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Preparing Activity: USACE Superseding
UFGS-23 09 23 (November 2008)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated October 2009

SECTION 23 09 23

DIRECT DIGITAL CONTROL FOR HVAC AND OTHER LOCAL BUILDING SYSTEMS 12/09

NOTE: This guide specification covers the requirements for direct digital control for HVAC and other local building systems.

Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

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).

Additional information and guidance on use of this guide specification is contained in ECB 2004-11., which may be found on the Internet on the TechInfo web site at:
<http://www.hnd.usace.army.mil/techinfo/ECbull.htm>

PART 1 GENERAL

NOTE: This specification covers installation of local (building-level) controls using LonWorks-based DDC. It is primarily intended for building level control systems which are to be integrated into a Utility Monitoring and Control System (UMCS) as specified in Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEM (UMCS). For projects that require the building system to provide UMCS functionality (without connection to a UMCS), the designer must

include the necessary requirements from UFGS 25 10
10. Some requirements to include in this case are:

- 1) LonWorks Network Configuration Tool
- 2) Monitoring and Control Software
- 3) Computer Workstations and Servers

Further details on specifying a stand-alone building system are in UFC 3-410-02A.

The HVAC Control System design shall be in accordance with UFC 3-410-02A. This specification is based on the use of standard HVAC control systems and the designer shall coordinate the design with this specification. Additionally, the standard drawings, as delineated in UFC 3-410-02A, must be used in the preparation of the contract drawings and those drawings must be included in the completed design package. Templates for typical contract type drawings, based on the standard drawings in UFC 3-410-02A, have been developed and are available in AutoCAD and MicroStation formats on the Internet on [the TECHINFO web site](http://www.hnd.usace.army.mil/techinfo/index.asp) located at:

<http://www.hnd.usace.army.mil/techinfo/index.asp>

1.1 REFERENCES

NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a RID outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

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

ASHRAE FUN IP (2009) Fundamentals Handbook, I-P Edition

ASHRAE FUN SI (2009) Fundamentals Handbook, SI Edition

ASME INTERNATIONAL (ASME)

ASME B16.15 (2006) Cast Bronze Threaded Fittings
Classes 125 and 250

ASME B16.34 (2009) Valves - Flanged, Threaded and
Welding End

ASME B40.100 (2005) Pressure Gauges and Gauge
Attachments

ASME BPVC SEC VIII D1 (2007; Addenda 2008) Boiler and Pressure
Vessel Code; Section VIII, Pressure
Vessels Division 1 - Basic Coverage

ASTM INTERNATIONAL (ASTM)

ASTM A 269 (2008) Standard Specification for Seamless
and Welded Austenitic Stainless Steel
Tubing for General Service

ASTM B 88 (2003) Standard Specification for Seamless
Copper Water Tube

ASTM B 88M (2005) Standard Specification for Seamless
Copper Water Tube (Metric)

ASTM D 1693 (2008) Standard Test Method for
Environmental Stress-Cracking of Ethylene
Plastics

ASTM D 635 (2006) Standard Test Method for Rate of
Burning and/or Extent and Time of Burning
of Self-Supporting Plastics in a
Horizontal Position

CONSUMER ELECTRONICS ASSOCIATION (CEA)

CEA-709.1B (2002) Control Network Protocol
Specification

CEA-709.3 (1999) Free-Topology Twisted-Pair Channel
Specification

CEA-852-A (2004) Tunneling Component Network
Protocols Over Internet Protocol Channels

FLUID CONTROLS INSTITUTE (FCI)

FCI 70-2 (2006) Control Valve Seat Leakage

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

- IEEE C62.41.1 (2002; R 2008) IEEE Guide on the Surges Environment in Low-Voltage (1000 V and Less) AC Power Circuits
- IEEE C62.41.2 (2002) IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits
- IEEE Std 142 (2007) Recommended Practice for Grounding of Industrial and Commercial Power Systems - IEEE Green Book (Color Book Series)

ISA - INTERNATIONAL SOCIETY OF AUTOMATION (ISA)

- ISA 7.0.01 (1996) Quality Standard for Instrument Air

LONMARK INTERNATIONAL (LonMark)

- LonMark Interoperability Guide (2002) LonMark Application-Layer Interoperability Guide; Version 3.3
- LonMark SNVT List (2002) LonMark SNVT Master List; Version 11 Revision 2
- LonMark XIF Guide (2001) LonMark External Interface File Reference Guide; Revision 4.0B

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

- NEMA 250 (2008) Enclosures for Electrical Equipment (1000 Volts Maximum)
- NEMA C12.1 (2008) Electric Meters; Code for Electricity Metering
- NEMA C12.10 (2004) Physical Aspects of Watthour Meters
- NEMA C12.20 (2002) Electricity Meter - 0.2 and 0.5 Accuracy Classes

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

- NFPA 70 (2008; AMD 1 2008) National Electrical Code - 2008 Edition
- NFPA 90A (2008; Errata 2009) Standard for the Installation of Air Conditioning and Ventilating Systems

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

- 47 CFR 15 Radio Frequency Devices

UNDERWRITERS LABORATORIES (UL)

- UL 5085-3 (2006e1; Rev thru Jun 2007) UL Standard for Safety Standard Low Voltage

Transformers - Part 3: Class 2 and Class 3
Transformers

UL 555	(2006; Rev thru Feb 2009) Standard for Fire Dampers
UL 555S	(1999; Rev thru Mar 2009) Smoke Dampers
UL 916	(2007) Energy Management Equipment
UL 94	(1996; Rev thru Jun 2009) Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

1.2 DEFINITIONS

The following list of definitions may contain terms not found elsewhere in the Section but are included here for completeness.

- a. Application Specific Controller: A device that is furnished with a pre-established built in application that is configurable but not re-programmable. An ASC has a fixed factory-installed application program (i.e Program ID) with configurable settings.
- b. Binary: A two-state system where an "ON" condition is represented by a high signal level and an "OFF" condition is represented by a low signal level. 'Digital' is sometimes used interchangeably with 'binary'.
- c. Binding: The act of establishing communications between CEA-709.1B devices by associating the output of a device to the input of another.
- d. Building Control Network: The CEA-709.1B control network installed under this Section, consisting of a backbone and one or more local control busses.
- e. Building Point of Connection (BPOC): The BPOC is the point of connection between the UMCS network backbone (an IP network) and the building control network backbone. The hardware at this location, that provides the connection is referred to as the BPOC Hardware. In general, the term "BPOC Location" means the place where this connection occurs, and "BPOC Hardware" means the device that provides the connection. Sometimes the term "BPOC" is used to mean either and its actual meaning (i.e. location or hardware) is determined by the context in which it is used.
- f. Channel: A portion of the control network consisting of one or more segments connected by repeaters. Channels are separated by routers. The device quantity limitation is dependent on the topology/media and device type. For example, a TP/FT-10 network with locally powered devices is limited to 128 devices per channel.
- g. Configuration Parameter: Controller setting usually written to EEPROM. Also see 'Standard Configuration Parameter Type (SCPT)'
- h. Control Logic Diagram: A graphical representation of control logic for multiple processes that make up a system.
- i. Domain: A grouping of up to 32,385 nodes that can communicate directly with each other. (Devices in different domains cannot communicate

directly with each other.) Part of the Node Addressing scheme.

- j. Explicit Messaging: A method of communication between devices where each message contains a message code that identifies the type of message and the devices use these codes to determine the action to take when the message is received. These messages are non-standard and often vendor (application) dependent.
- k. External Interface File (XIF): A file which documents a device's external interface, specifically the number and types of LonMark objects; the number, types, directions, and connection attributes of network variables; and the number of message tags.
- l. Functional Profile: The description of one or more LonMark Objects used to classify and certify devices.
- m. Gateway: A device that translates from one protocol to another. Gateways are also called Communications Bridges or Protocol Translators.
- n. General Purpose Programmable Controller (GPPC): Unlike an ASC, a GPPC is not furnished with a fixed application program. A GPPC can be (re-)programmed, usually using vendor-supplied software.
- o. LonMark Object: A collection of network variables, configuration parameters, and associated behavior defined by LonMark International and described by a Functional Profile. Defines how information is exchanged between devices on a network (inputs from and outputs to the network).
- p. LNS Plug-in: Software which runs in an LNS compatible software tool. Device configuration plug-ins provide a 'user friendly' interface to configuration parameters.
- q. LonMark: See LonMark International. Also, a certification issued by LonMark International to CEA-709.1B devices.
- r. LonMark International: Standards committee consisting of numerous independent product developers and systems integrators dedicated to determining and maintaining the interoperability guidelines for the LonWorks industry. Maintains guidelines for the interoperability of CEA-709.1B devices and issues the LonMark Certification for CEA-709.1B devices.
- s. LonMark Interoperability Association: See 'LonMark International'.
- t. LonWorks: The overall communications technology, developed by Echelon Corporation, for control systems. The term is often used to refer to the technology in general, and may include reference to any/all of the: protocol, network management, and interoperability guidelines where the technology is based on the CEA-709.1B protocol and employs interoperable devices along with the capability to openly manage these devices (via multiple vendors) using a network configuration (or service) tool.
- u. LonWorks Network Services (LNS): A network management and database standard for CEA-709.1B devices.
- v. Monitoring and Control (M&C) Software: The UMCS 'front end' software which performs supervisory functions such as alarm handling, scheduling

and data logging and provides a user interface for monitoring the system and configuring these functions.

- w. Network Variable: See 'Standard Network Variable Type (SNVT)'.
- x. Network Configuration Tool: The software used to configure the control network and set device configuration properties. This software creates and modifies the control network database (LNS Database).
- y. Node: A device that communicates using the CEA-709.1B protocol and is connected to an CEA-709.1B network.
- z. Node Address: The logical address of a node on the network. Variations in node addressing are possible, but the 'Domain, Subnet, Node' format is the established standard for this specification.
- aa. Node ID: A unique 48-bit identifier assigned (at the factory) to each CEA-709.1B device, sometimes called the Neuron ID.
- bb. Program ID: An identifier (number) stored in the device (usually EEPROM) that identifies the node manufacturer, functionality of device (application & sequence), transceiver used, and the intended device usage.
- cc. Repeater: A device that connects two control network segments and retransmits all information received on one side onto the other.
- dd. Router: A device that connects two channels and controls traffic between the channels by retransmitting signals received from one subnet onto the other based on the signal destination. Routers are used to subdivide a control network and to control bandwidth usage.
- ee. Segment: A 'single' section of a control network that contains no repeaters or routers. The device quantity limitation is dependent on the topology/media and device type. For example, a TP/FT-10 network with locally powered devices is limited to 64 devices per segment.
- ff. Service Pin: A hardware push-button on a device which causes the device to broadcast a message (over the control network) containing its Node ID and Program ID. This broadcast can also be initiated via software.
- gg. Standard Configuration Parameter Type (SCPT): Pronounced 'skip-it'. A standard format type (maintained by LonMark International) for Configuration Parameters.
- hh. Standard Network Variable Type (SNVT): Pronounced 'snivet'. A standard format type (maintained by LonMark International) used to define data information transmitted and received by the individual nodes. The term SNVT is used in two ways. Technically it is the acronym for Standard Network Variable Type, and is sometimes used in this manner. However, it is often used to indicate the network variable itself (i.e. it can mean "a network variable of a standard network variable type"). In general, the intended meaning should be clear from the context.
- ii. Subnet: Consists of a logical (not physical) grouping of up to 127 nodes, where the logical grouping is defined by node addressing. Part of the Node Addressing scheme.

- jj. TP/FT-10: A Free Topology Twisted Pair network defined by CEA-709.3. This is the most common media type for an ANSI-709.1 control network.
- kk. UMCS Network: An IP network connecting multiple building level control networks using the CEA-852-A standard.
- ll. User-defined Configuration Parameter Type (UCPT): Pronounced 'u-keep-it'. A Configuration Parameter format type that is defined by the device manufacturer.
- mm. User-defined Network Variable Type (UNVT): A network variable format defined by the device manufacturer. Note that UNVTs create non-standard communications (other vendor's devices may not correctly interpret it) and may close the system and therefore are not permitted by this specification.

1.3 SUBMITTALS

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control.

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, Air Force, and NASA projects.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

The submittals included in this guide specification are critical for new projects and require Government review. Any added submittals, normally, should be for information only and reviewed through the Contractor Quality Control system.

The acquisition of all technical data, data bases

and computer software items that are identified herein will be accomplished strictly in accordance with the Federal Acquisition Regulation (FAR) and the Department of Defense Acquisition Regulation Supplement (DOD FARS). Those regulations as well as the Services implementation thereof should also be consulted to ensure that a delivery of critical items of technical data is not inadvertently lost. Specifically, the Rights in Technical Data and Computer Software Clause, DOD FARS 52.227-7013, and the Data Requirements Clause, DOD FAR 52.227-7031, as well as any requisite software licensing agreements will be made a part of the CONTRACT CLAUSES or SPECIAL CONTRACT REQUIREMENTS. In addition, the appropriate DD Form 1423 Contract Data Requirements List, will be filled out for each distinct deliverable data item and made a part of the contract. Where necessary, a DD Form 1664, Data Item Description, will be used to explain and more fully identify the data items listed on the DD Form 1423. It is to be noted that all of these clauses and forms are required to ensure the delivery of the data in question and that such data is obtained with the requisite rights to use by the Government.

Include with the request for proposals a completed DD Form 1423, Contract Data Requirements List. This form is essential to obtain delivery of all documentation. Each deliverable will be clearly specified, both description and quantity being required.

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for [Contractor Quality Control approval.] [information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.]

Technical data packages consisting of technical data and computer software (meaning technical data which relates to computer software) which are specifically identified in this project and which may be defined/required in other specifications shall be delivered strictly in accordance with the CONTRACT CLAUSES and in accordance with the Contract Data Requirements List, DD Form 1423. Data delivered shall be identified by reference to the particular specification paragraph against which it is furnished. All submittals not specified as technical data packages are considered 'shop drawings' under the Federal Acquisition Regulation Supplement (FARS) and shall contain no proprietary information and be delivered with unrestricted rights.

Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES, the CONTRACT CLAUSES and DD Form 1423 and according to the sequencing specified in paragraph PROJECT SEQUENCING:

SD-02 Shop Drawings

DDC Contractor Design Drawings[; G][; G, [_____]]

DDC Contractor Design Drawings shall be submitted in hard copy and on CDROM in [AutoCAD] [Microstation] format.

Draft As-Built Drawings[; G][; G, [____]]

Draft As-Built Drawings shall be submitted in hard copy and on CDROM in [AutoCAD] [Microstation] format.

Final As-Built Drawings[; G][; G, [____]]

Final As-Built Drawings shall be submitted in hard copy and on CDROM in [AutoCAD] [Microstation] format.

SD-03 Product Data

Manufacturer's Catalog Data[; G][; G, [____]]

Product specific catalog cuts shall be submitted for each product provided under this specification.

Programming Software[; G][; G, [____]]

The most recent version of the Programming software for each type (manufacturer and model) of General Purpose Programmable Controller (GPPC) shall be submitted as a Technical Data Package and shall be licensed to the project site. Software shall be submitted on CD-ROM and [____] hard copies of the software user manual shall be submitted for each piece of software provided.

GPPC Application Programs[; G][; G, [____]]

All installed GPPC Application Programs shall be submitted on CD-ROM as a Technical Data Package. The CD-ROM shall include a list or table of contents clearly indicating which application program is associated with each device. [2][____] copies of the GPPC Application Program's CD-ROM shall be submitted.

XIF files[; G][; G, [____]]

External interface files (XIF files) shall be submitted as a technical data package for each model of DDC Hardware provided under this specification. XIF files shall be submitted on CD-ROM.

LNS Database[; G][; G, [____]]

Two copies of the LNS Database for the complete control network provided under this specification shall be submitted as a Technical Data Package. Each copy shall be on CD-ROM and shall be clearly marked identifying it as the LNS Database for the work covered under this specification and with the date of the most recent database modification.

LNS Plug-in[; G][; G, [____]]

LNS Plug-ins for each Application Specific Controller shall be submitted as a Technical Data Package. LNS Plug-ins distributed under a license shall be licensed to the project site. Plug-ins shall be submitted on CD-ROM. Hard copy manuals, if available, shall be submitted for each plug-in provided.

SD-05 Design Data

Network Bandwidth Usage Calculations[; G][; G, [_____]]

[Four][_____] copies of the Network Bandwidth Usage Calculations shall be submitted.

SD-06 Test Reports

Existing Conditions Report[; G][; G, [_____]]

[Four][_____] copies of the Existing Conditions Report shall be submitted.

Start-Up and Start-Up Testing Report[; G][; G, [_____]]

[Four][_____] copies of the Start-Up and Start-Up Testing Report shall be submitted. The Start-Up and Testing report may be submitted as a Technical Data Package.

PVT Procedures[; G][; G, [_____]]

[Four][_____] copies of the PVT Procedures shall be submitted. The PVT Procedures may be submitted as a Technical Data Package.

PVT Report[; G][; G, [_____]]

[Four][_____] copies of the PVT Phase Report shall be submitted. The PVT Phase Report may be submitted as a Technical Data Package.

Pre-Construction QC Checklist[; G][; G, [_____]]

[Four][_____] copies of the Pre-Construction QC Checklist shall be submitted.

Post-Construction QC Checklist[; G][; G, [_____]]

[Four][_____] copies of the Post-Construction QC Checklist shall be submitted.

SD-10 Operation and Maintenance Data

Operation and Maintenance (O&M) Instructions[; G][; G, [_____]]

[2][_____] copies of the Operation and Maintenance Instructions, indexed and in booklet form shall be submitted. The Operation and Maintenance Instructions shall be a single volume or in separate volumes, and may be submitted as a Technical Data Package.

Training Documentation[; G][; G, [_____]]

Training manuals shall be delivered for each trainee on the Course Attendee List with [2][_____] additional copies delivered for archival at the project site. [2][_____] copies of the Course Attendee List shall be delivered with the archival copies. The Training Documentation may be submitted as a Technical Data Package.

SD-11 Closeout Submittals

Closeout QC Checklist[; G][; G, [____]]

[Four][____] copies of the Closeout QC Checklist shall be submitted.

1.4 SYSTEM DESCRIPTION

NOTE: Designer is to add location and site specific requirements.

The Direct Digital Control (DDC) system shall be a complete system suitable for the control of the heating, ventilating and air conditioning (HVAC) and other building-level systems as specified and shown.

1.4.1 System Requirements

Systems installed under this guide specification shall have the following characteristics:.

- a. The control system shall be an open implementation of LonWorks technology using **CEA-709.1B** as the communications protocol and using LonMark Standard Network Variable Types as defined in **LonMark SNVT List** for communication over the network.
- b. LonWorks Network Services (LNS) shall be used for all network management including addressing and binding of network variables. A copy of the **LNS database** shall be submitted to the project site as specified.
- c. The hardware shall perform the control sequences as specified and shown to provide control of the equipment as specified and shown.
- d. Control sequence logic shall reside in DDC hardware in the building. The building control network shall not be dependent upon connection to a Utility Monitoring and Control System (UMCS) for performance of control sequences in this specification. The hardware shall, to the greatest extent practical, perform the sequences without reliance on the building network.
- e. The hardware shall be installed such that individual control equipment can be replaced by similar control equipment from other equipment manufacturers with no loss of system functionality.
- f. All necessary documentation, configuration information, configuration tools, programs, drivers, and other software shall be licensed to and otherwise remain with the Government such that the Government or their agents are able to perform repair, replacement, upgrades, and expansions of the system without subsequent or future dependence on the Contractor.
- g. The Contractor shall provide sufficient documentation and data, including rights to documentation and data, such that the Government or their agents can execute work to perform repair, replacement, upgrades, and expansions of the system without subsequent or future dependence on

the Contractor.

- h. Hardware shall be installed and configured such that the Government or their agents are able to perform repair, replacement, and upgrades of individual hardware without further interaction with the Contractor.
- i. Control hardware shall be installed and configured to provide all input and output Standard Network Variables (SNVTs) as shown and as needed to meet the requirements of this specification.
- j. All DDC devices installed under this specification shall communicate via **CEA-709.1B**. The control system shall be installed such that a SNVT output from any node on the network can be bound to any other node in the domain.

1.4.2 Verification of Dimensions

After becoming familiar with all details of the work, the Contractor shall verify all dimensions in the field, and shall advise the Contracting Officer of any discrepancy before performing any work.

1.4.3 Drawings

The Government will not indicate all offsets, fittings, and accessories that may be required on the drawings. The Contractor shall carefully investigate the mechanical, electrical, and finish conditions that could affect the work to be performed, shall arrange such work accordingly, and shall provide all work necessary to meet such conditions.

1.5 PROJECT SEQUENCING

TABLE I: PROJECT SEQUENCING lists the sequencing of submittals as specified in paragraph SUBMITTALS (denoted by an 'S' in the 'TYPE' column) and activities as specified in PART 3: EXECUTION (denoted by an 'E' in the 'TYPE' column).

- a. Sequencing for submittals: The sequencing specified for submittals is the deadline by which the submittal shall be initially submitted to the Government. Following submission there will be a Government review period as specified in Section **01 33 00 SUBMITTAL PROCEDURES**. If the submittal is not accepted by the Government, the Contractor shall revise the submittal and resubmit it to the Government within [14] [____] days of notification that the submittal has been rejected. Upon resubmittal there shall be an additional Government review period. If the submittal is not accepted the process repeats until the submittal is accepted by the Government.
- b. Sequencing for Activities: The sequencing specified for activities indicates the earliest the activity may begin.
- c. Abbreviations: In TABLE I the abbreviation AAO is used for 'after approval of' and 'ACO' is used for 'after completion of'.

TABLE I. PROJECT SEQUENCING

ITEM #	TYPE	DESCRIPTION	SEQUENCING (START OF ACTIVITY or DEADLINE FOR SUBMITTAL)	

1	S	Existing Conditions Report		
2	S	DDC Contractor Design Drawings		
3	S	Manufacturer's Catalog Data		
4	S	Network Bandwidth Usage Calculations		
5	S	Pre-construction QC Checklist		
6	E	Install Building Control System	AAO #1 thru #5	
7	E	Start-Up and Start-Up Testing	ACO #6	
8	S	Post-Construction QC Checklist	[] days ACO #7	
9	S	Programming Software	[] days ACO #7	
10	S	XIF Files	[] days ACO #7	
11	S	LNS Plug-ins	[] days ACO #7	
12	S	Start-Up and Start-Up Testing Report	[] days ACO #7	
13	S	Draft As-Built Drawings	[] days ACO #7	
14	S	PVT Procedures	[] days before schedule start of #15 and AAO #12	
15	E	PVT	AAO #13 and #14	
16	S	PVT Report	[] days ACO #15	
17	S	GPPC Application Programs	[] days AAO #16	
18	S	LNS Database	[] days AAO #16	
19	S	Final As-Built Drawings	[] days AAO #16	
20	S	O&M Instructions	AAO #19	
21	S	Training Documentation	AAO #12 and [] days before scheduled start of #22	
22	E	Training	AAO #20 and #21	
23	S	Closeout QC Checklist	ACO #22	

1.6 QUALITY CONTROL (QC) CHECKLISTS

The Contractor's Chief Quality Control (QC) Representative shall complete the QC Checklist in APPENDIX A and submit a [Pre-Construction QC Checklist](#), [Post-Construction QC Checklist](#) and a [Closeout QC Checklist](#) as specified. The QC Representative shall verify each item in the Checklist and initial in the provided area to indicate that the requirement has been met. The QC Representative shall sign and date the Checklist prior to submission to the Government.

1.7 DELIVERY AND STORAGE

Products shall be stored with protection from the weather, humidity, and temperature variations, dirt and dust, and other contaminants, within the storage condition limits published by the equipment manufacturer.

1.8 OPERATION AND MAINTENANCE (O&M) INSTRUCTIONS

The HVAC control System Operation and Maintenance Instructions shall include:

- a. "Manufacturer Data Package 3" as specified in Section [01 78 23](#)
OPERATION AND MAINTENANCE DATA for each piece of control equipment.

- b. "Manufacturer Data Package 4" as described in Section 01 78 23 OPERATION AND MAINTENANCE DATA for all air compressors.
- c. HVAC control system sequences of operation formatted as specified.
- d. Procedures for the HVAC system start-up, operation and shut-down including the manufacturer's supplied procedures for each piece of equipment, and procedures for the overall HVAC system.
- e. As-built HVAC control system detail drawings formatted as specified.
- f. Printouts of configuration settings for all devices.
- g. Routine maintenance checklist. The routine maintenance checklist shall be arranged in a columnar format. The first column shall list all installed devices, the second column shall state the maintenance activity or state no maintenance required, the third column shall state the frequency of the maintenance activity, and the fourth column for additional comments or reference.
- h. Qualified service organization list.
- i. Start-Up and Start-Up Testing Report.
- j. Performance Verification Test (PVT) Procedures and Report.

1.9 MAINTENANCE AND SERVICE

NOTE: The maintenance and service to be provided by the Contractor for the duration of the maintenance contract is specified in this paragraph. The Maintenance and Service may need to be a separate bid item funded by O&M funds.

Requirements should be coordinated with "WARRANTY MANAGEMENT" in Section 01 78 00 CLOSEOUT SUBMITTALS

Services, materials and equipment shall be provided as necessary to maintain the entire system in an operational state as specified for a period of one year after successful completion and acceptance of the Performance Verification Test. Impacts on facility operations shall be minimized.

1.9.1 Description of Work

The adjustment and repair of the system shall include the manufacturer's required sensor and actuator (including transducer) calibration, span and range adjustment.

1.9.2 Personnel

Service personnel shall be qualified to accomplish work promptly and satisfactorily. The Government shall be advised in writing of the name of the designated service representative, and of any changes in personnel.

1.9.3 Scheduled Inspections

Two inspections shall be performed at six-month intervals and all work required shall be performed. Inspections shall be scheduled in [June and December] [____]. These inspections shall include:

- a. Visual checks and operational tests of equipment.
- b. Fan checks and filter changes for control system equipment.
- c. Clean control system equipment including interior and exterior surfaces.
- d. Check and calibrate each field device. Check and calibrate 50 percent of the total analog inputs and outputs during the first inspection. Check and calibrate the remaining 50 percent of the analog inputs and outputs during the second major inspection. Certify analog test instrumentation accuracy to be twice the specified accuracy of the device being calibrated. Randomly check at least 25 percent of all digital inputs and outputs for proper operation during the first inspection. Randomly check at least 25 percent of the remaining digital inputs and outputs during the second inspection.
- e. Run system software diagnostics and correct diagnosed problems.
- f. Resolve any previous outstanding problems.

