall be rated at not less than 10 m/s 2000 fpm air velocity. All blade-operating linkages shall be within the frame so that blade-connecting devices within the same damper section will not be located directly in the air stream. Damper axles shall be 13 mm 0.5 inch (minimum) plated steel rods supported in the damper frame by stainless steel or bronze bearings. Blades mounted vertically shall be supported by thrust bearings. Pressure drop through dampers shall not exceed 10 Pa gage at 5 m/s 0.04 inch water gage at 1000 fpm in the wide-open position. Frames shall not be less than 50 mm 2 inches in width. Dampers shall be tested in accordance with AMCA 500-D.

c. Operating links external to dampers (such as crank arms, connecting rods, and line shafting for transmitting motion from damper actuators to dampers) shall withstand a load equal to twice the maximum required damper-operating force. Rod lengths shall be adjustable. Links shall be brass, bronze, zinc-coated steel, or stainless steel. Moving parts in contact with one another shall be of different materials. Working parts of joints and clevises shall be brass, bronze, or stainless steel. Adjustments of crank arms shall control the open and closed position of dampers.

2.3.2 Valves

****

NOTE: Avoid the selection of oversized control valves. Select valve Cv so that maximum pressure drops are used within constraints of available pressures, pipe velocities, economy of design, and noise criteria. Select steam valves using critical pressure drop (0.45 of absolute pressure) where available, and select connected equipment using resultant pressure on downstream side of valve. Size water system for a minimum drop through control valves of 21 kPa 3 psi and include in hydraulic calculations. List calculated Cv in schedules (not manufacturer's listed Cv) to allow bidders to personally select valves.

****

2.3.2.1 Valve Assembly

Valves shall have stainless steel stems. Valves shall be ANSI Class 125 or ANSI Class 150, as required by the following pressure-temperature design criteria: 150 percent of the system operating pressure at the system operating temperature. Valve leakage rating shall be 0.01 percent of rated Cv. Class 125 copper alloy valve bodies and Class 150 steel or stainless steel valves shall conform to ASME B16.5 as a minimum. Cast iron valve components shall conform to ASTM A 126 Class B or C as a minimum.

2.3.2.2 Butterfly Valve Assembly

Butterfly valves shall be threaded lug type suitable for dead-end service and for modulation to the fully closed position, with noncorrosive discs, stainless steel shafts supported by bearing, and EPDM seats suitable for temperatures from minus 29 degrees C to plus 121 degrees C minus 20 degrees F to plus 250 degrees F. Valves shall have a manual means of operation independent of the actuator.

2.3.2.3 Two-Way Valves

Two-way modulating valves shall have equal percentage characteristics.

2.3.2.4 Three-Way Valves

Three-way valves shall have equal percentage characteristics.

2.3.2.5 Duct Coil and Terminal Unit Coil Valves

Provide control valves with either flare-type or solder-type ends provided for duct or terminal-unit coils. Provide flare nuts for each flare-type end valve.

2.3.2.6 Valves for Chilled Water, Condenser Water and Glycol Service

a. Bodies for valves 40 mm 1 1/2 inches and smaller shall be brass or bronze, with threaded or union ends. Bodies for valves from 50 to 80 mm 2 inches to 3 inches inclusive shall be of brass, bronze or iron. Bodies for 50 mm 2 inch valves shall have threaded ends. Bodies for valves from 65 to 80 mm 2 1/2 to 3 inches shall have flanged-end connections. Internal valve trim shall be brass or bronze except that valve stems may be Type 316 stainless steel. Water valves shall be sized for a [21 kPa] [3 psi] [_____] differential through the valve at rated flow, except as indicated otherwise. Select valve flow coefficient (Cv) for an actual pressure drop not less than 50 percent or greater than 125 percent of the design pressure drop at design flow.

b. Valves 100 mm 4 inches and larger shall be butterfly valves.

2.3.2.7 Valves for Hot Water Service

Valves for hot water service below 121 degrees C 250 Degrees F:

a. Bodies for valves 40 mm 1 1/2 inches and smaller shall be brass or bronze with threaded or union ends. Bodies for valves larger than 50 mm 2 inches shall have flanged-end connections. Water valves shall be sized for a [21 kPa] [3 psi] [_____] differential through the valve at rated flow, except as indicated otherwise. Select valve flow coefficient (Cv) for an actual pressure drop not less than 50 percent or greater than 125 percent of the design pressure drop at design flow.

b. Internal trim, including seats, seat rings, modulation plugs, and springs, of valves controlling water hotter than 99 degrees C 210 degrees F shall be Type 316 stainless steel.

c. Internal trim for valves controlling water 99 degrees C 210 degrees F or less shall be brass or bronze.

d. Non-metallic parts of hot water control valves shall be suitable for a minimum continuous operating temperature of 121 degrees C or 28 degrees C 250 degrees F or 50 degrees F above the system design temperature, whichever is higher.

e. Valves 100 mm 4 inches and larger shall be butterfly valves.

2.3.2.8 Valves for Steam Service

Entire bodies for valves 40 mm 1 1/2 inches and smaller shall be brass or bronze, with threaded or union ends. Bodies for valves from 50 to 80 mm 2 to 3 inches inclusive shall be of brass, bronze, or iron. Bodies for valves 100 mm 4 inches and larger shall be iron. Bodies for 50 mm 2 inch valves shall have threaded ends. Provide bodies for valves 65 mm 2 1/2 inches and larger shall with flanged-end connections. Steam valves shall be sized for [103 kPa (gage)] [15 psig] [_____] inlet steam pressure with a maximum [90 kPa] [13 psi] [_____] differential through the valve at rated flow, except as indicated otherwise.

2.3.2.9 Valves for High Temperature Hot Water Service

Valves for high temperature hot water service above 121 degrees C 250 Degrees F. Valve bodies shall conform to ASME B16.34 Class 300. Valve and actuator combination shall be normally closed. Bodies shall be carbon steel, globe type with welded ends on valves 25 mm 1 inch and larger. Valves smaller than 25 mm 1 inch shall have socket-weld ends. Packing shall be virgin polytetrafluoroethylene (PTFE). Internal valve trim shall be Type 316 stainless steel. Water valves shall be sized for a [21 kPa] [3 psi] [_____] through the valve at rated flow, except as indicated otherwise. Select valve flow coefficient (Cv) for an actual pressure drop not less than 50 percent or greater than 125 percent of the design pressure drop at design flow.

2.3.3 Actuators

****

NOTE: Indicate on drawings and in sequence of operation, the normal position of each actuator without power or control signal. Select normal position with regard to power loss, freezing, moisture damage, and smoke or fire transmission. Indicate power return actuators where necessary for actuator timing and process requirements, or where rapid valve or damper opening or closing would be hazardous. Indicate spring return for actuators where normal position, but not timing, is required. Spring return closed is often desirable for steam actuators. Indicate requirements for standby or emergency power for actuators and devices controlling the actuators.

Indicate on drawings when a coordinated action is required. For example, coordinated action may be required when one control output may control both the hot water valve (3 - 7 psig or 4 to 10 ma) and the chilled water valve (8 - 13 psig or 12 to 18 ma).

Note: Electric actuators are generally preferable to pneumatic actuators for reduced maintenance, quality of control, and integration into DDC. Pneumatic actuators should be used in hazardous areas. They may be used in the retrofit of existing systems that use pneumatic actuators and costs prevent total actuator replacement.. In general, pneumatic actuation of large valves (greater than 4 inch), large dampers (greater than 9 sq. ft.), and

large numbers of valves and dampers may be more cost effective than using electric actuators. Include the cost of the air compressor, power, air distribution, and operation and maintenance in the life cycle cost analysis to justify pneumatic over electric actuation.

****

2.3.3.1 Electric Actuators

Provide direct drive electric actuators for all control applications, except where indicated otherwise. When operated at rated voltage, each actuator shall be capable of delivering torque required for continuous uniform motion and shall have end switch to limit travel, or shall withstand continuous stalling without damage. Actuators shall function properly with range of 85 to 110 percent of line voltage.

Provide gears manufactured from steel, copper alloy, fiber, or reinforced nylon. Provide hardened steel running shafts in sleeve bearing of copper alloy, hardened steel, nylon, or ball bearing. Provide two-position actuators of the single direction, spring return, or reversing type. Provide proportioning actuators capable of stopping at all points in the cycle and starting in either direction, from any point.

Provide reversing and proportioning actuators with limit switches to limit travel in either direction unless operator is stall type. Actuators shall have a simple switch for reversing direction, and a button to disengage clutch for manual adjustments. Provide reversible shaded pole, split capacitor, synchronous, or steper type electric motors.

2.3.3.2 Pneumatic Actuators

Provide piston or diaphragm type actuator, where indicated with full range or split range springs to provide required sequence specified and fail safe operation.

2.3.4 Output Signal Conversion

2.3.4.1 Electronic to Pneumatic Transducer

Electronic to pneumatic transducer shall convert 4 to 20 mA or 0 to 10 VDC digital controller output signal to a proportional 0 to 20 psig pressure signal (operator scaleable). Accuracy shall be 1.0 percent or better. Linearity shall be 0.1 percent. Transducer shall have feedback circuit that converts pneumatic signal to a proportional 4 to 20 mA or 0 to 10 VDC signal.

2.3.4.2 Pneumatic to Electronic Pressure Transducer

Pneumatic to electronic transducer shall convert 0 to 20 psig signal to a proportional 4 to 20 mA or 0 to 10 VDC signal (operator scaleable). Supply voltage shall be 24 VDC. Accuracy shall be 1.0 percent or better. Linearity shall be 0.1 percent.

2.3.5 Output Switches

2.3.5.1 Control Relays

Shall be double pole, double throw (DPDT), UL listed, with contacts rated to the application, indicator light, and dust proof enclosure. Light indicator is lit when coil is energized and is off when coil is not energized. Relays shall be socket type, plug into a fixed base, and replaceable without need of tools or removing wiring. Encapsulated "PAM" type relays are permissible for terminal control applications.

2.3.5.2 Solenoid Air Valves

Each valve shall have three port operation: common, normally open, and normally closed. Internal parts shall be brass, bronze, or stainless steel. Valves shall be rated at 50 psig minimum when used in a control system operating at 25 psig or less, or 150 psig when used in a control system operating in the range 25 to 100 psig.

****

NOTE: In most cases, use Naval Facilities Guide Specification 16402, "Interior Distribution Systems", for specifying electrical power and wiring. Delete redundant or ambiguous sections out of this specification after modifying NFGS 16402.

****

2.4 ELECTRICAL POWER AND DISTRIBUTION

For controller power provide a new, dedicated 120 VAC 60 Hz source, three wire (black, white, and green). Run green ground wire to panel ground; conduit grounds are not sufficient.

2.4.1 Transformers

Transformers shall conform to UL 506. Power digital controllers and terminal control units (TCU's) from dedicated circuit breakers with surge protection specified. Transformers for digital controllers serving terminal equipment on lower level LANs may be grouped to have specified surge protection sized for the number of controllers on a single transformer. Provide a fuse on the transformer secondary side.

2.4.2 Surge Protection

Surge and transient protection consist of devices installed externally to digital controllers.