1.9.4 Scheduled Work

This work shall be performed during regular working hours, Monday through Friday, excluding Federal holidays.

1.9.5 Emergency Service

The Government will initiate service calls when the system is not functioning properly. Qualified personnel shall be available to provide service to the system. A telephone number where the service supervisor can be reached at all times shall be provided. Service personnel shall be at the site within 24 hours after receiving a request for service. The control system shall be restored to proper operating condition as required per Section 01 78 00 CLOSEOUT SUBMITTALS.

1.9.6 Operation

Scheduled adjustments and repairs shall include verification of the control system operation as demonstrated by the applicable tests of the performance verification test.

1.9.7 Records and Logs

Dated records and logs shall be kept of each task, with cumulative records for each major component, and for the complete system chronologically. A continuous log shall be maintained for all devices. The log shall contain initial analog span and zero calibration values and digital points. Complete logs shall be kept and shall be available for inspection onsite, demonstrating that planned and systematic adjustments and repairs have been accomplished for the control system.

1.9.8 Work Requests

Each service call request shall be recorded as received and shall include its location, date and time the call was received, nature of trouble, names of the service personnel assigned to the task, instructions describing what has to be done, the amount and nature of the materials to be used, the time and date work started, and the time and date of completion. A record of the work performed shall be submitted within 5 days after work is accomplished.

1.9.9 System Modifications

Recommendations for system modification shall be submitted in writing. No system modifications, including operating parameters and control settings, shall be made without prior approval of the Government. Any modifications made to the system shall be incorporated into the Operations and Maintenance Instructions, and other documentation affected.

1.10 SURGE PROTECTION

1.10.1 Power-Line Surge Protection

Equipment connected to ac circuits shall be protected against or withstand power-line surges. Equipment protection shall meet the requirements of IEEE C62.41.1, IEEE C62.41.2. Fuses shall not be used for surge protection.

1.10.2 Surge Protection for Transmitter and Control Wiring

NOTE: Determine if any additional inputs or outputs
require surge protection and show the requirement
for them on the drawings.

DDC hardware shall be protected against or withstand surges induced on control and transmitter wiring installed outdoors and as shown. The equipment protection shall be protected against the following two waveforms:

- a. A waveform with a 10-microsecond rise time, a 1,000-microsecond decay time and a peak current of 60 amps.
- b. A waveform with an 8-microsecond rise time, a 20-microsecond decay time and a peak current of 500 amperes.

1.11 INPUT MEASUREMENT ACCURACY

NOTE: This paragraph is referenced elsewhere in the
specification. If this paragraph is edited,
removed, renamed etc make sure to verify that all
references to it are updated as needed.

Sensors, transmitters and DDC Hardware shall be selected, installed and configured such that the maximum error of the measured value at the SNVT output of the DDC hardware is less than 150% of the maximum allowable error specified for the sensor or instrumentation.

1.12 BUILDING CONTROL NETWORK

NOTE: TP/FT-10 is specified as the media type for the local control network as it is an ASA Standard and the most common media type for a LonWorks network. IP can be used as a high-speed backbone when needed, and guidance on including IP is found in the designer notes of this document and in UFC 3-410-02A

TP/FT-10 (and IP if needed) will generally meet all the needs of the building control network, and the use of other media types is strongly discouraged (see guidance in UFC 3-410-02A).

The building control network shall consist of a backbone and one or more local control busses as specified.

1.12.1 Backbone Media

The backbone shall be a TP/FT-10 network in accordance with CEA-709.3 or an IP network as specified in Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEMS (UMCS) according to the following criteria:

- a. The backbone shall be an IP network as specified in Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEMS (UMCS) if both of the following conditions are met:
 - (1) the Network Bandwidth Calculations for a heavily loaded network show that more than 70% of the 78 kbps (kilobits per second) bandwidth is used or the Network Bandwidth Calculations for a normally loaded network show that more than 30% of the 78 kbps bandwidth is used.
 - (2) the Government has approved the Network Bandwidth Calculations submittal.
- b. The backbone shall be a TP/FT-10 network otherwise.

1.12.2 Control Network Requirements

NOTE: Designer must indicate Building Point of Connection (BPOC) location (See item b.).

The control network shall meet the following requirements:

- a. The backbone shall have no control devices connected to it. Only CEA-709.1B Routers and CEA-709.1B TP/FT-10 to IP Routers may be connected to the backbone. CEA-709.1B TP/FT-10 to IP Routers are specified in Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEMS (UMCS)
- b. The backbone shall be installed such that a router at the Building Point of Connection (BPOC) location [as shown] [_____] may be connected to the backbone.

- c. The local control bus shall use CEA-709.1B over a TP/FT-10 network in doubly-terminated bus topology in accordance with CEA-709.3
- d. The local control busses shall be installed such that no node (device connected to the control network) has more than two CEA-709.1B Routers and CEA-709.3 Repeaters (in any combination) between it and the backbone, including the router connected to the backbone.
- e. All DDC Hardware shall connect to a local control bus.
- f. All DDC Hardware shall be locally powered; link power is not acceptable.

PART 2 PRODUCTS

PART 2 of this specification covers requirements for Products (equipment). Installation requirements for these products are covered in PART 3 of this specification.

2.1 EQUIPMENT

2.1.1 General Requirements

Units of the same type of equipment shall be products of a single manufacturer. Each major component of equipment shall have the manufacturer's name and address, and the model and serial number in a conspicuous place. Materials and equipment shall be standard products of a manufacturer regularly engaged in the manufacturing of these and similar products. The standard products shall have been in a satisfactory commercial or industrial use for two years prior to use on this project. The two year use shall include applications of equipment and materials under similar circumstances and of similar size. DDC Hardware not meeting the two-year field service requirement shall be acceptable provided it has been successfully used by the Contractor in a minimum of two previous projects. The equipment items shall be supported by a service organization. Items of the same type and purpose shall be identical, including equipment, assemblies, parts and components. Manufacturer's catalog data sheets documenting compliance with product specifications shall be submitted as specified for each product installed under this specification.

2.1.2 Operation Environment Requirements

All products shall be rated for continuous operation under the following conditions:

- a. Pressure: Pressure conditions normally encountered in the installed location.
- b. Vibration: Vibration conditions normally encountered in the installed location.
- c. Temperature:

NOTE: Designer must decide if suggested outside air temperature range is sufficient, and provide a range if it's not.

- (1) Products installed indoors: Ambient temperatures in the range of 0 to 50 degrees C 32 to 112 degrees F and temperature conditions outside this range normally encountered at the installed location.
- (2) Products installed outdoors or in unconditioned indoor spaces: Ambient temperatures in the range of [-37 to plus 66 degrees C -35 to plus 151 degrees F] [_____] and temperature conditions outside this range normally encountered at the installed location.
- d. Humidity: 10% to 95% relative humidity, noncondensing and humidity conditions outside this range normally encountered at the installed location.

2.2 ENCLOSURES AND WEATHERSHIELDS

2.2.1 Enclosures

NOTE: In outdoor applications specify Type 3 unless hosedown of the enclosure is anticipated, in which case specify Type 4.

For retrofit projects in older mechanical rooms or where hosedown of the enclosure is anticipated specify Type 4 enclosures. Type 4 provides a greater degree of protection in dirty and wet environments than does Type 2.

Enclosures shall meet the following minimum requirements:

- a. Outdoors: Enclosures located outdoors shall meet NEMA 250 [Type 3] [Type 4] requirements.
- b. Mechanical and Electrical Rooms: Enclosures located in mechanical or electrical rooms shall meet NEMA 250 [Type 2] [Type 4] requirements.
- c. Other Locations: Enclosures in other locations including but not limited to occupied spaces, above ceilings, and plenum returns shall meet NEMA 250 Type 1 requirements.

Enclosures supplied as an integral (pre-packaged) part of another product are acceptable.

2.2.2 Weathershields

Weathershields for sensors located outdoors shall prevent the sun from directly striking the sensor. The weathershield shall be provided with adequate ventilation so that the sensing element responds to the ambient conditions of the surroundings. The weathershield shall prevent rain from directly striking or dripping onto the sensor. Weathershields installed near outside air intake ducts shall be installed such that normal outside air flow does not cause rainwater to strike the sensor. Weathershields shall be constructed of galvanized steel painted white, unpainted aluminum, aluminum painted white, or white PVC.

2.3 TUBING

2.3.1 Copper

Copper tubing shall conform to [ASTM B 88](#) and [ASTM B 88M](#)

2.3.2 Stainless Steel

Stainless steel tubing shall conform to [ASTM A 269](#)

2.3.3 Plastic

Plastic tubing shall have the burning characteristics of linear low-density polyethylene tubing, shall be self-extinguishing when tested in accordance with [ASTM D 635](#), shall have [UL 94](#) V-2 flammability classification or better, and shall withstand stress cracking when tested in accordance with [ASTM D 1693](#). Plastic-tubing bundles shall be provided with Mylar barrier and flame-retardant polyethylene jacket.

2.4 NETWORK HARDWARE

2.4.1 CEA-709.1B Network Hardware

2.4.1.1 CEA-709.1B Routers

[CEA-709.1B](#) Routers (including routers configured as repeaters) shall meet the requirements of [CEA-709.1B](#) and shall provide connection between two or more [CEA-709.3](#) TP/FT-10 channels.

2.4.1.2 CEA-709.3 Repeater

[CEA-709.3](#) Repeaters shall be physical layer repeaters in accordance with [CEA-709.3](#).

2.4.2 Gateways

Gateways shall perform bi-directional protocol translation from one non-[CEA-709.1B](#) protocol to [CEA-709.1B](#). Gateways shall incorporate exactly two network connections: one shall be for connection to a TP/FT-10 network in accordance with [CEA-709.3](#) and the second shall be as required to communicate with the non-[CEA-709.1B](#) network.

2.5 WIRE AND CABLE

All wire and cable shall meet the requirements of [NFPA 70](#) and [NFPA 90A](#) in addition to the requirements of this specification.

2.5.1 Terminal Blocks

Terminal blocks which are not integral to other equipment shall be insulated, modular, feed-through, clamp style with recessed captive screw-type clamping mechanism, shall be suitable for rail mounting, and shall have end plates and partition plates for separation or shall have enclosed sides.

2.5.2 Control Wiring for Binary Signals

Control wiring for binary signals shall be 18 AWG copper and shall be rated for 300-volt service.

2.5.3 Wiring for 120-Volt Circuits

Wiring for 120-volt circuits shall be 18 AWG or thicker stranded copper and shall be rated for 600-volt service.

2.5.4 Control Wiring for Analog Signals

Control Wiring for Analog Signals shall be 18 AWG, copper, single- or multiple-twisted, minimum 50 mm 2 inch lay of twist, 100% shielded pairs, and shall have a 300-volt insulation. Each pair shall have a 20 AWG tinned-copper drain wire and individual overall pair insulation. Cables shall have an overall aluminum-polyester or tinned-copper cable-shield tape, overall 20 AWG tinned-copper cable drain wire, and overall cable insulation.

2.5.5 Transformers

Transformers shall be UL 5085-3 approved. Transformers shall be sized so that the connected load is no greater than 80% of the transformer rated capacity.

2.6 AUTOMATIC CONTROL VALVES

NOTE: Ball valves are generally less expensive than globe valves, but because of potential cavitation problems should only be used in 2-position and chilled water applications. It is recommended that you coordinate their use with the local maintenance staff because unlike globe valves maintenance is more likely to require complete removal of the valve.

Show each valve's Kv (m^3/hr) and/or Cv (gal/min) on the Valve Schedule. $Kv = 0.857 \times Cv$.

Valves shall have stainless-steel stems and stuffing boxes with extended necks to clear the piping insulation. Valve bodies shall meet ASME B16.34 or ASME B16.15 pressure and temperature class ratings based on the design operating temperature and 150% of the system design operating pressure. Unless otherwise specified or shown, valve leakage shall meet FCI 70-2 Class IV leakage rating (0.01% of valve Kv). Unless otherwise specified or shown, valves shall have globe-style bodies. Unless otherwise specified:

- a. Bodies for valves 38 mm 1.5 inches and smaller shall be brass or bronze, with threaded or union ends
- b. Bodies for 50 mm 2 inch valves shall have threaded ends
- c. Bodies for valves 50 to 80 mm 2 to 3 inches shall be of brass, bronze or iron.
- d. Bodies for valves 65 mm 2.5 inches and larger shall be provided with flanged-end connections.
- e. For modulating applications, valve Kv (Cv) shall be within 100 to 125% of the Kv (Cv) shown.

- f. For two position applications (where the two positions are full open and full closed) the Kv (Cv) shall be the largest available for the valve size.
- g. Valve and actuator combination shall be normally open or normally closed as shown.

2.6.1 Ball Valves

Balls shall be stainless steel or nickel plated brass. Valves shall have blow-out proof stems. In steam and high temperature hot water applications, the valve-to-actuator linkage shall provide a thermal break.

2.6.2 Butterfly Valves

Butterfly valves shall be threaded lug type suitable for dead-end service and modulation to the fully-closed position, with carbon-steel bodies and non-corrosive discs, stainless steel shafts supported by bearings, and EPDM seats suitable for temperatures from -29 to plus 121 degrees C -20 to plus 250 degrees F. The rated Kv (Cv) for butterfly valves shall be the value Kv (Cv) at 70% (60 degrees) open position. Valve leakage shall meet FCI 70-2 Class VI leakage rating.

2.6.3 Two-Way Valves

Two-way modulating valves used for liquids shall have an equal-percentage characteristic. Two-way modulating valves used for steam shall have a linear characteristic.

2.6.4 Three-Way Valves

Three-way modulating valves shall provide equal percentage flow control with constant total flow throughout full plug travel.

2.6.5 Duct-Coil and Terminal-Unit-Coil Valves

Control valves with either flare-type or solder-type ends shall be provided for duct or terminal-unit coils. Flare nuts shall be provided for each flare-type end valve.

2.6.6 Valves for Chilled-Water, Condenser-Water, and Glycol Service

Valve internal trim shall be Type 316 stainless steel. Valves 100 mm 4 inches and larger shall be butterfly valves.

2.6.7 Valves for High-Temperature Water, Hot-Water and Dual Temperature Service

Valves for hot water service between 99 and 121 degrees C 210 and 250 degrees F and dual-temperature service shall have internal trim (including seats, seat rings, modulating plugs, and springs) of Type 316 stainless steel. Internal trim for valves controlling water below 99 degrees C 210 degrees F shall be brass, bronze or Type 316 stainless steel. Nonmetallic valve parts shall be suitable for a minimum continuous operating temperature of 121 or 28 degrees C 250 or 50 degrees F above the system design temperature, whichever is higher. Valves 100 mm 4 inches and larger shall be butterfly valves.

For high-temperature hot water service above 121 degrees C 250 degrees F

valve 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.

2.6.8 Valves for Steam Service

Bodies for valves 100 mm 4 inches and larger shall be iron or carbon steel. Internal valve trim shall be Type 316 stainless steel. If the specified Kv (Cv) is not available the valve manufacturer's next largest size shall be used.

2.7 DAMPERS

2.7.1 Damper Assembly

A single damper section shall have blades no longer than 1.2 m 48 inch and shall be no higher than 1.8 m 72 inch. Maximum damper blade width shall be 203 mm 8 inch. Larger sizes shall be made from a combination of sections. Dampers shall be steel, or other materials where shown. Flat blades shall be made rigid by folding the edges. Blade-operating linkages shall be within the frame so that blade-connecting devices within the same damper section shall not be located directly in the air stream. Damper axles shall be 13 mm 1/2 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 0.04 inches water gauge at 5.1 m/s 1,000 ft/min in the wide-open position. Frames shall not be less than 50 mm 2 inch in width. Dampers shall be tested in accordance with AMCA 500-D.

2.7.2 Operating Linkages

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 at least 300% of the maximum required damper-operating force. Rod lengths shall be adjustable. Links shall be brass, bronze, zinc-coated steel, or stainless steel. Working parts of joints and clevises shall be brass, bronze, or stainless steel. Adjustments of crank arms shall control the open and closed positions of dampers.

2.7.3 Damper Types

NOTE: The designer should consider the application requirements and edit the leakage ratings as needed. Show exceptions to these specifications in the Damper Schedule.

AMCA 500 leakage classifications at 4 iwc (1017 Pa) static:

Class 1: 8 cfm per square foot of (406 L/s per square meter) damper area.

Class 2: 20 cfm/sf (102 L/s per square meter).

Class 3: 40 cfm/sf (203 L/s per square meter).

Class 4: 80 cfm/sf (406 L/s per square meter).

Consider specifying very low leakage (Class 1) and/or thermally broken (barrier) frames for OA dampers in very cold climates and/or where unit runs 24/7 during unoccupied mode. Edit specification as necessary.

2.7.3.1 Flow Control Dampers

Outside air, return air, relief air, exhaust, face and bypass dampers shall be provided where shown and shall be parallel-blade or opposed blade type as shown on the Damper Schedule. Blades shall have interlocking edges and 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. Unless otherwise shown, dampers shall be **AMCA 500-D** Class 2 and shall not leak in excess of **102 L/s per square meter 20 cfm per square foot** at **1017 Pa 4 inches water gauge** static pressure when closed. Outside air damper seals shall be suitable for an operating temperature range of **-40 to plus 75 degrees C -40 to plus 167 degrees F**. Dampers shall be rated at not less than **10 m/s 2000 ft/min** air velocity.

2.7.3.2 Mechanical Rooms and Other Utility Space Ventilation Dampers

Utility space ventilation dampers shall be as shown. Unless otherwise shown, dampers shall be **AMCA 500-D** class 4 and shall not leak in excess of **406 L/s per square meter 80 cfm per square foot** at **1017 Pa 4 inches water gauge** static pressure when closed. Dampers shall be rated at not less than **7.6 m/s 1500 ft/min** air velocity.

2.7.3.3 Smoke Dampers

Smoke-damper and actuator assembly shall meet the current requirements of **NFPA 90A**, **UL 555**, and **UL 555S**. Combination fire and smoke dampers shall be rated for **121 degrees C 250 degrees F** Class II leakage per **UL 555S**.

2.8 SENSORS AND INSTRUMENTATION

Unless otherwise specified, sensors and instrumentation shall incorporate an integral transmitter or be provided with a transmitter co-located with the sensor. Sensors and instrumentation, including their transmitters, shall meet the specified accuracy and drift requirements at the input of the connected DDC Hardware's analog-to-digital conversion. Sensors and instrumentation, including their transmitters, shall meet or exceed the specified range.

2.8.1 Transmitters

The transmitter shall match the characteristics of the sensor. Transmitters providing analog values shall produce a linear 4-20 mAdc, 0-10 Vdc or SNVT output corresponding to the required operating range and shall have zero and span adjustment. Transmitters providing binary values shall have dry contacts or SNVT output. Transmitters with SNVT output are Application Specific Controllers (ASCs) and shall meet all ASC requirements. (note: ASCs are specified in paragraph DIRECT DIGITAL CONTROL (DDC) HARDWARE)

2.8.2 Temperature Sensors

2.8.2.1 Sensor Ranges and Accuracy

Temperature sensors may be provided without transmitters. Temperature sensors, including transmitter if used, shall have minimum operating ranges, minimum accuracy and maximum drift as specified below for the application:

a. Conditioned Space Temperature

- (1) Operating Range: 10 to 30 degrees C 50 to 86 degrees F.
- (2) Accuracy: +/- 0.5 degrees C 1 degree F over the operating range.
- (3) Drift: Maximum 0.5 degrees C 1 degree F per year.

b. Unconditioned Space Temperature

- (1) Operating Range: -7 to plus 66 degrees C 20 to 150 degrees F.
- (2) Accuracy: +/- 0.5 degrees C 1 degree F over the range of -1 to plus 55 degrees C 30 to 131 degrees F and +/- 2 degrees C 4 degrees F over the rest of the operating range.
- (3) Drift: Maximum 0.5 degrees C 1 degree F per year.

c. Duct Temperature

- (1) Operating Range: 5 to 60 degrees C 40 to 140 degrees F.
- (2) Accuracy: +/- 1 degree C 2 degrees F.
- (3) Drift: Maximum 1 degree C 2 degrees F per year.

d. Outside Air Temperature

NOTE: Designer must choose a range for outside air
sensors suitable to the environment at the project
site.

- (1) Operating Range: [_____] to [_____] degrees C degrees F.
- (2) Accuracy:
 - (a) +/- 1 degree C 2 degrees F over the range of -35 to plus 55 degrees C -30 to plus 130 degrees F.
 - (b) +/- 0.5 degrees C 1 degree F over the range of -1 to plus 40 degrees C 30 to 100 degrees F.
- (3) Drift: Maximum 0.5 degrees C 1 degree F per year.

e. High Temperature Hot Water

- (1) Operating Range: 65 to 232 degrees C 150 to 450 degrees F.

(2) Accuracy: +/- 2 degrees C 3.6 degrees F.

(3) Drift: Maximum +/- 1 degree C 2 degrees F per year.

f. Chilled Water

(1) Operating Range: -1 to plus 38 degrees C 30 to 100 degrees F.

(2) Accuracy: +/- 0.4 degrees C 0.8 degrees F over the range of 2 to 18 degrees C 35 to 65 degrees F and +/- 1 degree C 2 degrees F over the rest of the operating range.

(3) Drift: Maximum 0.4 degrees C 0.8 degrees F per year.

g. Dual Temperature Water

(1) Operating Range: -1 to plus 116 degrees C 30 to plus 240 degrees F.

(2) Accuracy: +/- 1 degree C 2 degrees F.

(3) Drift: Maximum 1 degree C 2 degrees F per year.

h. Heating Hot Water

(1) Operating Range: 21 to 121 degrees C 70 to 250 degrees F.

(2) Accuracy: +/- 1 degree C 2 degrees F.

(3) Drift: Maximum 1 degree C 2 degrees F per year.

i. Condenser Water

(1) Operating Range: -1 to plus 54 degrees C 30 to 130 degrees F.

(2) Accuracy: +/- 0.6 degrees C 1 degree F.

(3) Drift: Maximum 0.6 degrees C 1 degree F per year.

2.8.2.2 Point Temperature Sensors

Point Sensors shall be encapsulated in epoxy, series 300 stainless steel, anodized aluminum, or copper.

2.8.2.3 Averaging Temperature Sensors

Averaging sensors shall be a continuous element with a minimum length equal to 3 m/square meter 1 foot/square foot of duct cross-sectional area at the installed location. The sensing element shall have a bendable copper sheath.

2.8.2.4 Thermowells

Thermowells shall be Series 300 stainless steel with threaded brass plug and chain, 50 mm 2 inch lagging neck and extension type well. Inside diameter and insertion length shall be as required for the application.

2.8.3 Relative Humidity Sensor

Relative humidity sensors shall use bulk polymer resistive or thin film

capacitive type non-saturating sensing elements capable of withstanding a saturated condition without permanently affecting calibration or sustaining damage. The sensors shall include removable protective membrane filters. Where required for exterior installation, sensors shall be capable of surviving below freezing temperatures and direct contact with moisture without affecting sensor calibration. When used indoors, the sensor shall be capable of being exposed to a condensing air stream (100% RH) with no adverse effect to the sensor's calibration or other harm to the instrument. The sensor shall be of the wall-mounted or duct-mounted type, as required by the application, and shall be provided with any required accessories. Sensors used in duct high-limit applications shall have a bulk polymer resistive sensing element. Duct-mounted sensors shall be provided with a duct probe designed to protect the sensing element from dust accumulation and mechanical damage. Relative humidity (RH) sensors shall measure relative humidity over a range of 0% to 100% with an accuracy of +/- 3%. RH sensors shall function over a temperature range of -4 to plus 55 degrees C 25 to 130 degrees F and shall not drift more than 2% per year.

2.8.4 Carbon Dioxide (CO2) Sensors

Carbon dioxide (CO2) sensors shall measure CO2 concentrations between 0 to 2000 parts per million (ppm) using non-dispersive infrared (NDIR) technology with an accuracy of +/- 75 ppm and a maximum response time of 1 minute. The sensor shall be rated for operation at ambient air temperatures within the range of 0 to 50 degrees C 32 to 122 degrees F and relative humidity within the range of 0 to 95% (non-condensing). The sensor shall have a maximum drift of 2%. The sensor chamber shall be manufactured with a non-corrosive material (such as gold-plating) that does not affect carbon dioxide sample concentration. Duct mounted sensors shall be provided with a duct probe designed to protect the sensing element from dust accumulation and mechanical damage.

2.8.5 Differential Pressure Instrumentation

2.8.5.1 Differential Pressure Sensors

Differential Pressure Sensor range shall be as shown or as required for the application. Pressure sensor ranges shall not exceed the high end range shown on the Points Schedule by more than 50%. The over pressure rating shall be a minimum of 150% of the highest design pressure of either input to the sensor. The accuracy shall be +/- 2% of full scale.

2.8.5.2 Differential Pressure Switch

The switch shall have a user-adjustable setpoint. The setpoint shall not be in the upper or lower quarters of the range. The over pressure rating shall be a minimum of 150% of the highest design pressure of either input to the sensor. The switch shall have two sets of contacts and each contact shall have a rating greater than it's connected load. Contacts shall open or close upon rise of pressure above the setpoint or drop of pressure below the setpoint as shown.

2.8.6 Flow Sensors

2.8.6.1 Airflow Measurement Array (AFMA)

Airflow Straightener.-AFMAs shall contain an airflow straightener if required by the AFMA manufacturer's published installation instructions.

The straightener shall be contained inside a flanged sheet metal casing, with the AFMA located as specified according to the published recommendation of the AFMA manufacturer. In the absence of published documentation airflow straighteners shall be provided if there is any duct obstruction within 5 duct diameters upstream of the AFMA. Air-flow straighteners, where required, shall be constructed of 3 mm 0.125 inch aluminum honeycomb and the depth of the straightener shall not be less than 40 mm 1.5 inches.