2.4.2.1 Power Line Surge Protection

Surge suppressors external to digital controller, shall be installed on all incoming AC power. Surge suppressor shall be rated by UL 1449, have a fault indicating light, and have clamping voltage ratings below the following levels:

a. Unit is a transient voltage surge suppressor 120 VAC/1 phase/2 wire plus ground, hard wire individual equipment protector.

b. Unit must react within 5 nanoseconds and automatically reset.

c. Voltage protection threshold, line to neutral, starts at no more than 211 volts peak on the 120 VAC line.

d. The transient voltage surge suppressor must have an independent secondary stage equal to or greater than the primary stage joule rating.

e. The primary suppression system components must be pure Silicon Avalanche Diodes.

f. Silicon Avalanche Diodes or Metal Oxide Varistors are acceptable in the independent secondary suppression system.

g. The Transient Suppression System shall incorporate an indication light which denotes whether the primary and/or secondary transient protection components is/are functioning.

h. All system functions of the Transient Suppression System must be individually fused and not short circuit the AC power line at any time.

i. The Transient Suppression System shall incorporate an EMI/RFI noise filter with a minimum attenuation of 13 dB at 10 kHz to 300 MHz.

j. The system must comply with IEEE C62.41, Class "B" requirements and be tested according to IEEE C62.45.

k. The system shall operate at -20 degrees C to +50 degrees C.

2.4.2.2 Telephone and Communication Line Surge Protection

Provide transient surge protection to protect the DDC controllers and LAN related devices from surges that occur on the phone lines (modem or direct connect) and on inter-unit LAN communications. Devices shall be UL listed.

a. The surge protection shall be a rugged package with continuous, non-interrupting protection and not use crowbar technology. Instant automatic reset after safely eliminating transient surges, induced lightning, and other forms of transient over voltages.

b. Unit must react within 5 nanoseconds using only solid-state silicone avalanche technology.

c. Unit shall be installed at the proper distance as recommended by the manufacturer.

2.4.2.3 Controller Input/Output Protection

Controller input/output points shall surge protection with optical isolation, metal oxide varistors (MOV), or silicon avalanche devices. Fuses are not permitted for surge protection.

2.4.3 Wiring

Provide complete electric wiring for DDC System, including wiring to transformer primaries. Control circuit wiring shall not run in the same conduit as power wiring over 100 volts. Circuits operating at more than 100 Volts shall be in accordance with Section 16402 INTERIOR DISTRIBUTION

SYSTEM. Circuits operating at 100 Volts or less shall be defined as low voltage and shall be run in rigid or flexible conduit, metallic tubing, metal raceways or wire trays, or armored cable. Provide circuit and wiring protection as required by NFPA 70. Aluminum-sheathed cable or aluminum conduit may be used but shall not be buried in concrete. Use conduit or plenum-rated cable in HVAC plenums. HVAC plenums include the space between a drop ceiling and the architectural ceiling, within walls, and within ductwork. Protect exposed wiring from abuse and damage.

2.4.3.1 AC Control Wiring

a. Control wiring for 24 V circuits shall be insulated copper 18 AWG minimum and rated for 300 VAC service.

b. Wiring for 120 V shall be 14 AWG minimum and rated for 600 V service.

2.4.3.2 Analog Signal Wiring

Analog signal wiring shall be 18 AWG single or multiple twisted pair. Each cable shall be 100 percent shielded, and have 20 AWG drain wire. Each wire shall have insulation rated to 300 V AC. Cables shall have an overall aluminum-polyester or tinned-copper (cable-shield tape). Install analog signal wiring in conduit separate from AC power circuits.

2.5 FIRE PROTECTION DEVICES

Provide smoke detectors in return and supply air ducts on downstream side of filters in accordance with NFPA 90A, except as otherwise indicated. Provide UL listed or FM approved detectors for duct installation.

2.5.1 Smoke Detectors

****
NOTE: Choose one of the three options below.
****

****
NOTE: Regarding text below, use this paragraph if project has Section 13852, "Interior Fire Alarm System."
****

[Provide in each air-handling system with supply air capacity greater than 944 L/s 2000 cfm in accordance with NFPA 90A. Locate downstream of the supply air filters and prior to any branch connection in accordance with NFPA 72. Provide in each air-handling system, serving more than one story, and having a return air capacity greater than 7079 L/s 15000 cfm in accordance with NFPA 90A. Locate at each story prior to connection to common return and at return connection to air handler prior to any fresh air inlet connection and prior to any recirculation connection in accordance with NFPA 72. Furnish detectors under Section 13852, "Interior Fire Alarm System," and install under this section.[Smoke control and exhaust systems shall have provision for [automatic and]manual operation by means of a key-operated switch to override any other shutdown features and shall be located[adjacent to the fire alarm system control panel][as indicated].]]

****

NOTE: Regarding text below: Use this paragraph if building has an existing fire evacuation alarm system. For connection to existing system, designer must determine if existing fire alarm control panel is compatible with smoke detectors and has spare zone capacity. Edit accordingly. When in doubt leave choice of connection to fire alarm panel or a separate control unit in paragraph. For some antiquated alarm systems, it may be necessary to replace the control panel in which case Section 13852, "Interior Fire Alarm System" must be included in project and the first option should be used.

****

[Provide in each air-handling system with supply air capacity greater than 944 L/s 2000 cfm in accordance with NFPA 90A. Locate downstream of the supply air filters and prior to any branch connection in accordance with NFPA 72. Provide in each air-handling system, serving more than one story, and having a return air capacity greater than 7079 L/s 15000 cfm in accordance with NFPA 90A. Locate at each story prior to connection to common return and at return connection to air handler prior to any fresh air inlet connection and prior to any recirculation connection in accordance with NFPA 72. Design for detection of abnormal smoke densities by the [ionization] [or] [photoelectric] principle, responsive to both invisible and visible particles of combustion, and not susceptible to undesired operation by changes to relative humidity. Provide UL listed or FM approved detectors for duct installation. Provide duct detectors with an approved duct housing, mounted exterior to the duct, and with perforated sampling tubes extending across the width of the duct. Provide permanent descriptive zone labels indicating in which air-handling units the detectors in alarm are located.
Provide detectors with a test port [, test switch] [and] [or] [, remote keyed test device]. Provide control and power modules required for operation of detectors [in their own control unit] [or] [integral with the main building fire alarm control panel]. A ground fault or single break or open condition in electrical circuitry to any detector or its control or power units shall cause activation of building fire alarm control panel trouble signals. Electrical supervision of wiring used exclusively for air-handling unit shutdown is not required provided a break in wiring would cause shutdown of the associated unit. Equipment and devices shall be compatible and operable in all respects with, and shall in no way impair reliability or operational functions of, the existing building fire alarm system. The existing fire alarm control panel was manufactured by [_____]. [Smoke control and exhaust systems shall have provisions for [automatic and] manual operation by means of a key-operated switch to override any other shutdown features and shall be located [adjacent to the fire alarm system control panel] [as indicated].]]