Resistance to airflow.-The resistance to air flow through the AFMA, including the airflow straightener shall not exceed 20 Pa 0.08 inch water gauge at an airflow of 10 m/s 2,000 fpm. AFMA construction shall be suitable for operation at airflows of up to 25 m/s 5,000 fpm over a temperature range of 4 to 49 degrees C 40 to 120 degrees F.

NOTE: Ensure that outside air temperature range is appropriate for the environment at the project site, and provide a range if it's not.

Outside air temperature.-In outside air measurement or in low-temperature air delivery applications, the AFMA shall be certified by the manufacturer to be accurate as specified over a temperature range of [-29 to plus 49 degrees C -20 to plus 120 degrees F] [_____].

Pitot Tube AFMA.-Each Pitot Tube AFMA shall contain an array of velocity sensing elements. The velocity sensing elements shall be of the multiple pitot tube type with averaging manifolds. The sensing elements shall be distributed across the duct cross section in the quantity and pattern specified by the published installation instructions of the AFMA manufacturer. Pitot Tube AFMAs shall have an accuracy of +/- 3% over a range of 2.5 to 12.5 m/s 500 to 2,500 fpm.

Electronic AFMA.-Each electronic AFMA shall consist of an array of velocity sensing elements of the resistance temperature detector (RTD) or thermistor type. The sensing elements shall be distributed across the duct cross section in the quantity and pattern specified by the published application data of the AFMA manufacturer. Electronic AFMAs shall have an accuracy of +/- 3% percent over a range of 0.6 to 12.5 m/s 125 to 2,500 fpm and the output shall be temperature compensated over a range of 0 to 100 degrees C 32 to 212 degrees F.

2.8.6.2 Orifice Plate

Orifice plate shall be made of an austenitic stainless steel sheet of 3.3 mm 0.125 inch nominal thickness with an accuracy of +/- 1% of full flow. The orifice plate shall be flat within 0.1 mm 0.002 inches. The orifice surface roughness shall not exceed 0.5 micro-meters 20 micro-inches. The thickness of the cylindrical face of the orifice shall not exceed 2% of the pipe inside diameter or 12.5% of the orifice diameter, whichever is smaller. The upstream edge of the orifice shall be square and sharp. Where orifice plates are used, concentric orifice plates shall be used in all applications except steam flow measurement in horizontal pipelines.

2.8.6.3 Flow Nozzle

Flow nozzle shall be made of austenitic stainless steel with an accuracy of +/- 1% of full flow. The inlet nozzle form shall be elliptical and the

nozzle throat shall be the quadrant of an ellipse. The thickness of the nozzle wall and flange shall be such that distortion of the nozzle throat from strains caused by the pipeline temperature and pressure, flange bolting, or other methods of installing the nozzle in the pipeline shall not cause the accuracy to degrade beyond the specified limit. The outside diameter of the nozzle flange or the design of the flange facing shall be such that the nozzle throat shall be centered accurately in the pipe.

2.8.6.4 Venturi Tube

Venturi tube shall be made of cast iron or cast steel and shall have an accuracy of $\pm 1\%$ of full flow. The throat section shall be lined with austenitic stainless steel. Thermal expansion characteristics of the lining shall be the same as that of the throat casting material. The surface of the throat lining shall be machined to a ± 1.2 micrometer 50 micro inch finish, including the short curvature leading from the converging entrance section into the throat.

2.8.6.5 Annular Pitot Tube

Annular pitot tube shall be made of austenitic stainless steel with an accuracy of $\pm 2\%$ of full flow and a repeatability of $\pm 0.5\%$ of measured value. The unit shall have at least one static port and no less than four total head pressure ports with an averaging manifold.

2.8.6.6 Insertion Turbine Flowmeter

Insertion Turbine Flowmeter accuracy shall be $\pm 1\%$ of reading for a minimum turndown ratio of 1:1 through a maximum turndown ratio of 50:1. Repeatability shall be $\pm 0.25\%$ of reading. The meter flow sensing element shall operate over a range suitable for the installed location with a pressure loss limited to 1% of operating pressure at maximum flow rate. Design of the flowmeter probe assembly shall incorporate integral flow, temperature, and pressure sensors. The turbine rotor assembly shall be constructed of Series 300 stainless steel and use Teflon seals.

2.8.6.7 Vortex Shedding Flowmeter

Vortex Shedding Flowmeter accuracy shall be within $\pm 0.8\%$ of the actual flow. The flow meter body shall be made of austenitic stainless steel. The vortex shedding flowmeter body shall not require removal from the piping in order to replace the shedding sensor.

2.8.6.8 Positive Displacement Flow Meter

The flow meter shall be a direct reading, gerotor, nutating disk or vane type displacement device rated for liquid service as shown. A counter shall be mounted on top of the meter, and shall consist of a non-resettable mechanical totalizer for local reading, and a pulse transmitter for remote reading. The totalizer shall have a six digit register to indicate the volume passed through the meter in [liters] [gallons], and a sweep-hand dial to indicate down to 1 liter 0.25 gallons. The pulse transmitter shall have a hermetically sealed reed switch which is activated by magnets fixed on gears of the counter. The meter shall have a bronze body with threaded or flanged connections as required for the application. Output accuracy shall be $\pm 2\%$ of the flow range. The maximum pressure drop at full flow shall be 34 kPa 5 psig.

2.8.6.9 Flow Meters, Paddle Type

Sensor shall be non-magnetic, with forward curved impeller blades designed for water containing debris. Sensor accuracy shall be +/- 2% of rate of flow, minimum operating flow velocity shall be 0.3 meters/second 1 foot per second. Sensor repeatability and linearity shall be +/- 1%. Materials which will be wetted shall be made from non-corrosive materials and shall not contaminate water. The sensor shall be rated for installation in pipes of 76 mm to 1 m 3 to 40 inch diameters. The transmitter housing shall be a NEMA 250 Type 4 enclosure.

2.8.6.10 Flow Switch

Flow switch shall have a repetitive accuracy of +/- 10% of actual flow setting. Switch actuation shall be adjustable over the operating flow range. The switch shall have Form C snap-action contacts, rated for the application. The flow switch shall have non flexible paddle with magnetically actuated contacts and be rated for service at a pressure greater than the installed conditions. Flow switch for use in sewage system shall be rated for use in corrosive environments encountered.

2.8.6.11 Gas Utility Flow Meter

Gas utility flow meter shall be diaphragm or bellows type (gas positive displacement meters) for flows up to 19.7 L/sec 2500 SCFH and axial flow turbine type for flows above 19.7 L/sec 2500 SCFH, designed specifically for natural gas supply metering, and rated for the pressure, temperature, and flow rates of the installation. Meter shall have a minimum turndown ratio of 10 to 1 with an accuracy of +/- 1% of actual flow rate. The meter index shall include a direct reading mechanical totalizing register and electrical impulse dry contact output for remote monitoring. For gas flows of less than 45 cubic-meters/second 1500 cubic-feet/second, the electrical impulse dry contact output shall provide not less than 1 pulse per 3 cubic meters 100 cubic feet of gas and shall not exceed 15 pulses per second for the installed application. For gas flows 45 cubic-meters/second 1500 cubic-feet/second or greater, the pulse rate shall not be the greatest pulse-rate available but not to exceed 15 pulses per second for the installed application. The electrical impulse dry contact output shall not require field adjustment or calibration.

2.8.7 Electrical Instruments

Electrical Instruments shall have an input range as shown or sized for the application. Unless otherwise specified, AC instrumentation shall be suitable for 60 Hz operation.

2.8.7.1 Watt or Watthour Transducers

Watt transducers shall measure voltage and current and shall output kW, kWh, or kW and kWh as shown. kW outputs shall have an accuracy of +/- 0.25% over a power factor range of 0.1 to 1. kWh outputs shall be a pulse output and shall have an accuracy of +/- 0.5% over a power factor range of 0.1 to 1.

2.8.7.2 Watthour Revenue Meter (with and without Demand Register)

**NOTE: The intent of including meters in this
Section is for energy monitoring as may be required**

for interface to a UMCS. Meters are typically only required by this Section for retrofit applications. Coordination of meter installation and meter requirements with other specifications may be required.

Select the revenue meter accuracy as required for the application. For most applications, the 0.5 accuracy class should be suitable/sufficient. (Note the 0.5 accuracy class allows a 0.5% error, while the 0.2 class allows 0.2%).

All Watthour revenue meters shall measure voltage and current and shall be in accordance with NEMA C12.1 with an NEMA C12.20 Accuracy class of [0.5] [0.2] and shall have pulse initiators for remote monitoring of Watthour consumption. Pulse initiators shall consist of form C contacts with a current rating not to exceed two amperes and voltage not to exceed 500 V, with combinations of VA not to exceed 100 VA, and a life rating of one billion operations. Meter sockets shall be in accordance with NEMA C12.10. Watthour revenue meters with demand registers shall have an analog output for instantaneous demand in addition to the pulse initiators.

2.8.7.3 Current Transducers

NOTE: Select the required accuracy for current transducers. Note that higher accuracy transducers will be more expensive and will likely require a more expensive/better quality controller.

Current transducers shall accept an AC current input and shall have an accuracy of +/- [0.5] [2]% of full scale. An integral power supply shall be provided if required for the analog output signal. The device shall have a means for calibration.

2.8.7.4 Current Sensing Relays (CSRs)

Current sensing relays (CSRs) shall provide a normally-open contact with a voltage and amperage rating greater than its connected load. Current sensing relays shall be of split-core design. The CSR shall be rated for operation at 200% of the connected load. Voltage isolation shall be a minimum of 600 volts. The CSR shall auto-calibrate to the connected load.

2.8.7.5 Voltage Transducers

Voltage transducers shall accept an AC voltage input and have an accuracy of +/- 0.25% of full scale. An integral power supply shall be provided if required for the analog output signal. The device shall have a means for calibration. Line side fuses for transducer protection shall be provided.

2.8.8 pH Sensor

The sensor shall be suitable for applications and chemicals encountered in water treatment systems of boilers, chillers and condenser water systems. Construction, wiring, fittings and accessories shall be corrosion and chemical resistant with fittings for tank or suspension installation. Housing shall be polyvinylidene fluoride with O-rings made of chemical

resistant materials which do not corrode or deteriorate with extended exposure to chemicals. The sensor shall be encapsulated. Periodic replacement shall not be required for continued sensor operation. Sensors shall use a ceramic junction and pH sensitive glass membrane capable of withstanding a pressure of 689 kPa at 66 degrees C 100 psig at 150 degrees F. The reference cell shall be double junction configuration. Sensor range shall be 0 to 12 pH, stability 0.05, sensitivity 0.02, and repeatability of +/- 0.05 pH value, response of 90% of full scale in one second and a linearity of 99% of theoretical electrode output measured at 24 degrees C 76 degrees F.

2.8.9 Oxygen Analyzer

Oxygen analyzer shall consist of a zirconium oxide sensor for continuous sampling and an air-powered aspirator to draw flue gas samples. The analyzer shall be equipped with filters to remove flue air particles. Sensor probe temperature rating shall be 435 degrees C 815 degrees F. The sensor assembly shall be equipped for flue flange mounting.

2.8.10 Carbon Monoxide Analyzer

NOTE: Enter the range for the CO Analyzer

Carbon monoxide analyzer shall consist of an infrared light source in a weather proof steel enclosure for duct or stack mounting. An optical detector/analyzer in a similar enclosure, suitable for duct or stack mounting shall be provided. Both assemblies shall include internal blower systems to keep optical windows free of dust and ash at all times. The third component of the analyzer shall be the electronics cabinet. Automatic flue gas temperature compensation and manual/automatic zeroing devices shall be provided. Unit shall read parts per million (ppm) of carbon monoxide in the range of [_____] to [_____] ppm and the response time shall be less than 3 seconds to 90% value. Unit measurement range shall not exceed specified range by more than 50%. Repeatability shall be +/- 2% of full scale with an accuracy of +/- 3% of full scale.

2.8.11 Occupancy Sensors

NOTE: Avoid using occupancy sensors with instant start fluorescent ballasts for instant start of lamps because they shorten the lamp life. Use only rapid start fluorescent ballasts.

Show which type of occupancy sensor to use
drawings: Ultrasonic sensors are best suited for spaces with partitions or dividers; Infrared sensors are best suited in line-of-sight applications.

Show occupancy sensor mounting location on drawings. Office furniture is less likely to interfere with (block) ceiling mounted sensors. In retrofit applications, occupancy sensors can be installed in place of existing light switches.

Dual-technology sensors (one sensor incorporating both types) ordinarily turn lighting ON when both

technologies sense occupancy. Then, detection by either technology will hold lighting ON.

Occupancy sensors shall have occupancy-sensing sensitivity adjustment and an adjustable off-delay timer with a range encompassing 30 seconds to 15 minutes. Occupancy sensors shall be rated for operation in ambient air temperatures ranging from 10 to 40 degrees C 50 to 104 degrees F or temperatures normally encountered in the installed location. Sensors integral to wall mount on-off light switches shall have an auto-off switch. Wall switch sensors shall be decorator style and shall fit behind a standard decorator type wall plate. All occupancy sensors, power packs, and slave packs shall be UL listed. In addition to any outputs required for lighting control, the occupancy sensor shall provide a contact output rated at 1A at 24 Vac or a SNVT output.

2.8.11.1 Passive Infrared (PIR) Occupancy Sensors

PIR occupancy sensors shall have a multi-level, multi-segmented viewing lens and a conical field of view with a viewing angle of 180 degrees and a detection of at least 6 meters 20 feet unless otherwise shown or specified. PIR Sensors shall provide field-adjustable background light-level adjustment with an adjustment range suitable to the light level in the sensed area, room or space. PIR sensors shall be immune to false triggering from RFI and EMI.

2.8.11.2 Ultrasonic Occupancy Sensors

Ultrasonic sensors shall operate at a minimum frequency 32 kHz and shall be designed to not interfere with hearing aids.

2.8.11.3 Dual-Technology Occupancy Sensor (PIR and Ultrasonic)

Dual-Technology Occupancy Sensors shall meet the requirements of both PIR and Ultrasonic Occupancy Sensors.

2.8.12 Vibration Switch

Vibration switch shall be solid state, enclosed in a NEMA 250 Type 4 or Type 4X housing with sealed wire entry. Unit shall have two independent sets of Form C switch contacts with one set to shutdown equipment upon excessive vibration and a second set for monitoring alarm level vibration. The vibration sensing range shall be a true rms reading, suitable for the application. The unit shall include either displacement response for low speed or velocity response for high speed application. The frequency range shall be at least 2 Hz to 200 Hz. Contact time delay shall be 3 seconds. The unit shall have independent start-up and running delay on each switch contact. Alarm limits shall be adjustable and setpoint accuracy shall be +/- 10% of setting with repeatability of plus or minus 2%.

2.8.13 Conductivity Sensor

NOTE: Remove the bracketed text for new construction (Contractor cannot meet this requirement). For retrofit projects, coordinate with the project site to determine need for this analysis.

Sensor shall include local indicating meter and shall be suitable for measurement of conductivity of water in boilers, chilled water systems, condenser water systems, distillation systems, or potable water systems as shown. Sensor shall sense from 0 to 10 microSeimens per centimeter (uS/cm) for distillation systems, 0 to 100 uS/cm for boiler, chilled water, and potable water systems and 0 to 1000 uS/cm for condenser water systems. Contractor shall field verify the ranges for particular applications and adjust the range as required.[Contractor shall submit a complete water quality analysis of a sample of the process to be monitored with the submittal of the sensor manufacturer's catalog data.] The output shall be temperature compensated over a range of 0 to 100 degrees C 32 to 212 degrees F. The accuracy shall be +/- 2% of the full scale reading. Sensor shall have automatic zeroing and shall require no periodic maintenance or recalibration.

2.8.14 Compressed Air Dew Point Sensor

Sensor shall be suitable for measurement of dew point from -40 to plus 27 degrees C -40 to plus 80 degrees F over a pressure range of 0 to 1 MPa 0 to 150 psig. The transmitter shall provide both dry bulb and dew point temperatures on separate outputs. The end to end accuracy of the dew point shall be +/- 2.8 degrees C 5 degrees F and the dry bulb shall be +/- 0.6 degrees C 1 degree F. Sensor shall be automatic zeroing and shall require no normal maintenance or periodic recalibration.

2.8.15 NOx Monitor

Monitor shall continuously monitor and give local indication of boiler stack gas for NOx content. It shall be a complete system designed to verify compliance with the Clean Air Act standards for NOx normalized to a 3% oxygen basis and shall have a range of from 0 to 100 ppm. Sensor shall be accurate to +/- 5 ppm. Sensor shall output NOx and oxygen levels and binary output that changes state when the NOx level is above a locally adjustable NOx setpoint. Sensor shall have normal, trouble and alarm lights. Sensor shall have heat traced lines if the stack pickup is remote from the sensor. Sensor shall be complete with automatic zero and span calibration using a timed calibration gas system, and shall not require periodic maintenance or recalibration.

2.8.16 Turbidity Sensor

Sensor shall include a local indicating meter and shall be suitable for measurement of turbidity of water. Sensor shall sense from 0 to 1000 Nephelometric Turbidity Units (NTU). Range shall be field-verified for the particular application and adjusted as required. The output shall be temperature compensated over a range of 0 to 100 degrees C 0 to 212 degrees F. The accuracy shall be +/- 5% of full scale reading. Sensor shall have automatic zeroing and shall not require periodic maintenance or recalibration.

2.8.17 Chlorine Detector

The detector shall measure concentrations of chlorine in water in the range 0 to 20 ppm with a repeatability of +/- 1% of full scale and an accuracy of +/- 2% of full scale. The Chlorine Detector transmitter shall be housed in a non-corrosive NEMA 250 Type 4X enclosure. Detector shall include a local panel with adjustable alarm trip level, local audio and visual alarm with silence function.

2.8.18 Floor Mounted Leak Detector

Leak detectors shall use electrodes mounted at slab level with a minimum built-in-vertical adjustment of 3 mm 0.125 inches. Detector shall have a binary output. The indicator shall be manual reset type.

2.8.19 Temperature Switch

2.8.19.1 Duct Mount Temperature Low Limit Safety Switch (Freezestat)

Duct mount temperature low limit switches (Freezestats) shall be manual reset, low temperature safety switches with a minimum element length of 3 m/square meter 1 foot/square-foot of coverage which shall respond to the coldest 450 mm 18 inch segment with an accuracy of +/- 2 degrees C 3.6 degrees F. The switch shall have a field-adjustable setpoint with a range of at least -1 to plus 10 degrees C 30 to 50 degrees F. The switch shall have two sets of contacts, and each contact shall have a rating greater than its connected load. Contacts shall open or close upon drop of temperature below setpoint as shown and shall remain in this state until reset.

2.8.19.2 Pipe Mount Temperature Limit Switch (Aquastat)

Pipe mount temperature limit switches (aquastats) shall have a field adjustable setpoint between 15 and 32 degrees C 60 and 90 degrees F, an accuracy of +/- 2 degrees C 3.6 degrees F and a 5 degrees C 10 degrees F fixed deadband. The switch shall have two sets of contacts, and each contact shall have a rating greater than its connected load. Contacts shall open or close upon change of temperature above or below setpoint as shown.

2.8.20 Damper End Switches

NOTE: If the HVAC system design includes smoke dampers in the return air and fan discharge, or other dampers requiring end switches, show the end switches on drawings.

Each end switch shall be a hermetically sealed switch with a trip lever and over-travel mechanism. The switch enclosure shall be suitable for mounting on the duct exterior and shall permit setting the position of the trip lever that actuates the switch. The trip lever shall be aligned with the damper blade.

2.9 INDICATING DEVICES

All indicating devices shall display readings in [metric (SI)] [English (inch-pound)] units.

2.9.1 Thermometers

Thermometers shall not contain mercury. Unless otherwise specified, thermometers shall have an accuracy of +/- 3% of scale range. Thermometers shall have a range suitable for the application with an upper end of the range not to exceed 150% of the design upper limit.

2.9.1.1 Piping System Thermometers

Piping system thermometers shall have brass, malleable iron or aluminum alloy case and frame, clear protective face, permanently stabilized glass tube with indicating-fluid column, white face, black numbers, and a 230 mm 9 inch scale. Piping system thermometers shall have an accuracy of +/- 1% of scale range. Thermometers for piping systems shall have rigid stems with straight, angular, or inclined pattern. Thermometer stems shall have expansion heads as required to prevent breakage at extreme temperatures. On rigid-stem thermometers, the space between bulb and stem shall be filled with a heat-transfer medium.

2.9.1.2 Air-Duct Thermometers

Air-duct thermometers shall have perforated stem guards and 45-degree adjustable duct flanges with locking mechanism.

2.9.2 Pressure Gauges

Gauges shall be suitable for field or panel mounting as required, shall have black legend on white background, and shall have a pointer traveling through a 270-degree arc. Gauge range shall be suitable for the application with an upper end of the range not to exceed 150% of the design upper limit. Accuracy shall be +/- 3% of scale range. Gauges shall meet requirements of ASME B40.100.

2.9.3 Low Differential Pressure Gauges

Gauges for low differential pressure measurements shall be a minimum of 90 mm 3.5 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. Gauge range shall be suitable for the application with an upper end of the range not to exceed 150% of the design upper limit. Accuracy shall be plus or minus two percent of scale range.

2.10 OUTPUT DEVICES

Output Devices with SNVT input are ASCs and shall meet all ASC requirements in addition to the output device requirements. (Note: ASCs are specified in paragraph DIRECT DIGITAL CONTROL (DDC) HARDWARE.)

2.10.1 Actuators

NOTE: Include the appropriate bracketed text if pneumatic actuators are used.

Edit the control Schematic drawing to show electric and/or pneumatic actuators along with their failsafe positions (NO, NC, or fail-in-last-position (FILP)). See the UFC for design guidance on choosing actuator fail-to positions.

Include the bracketed text if using electric actuator position feedback. This should be limited to primary equipment, such as built-up air handlers. Show this feedback signal on the control schematic drawings or specifically state where this requirement applies. Add the actuator position to

the Points Schedule as a network variable available
to be monitored by the UMCS (present or future).

Actuators shall be electric (electronic) [or pneumatic as shown]. All actuators shall be normally open (NO), normally closed (NC) or fail-in-last-position (FILP) as shown. Normally open and normally closed actuators shall be of mechanical spring return type. Electric actuators shall have an electronic cut off or other means to provide burnout protection if stalled. Actuators shall have a visible position indicator. [Electric actuators shall provide position feedback to the controller as shown.] Actuators shall smoothly open or close the devices to which they are applied. Pneumatic actuators shall have a full stroke response time matching the connected Electric to Pneumatic Transducer (EP). Electric actuators shall have a full stroke response time in both directions of 90 seconds or less at rated load. Electric actuators shall be of the foot-mounted type with an oil-immersed gear train or the direct-coupled type. Where multiple electric actuators operate from a common signal, the actuators shall provide an output signal identical to its input signal to the additional devices. [Pneumatic actuators shall be rated for 172 kPa 25 psi operating pressure except for high-pressure cylinder-type actuators.]

2.10.1.1 Valve Actuators

NOTE: Indicate in the Valve Schedule a close-off pressure that is 150% of the pump dead head pressure for 2-way valves and 200% of the valve differential pressure for 3-way valves, or equivalent torque values.

Valve actuators shall provide shutoff pressures and torques as shown on the Valve Schedule.

2.10.1.2 Damper Actuators

Damper actuators shall provide the torque necessary per damper manufacturer's instructions to modulate the dampers smoothly over its full range of operation and torque shall be at least 7 Nm/0.93 square m 6 inch-pounds/1 square foot of damper area for opposed blade dampers and 1 Nm/0.93 square m 9 inch-pounds/1 square foot of damper area for parallel blade dampers.

2.10.1.3 Positive Positioners

NOTE: Only larger valves and actuators or where high-speed actuation is needed may require positive positioners. Edit the drawings to show positive positioners when they are required. The typical drawings do not show/require them due to maintenance requirements for these devices. See UFC 3-410-02A for more information.

Positive positioners shall be a pneumatic relay with a mechanical position feedback mechanism and an adjustable operating range and starting point.

2.10.2 Solenoid-Operated Electric to Pneumatic Switch (EPS)

Solenoid-Operated Electric to Pneumatic Switches (EPS) shall accept a voltage input to actuate its air valve. Each valve shall have three-port operation: common, normally open, and normally closed. Each valve shall have an outer cast aluminum body and internal parts of brass, bronze, or stainless steel. The air connection shall be a 10 mm 0.38 inch NPT threaded connection. Valves shall be rated for 345 kPa 50 psig.

2.10.3 Electric to Pneumatic Transducers (EP)

NOTE: Depending on the application, the designer
may choose to select an EP and actuator combination
to operate over the full range in less than 90
seconds.

Electric to Pneumatic Transducers (EPs) shall convert either a 4-20 mAdc input signal, a 0-10 Vdc input signal, or SNVT input to a 21-103 kPa 3-15 psig pneumatic output with a conversion accuracy of +/- 2% of full scale, including linearity and hysteresis. The EP shall withstand pressures at least 150% of the system supply air pressure (main air). EPs shall include independent offset and span adjustment. Air consumption shall not be greater than 0.024 L/s 0.05 scfm. EPs shall have a manual adjustable override for the EP pneumatic output. EPs shall have sufficient output capacity to provide full range stroke of the actuated device in both directions within [90][_____] seconds.

2.10.4 Relays

Control relay contacts shall have utilization category and ratings selected for the application, with a minimum of two sets of contacts enclosed in a dust proof enclosure. Each set of contacts shall incorporate a normally open (NO), normally closed (NC) and common contact. Relays shall be rated for a minimum life of one million operations. Operating time shall be 20 milliseconds or less. Relays shall be equipped with coil transient suppression devices to limit transients to 150% of rated coil voltage.

2.11 USER INPUT DEVICES

User Input Devices, including potentiometers, switches and momentary contact push-buttons with SNVT output are Application Specific Controllers (ASCs) and shall meet all ASC requirements. (Note: ASCs are specified in paragraph DIRECT DIGITAL CONTROL (DDC) HARDWARE). Potentiometers shall be of the thumb wheel or sliding bar type. Momentary Contact Push-Buttons may include an adjustable timer for their output. User input devices shall be labeled for their function.