****

NOTE: Regarding the text below: Use this paragraph only with specific approval of the Engineering Field Division Fire Protection Engineer. Approval will normally be granted only if the building has no fire alarm system and none is required. When in doubt,

contact the EFD/EFA Fire Protection Engineer.
****

[Provide in each air-handling system with supply air capacity greater than 944 L/s 2000 cfm in accordance with NFPA 90A. Locate downstream of the supply air filters and prior to any branch connection in accordance with NFPA 72. Provide in each air-handling system, serving more than one story, and having a return air capacity greater than 7079 L/s 15000 cfm in accordance with NFPA 90A. Locate at each story prior to connection to common return and at return connection to air handler prior to any fresh air inlet connection and prior to any recirculation connection in accordance with NFPA 72. Design for detection of abnormal smoke densities by the [ionization] [or][photoelectric] principle, responsive to both invisible and visible particles of combustion, and not susceptible to undesired operation by changes in relative humidity. Provide UL listed or FM approved detectors for duct installation. Provide duct detectors with an approved duct housing, mounted exterior to the duct, and with perforated sampling tubes extending across the width of the duct. Provide 115 VAC power supply unit integral with duct housing. Obtain power from [the source to the air-handling unit or air-handling unit controls] [the location indicated].
Detectors shall have test port or test switch. [Provide remote alarm indicator [and keyed test] device at [_____] [the location indicated].] Provide each detector with a visible indicator lamp that lights when the detector is activated. Activation of duct detector shall cause shutdown of the associated air-handling unit [and closing of dampers] [and shall sound an alarm bell, with minimum 152 mm 6 inch diameter, in a normally occupied area] located [as directed] [as indicated]. [Provide a separate bell with an engraved plastic or metal label indicating which unit each bell annunciates for each air-handling unit.]]

2.6 INDICATORS

2.6.1 Thermometers

****
NOTE: Indicate on drawings which range or span is preferred.
****

Provide bi-metal thermometers in locations as indicated. Bi-metal thermometers shall have either 9 inch scales or 3.5 inch dials and shall have insertion, immersion or averaging elements as indicated. Provide thermowells for liquid sensing applications. Select thermometer ranges so normal temperatures are approximately equal to midpoint readings on the scale.

2.6.2 Pressure Gages

****
NOTE: Indicate on drawings which range or span is preferred.
****

a. Provide pressure gages for all pneumatic outputs. Select gage range so normal pressures are approximately equal to the midpoint readings on the scale, unless otherwise specified. Accuracy shall be plus or minus 2 percent of the range. Gages shall conform to ASME B40.1.

b. Gages indicating pneumatic outputs shall have 2 inch diameter faces. Scale shall be 0 to 30 psi, with 1 psi graduations.

c. Gages for low differential pressure measurements shall be 4 1/2 inch (nominal) size with two sets of pressure taps, and shall have a diaphragm actuated pointer, white dial with black figures, and pointer zero adjustment. Gage shall have ranges and graduations as shown. Accuracy shall be plus or minus 2 percent of scale range.

2.7 PNEUMATIC POWER SUPPLY AND TUBING

****
NOTE: Delete the following section if pneumatic actuators are not used in this specification.
****

****
NOTE: Show compressed air station location on the control drawings.
****

2.7.1 Air Compressors

****
NOTE: Provide duplex air compressors for systems having greater than 50 control air users or requiring greater than 1.5 CFM of air. Size duplex system air compressors for 50 percent run time and simplex systems for 33 percent run time. Show power sources for compressors, dryers and alternators.
****

Provide tank mounted, [duplex,] electric motor driven, oil type, air cooled, reciprocating type air compressor including motor, controller, pressure switch, belt guard, pressure relief valve, and automatic moisture drain valve. Piston speed shall not exceed 450 fpm. Set relief valve for 10 to 25 psig above the control switch cut-off pressure. Pressure switch shall start compressor at 70 psig and stop compressor at 90 psig. Size [each] compressor to run not more than [33] [50] percent of the time with full system control load. Compressor shall have maintaining type starter for automatic restart after power failure. [Provide duplex air compressors with electric alternator switch assembly.] Motors 0.5 hp and larger shall be three-phase, 208 or 460-volt, 60 Hz.

2.7.2 Compressed Air Tank

Provide steel tank constructed and labeled in accordance with ASME BPVC SEC VIII for a minimum of 125 psig working pressure. Tank shall be of sufficient volume so that the run time is not more than 50 percent for duplex or 33 percent for simplex units.

2.7.3 Intake Air Filter and Silencer

Provide dry-type combination intake air filter and silencer with baked enamel steel housing. Filter shall be 99 percent efficient at 10 micron rating.

2.7.4 Refrigerated Air Dryer

a. Provide a refrigerant dryer sized for continuous operation to reduce the compressed air dew point temperature, at 20 psig output pressure, to 30 degrees F with average tank pressure of 80 psig and ambient air temperature between 55 and 95 degrees F. Provide dryer with an automatic condensate drain trap with a manual override feature. Provide refrigerant gages for suction lines.

b. Connect dryer in the high pressure piping between tank and pressure -reducing valve.

2.7.5 Compressed Air Discharge Filter

a. Provide dry type filter, 99 percent efficient in removing oil and solid particles at 0.03 micron rating, with baked enamel steel housing and manual drain valve. Provide visual indicator to show when oil filter element should be changed.

b. Provide disposable filter directly before each control module with pneumatic outputs, Disposable filter shall eliminate 99.99 percent of all liquid or solid contaminants 0.1 micron or larger. Provide filter with easy to remove fittings.

2.7.6 Air Pressure-Reducing Station

Provide pressure-reducing valve (PRV) with field adjustable range of 0 to 50 psig discharge pressure, with inlet pressure of 70 to 90 psig. Provide factory-set pressure relief valve to relieve overpressure downstream of PRV exceeding 25 psig. Provide inlet pressure gage with range of 0 to 100 psig and outlet pressure gage with range of 0 to 30 psig. For two pressure systems, provide an additional PRV and outlet pressure gage.

2.7.7 Pneumatic Tubing

2.7.7.1 Copper Tubing

Provide ASTM B 75 or ASTM B 88M ASTM B 88 rated tubing. Tubing 0.64 mm 0.375 inch outside diameter and larger shall have minimum wall thickness equal to ASTM B 88M ASTM B 88, Type M. Tubing less than 10 mm 0.375 inch outside diameter shall have minimum wall thickness of 0.64 mm 0.025 inch. Concealed tubing shall be hard or soft copper; multiple tubing shall be racked or bundled. Exposed tubing shall be hard copper; rack multiple tubing. Tubing for working pressures greater than 30 psig shall be hard copper. Bundled tubing shall have each tube numbered each six feet minimum. Racked and individual tubes shall be permanently identified at each end. Fittings shall be solder type ASME B16.18 or ASME B16.22, using ASTM B 32, 95-5 tin-antimony solder, or compression type ASME B16.26.

2.7.7.2 Polyethylene Tubing

****

NOTE: Systems that are critical and systems required for smoke removal shall have tubing of noncombustible material only.

****

Use Polyethylene tubing only for systems with working pressure of 30 psig or less. Provide flame-resistant, multiple polyethylene tubing in flame-resistant protective sheath with Mylar barrier, or unsheathed polyethylene tubing in rigid metal, intermediate metal, or electrical metallic tubing conduit for areas where tubing is exposed. Single, unsheathed, flame-resistant polyethylene tubing may be used where concealed in walls or above ceilings and within control panels. Do not provide polyethylene tubing for [systems indicated as critical and] smoke removal systems. Provide polyethylene tubing only for working pressures of 30 psig or less. Number each tube in sheathing each two feet minimum. Permanently identify unsheathed tubing at each end. Provide compression or brass barbed push-on type fittings.Fittings shall be compression or barbed push-on type. Extruded seamless polyethylene tubing shall conform to the following:

a. Minimum Burst Pressure Requirements: 100 psig 690 kPA at 75 degrees F 24 degrees C to 25 psig 172 kPa at 150 degrees F 66 degrees C.

b. Stress Crack Resistance: ASTM D 1693, 200 hours minimum.

c. Tensile Strength (Minimum): ASTM D 638, 7583 kPa 1100 psi.

d. Flow Rate (Average): ASTM D 1238, 0.30 decigram per minute.

e. Density (Average): ASTM D 792, 920 kg/m3 57.5 pounds per cubic feet.

f. Burn rate: ASTM D 635

****

NOTE: Delete the following section if variable frequency motor drives are not used in this specification.

****

2.8 VARIABLE FREQUENCY MOTOR DRIVES

The variable frequency drive (VFD) shall convert 240 or 460 volt (+/- 10%), three phase, 60 hertz (+/- 2Hz), utility grade power to adjustable voltage/frequency, three phase, AC power for stepless motor control from 5% to 105% of base speed.

2.8.1 Description

The variable frequency drive (VFD) shall produce an adjustable AC voltage/ frequency output for complete motor speed control. The VFD must meet all of the following criteria:

a. The VFD shall use sine coded Pulse Width Modulation (PWM) technology. The sine coded PWM calculations are performed by the VFD microprocessor.

b. The VFD shall use Insulated Gate Bipolar Transistors (IGBT) transistors for the inverter's three phase output.

c. The VFD shall use a three phase diode bridge converter to charge the VFD constant voltage capacitor buss.

d. The VFD shall have the ability for control by either a remote 4-20 mA [0 to 10 VDC] control signal or from a local control panel located on the VFD itself.

e. The VFD shall use microprocessor technology for VFD control. The VFD shall be programmable with a permanently mounted keypad included with each VFD.

f. The VFD shall be fully self diagnostic. No external programmers, analyzers, interrogators, or diagnostic boards, shall be needed to annunciate VFD faults or drive internal status.

2.8.2 Code Standards

VFD shall be UL listed as delivered to the end user. The VFD shall meet current National Electrical Code.

2.8.3 VFD Quality Assurance

To ensure quality, each and every VFD shall be subject to a series of in-plant quality controlled inspections before approval for shipment from the manufacture's facilities.

a. All components shall be tested prior to assembly and the complete unit shall be tested under full load conditions to ensure maximum product reliability.

b. The VFDs shall be the current standard production unit with at least 10 identical units already in the field.

c. Engineering support shall be available from the factory of the VFD. Phone support shall be free of charge to the end user for the life of the equipment. Factory support shall be available in the English language.

2.8.4 VFD Service

The VFD shall be supplied with:

a. 24 month parts and labor warranty. The warranty shall start when the system is accepted by the end user or 30 months from date of shipment.

b. Installation, operation, and troubleshooting guide(s).

c. A district service support group shall provide the following additional services:

(1) Factory trained personal on-site for start-up for up to one working day at no additional cost. Personnel shall be competent in operation and repair of the particular model of VFD that is installed.

(2) On-site training of customer personnel in basic installation, troubleshooting, and operation of VFDs at no additional cost. This training shall be conducted for up to [6] personnel at the installation site for a minimum of 4 hours.

2.8.5 Basic VFD Features

The VFD shall have the following basic features with no more then three separate internal electronic boards.

a. VFD mounted operator control keypad capable of:

(1) Remote/Local operator selection with password access.