2.12 MULTIFUNCTION DEVICES

Multifunction devices are products which combine the functions of multiple sensor, user input or output devices into a single product. Unless otherwise specified, the multifunction device shall meet all requirements of each component device. Where the requirements for the component devices conflict, the multifunction device shall meet the most stringent of the requirements.

2.12.1 Current Sensing Relay Command Switch

The Current Sensing Relay portion shall meet all requirements of the Current Sensing Relay input device. The Command Switch portion shall meet all requirements of the Relay output device except that it shall have at least one normally-open (NO) contact.

2.12.2 Thermostats

Thermostats shall be multifunction devices incorporating a temperature sensor and a temperature indicating device. Thermostats shall not contain mercury (Hg). In addition, the thermostat shall have the following as specified and shown:

- a. A User Input Device which shall adjust a temperature setpoint output.
- b. A User Input Momentary Contact Button and an output indicating zone occupancy.
- c. A three position User Input Switch labeled to indicate heating, cooling and off positions ('HEAT-COOL-OFF' switch) and providing corresponding outputs.
- d. A two position User Input Switch labeled with 'AUTO' and 'ON' positions and providing corresponding outputs.
- e. A multi-position User Input Switch with 'OFF' and at least two fan speed positions and providing corresponding outputs.

2.13 COMPRESSED AIR STATIONS

NOTE: The designer will estimate the required control air consumption to calculate the required motor horsepower of the control air compressor and coordinate with the electrical designer.

For hospitals and critical installations, a standby compressor will be provided. For all other applications, the portion covering standby compressor will be deleted. For hospitals, delete the Contractor option permitting the use of polyethylene tubing in lieu of copper.

Indicate on the drawings the locations where metallic raceway or electric metallic tubing is not required for protection of nonmetallic tubing.

2.13.1 Air Compressor Assembly

The air compressor shall be a high pressure compressing unit with electric motor. The compressor shall be equipped with a motor with totally enclosed belt guard, an operating-pressure switch, safety relief valves, gauges, intake filter and intake silencer, and combination type magnetic starter with undervoltage protection and thermal-overload protection for each phase, and shall be supported by a steel base mounted on an air storage tank. The air compressor shall provide the compressed air required for control operation while operating not more than one-third of the time. The

air storage tank shall be fabricated for a working pressure of not less than 1380 kPa 200 psi and constructed and certified in accordance with ASME BPVC SEC VIII D1. The tank shall be of sufficient volume so that no more than six compressor starts per hour are required with the starting pressure switch differential set at 140 kPa 20 psi. The tank shall be provided with an automatic condensate drain trap with manual override feature. [A second (duplex arrangement) compressor of capacity equal to the primary compressor shall be provided, with interlocked control to provide automatic changeover upon malfunction or failure of either compressor. A manual selector switch shall be provided to index the lead compressor including the automatic changeover.]

2.13.2 Compressed Air Station Specialties

2.13.2.1 Refrigerated Dryer, Filters and, Pressure Regulator

A refrigerated dryer shall be provided in the air outlet line of the air storage tank. The dryer shall be of the size required for the full delivery capacity of the compressor. The air shall be dried at a pressure of not less than 483 kPa 70 psi to a temperature not greater than 2 degrees C 35 degrees F. The dryer shall be provided with an automatic condensate drain trap with manual override feature. The automatic drain trap shall have an adjustable cycle and drain time. The refrigerant used in the dryer shall be one of the fluorocarbon gases and have an Ozone Depletion Potential of not more than 0.05. A five micron pre-filter and coalescing-type 0.03 micron oil removal filter with shut-off valves shall be provided in the dryer discharge. Each filter bowl shall be rated for 1034 kPa 150 psi maximum working pressure. A pressure regulator, with high side and low side pressure gauges, and a safety valve shall be provided downstream of the filter. Pressure regulators of the relieving type shall not be used.

2.13.2.2 Flexible Pipe Connections

The flexible pipe connections shall be designed for 1034 kPa and 120 degrees C 150 psi and 250 degrees F service, and shall be constructed of rubber or tetrafluoroethylene resin tubing with a reinforcing protective cover of braided corrosion-resistant steel, bronze, monel, or galvanized steel. The connectors shall be suitable for the service intended and shall have threaded or soldered ends. The length of the connectors shall be as recommended by the manufacturer for the service intended.

2.13.2.3 Vibration Isolation Units

The vibration isolation units shall be standard products with published loading ratings, and shall be single rubber-in-shear, double rubber-in-shear, or spring type.

2.14 DIRECT DIGITAL CONTROL (DDC) HARDWARE

2.14.1 General Requirements

All DDC Hardware shall meet the following requirements:

- a. It shall incorporate a "service pin" which, when pressed will cause the DDC Hardware to broadcast its 48-bit NodeID and its ProgramID over the network. The service pin shall be distinguishable and accessible.
- b. It shall incorporate a light to indicate the device is receiving power.

- c. It shall incorporate a TP/FT-10 transceiver in accordance with CEA-709.3 and connections for TP/FT-10 control network wiring. It shall not have connections to any other network media type.
- d. It shall communicate on the network using only the CEA-709.1B protocol.

 NOTE: FYI, a link powered device gets it's power
 from the communication cable as opposed to from a
 separate power source.

- e. It shall be locally powered; link powered devices are not acceptable.
- f. LonMark external interface files (XIF files), as defined in the LonMark XIF Guide, shall be submitted for each type of DDC Hardware.
- g. Application programs and configuration settings shall be stored in a manner such that a loss of power does not result in a loss of the application program or configuration settings.
- h. It shall have all functionality specified and required to support the application (Sequence of Operation or portion thereof) in which it is used, including but not limited to:
 - (1) It shall provide input and output SNVTs as specified and required to support the sequence and application in which it is used.
 - (2) It shall be configurable via standard or user-defined configuration parameters (SCPT or UCPT), SNVT network configuration inputs (nci), or hardware settings on the controller itself as specified and as required to support the sequence and application in which it is used.
- i. It shall meet 47 CFR 15 requirements and have UL 916 or equivalent safety listing.

2.14.2 Hardware Input-Output (I/O) Functions

DDC Hardware incorporating hardware input-output (I/O) functions shall meet the following requirements:

- a. Analog Inputs: DDC Hardware analog inputs (AIs) shall perform analog to digital (A-to-D) conversion with a minimum resolution of 8 bits plus sign or better as needed to meet the accuracy requirements specified in paragraph INPUT MEASUREMENT ACCURACY. Signal conditioning including transient rejection shall be provided for each analog input. Analog inputs shall be capable of being individually calibrated for zero and span. The AI shall incorporate common mode noise rejection of at least 50 dB from 0 to 100 Hz for differential inputs, and normal mode noise rejection of at least 20 dB at 60 Hz from a source impedance of 10,000 ohms.
- b. Analog Outputs: DDC Hardware analog outputs (AOs) shall perform digital to analog (D-to-A) conversion with a minimum resolution of 8 bits plus sign, and output a signal with a range of 4-20 mAdc or 0-10 Vdc. Analog outputs shall be capable of being individually calibrated for zero and span.

- c. Binary Inputs: DDC Hardware binary inputs (BIs) shall accept contact closures and shall ignore transients of less than 5 milli-second duration. Isolation and protection against an applied steady-state voltage up to 180 Vac peak shall be provided.
- d. Binary Outputs: DDC Hardware binary outputs (BOs) shall provide relay contact closures or triac outputs for momentary and maintained operation of output devices.
 - (1) Relay Contact Closures: Closures shall have a minimum duration of 0.1 second. Relays shall provide at least 180V of isolation. Electromagnetic interference suppression shall be provided on all output lines to limit transients to non-damaging levels. Minimum contact rating shall be one ampere at 24 Vac.
 - (2) Triac outputs: Triac outputs shall provide at least 180 V of isolation.
- e. Pulse Accumulator: DDC Hardware pulse accumulators shall have the same characteristics as the BI. In addition, a buffer shall be provided to totalize pulses. The pulse accumulator shall accept rates of at least 20 pulses per second. The totalized value shall be reset to zero upon operator's command.

2.14.3 Application Specific Controller (ASC)

Application Specific Controllers (ASCs) have a fixed factory-installed application program (i.e. ProgramID) with configurable settings. ASCs shall meet the following requirements in addition to the General DDC Hardware and DDC Hardware Input-Output (I/O) Function requirements:

- a. ASCs shall be LonMark Certified.
- b. Unless otherwise approved, all necessary Configuration Parameters and network configuration inputs (*ncis*) for the sequence and application in which the ASC is used shall be fully configurable through an [LNS plug-in](#). This plug-in shall be submitted as specified for each type of ASC (manufacturer and model). (Note: configuration accomplished via hardware settings does not require configuration via plug-in)
- c. Local Display Panel (LDP): The Local Display Panel shall be an Application Specific Controller (ASC) with a display and navigation buttons. It shall provide display and adjustment of SNVT inputs and SNVT outputs as shown.

2.14.4 General Purpose Programmable Controller (GPPC)

A General Purpose Programmable Controller (GPPC) is not installed with a fixed factory-installed application program. GPPCs shall meet the following requirements in addition to the general DDC Hardware requirements and Hardware Input-Output (I/O) Function:

- a. The programmed GPPC shall conform to the [LonMark Interoperability Guide](#).
- b. All [programming software](#) required to program the GPPC shall be delivered to and licensed to the project site as specified.
- c. Copies of the installed [GPPC application programs](#) as source code

compatible with the supplied programming software shall be submitted as specified. The submitted GPPC application program shall be the complete application necessary for the GPPC to function as installed and be sufficient to allow replacement of the installed controller with a GPPC of the same type.

PART 3 EXECUTION

3.1 EXISTING CONDITIONS SURVEY

NOTE: Use the bracketed text for retrofit projects only.

The Contractor shall perform a field survey, including testing and inspection of the equipment to be controlled and submit an [Existing Conditions Report](#) documenting the current status and it's impact on the Contractor's ability to meet this specification. For those items considered nonfunctional, the Contractor shall provide (with the report) specification sheets, or written functional requirements to support the findings and the estimated costs to correct the deficiencies. As part of the report, the Contractor shall define the scheduled need date for connection to existing equipment.[The Contractor shall make written requests and obtain Government approval prior to disconnecting any controls and obtaining equipment downtime. Existing devices which are not to be replaced shall be inspected, calibrated, and adjusted as necessary to place them in proper working order.]

3.2 CONTROL SYSTEM INSTALLATION

3.2.1 General Installation Requirements

3.2.1.1 HVAC Control System

The HVAC control system shall be completely installed, tested and ready for operation. Dielectric isolation shall be provided where dissimilar metals are used for connection and support. Penetrations through and mounting holes in the building exterior shall be made watertight. The HVAC control system installation shall provide clearance for control system maintenance by maintaining access space required to calibrate, remove, repair, or replace control system devices. The control system installation shall not interfere with the clearance requirements for mechanical and electrical system maintenance.

3.2.1.2 Device Mounting Criteria

All devices shall be installed in accordance with manufacturer's recommendations and as specified and shown. Control devices to be installed in piping and ductwork shall be provided with required gaskets, flanges, thermal compounds, insulation, piping, fittings, and manual valves for shutoff, equalization, purging, and calibration. Strap-on temperature sensing elements shall not be used except as specified. Spare thermowells shall be installed adjacent to each thermowell containing a sensor and as shown. Devices located outdoors shall have a weathershield.

3.2.1.3 Labels and Tags

Labels and tags shall be keyed to the unique identifiers shown on the

As-Built drawings. All Enclosures and DDC Hardware shall be labeled. All sensors and actuators in mechanical rooms shall be tagged. Airflow measurement arrays shall be tagged to show flow rate range for signal output range, duct size, and pitot tube AFMA flow coefficient. Duct static pressure taps shall be tagged at the location of the pressure tap. Tags shall be plastic or metal and shall be mechanically attached directly to each device or attached by a metal chain or wire. Labels exterior to protective enclosures shall be engraved plastic and mechanically attached to the enclosure or DDC Hardware. Labels inside protective enclosures may be attached using adhesive, but shall not be hand written.

3.2.2 DDC Hardware

NOTE: Coordinate with the project site for domain and subnet values. These values must be selected so that there will not be a domain or subnet conflict when the building is integrated into a UMCS. Generally this information can be obtained from whoever maintains the UMCS (whoever integrates buildings into the UMCS).

DDC Hardware shall be installed in an enclosure. Except for DDC Hardware used to control Terminal Units, where multiple pieces of DDC Hardware are used to execute one sequence all DDC Hardware executing that sequence shall be on a common local control bus and isolated from all other DDC Hardware via an CEA-709.1B Router or CEA-709.3 Repeater. All DDC Hardware installed shall have an CEA-709.1B domain of [_____] and a subnet between [_____] and [_____].

3.2.3 Local Display Panel (LDP)

NOTE: Designer must indicate on each Points Schedule which points, if any, are to be displayed or adjustable from an LDP.

Designer should coordinate with the project site to determine number and location of LDPs needed and show on them on the drawings. Due to limitations of LDPs, the project site may opt to not specify LDPs and use a laptop instead.

Local Display Panels shall be installed [in each mechanical room containing an air handler] [_____] and shall provide SNVT inputs for display and outputs for adjusting SNVT values as shown on the Points Schedule.

3.2.4 Gateways

NOTE: The intent of this is to allow the use of gateways to packaged equipment controllers, not to allow the installation of a non-ANSI 709.1 network connected to a 15951 ANSI 709.1 network via a gateway.

Gateways may be used for communication with non-CEA-709.1B control hardware subject to all of the following limitations:

- a. Each gateway shall communicate with and perform protocol translation for non-CEA-709.1B control hardware controlling one and only one package unit.
- b. Non-CEA-709.1B control hardware shall not be used for controlling built-up units.
- c. Non-CEA-709.1B control hardware shall not perform system scheduling functions.

3.2.5 Network Interface Jack

NOTE: Choose the preferred location for network interface jacks by controllers with thermostats (coordinate with the project site to determine preference of O&M Staff).

Choose the number of interface cables to be furnished by the Contractor.

A standard network interface jack shall be provided for each node on the control network. For terminal unit controllers with hardwired thermostats this network interface jack shall be located at the thermostat or within 3 m 10 ft of the controller. Locating the interface jack [at the thermostat][near the controller] is preferred. For all other nodes the network interface jack shall be located within 3 m 10 ft of the node. If the network interface jack is other than a 3 mm 1/8 inch phone jack, the Contractor shall provide an interface cable with a standard 3 mm 1/8 inch phone jack on one end and a connector suitable for mating with installed network interface jack on the other. No more than one type of interface cable shall be required to access all network interface jacks. Contractor shall furnish [one][_____] interface cable(s).

3.2.6 Room Instrument Mounting

NOTE: Wall mounted thermostats and similar control system components containing user input devices in ADA compliant facilities and spaces are required to be mounted 1.2 meters (48 inches) above the floor for forward reach and 1.3 meters (54 inches) for side reach. Note the mounting height and location for these system components on the drawings or revise the following paragraph accordingly.

Room instruments, including but not limited to wall mounted thermostats and sensors located in occupied spaces shall be mounted 1.5 m 60 inches above the floor unless otherwise shown. Unless otherwise shown on the Thermostat Schedule:

- a. Thermostats for Fan Coil Units shall be unit mounted.
- b. All other Thermostats shall be wall mounted.

3.2.7 Indication Devices Installed in Piping and Liquid Systems

Gauges in piping systems subject to pulsation shall have snubbers. Gauges for steam service shall have pigtail fittings with cock. Thermometers and temperature sensing elements installed in liquid systems shall be installed in thermowells.

3.2.8 Duct Smoke Detectors

NOTE: Duct Smoke Detectors are installed by the fire alarm system Contractor. Duct detectors are intended to shut down air distribution fans and close smoke dampers where applicable. Each detector must be indicated on the schematic and associated ladder diagram.

Coordinate with the applicable Section 1385x used for the fire alarm system installation, to make sure that smoke detectors are installed in the proper location and that all detectors that are to be interfaced to the DDC system have auxiliary contacts for this purpose.

In the following paragraph indicate which Section is used for the installation of the fire alarm system (and the duct smoke detectors).

Duct smoke detectors will be provided in supply and return air ducts in accordance with [Section 28 31 64.00 10 FIRE DETECTION AND ALARM SYSTEM, ADDRESSABLE] [____]. Contractor shall connect the DDC System to the auxiliary contacts provided on the Smoke Detector as required for system safeties and to provide alarms to the DDC system.

3.2.9 Occupancy Sensors

A sufficient quantity of occupancy sensors shall be provided to provide complete coverage of the area (room or space). Occupancy sensors shall be installed in accordance with NFPA 70 requirements and the manufacturer's instructions. Occupancy sensors shall not be located within 1.8 m 6 feet of HVAC outlets or heating ducts. PIR and dual-technology PIR/ultrasonic sensors shall not be installed where they can "see" beyond any doorway. Ultrasonic sensors shall not be installed in spaces containing ceiling fans. Sensors shall detect motion to within 0.6 m 2 feet of all room entrances and shall not trigger due to motion outside the room. The off-delay timer shall be set to [15] [____] minutes unless otherwise shown. All sensor adjustments shall be made prior to beneficial occupancy, but after installation of furniture systems, shelving, partitions, etc. Each controlled area shall have one hundred percent coverage capable of detecting small hand-motion movements, accommodating all occupancy habits of single or multiple occupants at any location within the controlled room.

3.2.10 Temperature Limit Switch

A temperature limit switch (freezestat) shall be provided to sense the temperature at the location shown. A sufficient number of temperature limit switches (freezestats) shall be installed to provide complete

coverage of the duct section. Manual reset limit switches shall be installed in approved, accessible locations where they can be reset easily. The temperature limit switch (freezestat) sensing element shall be installed in a serpentine pattern and in accordance with the manufacturer's installation instructions.

3.2.11 Averaging Temperature Sensing Elements

Sensing elements shall be installed in a serpentine pattern located as shown.

3.2.12 Air Flow Measurement Arrays (AFMA))

NOTE: Air filters are specified in Section 23 00 00
AIR SUPPLY, DISTRIBUTION, VENTILATION AND EXHAUST
SYSTEMS and installed by the Mechanical Contractor
(not by the controls Contractor under this spec).

If MinOA ducts are not used, do not permit pitot
tube AFMA for OA measurement (keep bracketed text).

Outside Air AFMAs shall be located downstream from the Outside Air filters. Pitot Tube AFMA shall not be used if the expected velocity measurement is below 3.5 m/s 700 fpm [or for outside airflow measurements].

3.2.13 Duct Static Pressure Sensors

The duct static pressure sensing tap shall be located at 75% to 100% of the distance between the first and last air terminal units. If the transmitter is wired in a homerun configuration to an AHU controller, the transmitter shall be located in the same enclosure as the air handling unit (AHU) controller(s) for the AHU serving the terminal units.

3.2.14 Relative Humidity Sensors

Relative humidity sensors in supply air ducts shall be installed at least 3 m 10 feet downstream of humidity injection elements.

3.2.15 Flowmeters

The minimum straight unobstructed piping for the flowmeter installation shall be at least 10 pipe diameters upstream and at least 5 pipe diameters downstream and in accordance with the manufacturer's installation instructions.

3.2.16 Dampers

3.2.16.1 Damper Actuators

Actuators shall not be mounted in the air stream. Multiple actuators shall not be connected to a common drive shaft. Actuators shall be installed so that their action shall seal the damper to the extent required to maintain leakage at or below the specified rate and shall move the blades smoothly.

3.2.16.2 Damper Installation

Dampers shall be installed straight and true, level in all planes, and

square in all dimensions. Dampers shall move freely without undue stress due to twisting, racking (parallelogramming), bowing, or other installation error. Blades shall close completely and leakage shall not exceed that specified at the rated static pressure. Structural support shall be used for multi-section dampers. Acceptable methods include but are not limited to U-channel, angle iron, corner angles and bolts, bent galvanized steel stiffeners, sleeve attachments, braces, and building structure. Where multi-section dampers are installed in ducts or sleeves, they shall not sag due to lack of support. Jackshafts shall not be used to link more than three damper sections. Blade to blade linkages shall not be used. Outside and return air dampers shall be installed such that their blades direct their respective air streams towards each other to provide for maximum mixing of air streams.

3.2.17 Valves

3.2.17.1 Ball Valves

Two-position (open/closed) ball valves may only be used on chilled water, condenser water, hot water, or steam applications. Modulating ball valves may only be used for chilled water and condenser water applications (modulating ball valves shall not be used on steam or hot water applications). In modulating applications a characterizing equal-percentage disc shall be used.

3.2.17.2 Butterfly Valves

In two-way control applications, valve travel shall be limited to 70% (60 degrees) open position.

3.2.18 Local Gauges for Actuators

Pneumatic actuators shall have an accessible and visible pressure gauge installed in the tubing lines at the actuator as shown.

3.2.19 Wire and Cable

NOTE: Coordinate with the project site and indicate whether all wiring needs to be in raceways or whether low-voltage wiring can be run without raceways.

Note that requiring all wiring to be run in raceways will increase the project cost.

Wire and Cable shall be installed without splices between control devices and in accordance with NFPA 70 and NFPA 90A. Instrumentation grounding shall be installed per the device manufacturer's instructions and as necessary to prevent ground loops, noise, and surges from adversely affecting operation of the system. Ground rods installed by the Contractor shall be tested as specified in IEEE Std 142. Cables and conductor wires shall be tagged at both ends, with the identifier shown on the shop drawings. Electrical work shall be as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM and as shown. Wiring external to enclosures shall be run [in raceways] [as follows]:

- a. Wiring other than low-voltage control and low-voltage network wiring

shall be installed in raceways.

- b. Low-voltage control and low-voltage network wiring not in suspended ceilings over occupied spaces shall be installed in raceways, except that nonmetallic-sheathed cables or metallic-armored cables may be installed as permitted by NFPA 70.
- c. Low-voltage control and low-voltage network wiring in suspended ceilings over occupied spaces shall be installed in raceways, except:
 - (1) nonmetallic-sheathed cables or metallic-armored cables may be installed as permitted by NFPA 70.
 - (2) plenum rated cable in suspended ceilings over occupied spaces may be run without raceways.]

3.2.20 Copper Tubing

Copper tubing shall be hard-drawn in exposed areas and either hard-drawn or annealed in concealed areas. Only tool-made bends shall be used. Fittings for copper tubing shall be brass or copper solder joint type except at connections to apparatus, where fittings shall be brass compression type.

3.2.21 Plastic Tubing

Plastic tubing shall be run within covered raceways or conduit except when otherwise specified. Plastic tubing shall not be used for applications where the tubing could be subjected to a temperature exceeding 55 degrees C 130 degrees F. Fittings for plastic tubing shall be for instrument service and shall be brass or acetal resin of the compression or barbed push-on type. Except in walls and exposed locations, plastic multitube instrument tubing bundle without conduit or raceway protection may be used where a number of air lines run to the same points, provided the multitube bundle is enclosed in a protective sheath, is run parallel to the building lines and is adequately supported as specified.

3.2.22 Pneumatic Lines

Pneumatic lines shall be installed such that they are not exposed to outside air temperatures. Pneumatic lines shall be concealed except in mechanical rooms and other areas where other tubing and piping is exposed.

All tubes and tube bundles exposed to view shall be installed neatly in lines parallel to the lines of the building. Tubing in mechanical/electrical spaces shall be routed so that the lines are easily traceable.

Air lines shall be purged of dirt, impurities and moisture before connecting to the control equipment. Air lines shall be number coded or color coded and keyed in the As-Built Drawings for future identification and servicing the control system.

3.2.22.1 Pneumatic Lines in Mechanical/Electrical Spaces

In mechanical/electrical spaces, pneumatic lines shall be plastic or copper tubing. Horizontal and vertical runs of plastic tubing or soft copper tubing shall be installed in raceways or rigid conduit dedicated to tubing. Dedicated raceways, conduit, and hard copper tubing not installed in raceways shall be supported every 2 m 6 feet for horizontal runs and

every 2.5 m 8 feet for vertical runs.

3.2.22.2 Pneumatic Lines External to Mechanical/Electrical Spaces

NOTE: Delete protective sheath for nonmetallic
tubing in concealed, accessible areas not subject to
abuse.

Tubing external to mechanical/electrical spaces shall be soft copper with sweat fittings or plastic tubing in raceways not containing power wiring. Raceways and tubing not in raceways shall be supported every 2.5 m 8 feet. Pneumatic lines concealed in walls shall be hard-drawn copper tubing or plastic tubing in rigid conduit. Plastic tubing in a protective sheath, run parallel to the building lines and supported as specified, may be used above accessible ceilings and in other concealed but accessible locations.

3.2.22.3 Terminal Single Lines

Terminal single lines shall be hard-drawn copper tubing, except when the run is less than 300 mm 12 inch in length, flexible polyethylene may be used.

3.2.22.4 Connection to Liquid and Steam Lines

NOTE: The designer will select tubing and fitting
and fitting materials appropriate for the ductwork
and piping services. Stainless steel tubing will
only be used when required for the application such
as in corrosive atmospheres.

Tubing for connection of sensing elements and transmitters to liquid and steam lines shall be [copper] [Series 300 stainless steel] with [brass compression] [stainless-steel compression] fittings.

3.2.22.5 Connection to Ductwork

Connections to sensing elements in ductwork shall be plastic tubing.

3.2.22.6 Tubing in Concrete

Tubing in concrete shall be installed in rigid conduit. Tubing in walls containing insulation, fill, or other packing materials shall be installed in raceways dedicated to tubing.

3.2.22.7 Tubing Connection to Actuators

Final connections to actuators shall be plastic tubing 300 mm 12 inches long and unsupported at the actuator.

3.2.23 Compressed Air Stations

NOTE: If possible, foundations and housekeeping
pads should be specified in Section 23 00 00 AIR
SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST

SYSTEMS.

The air compressor assembly shall be mounted on vibration eliminators, in accordance with ASME BPVC SEC VIII D1 for tank clearance. The air line shall be connected to the tank with a flexible pipe connector. Compressed air station specialties shall be installed with required tubing, including condensate tubing to a floor drain. Compressed air stations shall deliver control air meeting the requirements of ISA 7.0.01. Foundations and housekeeping pads shall be provided for the HVAC control system air compressors [in accordance with the air compressor manufacturer's instructions] [as specified in Section 23 00 00 AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEMS].

3.3 DRAWINGS AND CALCULATIONS

Contractor shall prepare and submit shop drawings.