(2) Run/Stop and manual speed commands.

(3) All programming functions.

(4) Scrolling through all display functions.

b. Digital display capable of indicating:

(1) VFD status.

(2) Frequency.

(3) RPM of motor.

(4) Phase current.

(5) Fault diagnostics in descriptive text.

(6) All programmed parameters.

c. Standard PI loop controller with input terminal for controlled variable and parameter settings made while inverter running.

d. User interface terminals for end-user remote control of VFD speed, speed feedback, and isolated form C SPDT relay energized on drive fault condition.

e. An isolated form C SPDT auxiliary relay energized on run command.

f. The VFD shall have a metal NEMA 1 enclosure.

g. The VFD shall have an adjustable carrier frequency with 16 KHz minimum upper limit.

h. The VFD shall have a built in or external line reactor with 3% minimum impedance to protect DC buss capacitors and rectifier section diodes.

2.8.6 Programmable Parameters

The VFD shall include the following operator programmable parameters:

a. Upper limit frequency.

b. Lower limit frequency.

c. Acceleration rate.

d. Deceleration rate.

e. Variable torque volts per Hertz curve.

f. Starting voltage level.

g. Starting frequency level.

h. Display speed scaling.

i. Enable/disable auto-restart feature.

j. Enable/disable soft stall feature.

k. Motor overload level.

l. Motor stall level.

m. Jump frequency and hysteresis band.

n. PWM carrier frequency.

2.8.7 Protective Circuits and Features

a. An electronic adjustable inverse time current limit with consideration for additional heating of the motor at frequencies below 45Hz, for the protection of the motor.

b. An electronic adjustable soft stall feature, allowing the VFD to lower the frequency to a point were the motor will run at FLA when an overload condition exists at the requested frequency. The VFD will automatically return to the requested frequency when load condition permit.

c. The VFD will have a separate electronic stall at 110% VFD rated current and a separate hardware trip at 190% current.

d. The VFD shall have ground fault protection that protects output cables and motor from grounds during both starting and continuous running conditions.

e. The VFD shall have the ability to restart after the following faults:

(1) Overcurrent (drive or motor).

(2) Power outage.

(3) Phase loss.

(4) Overvoltage/Undervoltage.

e. The VFD shall restart into a rotating load without tripping or damaging the VFD or the motor.

f. The VFD shall keep a log of a minimum of four previous fault conditions, indicating type and time of occurrence in descriptive text.

g. The VFD shall be able to sustain 110% rated current for 60 sec.

h. The VFD shall respond to and record the following fault conditions:

(1) Over current (and have an indication if the over current was during acceleration, deceleration, or running).

(2) Overcurrent internal to the drive.

(3) Motor overload at start-up.

(4) Over voltage from the utility power.

(5) Motor running overload.

(6) Overvoltage during deceleration.

(7) VFD over heat.

(8) Load end ground fault.

(9) Abnormal parameters or data in VFD EEPROM.

2.8.8 Operational Conditions

The VFD shall be designed and constructed to operate within the following service conditions.

a. Ambient Temperature Range, 0 to 120 deg. F.

b. Non-condensing relative humidity to 90%.

2.8.9 Available Options

Provide [Allow for future capability of] the following options:

[a. RFI/EMI filters]

[b. RS232 or RS422/485 interface card with application software which can both control and monitor the VFD from attached computer.]

[c. A manual bypass circuit and switch integral [external] to the drive to allow drive bypass and operation at 100% speed. Overload fuses and other protective hardware shall remain in the circuit during bypass.]

[d. One set of spare parts [per drive] including: all replaceable circuit cards, power diode assemble, DC Buss capacitor, power output transistor assembly, all fuses, and all lights. Package parts individually for long term storage and clearly label contents.]

PART 3 EXECUTION

3.1 INSTALLATION

Perform installation under supervision of competent technicians regularly employed in the installation of DDC systems.

3.1.1 Wiring Criteria

a. Input/output identification: Permanently label each field wire, cable, or pneumatic tube at each end with unique descriptive identification.

b. Rigid or flexible conduit shall be terminated at all sensors, panels, troughs, and output devices.

c. Surge Protection: Install surge protection per manufacturer's specification.

d. Grounding: Ground controllers and cabinets to a good earth ground. Ground controller to a ground in accordance with Section 16402 INTERIOR DISTRIBUTION SYSTEM. Conduit grounding alone is not sufficient; all grounding must have a direct path to building earth ground. Ground sensor drain wire shields at controller end.

e. Contractor is responsible for correcting all associated ground loop problems.

f. Wiring in panel enclosures shall run in covered wire track.

3.1.2 Digital Controllers

Do not divide control of a single mechanical system such as an air handling unit, boiler, chiller, or terminal equipment between two or more controllers. A single controller shall manage control functions for a single mechanical system. It is permissible, however, to manage more than one mechanical system with a single controller.

3.1.3 Temperature Sensors

Provide temperature sensors in locations to sense the appropriate condition. Provide sensor where they are easy to access and service without special tools. Calibrate sensors to accuracy specified. In no case will sensors designed for one application be installed for another application.

3.1.3.1 Room Temperature Sensors

Provide on interior walls to sense average room temperature conditions. Avoid locations near heat sources or which may be covered by office furniture. Room temperature sensors should not be mounted on exterior walls when other locations are available. Mount center of sensor at 5 feet above finished floor.

3.1.3.2 Duct Temperature Sensors

a. Provide sensors in ductwork in general locations as indicated. Select specific sensor location within duct to accurately sense appropriate air temperatures. Do not locate sensors in dead air spaces or positions obstructed by ducts or equipment. Install gaskets between the sensor housing and duct wall. Seal duct and insulation penetrations.

b. String duct averaging sensors horizontally between two rigid supports in a serpentine position to sense average conditions. Insulate temperature sensing elements from supports. Provide hinged duct access doors to install averaging sensors if needed.

c. Locate freeze protection sensors in appropriate locations to sense lowest temperatures, to avoid potential problems with air stratification. Lowest horizontal pass shall be not more than 300 mm 1 foot above bottom tube of coil.