3.3.1 Network Bandwidth Usage Calculations

NOTE:

1) use [the UMCS] when there is an existing UMCS.

2) use [the Building Point of Connection (BPOC) location] when a UMCS is anticipated and the BPOC location is on the drawing.

3) use [a single point on the backbone that is not on a local control bus] for a truly stand-alone building (no current or anticipated UMCS).

In cases 2) and 3) the Contractor may/will have to put a device on the network temporarily to provide a point for testing purposes.

The Contractor shall perform Building Control Network Bandwidth Usage Calculations for a normally loaded and a heavily loaded control network. Calculations shall be performed for network traffic on the backbone.

A heavily loaded control network is characterized as one performing the following activities simultaneously:

- a. Transmitting every point in the building indicated on Points Schedules as being available to [the UMCS] [the Building Point of Connection (BPOC) location] [a single point on the backbone that is not on a local control bus] in response to polling requests at 15-minute intervals (for trending at UMCS).
- b. Transmitting five points to [the UMCS] [the Building Point of Connection (BPOC) location] [a single point on the backbone that is not on a local control bus] in response to polling requests at 2-second intervals.
- c. Transmitting 100 points to [the UMCS] [the Building Point of Connection (BPOC) location] [a single point on the backbone that is not on a local control bus] in response to polling requests at 5-second intervals.
- d. Transmitting occupancy commands from [the UMCS] [the Building Point of

Connection (BPOC) location] [a single point on the backbone that is not on a local control bus] to every system schedule sequence in a one-minute interval.

- e. Transmitting occupancy override commands from [the UMCS] [the Building Point of Connection (BPOC) location] [a single point on the backbone that is not on a local control bus] to every system schedule sequence in a one-minute interval.

A normally loaded control network is characterized as one performing the following activities simultaneously:

- a. Transmitting every point in the building indicated on Points Schedules as requiring a trend to the UMCS in response to polling requests at 15-minute intervals (for trending at UMCS).
- b. Transmitting 50 points to the UMCS in response to polling requests at 5-second intervals.
- c. Transmitting occupancy commands from the UMCS to every system scheduler sequence in a one-minute interval.

3.3.2 DDC Contractor Design Drawings

NOTE: Designer must decide whether to require a specific drawing size (approx 11x17 or 22x34) or to leave it up to the Contractor.

Designer may choose to include a Riser Diagram in the design package to show project specific requirements such as DDC Hardware locations etc.

Drawings shall be on [ISO A1 841 by 594 mm 34 by 22 inches] [or] [A3 420 by 297 mm 17 by 11 inches] sheets in the form and arrangement shown. The drawings shall use the same abbreviations, symbols, nomenclature and identifiers shown. Each control system element on a drawing shall be assigned a unique identifier as shown. The DDC Contractor Design Drawings shall be delivered together as a complete submittal. Deviations shall be approved by the Contracting Officer. DDC Contractor Design Drawings shall include the following:

- a. Drawing Index and HVAC Design Drawing Legend: The HVAC Control System Drawing Index shall show the name and number of the building, military site, State or other similar designation, and Country. The Drawing Index shall list all Contractor Design Drawings, including the drawing number, sheet number, drawing title, and computer filename when used. The Design Drawing Legend shall show and describe all symbols, abbreviations and acronyms used on the Design Drawings.
- b. Valve Schedule: The valve schedule shall contain each valve's unique identifier, size, flow coefficient Kv (Cv), pressure drop at specified flow rate, spring range, positive positioner range, actuator size, close-off pressure to torque data, dimensions, and access and clearance requirements data. The valve schedule shall contain actuator selection data supported by calculations of the force required to move and seal the valve, access and clearance requirements. A valve schedule shall be submitted for each HVAC system.

- c. Damper Schedule: The damper schedule shall contain each damper's unique identifier, type (opposed or parallel blade), nominal and actual sizes, orientation of axis and frame, direction of blade rotation, actuator size and spring ranges, operation rate, positive positioner range, location of actuators and damper end switches, arrangement of sections in multi-section dampers, and methods of connecting dampers, actuators, and linkages. The Damper Schedule shall include the **AMCA 500-D** maximum leakage rate at the operating static-pressure differential. A damper schedule shall be submitted for each HVAC system.
- d. Thermostat and Occupancy Sensor Schedule: The thermostat and occupancy sensor schedule shall contain each thermostat's unique identifier, room identifier and control features and functions as shown. A thermostat and occupancy sensor schedule shall be submitted for each HVAC system.
- e. Critical Alarm Handling Schedule: The critical alarm handling schedule shall contain the same fields as the critical alarm handling schedule Contract Drawing with Contractor updated information and any other project-specific information required to implement the alarm handling function. A critical alarm handling schedule shall be submitted for each HVAC system.
- f. Equipment Schedule: The equipment schedule shall contain the unique identifier, manufacturer, model number, part number and descriptive name for each control device, hardware and component provided under this specification. An equipment schedule shall be submitted for each HVAC system.
- g. Occupancy Schedule: The occupancy schedule drawing shall contain the same fields as the occupancy schedule Contract Drawing with Contractor updated information. An occupancy schedule shall be submitted for each HVAC system.
- h. Points Schedule: The Points Schedule drawing shall contain the same fields as the Points Schedule Contract Drawing with Contractor updated information. A Points Schedule shall be submitted for each HVAC system.
- i. Compressed Air Station Schematic: The compressed air station schematic diagram shall show all equipment, including: compressor with motor horsepower and voltage; starter; isolators; manual bypasses; tubing sizes; drain piping and drain traps; reducing valves; dryer; and data on manufacturer's names and model numbers, mounting, access, and clearance requirements. Air Compressor and air dryer data shall include calculations of the air consumption of all electric-to-pneumatic transducers and of any other control system devices to be connected to the compressed air station, and the compressed air supply dewpoint temperature at **140 kPa 20 psig**. Compressed air station schematic drawings shall be submitted for each compressed air station.
- j. Riser diagram of building control network: The Riser Diagram of the Building Control Network shall show all network cabling, DDC Hardware, and Network Hardware including:
 - (1) All DDC Hardware with room number and location within room.
 - (2) DDC Hardware unique identifiers and common descriptive names.

- (3) All Network hardware with room number and location within room.
 - (4) Network hardware unique identifiers.
 - (5) All cabling.
 - (6) Room number and location within room of all cabling termination points.
 - (7) Room number and location within room of all network interface jacks.
- k. A single riser diagram shall be submitted for each building.
- l. Control System Schematics: The control system schematics shall be in the same form as the control system schematic Contract Drawing with Contractor updated information. A control system schematic shall be submitted for each HVAC system.

**NOTE: Require Control Logic Diagrams if they have
 been included in the contract drawings.**

- m. Sequences of Operation[including Control Logic Diagrams]: The HVAC control system sequence of operation and [control logic diagrams] shall be in the same format as the Contract Drawings and shall refer to the devices by their unique identifiers. No operational deviations from specified sequences will be permitted without prior written approval of the Government. Sequences of operation[and control logic diagrams] shall be submitted for each HVAC control system.
- n. Controller, Motor Starter and Relay Wiring Diagram: The controller wiring diagrams shall be functional wiring diagrams which show the interconnection of conductors and cables to each controller and to the identified terminals of input and output devices, starters and package equipment. The wiring diagrams shall show necessary jumpers and ground connections. The wiring diagrams shall show the labels of all conductors. Sources of power required for control systems and for packaged equipment control systems shall be identified back to the panel board circuit breaker number, controller enclosures, magnetic starter, or packaged equipment control circuit. Each power supply and transformer not integral to a controller, starter, or packaged equipment shall be shown. The connected volt-ampere load and the power supply volt-ampere rating shall be shown. Wiring diagrams shall be submitted for each HVAC control system.

3.3.3 Draft As-Built Drawings

The Contractor shall update the Contractor Design Drawings with all as-built data and submit as specified.

3.3.4 Final As-Built Drawings

The Contractor shall update the Draft As-Built Drawings with all final as-built data and submit as specified.

3.4 HVAC SYSTEMS SEQUENCES OF OPERATION

NOTE: These sequences are 'template' sequences. When editing this specification, the sequences should be put onto the drawings and these template sequences should be deleted. Note that the Alarm Handling and Scheduling sequences each need to be edited and placed onto their own drawing.

When removing the sequences, keep this subpart number and title intact, but replace the entire contents of the subpart with a note such as "All Sequences of Operation are located on drawings".

3.4.1 Alarm Handling

NOTE: Alarm handling is generally performed by the Monitoring and Control (M&C) software (Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEM (UMCS)). The alarm handling described here is for redundant notification of critical alarms. These are alarms which must be received even if the UMCS/front-end is not functioning/present.

Choose the required functionality for the alarm handling notification and indicate alarms which are critical/require a redundant notification and the notification requirements on the Critical Alarm Schedule.

Selection of notification methods other than a. below may require a more complicated/expensive/sophisticated device. Note that option c. is most useful if the IP network connected to the Alarm Handler is different than the UMCS IP network (so that there is no single point of failure for both UMCS alarm handling and this device).

The Contractor shall install and configure DDC Hardware to provide alarm handling functionality for critical alarms as specified and shown, either in a piece of DDC Hardware dedicated to this function or in DDC Hardware performing other functions. The DDC Hardware providing alarm handling functionality shall provide the following capabilities as required:

- a. Dial to a pager: The node shall be able to dial a paging service and leave a numeric message.
- [b. Dial to an e-mail server: The node shall be able to dial and connect to a remote server and send an e-mail via Simple Mail Transfer Protocol (SMTP).]
- [c. Send e-mail over IP Network: The alarm handling node shall be capable of connecting to an IP network and sending e-mail via Simple Mail Transfer Protocol (SMTP).]

- [d. Provide network access: The node shall be capable of receiving a connection via the modem to allow a remote computer access to the control network.]

3.4.2 Scheduling

NOTE: FYI: Scheduling is normally performed by the Monitoring and Control (M&C) software (Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEM (UMCS)). The UMCS (Section 25 10 10) Contractor will set this up. In the absence of a UMCS or if communication with the UMCS is lost, a default schedule will be active.

The M&C software will have capabilities to perform scheduling according to day of week, holidays, etc and will have the capability to override system occupancy modes based on demand limiting programs or operator overrides.

3.4.2.1 System Mode

AHUs shall operate in Occupied, Warm-Up-Cool-Down, or Unoccupied modes as specified. VAV boxes, Fan Coils, and other terminal equipment shall operate in Occupied or Unoccupied modes as specified. Chillers, boilers, and other sources of heating/cooling for hydronic loads do not require scheduling; these systems receive requests for heating/cooling from their loads.

3.4.2.2 System Scheduler Requirements

NOTE: Indicate if a common schedule may be used for multiple Terminal Units (TUs). If allowing a common schedule for multiple TUs: keep the 'group of' bracketed text, and decide if TU groupings will be included on the drawings (keep the 'as shown' bracketed text) or if the Contractor should decide on groupings (remove the 'as shown' bracketed text).

The System Scheduler functionality shall reside in either a piece of DDC Hardware dedicated to this functionality or in the DDC Hardware controlling the system AHU. A single piece of DDC Hardware may contain multiple System Schedulers. A unique System Scheduler shall be provided for: each AHU including it's associated Terminal Units, and each stand-alone Terminal Unit (those not dependent upon AHU service) [or group of stand-alone Terminal Units acting according to a common schedule]. Each System Scheduler shall provide the following functionality:

- a. Scheduled Occupancy Input: Accept network variable of type SNVT_occupancy (as defined in the LonMark SNVT List). Input shall support the following possible values: OC_STANDBY, OC_OCCUPIED and OC_UNOCCUPIED.
- b. Occupancy Override Input: Accept network variable of type SNVT_occupancy (as defined in the LonMark SNVT List). Input shall

support the following possible values: OC_STANDBY, OC_OCCUPIED, OC_UNOCCUPIED, and OC_NUL.

- c. Space Occupancy Inputs: For systems with multiple occupancy sensors, accept multiple inputs of network variable type SNVT_Occupancy (as defined in the [LonMark SNVT List](#)). Input shall support the following possible values: OC_OCCUPIED, OC_UNOCCUPIED, and OC_NUL. For systems with a single occupancy sensor, accept a network variable input of type SNVT_Occupancy or a hardware binary input (BI) indicating the space occupancy status as Occupied or Unoccupied.
- d. Air Handler Occupancy Output: For a System Scheduler for a system containing an air handler, output one or more SNVTs indicating the desired occupancy status as one of the following possible values: Warm-Up-Cool-Down (when required by the AHU Sequence of Operation), Occupied and Unoccupied.
- e. Terminal Unit Occupancy Output: For a System Scheduler for a stand-alone terminal unit, [a group of stand-alone terminal units acting according to a common schedule,] or a group of terminal units served by a single air handler, output one or more SNVTs indicating the desired occupancy status as one of the following possible values: Occupied and Unoccupied.

NOTE: Designer must provide the default (backup)
24-hour 7-day schedule on the Points Schedule (i.e.
Occupied from 6AM - 10PM Monday through Friday,
Unoccupied Saturday and Sunday).

- f. Default Schedule: Incorporate a 24-hour 7-day default schedule as shown on the drawings which may be activated and deactivated by the System Scheduler Logic.
- g. Communication Determination: Determine the time elapsed between receipts of the scheduled occupancy input SNVT, and use this elapsed time to activate and deactivate the Default Schedule as specified. (This provides the capability for the system scheduler to use its Default Schedule if it loses communication with the UMCS).

3.4.2.3 System Scheduler Output Determination

- a. Air Handler Occupancy Output: If more than 95 minutes have passed since the last receipt of the Scheduled Occupancy input, the Air Handler Occupancy Output shall be determined by the default schedule and the Space Occupancy Inputs. Otherwise, the output shall be determined as follows:
 - (1) If the Override Occupancy Input is not OC_NUL, the Air Handler Occupancy Output shall be determined as follows:
 - (a) The output shall be Occupied when the Override OccupancyInput is OC_OCCUPIED.
 - (b) The output shall be Unoccupied when the Override OccupancyInput is OC_UNOCCUPIED.
 - (c) If the system Sequence Of Operation specifies

Warm-Up-Cool-Down mode, the output shall be Warm-Up-Cool-Down when the Override Occupancy Input is OC_STANDBY.

- (2) If the Override Occupancy Input is OC_NUL and the Schedule Occupancy input is OC_OCCUPIED, the Air Handler and Stand-Alone Terminal Unit Occupancy Output shall be OC_OCCUPIED.
- (3) If the Override Occupancy Input is OC_NUL, the Schedule Occupancy input is not OC_OCCUPIED, and less than required number of Space Occupancy Inputs (as shown on the Occupancy Schedule Drawing) are OC_OCCUPIED (or the hardware BI is Unoccupied), the Air Handler Occupancy Output shall be determined by the Scheduled Occupancy Input
 - (a) The output shall be Occupied when the Scheduled Occupancy Input is OC_OCCUPIED.
 - (b) The output shall be Unoccupied when the Scheduled Occupancy Input is OC_UNOCCUPIED.
 - (c) If the system Sequence Of Operation specifies Warm-Up-Cool-Down mode the output shall be Warm-Up-Cool-Down when the Scheduled Occupancy Input is OC_STANDBY.
- (4) If the Override Occupancy Input is OC_NUL and at least the required number (as shown on the Occupancy Schedule Drawing) of Space Occupancy Inputs are OC_OCCUPIED (or the hardware BI is Occupied), the Air Handler Occupancy Output shall be Occupied.

b. Terminal Unit Occupancy Output: If more than 95 minutes have passed since the last receipt of the Scheduled Occupancy input, the Terminal Unit Occupancy Output shall be determined by the default schedule. Otherwise, the output shall be determined as follows:

- (1) If the Override Occupancy Input is not OC_NUL, the Terminal Unit Occupancy Output shall be determined as follows:
 - (a) The output shall be Occupied when the Override Occupancy Input is OC_OCCUPIED or OC_STANDBY (to allow AHU-dependent Terminal Units to operate in Occupied mode when their associated AHU is in Warm-Up-Cool-Down.
 - (b) The output shall be Unoccupied when the Override Occupancy Input is OC_UNOCCUPIED.
- (2) If the Override Occupancy Input is OC_NUL, the AHU-Dependent Terminal Unit Occupancy Output shall determined as follows:
 - (a) The output shall be Occupied when the Scheduled Occupancy Input is OC_OCCUPIED or OC_STANDBY (to allow AHU-dependent Terminal Units to operate in Occupied mode when their associated AHU is in Warm-Up-Cool-Down.
 - (b) The output shall be Unoccupied when the Scheduled Occupancy Input is OC_UNOCCUPIED.

3.4.2.4 Air Handler System Scheduling

The AHU Occupancy Output SNVT shall be bound from the System Scheduler to

the DDC Hardware that executes the Occupancy Mode Determination part of the Air Handler Sequence of Operation.

For Air Handlers using occupancy sensors, the occupancy sensor output SNVT (of type SNVT_Occupancy) shall be bound to a Space Occupancy Input of the System Scheduler.

The Terminal Unit Occupancy Output SNVT shall be bound from the System Scheduler to each AHU-Dependent Terminal Unit.

AHU-Dependent Terminal Units with occupancy sensors shall have their Effective Occupancy SNVT (of type SNVT_Occupancy) bound to a Space Occupancy Input of the System Scheduler.

3.4.2.5 Stand-Alone Terminal Unit Scheduling

The Terminal Unit Occupancy Output shall be bound from the System Scheduler to the DDC Hardware that executes the Occupancy Mode Determination part of the Terminal Unit Sequence of Operation.

3.4.3 Sequences of Operation for Air Handling Units

NOTE:

- 1) The following sequences, with few exceptions, assume the use of a System Scheduler and space occupancy input(s) to switch between occupied and unoccupied mode setpoints.
- 2) Show occupied and unoccupied mode setpoints on the Points Schedule. A configured setpoint is operator adjustable over the control network, but resides in the local DDC Hardware. In these sequences it serves as the default occupied mode setpoint and (at a separate setting/value) as an unoccupied mode 'setback' setpoint.
- 3) Space occupancy input(s) may consist of an occupancy sensor and/or a local push-button. Indicate the use of a sensor and/or push-button by placing an 'X' in the 'Thermostat and Occupancy Sensor Schedule'. If a push-button is used, show the override time duration in the Schedule. The occupancy sensor specification requires a 15 minute off-mode delay prior to leaving the occupied mode. If a different time is desired, show it in the thermostat schedule and ensure that it is consistent with the Occupancy Sensor Product specification.
- 4) Occupancy sensor location is left up to the Contractor. If ceiling mount sensors are preferred, edit the sequences and/or indicate in the Thermostat and Occupancy Sensor Schedule.
- 5) For each unit, as applicable, indicate if the zone temperature setpoint will be occupant adjustable by placing an 'X' in the 'Thermostat and Occupancy Sensor Schedule'. For non-occupant-adjustable setpoints, show the setpoint

in the Points Schedule. The intent is that the Contractor provides one or the other as shown. Non-occupant-adjustable setpoints are adjustable by a system operator using a local display panel (LDP) or an operator workstation (and appropriate software).

3.4.3.1 All-Air Small Package Unitary System

NOTE: For heating-only or cooling-only systems, edit the sequence as required. Where applicable, select 'Emerg Heat' for heat pump systems.

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

a. Fan ON-AUTO Switch

- (1) ON: With the thermostat fan ON-AUTO switch in the ON position, the DDC Hardware shall start the fan and it shall run continuously.
- (2) AUTO: With the thermostat fan ON-AUTO switch in the AUTO position, the DDC Hardware operates the fan according to HEAT-OFF-COOL[-EMERG HEAT] switch.

b. HEAT-OFF-COOL[-EMERG HEAT] Switch

- (1) HEAT-COOL[-EMERG HEAT]: With the thermostat switch in the HEAT or COOL [or EMERG HEAT] positions, the DDC Hardware shall operate the package unit according to the Occupancy Mode.
- (2) OFF: With the thermostat switch in the OFF position, the DDC Hardware shall de-energize the heating unit and cooling unit [and emergency supplemental heat].

c. Occupancy Modes

- (1) Occupied: The unit DDC Hardware shall be in the Occupied Mode when the local space occupancy input(s) indicate that the space is occupied or when the input from the System Scheduler is occupied.
- (2) Unoccupied: The unit DDC Hardware shall be in the Unoccupied Mode when the local space occupancy input(s) indicate that the space is unoccupied and when the input from the System Scheduler is unoccupied.

d. Safeties: The unit shall run subject to the unit manufacturer's safeties.

e. Zone Temperature Control

- (1) In the Occupied Mode the zone temperature setpoint (ZN-T-SP) shall be at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as shown.

- (2) In the Unoccupied Mode the zone temperature setpoint (ZN-T-SP) shall be at the configured setpoint (ZN-T-SP) as shown.
- (3) The DDC Hardware shall cycle the fan, cooling unit, heating unit[, and emergency supplemental heat], in accordance with the HEAT-COOL[-EMERG HEAT] switch setting, to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP).

3.4.3.2 Heating and Ventilating Unit (or Unit Ventilator)

NOTE:

1) A special interlock control sequence for each fan system will be developed by the designer if required.

2) This system has a single outside air duct. Select either 2-position outside air dampers or modulating dampers.

3) Indicate the System Scheduler and M&C Software Occupancy Schedule on the Occupancy Schedule drawing. The designer needs to coordinate System Scheduler (occupancy mode determination) with space occupancy sensor input and pushbutton override switch input use. As described in the System Scheduler sequence, 'occupied' inputs from two different spaces are required to help avoid needless turning on of the system (due to cleaning staff or security staff passing through after hours).

4) The inclusion of filter pressure switches should be coordinated with the local O&M staff. Pressure switches may not be desired/needed, particularly if filters are replaced on a regular schedule. Edit the Points Schedule as required.

5) Absence of fan proof(s) or activation of any safety will result in system shutdown. The system remains shutdown until manually reset devices are reset and a manual reset button (RST-BUT), local to the DDC controller, is pressed. Reset could also be performed from a workstation (via SNVT) or local display panel (LDP). It is recommended that you coordinate the decision with the local O&M staff. Edit the Control Logic Diagram and Points Schedule to indicate which reset method is to be provided by the Contractor.

6) The hardware (product) specification requires that the low limit (freezestat) device include a manual reset at the device. In the event of shutdown due to freeze stat trip the system will remain shutdown until the device is reset and a separate DDC reset, as described above, is also used.

7) Smoke control is not addressed in this guide specification. Smoke control sequence of operation

for each fan system, if beyond the requirements described, will be developed by the designer, based on the requirements and parameters of the project. The designer will account for operation of dampers and fans for pressurization and manual override of interlocks to the fire alarm system. All automatic overrides of normal HVAC control sequences will be activated through the fire protection and smoke control interface panel that the designer will design for the project. With the present control sequence, in the event of shutdown due to smoke detector input the system will remain shutdown until the smoke detector is reset and a separate DDC reset, as described above, is also used. The Fire Alarm Panel (FAP) input takes precedence over any DDC input to force the fan(s) to run.

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

- a. HAND-OFF-AUTO switches: Supply fan motor starter shall accept a Fire Alarm Panel (FAP) signal that takes precedence over all other starter inputs and switches and shall start the fan. The fan motor starter shall accept an occupant accessible emergency shutoff switch as shown. The supply fan motor starter shall have an H-O-A switch:
 - (1) HAND: With the H-O-A switch in HAND position, the supply fan shall start and run continuously, subject to Safeties.
 - (2) OFF: With the H-O-A switch in OFF position, the supply fan shall stop.
 - (3) AUTO: With the H-O-A switch in AUTO position, the supply fan shall run subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.
- b. Occupancy Modes: The system shall obtain its Occupancy Mode input from the System Scheduler as specified and shown. The system shall operate in one of the following modes:
 - (1) Occupied: The Unit's DDC Hardware shall be in the Occupied Mode when the input from the System Scheduler (SYS-OCC) is occupied [or when the local space occupancy input(s) (ZN-OCC) indicate that the space is occupied].
 - (2) Unoccupied: The Unit's DDC Hardware shall be in the Unoccupied Mode when the input from the System Scheduler (SYS-OCC) is unoccupied [and when the local space occupancy input(s) (ZN-OCC) indicate that the space is unoccupied].
 - [(3) Warm Up/Cool Down: The Unit's DDC Hardware shall be in the Warm Up/Cool Down Mode based on input from the System Scheduler.]
- c. System Enable and Loop Enable

**NOTE: Select Mixed Air Damper Control for systems
with 2-position dampers.**

(1) Occupied mode: The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS). The Zone Temperature Control loop [and Mixed Air Damper Control]shall be enabled.

(2) Unoccupied mode: All control loops shall be disabled. When BLDG-T drops below BLDG-T-LL-SP (with a 3 degrees C 5 degrees F deadband) the supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS) and the Zone Temperature Control loop shall be enabled.

[(3) Warm Up/Cool Down: The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS). The Zone Temperature Control loop [and Mixed Air Damper Control]shall be enabled.]

d. Proofs and Safeties

(1) The supply fan and all DDC Hardware control loops shall be subject to Proofs and Safeties. Safeties shall be direct-hardwire interlocked to the fan starter circuit as shown. DDC Hardware shall monitor all proofs and safeties and failure of any proof or activation of any safety shall result in all control loops being disabled and the AHU fan being commanded off until reset.

(2) Proofs: Supply fan status (proof) (SF-S)

(3) Safeties:

(a) Heating Coil discharge air temperature low limit (freeze stat) (HTG-DA-T-LL)

(b) Supply air smoke (SA-SMK)

[(c) Return air smoke (RA-SMK)]

(4) DDC Hardware reset of all proofs and safeties shall be via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

**NOTE: If the system has modulating dampers, select
bracketed damper text in Zone Temperature Control
paragraph. Otherwise, select Mixed Air Damper
Control.**

e. Zone Temperature Control

(1) When this loop is enabled, the DDC Hardware shall modulate the heating valve [and outside air, relief, and return air dampers in sequence] to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP). [Sequencing shall be as shown: Upon a rise in zone temperature above zone temperature setpoint (ZN-T-SP), subject to

the zone temperature setpoint deadband as shown, the outside air, relief, and return air dampers shall modulate to maintain zone temperature at setpoint. During occupied mode, outside air damper minimum position (OA-D-MIN) shall be as shown.] Upon a fall in zone temperature below zone temperature setpoint, subject to the deadband as shown, the heating valve shall modulate towards open to maintain zone temperature setpoint.

- (2) When this loop is disabled, the heating valve shall be closed [and the outside air damper and relief damper shall be closed and the return damper shall be open].

[f. Mixed Air Damper Control: When this is enabled, the outside air and relief air dampers shall be open and the return air damper shall be closed. When this is disabled, the outside air and relief air dampers shall be closed and the return air damper shall be open.]

3.4.3.3 Single Zone with Heating and [DX] [Cooling] Coils

NOTE:

1) Edit the sequence and drawings as necessary for systems with/without a preheat coil, economizer, and other project specific control loop requirements.

2) Minimum outside air flow control can be accomplished several different ways. Refer to the UFC, but don't use flow measurement in a constant volume system.

3) The inclusion of filter pressure switches should be coordinated with the local O&M staff. Pressure switches may not be desired/needed, particularly if filters are replaced on a regular schedule. Edit the Points Schedule and Control Schematic as required.

4) Indicate the System Scheduler and M&C Software Occupancy Schedule on the Occupancy Schedule drawing. The designer needs to coordinate System Scheduler (occupancy mode determination) with space occupancy sensor input and pushbutton override switch input use. As described in the System Scheduler sequence, 'occupied' inputs from two different spaces are required to help avoid needless turning on of the system (due to cleaning staff or security staff passing through after hours).

5) Absence of fan proof(s) or activation of any safety will result in system shutdown. The system remains shutdown until manually reset devices are reset and a manual reset button (RST-BUT), local to the DDC controller, is pressed. Reset could also be performed from a workstation (via SNVT) or local display panel (LDP). It is recommended that you coordinate the decision with the local O&M staff. Edit the Control Logic Diagram and Points Schedule to indicate which reset method is to be provided by the Contractor.

6) The hardware (product) specification requires that the low limit (freezestat) device include a manual reset at the device. In the event of shutdown due to freeze stat trip the system will remain shutdown until the device is reset and a separate DDC reset, as described above, is also used.

7) Smoke control is not addressed in this guide specification. Smoke control sequence of operation for each fan system, if beyond the requirements described, will be developed by the designer, based on the requirements and parameters of the project. The designer will account for operation of dampers and fans for pressurization and manual override of interlocks to the fire alarm system. All automatic overrides of normal HVAC control sequences will be activated through the fire protection and smoke control interface panel that the designer will design for the project. With the present control sequence, in the event of shutdown due to smoke detector input the system will remain shutdown until the smoke detector is reset and a separate DDC reset, as described above, is also used. The Fire Alarm Panel (FAP) input takes precedence over any DDC input to force the fan(s) to run.

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

- a. HAND-OFF-AUTO switch: Supply fan motor starter shall accept a Fire Alarm Panel (FAP) signal that takes precedence over all other starter inputs and switches and shall start the fan. The fan motor starter shall accept an occupant accessible emergency shutoff switch as shown. The supply fan motor starter shall have an H-O-A switch:
 - (1) HAND: With the H-O-A switch in HAND position, the supply fan shall start and run continuously, subject to Safeties.
 - (2) OFF: With the H-O-A switch in OFF position, the supply fan shall stop.
 - (3) AUTO: With the H-O-A switch in AUTO position, the supply fan shall run subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.
- b. Occupancy Modes: The system shall obtain its Occupancy Mode input from the System Scheduler as specified and shown. The system shall operate in one of the following modes: Occupied, Unoccupied[, or WarmUp/CoolDown].
- c. System Enable and Loop Enable:
 - (1) Occupied Mode: The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS) and all control loops shall be enabled.

(2) Unoccupied mode: While the building temperature (BLDG-T) is above setpoint (BLDG-T-LL-SP) all control loops shall be disabled and the supply fan shall not run. When BLDG-T drops below BLDG-T-LL-SP (with a 3 degrees C 5 degrees F deadband) the supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS) and the Heating Coil Temperature Control loop shall be enabled. The Outside Air Flow Control, Economizer Damper Control, and [DX] Cooling Coil Control loops shall be disabled.

[(3) Warm Up / Cool Down Mode: The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS) and the Minimum Outside Air Flow Control loop shall be disabled. All other control loops shall be enabled.]

d. Proofs and Safeties:

(1) The supply fan and all DDC Hardware control loops shall be subject to Proofs and Safeties. Safeties shall be direct-hardwire interlocked to the fan starter circuit as shown. DDC Hardware shall monitor all proofs and safeties and failure of any proof or activation of any safety shall result in all control loops being disabled and the AHU fan being commanded off until reset.

(2) Proofs:
(a) Supply fan status (proof) (SF-S)

(3) Safeties:
(a) Heating coil discharge air temperature low limit (freeze stat) (HTG-DA-T-LL)

(b) Supply air smoke (SA-SMK)

(c) Return air smoke (RA-SMK)

(4) DDC Hardware reset of all proofs and safeties shall be via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

e. Minimum Outside Air Flow Control: When this loop is enabled the DDC Hardware shall open the 2-position minimum outside air damper to introduce the minimum outside air flow quantity as shown. When this loop is disabled, the minimum outside air damper shall be closed.

f. Economizer Damper Control:

(1) When this loop is enabled, and the Economizer is ON as determined by the Economizer Enable Logic, the DDC Hardware shall modulate the economizer outside air, relief, and return air dampers (Economizer dampers) in sequence with the [DX] cooling coil control and heating coil control valve as shown to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown.

(2) When this loop is disabled, or the Economizer is OFF as determined by the Economizer Enable Logic, the economizer outside air and relief air dampers shall be closed, and the return air

damper shall be open.

- (3) Economizer Enable Logic. The economizer shall be ON when the outside air dry bulb temperature is between the high limit (ECO-HL-SP) and low limit (ECO-LL-SP) setpoints as shown. The Economizer shall otherwise be OFF. ECO-HL-SP and ECO-LL-SP shall each have a 1 degree C 2 degrees F deadband.

- g. Heating Coil Control: When this loop is enabled the DDC Hardware shall modulate the heating coil control valve in sequence with the cooling coil valve and economizer dampers as shown to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown. When this loop is disabled, the heating coil control valve shall be closed.
- h. [DX] Cooling Coil Control: When this loop is enabled the DDC Hardware shall [stage the DX Unit] [modulate the cooling coil control valve] in sequence with the heating coil valve and economizer dampers as shown to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown. When this loop is disabled, the [DX unit shall be off] [cooling coil control valve shall be closed].

3.4.3.4 Single Zone with Dual-Temperature Coil

NOTE:

1) Edit the sequence and drawings as necessary for systems with/without a preheat coil, economizer, and other project specific control loop requirements.

2) Minimum outside air flow control can be accomplished several different ways. Refer to the UFC, but don't use flow measurement in a constant volume system.

3) The inclusion of filter pressure switches should be coordinated with the local O&M staff. Pressure switches may not be desired/needed, particularly if filters are replaced on a regular schedule. Edit the Points Schedule and Control Schematic as required.

4) Indicate the System Scheduler and M&C Software Occupancy Schedule on the Occupancy Schedule drawing. The designer needs to coordinate System Scheduler (occupancy mode determination) with space occupancy sensor input and pushbutton override switch input use. As described in the System Scheduler sequence, 'occupied' inputs from two different spaces are required to help avoid needless turning on of the system (due to cleaning staff or security staff passing through after hours).

5) Absence of fan proof(s) or activation of any safety will result in system shutdown. The system remains shutdown until manually reset devices are reset and a manual reset button (RST-BUT), local to the DDC controller, is pressed. Reset could also be performed from a workstation (via SNVT) or local display panel (LDP). It is recommended that you

coordinate the decision with the local O&M staff.
Edit the Control Logic Diagram and Points Schedule
to indicate which reset method is to be provided
by the Contractor.

6) The hardware (product) specification requires
that the low limit (freezestat) device include a
manual reset at the device. In the event of
shutdown due to freeze stat trip the system will
remain shutdown until the device is reset and a
separate DDC reset, as described above, is also used.

7) Smoke control is not addressed in this guide
specification. Smoke control sequence of operation
for each fan system, if beyond the requirements
described, will be developed by the designer, based
on the requirements and parameters of the project.
The designer will account for operation of dampers
and fans for pressurization and manual override of
interlocks to the fire alarm system. All automatic
overrides of normal HVAC control sequences will be
activated through the fire protection and smoke
control interface panel that the designer will
design for the project. With the present control
sequence, in the event of shutdown due to smoke
detector input the system will remain shutdown until
the smoke detector is reset and a separate DDC
reset, as described above, is also used. The Fire
Alarm Panel (FAP) input takes precedence over any
DDC input to force the fan(s) to run.

Contractor shall install DDC hardware to perform this Sequence of Operation
and to provide SNVT inputs, outputs and alarms as specified and shown on
the Points Schedule. Unless otherwise specified, all modulating control
shall be proportional-integral (PI) control.

- a. HAND-OFF-AUTO switch: Supply fan motor starter shall accept a Fire
Alarm Panel (FAP) signal that takes precedence over all other starter
inputs and switches and shall start the fan. The fan motor starter
shall accept an occupant accessible emergency shutoff switch as shown.
The supply fan motor starter shall have an H-O-A switch:
 - (1) HAND: With the H-O-A switch in HAND position, the supply fan
shall start and run continuously, subject to Safeties.
 - (2) OFF: With the H-O-A switch in OFF position, the supply fan shall
stop.
 - (3) AUTO: With the H-O-A switch in AUTO position, the supply fan
shall run subject to the Supply Fan Start/Stop (SF-SS) command and
Safeties.
- b. Occupancy Modes: The system shall obtain its Occupancy Mode input from
the System Scheduler as specified and shown. The system shall operate
in one of the following modes: Occupied, Unoccupied[, or
WarmUp/CoolDown].
- c. System Enable and Loop Enable:

- (1) Occupied Mode: The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS) and all control loops shall be enabled.
- (2) Unoccupied mode: While the building temperature (BLDG-T) is above setpoint (BLDG-T-LL-SP) all control loops shall be disabled and the supply fan shall not run. When BLDG-T drops below BLDG-T-LL-SP (with a 3 degrees C 5 degrees F deadband) the supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS) and the Dual Temperature Coil Temperature Control loop shall be enabled. The Minimum Outside Air Flow Control, and Economizer Damper Control loops shall be disabled.
- [(3) Warm Up / Cool Down Mode: The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS). The Minimum Outside Air Flow Control loop shall be disabled and all other control loops enabled.]

d. Proofs and Safeties:

- (1) The supply fan and all DDC Hardware control loops shall be subject to Proofs and Safeties. Safeties shall be direct-hardwire interlocked to the fan starter circuit as shown. DDC Hardware shall monitor all proofs and safeties and failure of any proof or activation of any safety shall result in all control loops being disabled and the AHU fan being commanded off until reset.
- (2) Proofs: Supply fan status (proof) (SF-S)
- (3) Safeties:
 - (a) Dual Temperature coil discharge air temperature low limit (freeze stat) (DT-DA-T-LL)
 - (b) Supply air smoke (SA-SMK)
 - (c) Return air smoke (RA-SMK)
- (4) DDC Hardware reset of all proofs and safeties shall be via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

e. Minimum Outside Air Flow Control: When this loop is enabled the DDC Hardware shall open the 2-position minimum outside air damper to introduce the minimum outside air flow quantity as shown. When this loop is disabled, the minimum outside air damper shall be closed.

f. Economizer Damper Control:

- (1) When this loop is enabled, and the Economizer is ON as determined by the Economizer Enable Logic, the DDC Hardware shall modulate the economizer outside air, relief, and return air dampers (Economizer dampers) to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown.
- (2) When this loop is disabled, or the Economizer is OFF as

determined by the Economizer Enable Logic, the economizer outside air and relief air dampers shall be closed, and the return air damper shall be open.

- (3) Economizer Enable Logic. The economizer shall be ON when the outside air dry bulb temperature is between the high limit (ECO-HL-SP) and low limit (ECO-LL-SP) setpoints as shown. The Economizer shall otherwise be OFF. ECO-HL-SP and ECO-LL-SP shall each have a 1 degree C 2 degrees F deadband.

g. Dual Temperature Coil Control:

- (1) When this loop is enabled, the DDC Hardware shall select heating or cooling mode based on a pipe-mounted dual-temperature supply water sensor. A single sensor may be used for multiple instances of this sequence.
- (2) The DDC Hardware shall modulate the coil control valve in sequence with the economizer dampers as shown to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown.
- (3) When this loop is disabled, the control valve shall be closed.

3.4.3.5 Single Zone with Heating and Cooling Coils and Return Air Bypass

NOTE:

1) Edit the sequence and drawings as necessary for systems with/without a preheat coil, economizer, and other project specific control loop requirements.

2) Coordinate the enable/disable of the cooling coil 2-position valve with the chilled water source. If it is from a local chiller define and share the enabling signal that turns on the chiller and opens the 2-position valve. Do not use a DX unit in place of the chilled water cooling coil.

3) Minimum outside air flow control can be accomplished several different ways. Refer to the UFC, but don't use flow measurement in a constant volume system.

4) The inclusion of filter pressure switches should be coordinated with the local O&M staff. Pressure switches may not be desired/needed, particularly if filters are replaced on a regular schedule. Edit the Points Schedule and Control Schematic as required.

5) Indicate the System Scheduler and M&C Software Occupancy Schedule on the Occupancy Schedule drawing. The designer needs to coordinate System Scheduler (occupancy mode determination) with space occupancy sensor input and pushbutton override switch input use. As described in the System Scheduler sequence, 'occupied' inputs from two different spaces are required to help avoid needless turning on of the system (due to cleaning staff or

security staff passing through after hours).

6) Absence of fan proof(s) or activation of any safety will result in system shutdown. The system remains shutdown until manually reset devices are reset and a manual reset button (RST-BUT), local to the DDC controller, is pressed. Reset could also be performed from a workstation (via SNVT) or local display panel (LDP). It is recommended that you coordinate the decision with the local O&M staff. Edit the Control Logic Diagram and Points Schedule to indicate which reset method is to be provided by the Contractor.

7) The hardware (product) specification requires that the low limit (freezestat) device include a manual reset at the device. In the event of shutdown due to freeze stat trip the system will remain shutdown until the device is reset and a separate DDC reset, as described above, is also used.

8) Smoke control is not addressed in this guide specification. Smoke control sequence of operation for each fan system, if beyond the requirements described, will be developed by the designer, based on the requirements and parameters of the project. The designer will account for operation of dampers and fans for pressurization and manual override of interlocks to the fire alarm system. All automatic overrides of normal HVAC control sequences will be activated through the fire protection and smoke control interface panel that the designer will design for the project. With the present control sequence, in the event of shutdown due to smoke detector input the system will remain shutdown until the smoke detector is reset and a separate DDC reset, as described above, is also used. The Fire Alarm Panel (FAP) input takes precedence over any DDC input to force the fan(s) to run.

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

a. HAND-OFF-AUTO switch: Supply fan motor starter shall accept a Fire Alarm Panel (FAP) signal that takes precedence over all other starter inputs and switches and shall start the fan. The fan motor starter shall accept an occupant accessible emergency shutoff switch as shown. The supply fan motor starter shall have an H-O-A switch:

- (1) HAND: With the H-O-A switch in HAND position, the supply fan shall start and run continuously, subject to Safeties.
- (2) OFF: With the H-O-A switch in OFF position, the supply fan shall stop.
- (3) AUTO: With the H-O-A switch in AUTO position, the supply fan

shall run subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.

- b. Occupancy Modes: The system shall obtain its Occupancy Mode input from the System Scheduler as specified and shown. The system shall operate in one of the following modes: Occupied, Unoccupied[, or WarmUp/CoolDown].

- c. System Enable and Loop Enable:

- (1) Occupied Mode: The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS) and all control loops shall be enabled.
- (2) Unoccupied mode: While the building temperature (BLDG-T) is above setpoint (BLDG-T-LL-SP) all control loops shall be disabled and the supply fan shall not run. When BLDG-T drops below BLDG-T-LL-SP (with a 3 degrees C 5 degrees F deadband) the supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS) and the Heating Coil Temperature Control loop shall be enabled. All other control loops shall be disabled.

- [(3) Warm Up / Cool Down Mode: The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS). The Minimum Outside Air Flow Control loop shall be disabled and all other control loops shall be enabled.]

- d. Proofs and Safeties:

- (1) The supply fan and all DDC Hardware control loops shall be subject to Proofs and Safeties. Safeties shall be direct-hardwire interlocked to the fan starter circuit as shown. DDC Hardware shall monitor all proofs and safeties and failure of any proof or activation of any safety shall result in all control loops being disabled and the AHU fan being commanded off until reset.
- (2) Proofs: Supply fan status (proof) (SF-S)
- (3) Safeties:
 - (a) Heating coil discharge air temperature low limit (freezestat) (HTG-DA-T-LL)
 - (b) Supply air smoke (SA-SMK)
 - (c) Return air smoke (RA-SMK)
- (4) DDC Hardware reset of all proofs and safeties shall be via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

- e. Minimum Outside Air Flow Control: When this loop is enabled the DDC Hardware shall open the 2-position minimum outside air damper to introduce the minimum outside air flow quantity as shown. When this loop is disabled, the minimum outside air damper shall be closed.

- f. Economizer Damper Control:

- (1) When this loop is enabled, and the Economizer is ON as determined by the Economizer Enable Logic, the DDC Hardware shall modulate the economizer outside air, return air, [and relief air dampers] (Economizer dampers) in sequence with the bypass and supply dampers and the heating coil control valve as shown to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown.
 - (2) When this loop is disabled, or the Economizer is OFF as determined by the Economizer Enable Logic, the economizer outside air and relief air dampers shall be closed, and the return air damper shall be open.
 - (3) Economizer Enable Logic. The economizer shall be ON when the outside air dry bulb temperature is between the high limit (ECO-HL-SP) and low limit (ECO-LL-SP) setpoints as shown. The Economizer shall otherwise be OFF. ECO-HL-SP and ECO-LL-SP shall each have a 1 degree C 2 degrees F deadband.
- g. Heating Coil Control: When this loop is enabled the DDC Hardware shall modulate the heating coil control valve in sequence with the bypass and supply dampers and the economizer dampers as shown to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown. When this loop is disabled, the heating coil control valve shall be closed.
 - h. Cooling Coil Control: When this loop is enabled the DDC Hardware shall open the 2-position cooling coil control valve. When this loop is disabled, the 2-position cooling coil control valve shall be closed.
 - i. Bypass and Supply Air Damper Control: When this loop is enabled the DDC Hardware shall modulate the bypass and supply air dampers in sequence with the heating coil control valve and the Economizer dampers as shown to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown. When this loop is disabled the bypass damper shall be closed and supply air damper open.

3.4.3.6 Single Zone with Humidity Control

NOTE:

1) Edit the sequence and drawings as necessary for systems with/without a preheat coil and other project specific control loop requirements.

2) The inclusion of filter pressure switches should be coordinated with the local O&M staff. Pressure switches may not be desired/needed, particularly if filters are replaced on a regular schedule. Edit the Points Schedule and Control Schematic as required.

3) Indicate the System Scheduler and M&C Software Occupancy Schedule on the Occupancy Schedule drawing. The designer needs to coordinate System Scheduler (occupancy mode determination) with space occupancy sensor input and pushbutton override switch input use. As described in the System Scheduler sequence, 'occupied' inputs from 2 different spaces are required to help avoid needless

turning on of the system (due to cleaning staff or security staff passing through after hours).

3) Absence of fan proof(s) or activation of any safety will result in system shutdown. The system remains shutdown until manually reset devices are reset and a manual reset button (RST-BUT), local to the DDC controller, is pressed. Reset could also be performed from a workstation (via SNVT) or local display panel (LDP). It is recommended that you coordinate the decision with the local O&M staff. Edit the Control Logic Diagram and Points Schedule to indicate which reset method is to be provided by the Contractor.

4) The hardware (product) specification requires that the low limit (freezestat) device include a manual reset at the device. In the event of shutdown due to freeze stat trip the system will remain shutdown until the device is reset and a separate DDC reset, as described above, is also used.

5) Smoke control is not addressed in this guide specification. Smoke control sequence of operation for each fan system, if beyond the requirements described, will be developed by the designer, based on the requirements and parameters of the project. The designer will account for operation of dampers and fans for pressurization and manual override of interlocks to the fire alarm system. All automatic overrides of normal HVAC control sequences will be activated through the fire protection and smoke control interface panel that the designer will design for the project. With the present control sequence, in the event of shutdown due to smoke detector input the system will remain shutdown until the smoke detector is reset and a separate DDC reset, as described above, is also used. The Fire Alarm Panel (FAP) input takes precedence over any DDC input to force the fan(s) to run.

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

a . HAND-OFF-AUTO switch: Supply fan motor starter shall accept a Fire Alarm Panel (FAP) signal that takes precedence over all other starter inputs and switches and shall start the fan. The fan motor starter shall accept an occupant accessible emergency shutoff switch as shown. The supply fan motor starter shall have an H-O-A switch:

- (1) HAND: With the H-O-A switch in HAND position, the supply fan shall start and run continuously, subject to Safeties.
- (2) OFF: With the H-O-A switch in OFF position, the supply fan shall stop.

- (3) AUTO: With the H-O-A switch in AUTO position, the supply fan shall run subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.
- b. Occupancy Modes: The system shall obtain its Occupancy Mode input from the System Scheduler as specified and shown. The system shall operate in one of the following modes: Occupied, Unoccupied[, or WarmUp/CoolDown].
 - c. System Enable and Loop Enable:
 - (1) Occupied Mode: The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS) and all control loops shall be enabled.
 - (2) Unoccupied mode: While the building temperature (BLDG-T) is above setpoint (BLDG-T-LL-SP) all control loops shall be disabled and the supply fan shall not run. When BLDG-T drops below BLDG-T-LL-SP (with a 3 degrees C 5 degrees F deadband) the supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS), the Preheat Coil Control loop and Reheat Coil Control loop shall be enabled and all other loops shall be disabled.
 - [(3) Warm Up / Cool Down Mode: The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS). The Minimum Outside Air Flow Control loop shall be disabled and all other control loops shall be enabled.]
 - d. Proofs and Safeties
 - (1) The supply fan and all DDC Hardware control loops shall be subject to Proofs and Safeties. Safeties shall be direct-hardwire interlocked to the fan starter circuit as shown. DDC Hardware shall monitor all proofs and safeties and failure of any proof or activation of any safety shall result in all control loops being disabled and the AHU fan being commanded off until reset.
 - (2) Proofs: Supply fan status (proof) (SF-S)
 - (3) Safeties:
 - (a) Preheat coil discharge air temperature low limit (freezestat) (PH-DA-T-LL)
 - (b) Supply air smoke (SA-SMK)
 - (c) Return air smoke (RA-SMK)
 - (4) DDC Hardware reset of all proofs and safeties shall be via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.
 - e. Minimum Outside Air Flow Control: When this loop is enabled the DDC Hardware shall open the 2-position minimum outside air damper to introduce the minimum outside air flow quantity as shown. When this loop is disabled, the minimum outside air damper shall be closed.

- f. Preheat Coil Control Loop: When this loop is enabled the DDC Hardware shall modulate the preheat coil valve to maintain the preheat coil discharge air temperature (PH-T) at setpoint (PH-T-SP) as shown. When this loop is disabled, the preheat coil valve shall be closed.
- g. Cooling-and-Dehumidification Coil Control: When this loop is enabled the DDC Hardware shall modulate the cooling and dehumidification valve to maintain either the zone temperature (ZN-T) at setpoint (ZN-T-SP) or zone relative humidity (ZN-RH) at setpoint (ZN-RH-SP), whichever calls for more chilled water flow. The valve shall be modulated in sequence with the reheat valve and humidification valve as shown to avoid simultaneous cooling and reheating, and simultaneous dehumidification and humidification. When this loop is disabled, the coil valve shall be closed.
- h. Reheat Coil Control: When this loop is enabled the DDC Hardware shall modulate the reheat coil valve to maintain the zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown. The valve shall be modulated in sequence with the cooling-and-dehumidification valve as shown to avoid simultaneous cooling and reheating. When this loop is disabled, the coil valve shall be closed.
- i. Humidification Control: When this loop is enabled the DDC Hardware shall modulate the humidifier valve to maintain zone relative humidity (ZN-RH) at setpoint (ZN-RH-SP). The valve shall be modulated in sequence with the cooling-and-dehumidification valve as shown to avoid simultaneous dehumidification and humidification. When the supply air duct humidity (SA-RH) rises above 80% relative humidity, the humidifier valve shall begin to modulate towards closed and shall, under proportional control, continue to gradually move towards closed until the supply air duct humidity reaches 90% relative humidity, at which point the humidifier valve shall be fully closed. When this loop is disabled, the humidifier valve shall be closed.

3.4.3.7 Multizone [Dual-Duct] [with] [without] Return Fan

NOTE:

- 1) The sequence is identical for a Dual-Duct system. You need only change hot/cold deck to hot/cold duct.
- 2) Edit the sequence and drawings as necessary for systems with/without a return fan, preheat coil, economizer, and other project specific control loop requirements.
- 3) Choose whether or not to require setpoint reset of the hot deck temperature setpoint, and whether the reset should be based on Outside Air Temperature or Coldest Zone Temperature. Edit the control schematic drawing to show the reset parameters.
- 4) Minimum outside air flow control can be accomplished several different ways. Refer to the UFC, but don't use flow measurement in a constant volume system.

5) The inclusion of filter pressure switches should be coordinated with the local O&M staff. Pressure switches may not be desired/needed, particularly if filters are replaced on a regular schedule. Edit the Points Schedule and Control Schematic as required.

6) Indicate the System Scheduler and M&C Software Occupancy Schedule on the Occupancy Schedule drawing. The designer needs to coordinate System Scheduler (occupancy mode determination) with space occupancy sensor input and pushbutton override switch input use. As described in the System Scheduler sequence, 'occupied' inputs from 2 different spaces are required to help avoid needless turning on of the system (due to cleaning staff or security staff passing through after hours).

7) Absence of fan proof(s) or activation of any safety will result in system shutdown. The system remains shutdown until manually reset devices are reset and a manual reset button (RST-BUT), local to the DDC controller, is pressed. Reset could also be performed from a workstation (via SNVT) or local display panel (LDP). It is recommended that you coordinate the decision with the local O&M staff. Edit the Control Logic Diagram and Points Schedule to indicate which reset method is to be provided by the Contractor.