3.1.3.3 Immersion Temperature Sensors

Provide thermowells for sensors measuring temperatures in liquid applications or pressure vessels. Locate wells to sense continuous flow conditions. Do not install wells using extension couplings. Where piping diameters are smaller than the length of the wells, provide wells in piping at elbows to sense flow across entire area of well. Wells shall not restrict flow area to less than 70 percent of pipe area. Increase piping size as required to avoid restriction. Provide thermowells with thermal transmission material within the well.

****

NOTE: Designers should show the OA temperature sensor on the north side of the building. This location should be shown on the mechanical floor plan drawings.

****

3.1.3.4 Outside Air Temperature Sensors

Provide outside air temperature sensor in weatherproof enclosure on north side of the building, away from exhaust hoods, air intakes and other areas that may affect temperature readings. Provide sun shields to from direct sunlight.

3.1.4 Damper Actuators

Actuators shall not be mounted in the air stream.

3.1.5 Thermometers

Provide thermometers at locations indicated. Mount thermometers to allow reading when standing on the floor.

3.1.6 Differential Pressure Sensors

a. Duct Static Pressure Sensing: Locate duct static pressure tip approximately two-thirds of distance from supply fan to end of duct with the greatest pressure drop.

b. Pumping Proof with Differential Pressure Switches: Install high pressure side between pump discharge and check valve.

c. Steam Pressure Sensing: Install snubbers and isolation valves on steam pressure sensing applications.

d. Variable Speed Control: The cycle time and characteristics of the input signal from the differential pressure sensors shall be fully compatible with the variable speed controller. Coordinate the requirements with the provided associated equipment.

3.1.7 Pressure Gages

Pneumatic output lines shall have pressure gages mounted near the digital controllers.

3.1.8 Pneumatic Tubing

Run concealed tubing in finished areas, and run exposed tubing in unfinished areas such as mechanical equipment rooms. For tubing to be enclosed in concrete, provide rigid metal conduit or intermediate metal conduit. Provide tubing parallel and perpendicular to building walls throughout. Maximum spacing between tubing supports shall be 5 feet. With the compressor turned off, test each tubing system pneumatically at 1.5 times the working pressure, with a maximum pressure drop of 1 psig. Correct leaks. Caulking of joints will not be permitted. Do not run tubing and electrical power conductors in the same conduit.

3.1.9 Control Drawings

a. Post laminated copies of as-built control system drawings in each mechanical room.

b. Provide 3 sets of as-built control drawings to the Contracting Officer.

3.2 Test and balance support

Controls contractor will coordinate with and provide full time on-site technical support to test and balance (TAB) personnel specified under Section 15950N HVAC TESTING/ADJUSTING/BALANCING or any other documents in the project specification. This support shall include:

a. On-site operation of control systems for proper operating modes during all phases of balancing and testing.

b. Control setpoint adjustments for proper balancing of all relevant mechanical systems, including VAV boxes.

c. Setting all control loops with setpoints and adjustments determined by TAB personnel.

3.3 FIELD QUALITY CONTROL

3.3.1 General

a. Obtain approval of the field test plan and performance verification test plan for each phase of testing before beginning that phase of testing. Give the Contracting Officer written notification of planned testing at least 30 days prior to test. Notification shall be accompanied by the proposed test procedures. In no case will the Contractor be allowed to start testing without written Government approval of field test plan and performance verification test plan.

b. Demonstrate compliance of the heating, ventilating, and air conditioning control system with the contract documents. Furnish personnel, equipment, instrumentation, and supplies necessary to perform calibration and site testing. Ensure that test personnel are regularly employed in the testing and calibration of DDC systems.

c. Testing will include field tests and performance verification tests. Field tests shall demonstrate proper calibration of input and output devices, and the operation of specific equipment. Performance verification test shall ensure proper execution of the sequence of operation and proper tuning of control loops.

d. Before scheduling the performance verification test, furnish field test documentation and written Certified Statement of Field Test Completion to the Contracting Officer for approval. The statement, certified by the DDC system provider, states that the installed system has been calibrated, tested, and is ready for the performance verification test. Do not start the performance verification test prior to receiving written permission from the Government.

e. Tests are subject to oversight and approval by the Contracting Officer. The testing shall not be run during scheduled seasonal off-periods of heating and cooling systems.

3.3.2 Test Reporting for Field Testing and Performance Verification Tests

a. During and after completion of the Field Tests, and again after the Performance Verification Tests, identify, determine causes, replace, repair or calibrate equipment that fails to meet the specification, and submit a written report to the Government.

b. Document all tests with detailed test results. Explain in detail the nature of each failure and corrective action taken. Provide a written report containing test documentation after the Field Tests and again after the Performance Verification Tests. Convene a test review meeting at the job site to present the results to the Government. As part of this test review meeting, demonstrate by performing all portions of the field tests or performance verification test that each failure has been corrected. Based on the report and test review meeting, the Government will determine either the restart point or successful completion of testing. Do not retest until after receipt of written notification by the Government. At the conclusion of retest, assessment will be repeated.

3.3.3 Field Test Plan

Obtain approval of the field test plan for each phase of testing before beginning that phase of testing. Give to the Contracting Officer written notification of planned testing at least 45 days prior to test. Notification shall be accompanied by the proposed test procedures. In no case will the Contractor be allowed to start testing without written Government approval of test procedures. The field test plan shall consist of detailed instructions for complete testing to prove performance of the heating, ventilating and air-conditioning system and digital control system and shall include tests requirements specified in the PART 3 paragraph entitled "Contractor's Field Tests".

3.3.4 Performance Verification Test Plan

Obtain approval of the performance verification test plan for each phase of testing before beginning that phase of testing. These test phases shall cover the same phases as those for the field tests. Submit this test plan along with the field test plan. In no case will the Contractor be allowed to start performance verification testing without written Government approval of the performance verification test plan. The test plan shall consist of detailed step-by-step instructions for complete testing to prove control system maintains set points, control loops are tuned, and controllers are programmed for the correct sequence of operation. The test plan shall also cover test requirements specified in the PART 3 paragraph entitled "Performance Verification Test."

3.3.5 Contractor's Field Tests

Field tests shall include the following:

3.3.5.1 System Inspection

Observe the HVAC system in its shutdown condition. Check dampers and valves for proper normal positions. Document each position for the test report.

3.3.5.2 Calibration Accuracy and Operation of Inputs Test

Verify correct calibration and operation of input instruments. For each sensor and transmitter, including those for temperature, pressure, humidity, and air quality, record the reading at the sensor or transmitter location using calibrated test equipment. On the same table, record the corresponding reading at the digital controller for the test report. The test equipment shall have been calibrated within one year of use. Test equipment calibration shall be traceable to the measurement standards of the National Institute of Standards and Technology.

3.3.5.3 Actuator Range Adjustment Test

With the digital controller, apply a control signal to each actuator and verify that the actuator operates properly from its normal position to full range of stroke position. Record actual spring ranges and normal positions for all modulating control valves and dampers. Include documentation in the test report.

3.3.5.4 Digital Controller Startup and Memory Test

Demonstrate that programming is not lost after a power failure, and digital controllers automatically resume proper control after a power failure.

3.3.5.5 Surge Protection Test

Show that surge protection, meeting the requirements of this specification, has been installed on incoming power to the digital controllers and on communications lines.

****

NOTE: Use the following paragraph only when requiring workstation software in this contract.

****

3.3.5.6 Application Software Operation Test

Test compliance of the application software for:

a. Ability to communicate with digital controllers, uploading and downloading of control programs

b. Text editing program: Demonstrate ability to edit the control program off line.

c. Reporting of alarm conditions: Force alarms conditions for each alarm, and ensure workstation receives alarms.

d. Reporting trend and status reports: Demonstrate ability of software to receive, display, and save trend and status reports.

3.3.6 Performance Verification Tests

Conduct the performance verification tests to demonstrate control system maintains setpoints, control loops are tuned, and controllers are programmed for the correct sequence of operation. Conduct performance verification test during seven days of continuous HVAC and DDC systems operation and before final acceptance of work. Specifically the performance verification test shall demonstrate the following:

3.3.6.1 Execution of Sequence of Operation

Demonstrate the HVAC system operates properly through the complete sequence of operation, for example seasonal, occupied/unoccupied, and warm-up. Demonstrate proper control system response for abnormal conditions by simulating these conditions. Demonstrate hardware interlocks and safeties work. Demonstrate the control system performs the correct sequence of control after a loss of power.

3.3.6.2 Control Loop Stability and Accuracy

Furnish the Government graphed trends of control loops to demonstrate the control loop is stable and that setpoint is maintained. Control loop response shall respond to setpoint changes and stabilize in 3 minutes. Control loop trend data shall be real time and the time between data points shall not be greater than one minute. The contractor shall provide a printer, either the project printer or temporary, at the job site for printing graphed trends. The printer shall remain on the job site throughout Performance Verification Testing to allow printing trends.

****

NOTE: The A&E or designer of the system should prepare a spreadsheet for the PVT testing (performance verification test) as applied to the installed system. It is suggested that the PVT be shown on a separate "M" drawing immediately after the Sequence of Operation with requirements for conducting the test using the workstation provided by this specification. Use the Sequence of Operation as a guideline. Show on the spreadsheet the workstation requirements, surge protection, and special inputs/outputs. As a minimum the spreadsheet should contain the following elements... PVT REQUIREMENT--EXPECTED RESULT--DATE--REVIEWER'S SIGNATURE

****

3.4 TRAINING

Submit a training course schedule, syllabus, and training materials 14 days prior to the start of training. Obtain approval of the training course before beginning that phase of training. Furnish a qualified instructor to conduct training courses for designated personnel in the maintenance and operation of the HVAC and DDC system. Orient training to the specific system being installed under this contract. Use operation and maintenance manual as the primary instructional aid in contractor provided activity personnel training. Base training on the Operations and Maintenance manuals and a DDC training manual. Manuals shall be delivered for each trainee with two additional sets delivered for archiving at the project site. Training manuals shall include an agenda, defined objectives and a detailed description of the subject matter for each lesson. Furnish audio-visual equipment and all other training materials and supplies. A training day is defined as 8 hours of classroom or lab instruction, including two 15 minute breaks and excluding lunch time, Monday through Friday, during the daytime shift in effect at the training facility. For guidance, the Contractor should assume the attendees will have a high school education and are familiar with HVAC systems.

3.4.1 DDC Training Phase I

The first class shall be taught for a period of [2] consecutive training days at least 2 weeks prior to the scheduled Performance Verification Test. The first course shall be taught in a government provided facility on base. Training shall be classroom, but have hands-on operation of similar digital controllers. A maximum of [5] [_____] personnel will attend this course. Upon completion of this course, each student should be able to perform elementary operations and describe the general hardware architecture and functionality of the system. This course shall include but not be limited to:

a. Theory of operation

b. Hardware architecture

c. Operation of the system

d. Operator commands

e. Control sequence programming

f. Data base entry

g. Reports and logs

h. Alarm reports

i. Diagnostics

3.4.2 DDC Training Phase II

The second course shall be taught in the field, using the operating equipment at the project site[s] for a total of 2 consecutive days. A maximum of [5] [_____] personnel will attend the course. The course shall consist of hands-on training under the constant monitoring of the instructor. Course content should duplicate DDC Training Phase I course as applied to the installed system. The instructor shall determine password issued to each student before each session. Upon completion of this course, students should be fully proficient in the operation of each system function.

-- End of Section --