8) The hardware (product) specification requires that the low limit (freezestat) device include a manual reset at the device. In the event of shutdown due to freeze stat trip the system will remain shutdown until the device is reset and a separate DDC reset, as described above, is also used.

9) Smoke control is not addressed in this guide specification. Smoke control sequence of operation for each fan system, if beyond the requirements described, will be developed by the designer, based on the requirements and parameters of the project. The designer will account for operation of dampers and fans for pressurization and manual override of interlocks to the fire alarm system. All automatic overrides of normal HVAC control sequences will be activated through the fire protection and smoke control interface panel that the designer will design for the project. With the present control sequence, in the event of shutdown due to smoke detector input the system will remain shutdown until the smoke detector is reset and a separate DDC reset, as described above, is also used. The Fire Alarm Panel (FAP) input takes precedence over any DDC input to force the fan(s) to run.

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on

the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

a. HAND-OFF-AUTO switches:

Supply fan motor starter shall accept a Fire Alarm Panel (FAP) signal that takes precedence over all other starter inputs and switches and shall start the fan. The fan motor starter shall accept an occupant accessible emergency shutoff switch as shown. The supply fan motor starter shall have an H-O-A switch:

- (1) HAND: With the H-O-A switch in HAND position, the supply fan shall start and run continuously, subject to Safeties.
- (2) OFF: With the H-O-A switch in OFF position, the supply fan shall stop.
- (3) AUTO: With the H-O-A switch in AUTO position, the supply fan shall run subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.

[Return fan motor starter shall accept a Fire Alarm Panel (FAP) signal that takes precedence over all other starter inputs and switches shall start the fan. The return fan motor starter shall have an H-O-A switch:

- (1) HAND: With the H-O-A switch in HAND position, the return fan shall run subject to Safeties.
- (2) OFF: With the H-O-A switch in OFF position, the return fan shall be off.
- (3) AUTO: With the H-O-A switch in AUTO position, the return fan shall run subject to the supply fan running.]

b. Occupancy Modes: The system shall obtain its Occupancy Mode input from the System Scheduler as specified and shown. The system shall operate in one of the following modes: Occupied, Unoccupied[, or WarmUp/CoolDown].

c. System Enable and Loop Enable:

- (1) Occupied Mode: The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS). All control loops shall be enabled. The Zone Temperature Control loops serviced by the AHU shall also be enabled.
- (2) Unoccupied mode: While the building temperature (BLDG-T) is above setpoint (BLDG-T-LL-SP) all control loops shall be disabled and the supply fan shall not run. When BLDG-T drops below BLDG-T-LL-SP (with a 3 degrees C 5 degrees F deadband) the supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS), the Hot Deck Coil Control loop and all Zone Temperature Control loops shall be enabled, and all other control loops shall be disabled.
- [(3) Warm Up / Cool Down Mode: The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS). The Minimum Outside Air Flow Control loop shall be disabled and all control loops shall be enabled. The Zone Temperature Control loops serviced by the AHU shall also be enabled.]

d. Proofs and Safeties:

(1) The supply fan[, return fan,] and all DDC Hardware control loops shall be subject to Proofs and Safeties. Safeties shall be direct-hardwire interlocked to the fan starter circuit as shown. DDC Hardware shall monitor all proofs and safeties and failure of any proof or activation of any safety shall result in all control loops being disabled and the AHU fan being commanded off until reset.

(2) Proofs:

(a) Supply fan status (proof) (SF-S)

[(b) Return fan status (proof) (RF-S)]

(3) Safeties:

(a) Mixed air temperature low limit (freeze stat) (MA-T-LL)

(b) Supply air smoke (SA-SMK)

[(c) Return air smoke (RA-SMK)]

(4) DDC Hardware reset of all proofs and safeties shall be via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

e. Minimum Outside Air Flow Control: When this loop is enabled the DDC Hardware shall open the 2-position minimum outside air damper to introduce the minimum outside air flow quantity as shown. When this loop is disabled, the minimum outside air damper shall be closed.

f. Mixed Air Temperature Control With Economizer:

(1) When this loop is enabled, and the Economizer is ON as determined by the Economizer Enable Logic, the DDC Hardware shall modulate the economizer outside air, relief, and return air dampers to maintain the mixed air temperature (MA-T) at setpoint (MA-T-SP) as shown.

(2) When this loop is disabled, or the Economizer is OFF as determined by the Economizer Enable Logic, the economizer outside air and relief air dampers shall be closed, and the return air damper shall be open.

(3) Economizer Enable Logic. The economizer shall be ON when the outside air dry bulb temperature is between the high limit (ECO-HL-SP) and low limit (ECO-LL-SP) setpoints as shown. The Economizer shall otherwise be OFF. ECO-HL-SP and ECO-LL-SP shall each have a 1 degree C 2 degrees F deadband.

g. Hot Deck Coil Control:

(1) When this loop is enabled the DDC Hardware shall modulate the hot deck heating coil valve to maintain the hot deck temperature

(HD-T) at setpoint (HD-T-SP) as shown. When this loop is disabled, the hot deck coil valve shall be closed.

- [(2) The DDC Hardware shall reset the hot deck temperature setpoint (HD-T-SP) using a linear reset schedule as shown. Reset of the setpoint (HD-T-SP) shall be based on [Outside Air Temperature] [Coldest Zone Temperature].]
- h. Cold Deck Coil Control: When this loop is enabled the DDC Hardware shall modulate the cold deck cooling coil valve to maintain the cold deck temperature (CD-T) at setpoint (CD-T-SP) as shown. When this loop is disabled, the cold deck cooling coil valve shall be closed.
- i. Zone Temperature Control:
 - (1) The zone temperature setpoint (ZN-T-SP) shall be at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as shown.
 - (2) The DDC Hardware shall modulate the hot deck and cold deck dampers to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP). Sequencing shall be as shown: Upon a rise in zone temperature above zone temperature setpoint the zone cold deck damper shall modulate towards open as the hot deck damper modulates towards closed. Upon a fall in zone temperature below zone temperature setpoint the hot deck damper shall modulate towards open as the cold deck damper modulates towards closed.

3.4.3.8 Multizone with Hot Deck Bypass [with] [without] Return Fan

NOTE:

1) NOTE: Edit the sequence and drawings as necessary for systems with/without a return fan, preheat coil, economizer, and other project specific control loop requirements.

2) Minimum outside air flow control can be accomplished several different ways. Refer to the UFC, but don't use flow measurement in a constant volume system.

3) The inclusion of filter pressure switches should be coordinated with the local O&M staff. Pressure switches may not be desired/needed, particularly if filters are replaced on a regular schedule. Edit the Points Schedule and Control Schematic as required.

4) Indicate the System Scheduler and M&C Software Occupancy Schedule on the Occupancy Schedule drawing. The designer needs to coordinate System Scheduler (occupancy mode determination) with space occupancy sensor input and pushbutton override switch input use. As described in the System Scheduler sequence, 'occupied' inputs from 2 different spaces are required to help avoid needless turning on of the system (due to cleaning staff or security staff passing through after hours).

5) Absence of fan proof(s) or activation of any safety will result in system shutdown. The system remains shutdown until manually reset devices are reset and a manual reset button (RST-BUT), local to the DDC controller, is pressed. Reset could also be performed from a workstation (via SNVT) or local display panel (LDP). It is recommended that you coordinate the decision with the local O&M staff. Edit the Control Logic Diagram and Points Schedule to indicate which reset method is to be provided by the Contractor.

6) The hardware (product) specification requires that the low limit (freezestat) device include a manual reset at the device. In the event of shutdown due to freeze stat trip the system will remain shutdown until the device is reset and a separate DDC reset, as described above, is also used.

7) Smoke control is not addressed in this guide specification. Smoke control sequence of operation for each fan system, if beyond the requirements described, will be developed by the designer, based on the requirements and parameters of the project. The designer will account for operation of dampers and fans for pressurization and manual override of interlocks to the fire alarm system. All automatic overrides of normal HVAC control sequences will be activated through the fire protection and smoke control interface panel that the designer will design for the project. With the present control sequence, in the event of shutdown due to smoke detector input the system will remain shutdown until the smoke detector is reset and a separate DDC reset, as described above, is also used. The Fire Alarm Panel (FAP) input takes precedence over any DDC input to force the fan(s) to run.

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

a. HAND-OFF-AUTO switches:

Supply fan motor starter shall accept a Fire Alarm Panel (FAP) signal that takes precedence over all other starter inputs and switches and shall start the fan. The fan motor starter shall accept an occupant accessible emergency shutoff switch as shown. The supply fan motor starter shall have an H-O-A switch:

- (1) HAND: With the H-O-A switch in HAND position, the supply fan shall start and run continuously, subject to Safeties.
- (2) OFF: With the H-O-A switch in OFF position, the supply fan shall stop.
- (3) AUTO: With the H-O-A switch in AUTO position, the supply fan

shall run subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.

[Return fan motor starter shall accept a Fire Alarm Panel (FAP) signal that takes precedence over all other starter inputs and switches shall start the fan. The return fan motor starter shall have an H-O-A switch:

- (1) HAND: With the H-O-A switch in HAND position, the return fan shall run subject to Safeties.
- (2) OFF: With the H-O-A switch in OFF position, the return fan shall be off.
- (3) AUTO: With the H-O-A switch in AUTO position, the return fan shall run subject to the supply fan running.]

b. Occupancy Modes: The system shall obtain its Occupancy Mode input from the System Scheduler as specified and shown. The system shall operate in one of the following modes: Occupied, Unoccupied[, or WarmUp/CoolDown].

c. System Enable and Loop Enable:

- (1) Occupied Mode: The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS). All control loops shall be enabled. The Zone Temperature Control loops serviced by the AHU shall also be enabled.
- (2) Unoccupied mode: While the building temperature (BLDG-T) is above setpoint (BLDG-T-LL-SP) all control loops shall be disabled and the supply fan shall not run. When BLDG-T drops below BLDG-T-LL-SP (with a 3 degrees C 5 degrees F deadband) the supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS), and all Zone Temperature Control loops shall be enabled. The Minimum Outside Air Flow Control, Mixed Air Temperature Control With Economizer, and Cold Deck Coil Control loops shall be disabled.
- [(3) Warm Up / Cool Down Mode: The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS). The Minimum Outside Air Flow Control loop shall be disabled and all other control loops shall be enabled. The Zone Temperature Control loops serviced by the AHU shall also be enabled.]

d. Proofs and Safeties:

- (1) The supply fan[, return fan,] and all DDC Hardware control loops shall be subject to Proofs and Safeties. Safeties shall be direct-hardwire interlocked to the fan starter circuit as shown. DDC Hardware shall monitor all proofs and safeties and failure of any proof or activation of any safety shall result in all control loops being disabled and the AHU fan being commanded off until reset.

(2) Proofs:

(a) Supply fan status (proof) (SF-S)

[(b) Return fan status (proof) (RF-S)]

- (3) Safeties:
 - (a) Mixed air temperature low limit (freeze stat) (MA-T-LL)
 - (b) Supply air smoke (SA-SMK)
 - [(c) Return air smoke (RA-SMK)]
- (4) DDC Hardware reset of all proofs and safeties shall be via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.
- e. Minimum Outside Air Flow Control: When this loop is enabled the DDC Hardware shall open the 2-position minimum outside air damper to introduce the minimum outside air flow quantity as shown. When this loop is disabled, the minimum outside air damper shall be closed.
- f. Mixed Air Temperature Control With Economizer:
 - (1) When this loop is enabled, and the Economizer is ON as determined by the Economizer Enable Logic, the DDC Hardware shall modulate the economizer outside air, relief, and return air dampers to maintain the mixed air temperature (MA-T) at setpoint (MA-T-SP) as shown.
 - (2) When this loop is disabled, or the Economizer is OFF as determined by the Economizer Enable Logic, the economizer outside air and relief air dampers shall be closed, and the return air damper shall be open.
 - (3) Economizer Enable Logic. The economizer shall be ON when the outside air dry bulb temperature is between the high limit (ECO-HL-SP) and low limit (ECO-LL-SP) setpoints as shown. The Economizer shall otherwise be OFF. ECO-HL-SP and ECO-LL-SP shall each have a 1 degree C 2 degrees F deadband.
- g. Cold Deck Coil Control: When this loop is enabled the DDC Hardware shall modulate the cooling coil valve to maintain the cold deck supply air temperature (SA-T) at setpoint (SA-T-SP) as shown. When this loop is disabled, the cooling coil valve shall be closed.
- h. Zone Temperature Control: The Zone Temperature Control loops shall always be enabled.
 - (1) The zone temperature setpoint (ZN-T-SP) shall be at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as shown.
 - (2) The DDC Hardware shall modulate the zone bypass and cold deck dampers, and the zone reheat coil valve to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP). Sequencing shall be as shown: Upon a rise in zone temperature above zone temperature setpoint, subject to the zone temperature setpoint deadband as shown, the zone cold deck damper shall modulate towards open as the bypass deck damper modulates towards closed. Upon a fall in zone temperature below zone temperature setpoint, subject to the

deadband as shown, the bypass damper shall be full open and the zone heating valve shall modulate towards open.

3.4.3.9 Variable Air Volume System [with] [without] Return Fan

NOTE:

- 1) Edit the sequence and drawings as necessary for systems with/without a return fan, preheat coil, economizer, and other project specific control loop requirements.
- 2) Minimum outside air flow control can be accomplished several different ways. Refer to the UFC.
- 3) The inclusion of filter pressure switches should be coordinated with the local O&M staff. Pressure switches may not be desired/needed, particularly if filters are replaced on a regular schedule. Edit the Points Schedule and Control Schematic as required.
- 4) This spec does not include a variable frequency drive (VFD) specification. Specify a VFD that meets the requirements of the control sequence including the integral H-O-A and a safety shutdown input circuit that is separate from the start/stop input circuit and Fire Alarm Panel (FAP) override switch.
- 5) Indicate the System Scheduler and M&C Software Occupancy Schedule on the Occupancy Schedule drawing. The designer needs to coordinate System Scheduler (occupancy mode determination) with space occupancy sensor input and pushbutton override switch input use. As described in the System Scheduler sequence, 'occupied' inputs from 2 different spaces are required to help avoid needless turning on of the system (due to cleaning staff or security staff passing through after hours).
- 6) Absence of fan proof(s) or activation of any safety will result in system shutdown. The system remains shutdown until manually reset devices are reset and a manual reset button (RST-BUT), local to the DDC controller, is pressed. Reset could also be performed from a workstation (via SNVT) or local display panel (LDP). It is recommended that you coordinate the decision with the local O&M staff. Edit the Control Logic Diagram and Points Schedule to indicate which reset method is to be provided by the Contractor.
- 7) The hardware (product) specification requires that the low limit (freezestat) device include a manual reset at the device. In the event of shutdown due to freeze stat trip the system will remain shutdown until the device is reset and a separate DDC reset, as described above, is also used.

8) Smoke control is not addressed in this guide specification. Smoke control sequence of operation for each fan system, if beyond the requirements described, will be developed by the designer based on the requirements and parameters of the project. The designer will account for operation of dampers and fans for pressurization and manual override of interlocks to the fire alarm system. All automatic overrides of normal HVAC control sequences will be activated through the fire protection and smoke control interface panel that the designer will design for the project. With the present control sequence, in the event of shutdown due to smoke detector input the system will remain shutdown until the smoke detector is reset and a separate DDC reset, as described above, is also used. The Fire Alarm Panel (FAP) input takes precedence over any DDC input to force the fan(s) to run.

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

a. HAND-OFF-AUTO switches:

Supply fan variable frequency drive (VFD) unit shall accept a Fire Alarm Panel (FAP) signal that takes precedence over all other VFD inputs and switches and shall cause the VFD to run at 100% speed. The VFD shall accept an occupant accessible emergency shutoff switch as shown. The supply fan variable frequency drive (VFD) unit shall have an integral H-O-A switch:

- (1) HAND: With the H-O-A switch in HAND position, the supply fan shall start and run continuously, subject to Safeties. Fan speed shall be under manual-operator control.
- (2) OFF: With the H-O-A switch in OFF position, the supply fan shall stop.
- (3) AUTO: With the H-O-A switch in AUTO position, the supply fan shall run subject to the Supply Fan Start/Stop Signal (SF-SS) and Safeties. Fan speed shall be under control of the DDC Hardware.

[Return fan variable frequency drive (VFD) unit shall accept a Fire Alarm Panel (FAP) signal that takes precedence over all other VFD inputs and switches and shall cause the VFD to run at 100% speed. The return fan variable frequency drive (VFD) unit shall have an integral H-O-A switch:

- (1) HAND: With the H-O-A switch in HAND position, the return fan shall run subject to Safeties. Fan speed shall be under manual-operator control.
- (2) OFF: With the H-O-A switch in OFF position, the return fan shall be off.
- (3) AUTO: With the H-O-A switch in AUTO position, the return fan

shall run subject to the supply fan running. Fan speed shall be under control of the DDC Hardware.]

- b. Occupancy Modes: The system shall obtain its Occupancy Mode input from the System Scheduler as specified and shown. The system shall operate in one of the following modes: Occupied, Unoccupied[, or Warm Up/Cool Down].

- c. Proofs and Safeties:

- (1) The supply fan[, return fan,] and all DDC Hardware control loops shall be subject to Proofs and Safeties. Safeties shall be direct-hardwire interlocked to the VFD as shown. DDC Hardware shall monitor all proofs and safeties and failure of any proof or activation of any safety shall result in all control loops being disabled and the AHU fan being commanded off until reset.

- (2) Proofs:

- (a) Supply fan status (SF-S)

- [
 - (b) Return fan status (RF-S)]

- (3) Safeties:

- (a) Cooling coil discharge air temperature low limit (freezestat) (CLG-DA-T-LL)

- (b) Supply air duct pressure high limit (SA-P-HL)

- (c) Supply air smoke (SA-SMK)

- (d) Return air smoke (RA-SMK)

- (4) DDC Hardware reset of all proofs and safeties shall be via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

- d. System Enable and Loop Enable

- (1) Occupied mode: The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS). All control loops shall be enabled. The Zone Temperature Control loops for VAV boxes serviced by the AHU shall also be enabled.

- (2) Unoccupied mode: While the building temperature (BLDG-T) is above setpoint (BLDG-T-LL-SP) all control loops shall be disabled (except fan-powered VAV box Zone Temperature Control loops) and the supply fan shall not run. When BLDG-T drops below BLDG-T-LL-SP (with a 3 degrees C 5 degrees F deadband) the supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS), the Supply Duct Static Pressure Control[, Return Fan Volume Control][, Preheat Control] loops shall be enabled. The Minimum Outside Air Flow Control, Mixed Air Temperature Control, and Cooling Coil Control loops shall be disabled.

- [(3) Warm Up/Cool Down: The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS). The Minimum Outside Air Flow Control loop shall be disabled and all other control loops shall be enabled. The Zone Temperature Control loops for VAV boxes serviced by the AHU shall also be enabled.]
- e. Fan Capacity Control:
- (1) Supply Duct Static Pressure Control. When this loop is enabled the DDC Hardware shall modulate the supply fan variable frequency drive unit to maintain the duct static pressure (SA-P) at setpoint (SA-P-SP) as shown, as measured by the duct static pressure tap and sensor as shown. When this loop is disabled, the DDC Hardware capacity modulation output to the VFD shall be zero percent.
- (2) Return Fan Volume Control. When this loop is enabled the DDC Hardware shall modulate the return fan variable frequency drive unit to maintain a constant volumetric airflow difference at setpoint (F-DIFF-SP) as shown, as measured by the airflow measurement arrays located in the supply and return ducts as shown. When this loop is disabled, the output to the VFD shall be zero percent.]
- f. Minimum Outside Air Flow Control: When this loop is enabled the DDC Hardware shall modulate the minimum outside air damper to maintain the minimum OA volumetric flow (MINOA-F) at setpoint (MINOA-F-SP) as shown. When this loop is disabled, the minimum outside air damper shall be closed.
- g. Mixed Air Temperature Control With Economizer
- (1) When this loop is enabled, and the Economizer is ON as determined by the Economizer Enable Logic, the DDC Hardware shall modulate the economizer outside air, relief, and return air dampers to maintain the mixed air temperature (MA-T) at setpoint (MA-T-SP) as shown.
- (2) When this loop is disabled, or the Economizer is OFF as determined by the Economizer Enable Logic, the economizer outside air and relief air dampers shall be closed, and the return air damper shall be open.
- (3) Economizer Enable Logic. The economizer shall be ON when the outside air dry bulb temperature is between the high limit (ECO-HL-SP) and low limit (ECO-LL-SP) setpoints as shown. The Economizer shall otherwise be OFF. ECO-HL-SP and ECO-LL-SP shall each have a 1 degree C 2 degrees F deadband.
- h. Cooling Coil Control: When this loop is enabled the DDC Hardware shall modulate the cooling coil valve to maintain the supply air temperature (SA-T) setpoint (SA-T-SP) as shown. When this loop is disabled, the cooling coil valve shall be closed.
- [i. Preheat Coil Control: When this loop is enabled the DDC Hardware shall modulate the preheat coil valve to maintain the preheat coil discharge air temperature (PH-DA-T) at setpoint (PH-DA-T-SP) as shown. When this loop is disabled, the preheat coil valve shall be closed.]

3.4.4 Sequences of Operation for Terminal Units

NOTE: For the VAV Box Sequences:

1) Show the occupancy schedule (days/times) on the Occupancy Schedule drawing. For simplicity, it is recommended that all boxes, served by a common air handler, operate on the same schedule.

2) Space occupancy input(s) may consist of an occupancy sensor and/or a local push-button. Indicate the use of a sensor and/or push-button by placing an 'X' in the 'Thermostat and Occupancy Sensor Schedule'. If a push-button is used, show the override time duration in the Schedule. The occupancy sensor specification requires a 15 minute off-mode delay prior to leaving the occupied mode. If a different time is desired, show it in the thermostat schedule and ensure that it is consistent with the Occupancy Sensor Product specification.

3) For each VAV box thermostat, indicate if the zone temperature setpoint will be occupant adjustable placing an 'X' in the 'Thermostat and Occupancy Sensor Schedule'. For non-occupant-adjustable setpoints, show the setpoint in the Points Schedule. The intent is that the Contractor provides one or the other as shown. Non-occupant-adjustable setpoints are adjustable by a system operator using a local display panel (LDP) or operator workstation (and appropriate software).

3.4.4.1 Zone Temperature Control - Cooling-Only VAV Box

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

a. Occupancy Modes:

- (1) Occupied: The VAV box DDC Hardware shall be in the Occupied Mode when the local space occupancy input(s) (ZN-OCC) indicate that the space is occupied or when the input from the System Scheduler (SYS-OCC) is occupied.
- (2) Unoccupied: The VAV box DDC Hardware shall be in the Unoccupied Mode when the local space occupancy input(s) (ZN-OCC) indicate that the space is unoccupied and the input from the System Scheduler (SYS-OCC) is unoccupied.

b. Safeties: This system has no safeties.

c. Zone Temperature Control

- (1) In the Occupied Mode the zone temperature setpoint (ZN-T-SP) shall be at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as shown. The DDC

Hardware shall modulate the VAV box damper to maintain VAV box supply air flow (VAV-SA-F) at setpoint as measured by a multi-point flow sensing element at the inlet to the VAV box. Sequencing shall be as shown: Upon a rise in zone temperature (ZN-T) above zone setpoint (ZN-T-SP), subject to the zone temperature setpoint deadband as shown, the airflow setpoint shall be adjusted between minimum and maximum flow based on the difference between zone temperature and zone temperature setpoint as shown.

- (2) In the Unoccupied Mode the VAV box damper shall be at its minimum position.

3.4.4.2 Zone Temperature Control - VAV Box with Reheat

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

a. Occupancy Modes:

- (1) Occupied: The VAV box DDC Hardware shall be in the Occupied Mode when the local space occupancy input(s) (ZN-OCC) indicate that the space is occupied or when the input from the System Scheduler (SYS-OCC) is occupied.
- (2) Unoccupied: The VAV box DDC Hardware shall be in the Unoccupied Mode when the local space occupancy input(s) (ZN-OCC) indicate that the space is unoccupied and the input from the System Scheduler (SYS-OCC) is unoccupied.

- ##### b. Safeties: VAV boxes with electric resistance heating elements shall require proof of air flow before activating the heating elements.

c. Zone Temperature Control:

- (1) In the Occupied Mode the zone temperature setpoint (ZN-T-SP) shall be at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as shown.
- (2) In the Unoccupied Mode the zone temperature setpoint (ZN-T-SP) shall be at the configured setpoint as shown.
- (3) The DDC Hardware shall modulate the VAV box damper to maintain VAV box supply air flow (VAV-SA-F) at setpoint as measured by a multi-point flow sensing element at the inlet to the VAV box. Sequencing shall be as shown: Upon a rise in zone temperature above zone temperature setpoint (ZN-T-SP), subject to the zone temperature setpoint deadband as shown, the airflow setpoint shall be adjusted between minimum and maximum flow based on the difference between zone temperature and zone temperature setpoint as shown. Upon a fall in zone temperature below zone temperature setpoint, subject to the deadband as shown, the airflow shall be maintained at a fixed air flow setpoint (with a setting independent of the cooling minimum air flow), and the heating valve shall modulate towards open or the staged electric resistance heating coil(s) shall cycle on in sequence.

3.4.4.3 Zone Temperature Control - Fan Powered VAV Box

NOTE: This sequence is applicable to both Series
and Parallel fan powered VAV boxes.

As specified in Section 23 00 00 AIR SUPPLY,
DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEM, fans
located in series fan-powered VAV boxes must start
whenever the AHU fan that serves these boxes is
started. Therefore, this sequence allows the AHU to
start regardless of the VAV box fan status.

Contractor shall install DDC hardware to perform this Sequence of Operation
and to provide SNVT inputs, outputs and alarms as specified and shown on
the Points Schedule. Unless otherwise specified, all modulating control
shall be proportional-integral (PI) control.

a. Occupancy Modes:

(1) Occupied: The VAV box DDC Hardware shall be in the Occupied Mode
when the local space occupancy input(s) (ZN-OCC) indicate that the
space is occupied or when the input from the System Scheduler
(SYS-OCC) is occupied.

(2) Unoccupied: The VAV box DDC Hardware shall be in the
Unoccupied Mode when the local space occupancy input(s) (ZN-OCC)
indicate that the space is unoccupied and the input from the
System Scheduler (SYS-OCC) is unoccupied.

b. Safeties: VAV boxes with electric resistance heating elements shall
require proof of air flow before activating the heating elements.

c. Zone Temperature Control

(1) In the Occupied Mode the zone temperature setpoint (ZN-T-SP)
shall be at the configured setpoint or at the occupant-adjustable
setpoint via the wall-mounted thermostat, as shown.

(2) In the Unoccupied Mode the zone temperature setpoint (ZN-T-SP)
shall be at the configured setpoint as shown.

(3) Sequencing shall be as shown:

(a) In occupied and unoccupied modes, upon a rise in zone
temperature above zone temperature setpoint (ZN-T-SP), subject to
the zone temperature setpoint deadband as shown, the airflow
setpoint shall be adjusted between minimum and maximum based on
the difference between zone temperature and zone temperature
setpoint as shown. The DDC Hardware shall modulate the VAV box
damper to mix supply and plenum return air as it maintains VAV box
supply airflow (VAV-SA-F) at setpoint as measured by a multi-point
flow sensing element at the inlet to the VAV box.

(b) In occupied mode, upon a fall in zone temperature below zone
temperature setpoint, subject to the deadband as shown, the VAV
box fan shall cycle on (note that the fan is always on in the
occupied mode for a series box), the DDC Hardware shall modulate

the VAV box damper to mix supply and plenum return air to maintain a fixed air flow setpoint (with a setting independent of the cooling minimum air flow), and the heating valve shall modulate towards open or the staged electric resistance heating coil(s) shall cycle on in sequence.

(c) In unoccupied mode, upon a fall in zone temperature below zone temperature setpoint, subject to the deadband as shown, the VAV box fan shall cycle on (note that the fan is always on in the occupied mode for a series box), the VAV box damper shall be at its minimum position, and the heating valve shall modulate towards open or the staged electric resistance heating coil(s) shall cycle on in sequence.

3.4.4.4 Perimeter Radiation Control Sequence

NOTE:

1) Show the occupancy schedule (days/times) on the Occupancy Schedule drawing. For simplicity, it is recommended that all units operate on the same schedule.

2) Space occupancy input(s) may consist of an occupancy sensor and/or a local push-button. Indicate the use of a sensor and/or push-button by placing an 'X' in the Thermostat Schedule. If a push-button is used, show the override time duration in the Schedule. The occupancy sensor specification requires a 15 minute off-mode delay prior to leaving the occupied mode. If a different time is desired, show it in the thermostat schedule and ensure that it is consistent with the Occupancy Sensor Product specification.

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

a. Occupancy Modes

- (1) Occupied: The radiator DDC Hardware shall be in the Occupied Mode when the local space occupancy input(s) indicate that the space is occupied or when the input from the System Scheduler is occupied.
- (2) Unoccupied: The radiator DDC Hardware shall be in the Unoccupied Mode when the local space occupancy input(s) indicate that the space is unoccupied and when the input from the System Scheduler is unoccupied.

b. Safeties: This system has no safeties.

c. Space Temperature Control

- (1) In the Occupied Mode the DDC Hardware shall modulate the heating control valve to maintain space temperature at the configured setpoint or at the occupant-adjustable setpoint via the

wall-mounted thermostat, as shown.

- (2) In the Unoccupied Mode the DDC Hardware shall modulate the heating control valve to maintain space temperature at the configured setpoint as shown.

3.4.4.5 Unit Heater and Cabinet Unit Heater

NOTE:

1) Show the occupancy schedule (days/times) on the Occupancy Schedule drawing. For simplicity, it is recommended that all units operate on the same schedule.

2) Space occupancy input(s) may consist of an occupancy sensor and/or a local push-button. Indicate the use of a sensor and/or push-button by placing an 'X' in the Thermostat Schedule. If a push-button is used, show the override time duration in the Schedule. The occupancy sensor specification requires a 15 minute off-mode delay prior to leaving the occupied mode. If a different time is desired, show it in the thermostat schedule and ensure that it is consistent with the Occupancy Sensor Product specification.

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

a. Off-Auto Switch

- (1) OFF: With the thermostat OFF-AUTO switch in the OFF position, the DDC Hardware shall stop the fan and close the heating control valve.
- (2) AUTO: With the thermostat OFF-AUTO switch in the AUTO position, the DDC Hardware shall control the unit in accordance with its Occupancy Mode.

b. Occupancy Modes

- (1) Occupied: The unit heater DDC Hardware shall be in the Occupied Mode when the local space occupancy input(s) indicate that the space is occupied or when the input from the System Scheduler is occupied.
- (2) Unoccupied: The unit heater DDC Hardware shall be in the Unoccupied Mode when the local space occupancy input(s) indicate that the space is unoccupied and when the input from the System Scheduler is unoccupied.

c. Safeties: The unit shall run subject to the unit manufacturer's safeties.

d. Space Temperature Control

- (1) In the Occupied Mode the DDC Hardware shall modulate the heating control valve and cycle the multi-speed fan to maintain space temperature at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as shown.
- (2) In the Unoccupied Mode the DDC Hardware shall modulate the heating control valve and cycle the multi-speed fan to maintain space temperature at the configured setpoint as shown.

3.4.4.6 Gas-Fired Infrared Heater

NOTE:

1) Use of a System Scheduler is likely not needed in this application. If it is, edit the sequence and the drawings.

2) Space occupancy input(s) may consist of an occupancy sensor and/or a local push-button. Indicate the use of a sensor and/or push-button by placing an 'X' in the Thermostat Schedule. If a push-button is used, show the override time duration in the Schedule. The occupancy sensor specification requires a 15 minute off-mode delay prior to leaving the occupied mode. If a different time is desired, show it in the thermostat schedule and ensure that it is consistent with the Occupancy Sensor Product specification.

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

a. On-Off-Auto Switch

- (1) ON: With the thermostat ON-OFF-AUTO switch in the ON position, the DDC Hardware shall energize the heater and the heater shall run continuously.
- (2) OFF: With the thermostat ON-OFF-AUTO switch in the OFF position, the DDC Hardware shall de-energize the heater.
- (3) AUTO: With the thermostat ON-OFF-AUTO switch in the AUTO position, the DDC Hardware shall control the heater in accordance with its Occupancy Mode.

b. Occupancy Modes

- (1) Occupied: The unit DDC Hardware shall be in the Occupied Mode when the local space occupancy input(s) indicate that the space is occupied.
- (2) Unoccupied: The unit DDC Hardware shall be in the Unoccupied Mode when the local space occupancy input(s) indicate that the space is unoccupied.

c. Safeties: The heater shall run subject to the unit manufacturer's safeties.

d. Space Temperature Control

- (1) In the Occupied Mode the DDC Hardware shall operate the heater to maintain space temperature at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as shown.
- (2) In the Unoccupied Mode the DDC Hardware shall operate the heater to maintain space setpoint at the configured unoccupied setpoint as shown.

3.4.4.7 Dual Temperature Fan-Coil Unit

NOTE:

1) Show the occupancy schedule (days/times) on the Occupancy Schedule drawing. For simplicity, it is recommended that all units operate on the same schedule.

2) Space occupancy input(s) may consist of an occupancy sensor and/or a local push-button. Indicate the use of a sensor and/or push-button by placing an 'X' in the Thermostat Schedule. If a push-button is used, show the override time duration in the Schedule. The occupancy sensor specification requires a 15 minute off-mode delay prior to leaving the occupied mode. If a different time is desired, show it in the thermostat schedule and ensure that it is consistent with the Occupancy Sensor Product specification.

3) Show 2-way and 3-way valve selections on the Valve Schedule.

4) Fan coil units typically have unit-mounted thermostats. Indicate if wall mounting is desired and/or show in the Thermostat Schedule for the individual fan coil units.

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

a. Off-Auto Switch

- (1) OFF: With the thermostat OFF-AUTO switch in the OFF position, the DDC Hardware shall stop the fan and close the dual-temperature control valve.
- (2) AUTO: With the thermostat OFF-AUTO switch in the AUTO position, the DDC Hardware shall control the unit in accordance with its Occupancy Mode.

b. Occupancy Modes

- (1) Occupied: The unit DDC Hardware shall be in the Occupied Mode when the local space occupancy input(s) indicate that the space is occupied or when the input from the System Scheduler is occupied.
- (2) Unoccupied: The unit DDC Hardware shall be in the Unoccupied Mode when the local space occupancy input(s) indicate that the space is unoccupied and when the input from the System Scheduler is unoccupied.

c. Heat/Cool Modes: The DDC Hardware shall automatically switch the fan coil unit DDC Hardware between the heating and cooling modes and the resultant control action, based on a pipe-mounted dual-temperature supply water temperature sensor.

d. Safeties: The unit shall run subject to the unit manufacturer's safeties.

e. Space Temperature Control

- (1) In the Occupied Mode the DDC Hardware shall modulate the dual-temperature control valve and cycle the multi-speed fan to maintain space temperature at the configured setpoint or at the occupant-adjustable setpoint via the [wall-mounted] thermostat, as shown.
- (2) In the Unoccupied Mode the DDC Hardware shall modulate the dual-temperature control valve and cycle the multi-speed fan to maintain space temperature at the configured setpoint as shown.

3.4.5 Sequences of Operation for Hydronic Systems

3.4.5.1 Hydronic Heating Hot Water from Distributed [Steam] [HTHW] Converter

NOTE:

1) Select Steam or High Temperature Hot Water as required.

2) The designer may want to consider other conditions under which this system is enabled, such as outside air temperature.

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

a. System Enable and loop enable

- (1) This system shall monitor the enabled status of all systems served by this system. If one or more systems served by this system are enabled, this system shall be enabled (SYS-ENA). If all systems served by this system are not enabled, this system shall not be enabled.

(2) When this system is enabled (SYS-ENA) and the hot water pump is proofed on, the Heat Exchanger Control loop shall be enabled.

b. HAND-OFF-AUTO Switch: The hot water pump motor starter shall have an H-O-A switch:

(1) HAND: With the H-O-A switch in HAND position, the pump shall start and run continuously.

(2) OFF: With the H-O-A switch in OFF position, the pump shall stop.

(3) AUTO: With the H-O-A switch in AUTO position, the pump shall run subject to the Hot Water Pump Start/Stop (HW-PMP-SS) command.

c. Proofs and Safeties:

(1) DDC Hardware shall monitor all proofs and safeties.

(2) Proofs: Hot water pump status (HW-PMP-S)

(3) Safeties: None

(4) DDC Hardware reset of all proofs and safeties shall be via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

NOTE: If a reset schedule is not required delete this option ([determined from a linear reset schedule]) from the sequence along with the reset schedule in the drawing. Where reset is used, edit the temperatures shown in the reset schedule on the drawing.

d. Heat Exchanger Valve Control: When this loop is enabled DDC Hardware shall modulate the [steam][high temperature hot water] valve to maintain the Hot Water Supply Temperature (HWS-T) at setpoint (HWS-T-SP). The Hot Water Supply Temperature Setpoint (HW-T-SP) shall be [determined from a linear reset schedule] as shown. When this loop is disabled, the valve shall be closed.

3.4.5.2 Hydronic Heating Hot Water From Single-Building Boiler

NOTE: The designer may want to consider other conditions under which this system is enabled, such as outside air temperature.

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

a. System Enable and loop enable

- (1) This system shall monitor the enabled status of all systems served by this system. If one or more systems served by this system are enabled, this system shall be enabled (SYS-ENA). If all systems served by this system are not enabled, this system shall not be enabled.
 - (2) When this system is enabled (SYS-ENA) and the hot water pump is proofed on, the boiler control and hot water temperature control loops shall be enabled.
- b. HAND-OFF-AUTO Switch: The hot water pump motor starter shall have an H-O-A switch:
- (1) HAND: With the H-O-A switch in HAND position, the pump shall start and run continuously.
 - (2) OFF: With the H-O-A switch in OFF position, the pump shall stop.
 - (3) AUTO: With the H-O-A switch in AUTO position, the pump shall run subject to the Hot Water Pump Start/Stop (HW-PMP-SS) command.
- c. Proofs and Safeties:
- (1) DDC Hardware shall monitor all proofs and safeties.
 - (2) Proofs: Hot water pump
 - (3) Safeties: None
 - (4) DDC Hardware reset of all proofs and safeties shall be via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.
- d. Boiler Control: When this loop is enabled, the DDC Hardware shall turn the boiler on. When this loop is disabled, the boiler shall be off.
- e. Hot Water Temperature Control: When this loop is enabled the DDC Hardware shall modulate the 3-way mixing valve to maintain hot water supply temperature (HWS-T) at setpoint (HWS-T-SP). The Hot Water Supply Temperature Setpoint (HWS-T-SP) shall be [determined from a linear reset schedule] as shown. When this loop is disabled, the valve shall be in its normal (failsafe) position.

3.4.5.3 Hydronic Dual-Temperature System with [Steam] [High Temperature Hot Water] and Chilled Water

NOTE:

1) Select Steam or High Temperature Hot Water as required.

2) The Heating Mode low-limit switch is needed only if there is a boiler (to avoid boiler shock). You may choose to delete the switch from the control schematic drawing, ladder diagram and sequence when

using a heat exchanger.

3) The designer may want to consider other conditions under which this system is enabled, such as outside air temperature.

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

a. System Enable and loop enable

- (1) This system shall monitor the enabled status of all systems served by this system. If one or more systems served by this system are enabled, this system shall be enabled (SYS-ENA). If all systems served by this system are not enabled, this system shall not be enabled.
- (2) When this system is enabled (SYS-ENA), and the HEATING/COOLING switch is in HEATING and the dual-temperature return water temperature (DTWR-T) is above the dual-temperature return water low-limit temperature (DTWRR-T-LL) setpoint of 18 degrees C 65 degrees F, the [single-building boiler] [Heat Exchanger Control loop] shall be enabled.

NOTE: Chiller Enable (the following paragraph) is only required when there is a local chiller. In cases where chilled water is from a central plant delete the chiller enable requirement.

- (3) When this system is enabled (SYS-ENA), and the HEATING/COOLING switch is in COOLING and the dual-temperature return water temperature (DTWR-T) is below the dual-temperature return water high-limit temperature (DTWR-T-HL) setpoint of 29 degrees C 85 degrees F, the chiller shall be enabled.]

b. Switchover valve operation

- (1) With the HEATING/COOLING switch in the HEATING position, the switchover valve shall open the heat-cool system piping to the [heat exchanger] [boiler] and close the heat-cool system piping to the [central plant chilled water] [single-building chiller] whenever the dual-temperature return water temperature (DTWR-T) is above the dual-temperature return water low-limit temperature (DTWR-T-LL) setpoint of 18 degrees C 65 degrees F.
- (2) With the HEATING/COOLING switch in the COOLING position, the switchover valve shall open the heat-cool system piping to the [central plant chilled water] [single-building chiller] and close the heat-cool system piping to the [heat exchanger] [boiler] whenever the dual-temperature return water temperature (DTWR-T) is below the dual-temperature return water high-limit temperature (DTWR-T-HL) setpoint of 29 degrees C 85 degrees F.

- (3) For any other combination of HEATING/COOLING mode switch position, DTWR-T-LL switch position, and DTWR-T-HL switch position, the heat-cool switchover valve shall maintain its last state.
 - (4) The DDC Hardware shall monitor the status of the DTWR-T-LL and DTWR-T-HL switches.
- c. HAND-OFF-AUTO Switch: The Dual-Temperature water pump motor starter shall have an H-O-A switch:
- (1) HAND: With the H-O-A switch in HAND position, the pump shall start and run continuously.
 - (2) OFF: With the H-O-A switch in OFF position, the pump shall stop.
 - (3) AUTO: With the H-O-A switch in AUTO position, the pump shall run subject to the Dual-Temperature Water Pump Start/Stop (DTW-PMP-SS) System Enable (SYS-ENA) command.
- d. Proofs and Safeties
- (1) DDC Hardware shall monitor all proofs and safeties.
 - (2) Proofs: None
 - (3) Safeties: Heat exchanger differential pressure switch (HX-P-LL) shall be direct-hardwire interlocked to the [steam] [high temperature hot water] valve.
 - (4) DDC Hardware reset of all proofs and safeties shall be via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.
- [e. Heat Exchanger Valve Control: When this loop is enabled and there is hot water flow through the heat exchanger as sensed by the differential pressure switch (HX-P-LL) safety, the DDC Hardware shall modulate the [steam] [high temperature hot water] valve to maintain the Hot Water Supply Temperature (HWS-T) at setpoint (HWS-T-SP). The Hot Water Supply Temperature Setpoint (HW-T-SP) shall be [determined from a linear reset schedule] as shown. The DDC Hardware shall monitor the status of the HX-P-LL safety. When this loop is disabled, the valve shall be closed.]

3.4.5.4 Hydronic Secondary with Variable Speed Pump

NOTE:

1) This spec does not include a variable frequency drive (VFD) specification. Specify a VFD that meets the requirements of the control sequence including the integral H-O-A.

2) The designer may want to consider other conditions under which this system is enabled, such as outside air temperature.

Contractor shall install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs, outputs and alarms as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be proportional-integral (PI) control.

a. System Enable and loop enable:

- (1) This system shall monitor the enabled status of all systems served by this system. If one or more systems served by this system are enabled, this system shall be enabled (SYS-ENA). If all systems served by this system are not enabled, this system shall not be enabled.
- (2) When this system is enabled (SYS-ENA) the Pressure Control loop shall be enabled.

b. HAND-OFF-AUTO Switch: The hot water pump variable frequency drive (VFD) unit shall have an integral H-O-A switch:

- (1) HAND: With the H-O-A switch in HAND position, the pump shall start and run continuously. Pump speed shall be under manual-operator control.
- (2) OFF: With the H-O-A switch in OFF position, the pump shall stop.
- (3) AUTO: With the H-O-A switch in AUTO position, the pump shall run subject to the Hot Water Pump Start/Stop (HW-PMP-SS) command and pump speed shall be under control of the DDC system.

c. roofs and Safeties

- (1) DDC Hardware shall monitor all proofs and safeties.
- (2) Proofs: None
- (3) Safeties: None
- (4) DDC Hardware reset of all proofs and safeties shall be via a local binary push-button (RST-BUT) input to the DDC Hardware, via a remote command to the DDC Hardware via SNVT or both (where the Contractor provides both reset functions and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

d. Pressure Control: When this loop is enabled the DDC Hardware shall modulate the pump variable frequency drive unit to maintain the pipe system pressure at setpoint as shown, as measured by the differential pressure tap and sensor as shown. When this loop is disabled, the DDC Hardware capacity modulation output to the VFD shall be zero percent.

3.5 CONTROLLER TUNING

The Contractor shall tune each controller in a manner consistent with that described in the [ASHRAE FUN SI](#) [ASHRAE FUN IP](#). Tuning shall consist of adjustment of the proportional, integral, and where applicable, the derivative (PID) settings to provide stable closed-loop control. Each loop shall be tuned while the system or plant is operating at a high gain (worst

case) condition, where high gain can generally be defined as a low-flow or low-load condition. Upon final adjustment of the PID settings, in response to a change in controller setpoint, the controlled variable shall settle out at the new setpoint with no more than two (2) oscillations above and below setpoint. Upon settling out at the new setpoint the controller output shall be steady. With the exception of naturally slow processes such as zone temperature control, the controller shall settle out at the new setpoint within five (5) minutes. The Contractor shall return the controller to its original setpoint and shall record and submit the final PID configuration settings with the O&M Instructions and on the associated Points Schedule.

3.6 START-UP AND START-UP TEST

The Contractor shall perform the following startup tests for each control system to ensure that the described control system components are installed and functioning per this specification.

- a. General: The Contractor shall adjust, calibrate, measure, program, configure, set the time schedules, set alarms, and otherwise perform all necessary actions to ensure that the systems function as specified and shown in the sequence of operation and other contract documents.
- b. Systems Check: An item-by-item check shall be performed for each HVAC system;

NOTE: If the specification has been edited to include M&C Software (from Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEMS (UMCS)), include the requirement to inspect M&C Clients to make sure they display shutdown conditions.

- (1) Step 1 - System Inspection: With the system shut down, it shall be verified that power and main air are available where required and that all output devices are in their failsafe and normal positions. Each local display panel [and each M&C Client] shall be inspected to verify that all displays indicate shutdown conditions.
- (2) Step 2 - Calibration Accuracy Check: A two-point accuracy check of the calibration of each HVAC control system sensing element and transmitter shall be performed by comparing the SNVT output from the DDC Hardware the sensor is connected to the actual value of the variable measured at the sensing element. Digital indicating test instruments shall be used, such as digital thermometers, motor-driven psychrometers, and tachometers. The test instruments shall be at least twice as accurate as the specified sensor accuracy. The calibration of the test instruments shall be traceable to National Institute Of Standards And Technology standards. The first check point shall be with the HVAC system in the shutdown condition, and the second check point shall be with the HVAC system in an operational condition. Calibration checks shall verify that the sensing element-to-DDC system readout accuracies at two points are within the specified product accuracy tolerances. If not, the device shall be recalibrated or replaced and the calibration check repeated.

(3) Step 3 - Actuator Range Check: With the system running, a signal shall be applied to each actuator through the DDC Hardware controller. Proper operation of the actuators and positioners for all actuated devices shall be verified and the signal levels shall be recorded for the extreme positions of each device. The signal shall be varied from live zero to full range, and it shall be verified that the actuators travel from zero stroke to full stroke within the signal range. Where applicable, it shall be verified that all sequenced actuators move from zero stroke to full stroke in the proper direction, and move the connected device in the proper direction from one extreme position to the other.

- c. Weather Dependent Test: Weather dependent test procedures that cannot be performed by simulation shall be performed in the appropriate climatic season. When simulation is used, the actual results shall be verified in the appropriate season.

Test Report: Upon completion of the Start-Up Test, the Contractor shall prepare and submit a [Start-Up and Start-Up Testing Report](#) documenting the results of the tests performed and certifying that the system is installed and functioning per this specification, and is ready for the Performance Verification Test (PVT).

3.7 PERFORMANCE VERIFICATION TEST (PVT)

NOTE: A set of Field Test Procedures are being developed by an A/E under contract with Huntsville Center. Once complete, these Test Procedures will be included or referenced here.

Brief interim guidance is provided here.

3.7.1 [PVT Procedures](#)

NOTE: The designer must decide whether to require a one-point accuracy check and/or inlet and outlet air temperature measurements.

Project specific requirements should be added, particularly for problematic controls based on designer and user experience.

The performance verification test procedures shall explain, step-by-step, the actions and expected results that will demonstrate that the control system performs in accordance with the sequences of operation, and other contract documents. [The PVT shall include a one-point accuracy check of each sensor.] [The PVT shall include inlet and outlet air temperature measurements for all AHU-dependent terminal units.] The PVT Procedure shall describe a methodology to measure and trend the network bandwidth usage on the network backbone and compare it to the Bandwidth Usage Calculation submittal. A control system performance verification test equipment list shall be included that lists the equipment to be used during performance verification testing. The list shall include manufacturer name, model number, equipment function, the date of the latest calibration, and the results of the latest calibration.

3.7.2 PVT Execution

The Contractor shall demonstrate compliance of the control system with the contract documents. Using test plans and procedures approved by the Government, the Contractor shall demonstrate all physical and functional requirements of the project. The performance verification test shall show, step-by-step, the actions and results demonstrating that the control systems perform in accordance with the sequences of operation. The performance verification test shall measure and trend the Network Bandwidth Usage and compare it to the Bandwidth Usage Calculation submittal. The performance verification test shall not be started until after receipt by the Contractor of written permission by the Government, based on Government approval of the Start-Up and Start-Up Testing Report and completion of balancing. The tests shall not be conducted during scheduled seasonal off periods of base heating and cooling systems.

3.7.3 PVT Report

Contractor shall prepare a PVT report documenting all tests performed during the PVT and their results. The PVT report shall include all tests in the PVT Procedures and any other testing performed during the PVT. Failures and repairs shall be documented with test results.

3.8 TRAINING

NOTE: Training requirements should be coordinated with the user (including the Controls/HVAC/Electrical shop supervisor). Extent of training should be based on the needs of the installation personnel.

A training course shall be conducted for [_____] operating staff members designated by the Government in the maintenance and operation of the system, including specified hardware and software. The training period, for a total of [32][_____] hours of normal working time, shall be conducted within 30 days after successful completion of the performance verification test. The training course shall be conducted at the project site and the Government reserves the right to videotape the training sessions for later use. Audiovisual equipment and [_____] sets of all other training materials and supplies shall be provided. A training day is defined as 8 hours of classroom instruction, including two 15 minute breaks and excluding lunchtime, Monday through Friday, during the daytime shift in effect at the training facility.

3.8.1 Training Documentation

NOTE: Designer must choose appropriate shop supervisor(s) to coordinate training attendance.

The Contractor shall prepare training documentation consisting of:

- a. Course Attendee List: A List of course attendees which shall be developed in coordination with and signed by the [Controls] [HVAC] [Electrical] shop supervisor.

- b. Training Manuals: Training manuals shall include an agenda, defined objectives for each lesson, and a detailed description of the subject matter for each lesson. Where the Contractor presents portions of the course material by audiovisuals, copies of those audiovisuals shall be delivered to the Government as a part of the printed training manuals. Training manuals shall be delivered for each trainee with two additional copies delivered for archival at the project site.

3.8.2 Training Course Content

For guidance in planning the required instruction, the Contractor shall assume that attendees will have a high school education or equivalent, and are familiar with HVAC systems. The training course shall cover all of the material contained in the Operating and Maintenance Instructions, the layout and location of each controller enclosure, the layout of one of each type of unitary equipment and the locations of each, the location of each control device external to the panels, the location of the compressed air station, preventive maintenance, troubleshooting, diagnostics, calibration, adjustment, commissioning, tuning, repair procedures, use of LNS Plug-ins, and use of the GPPC Programming software. Typical systems and similar systems may be treated as a group, with instruction on the physical layout of one such system. The results of the performance verification test and the Start-Up and Start-Up Testing Report shall be presented as benchmarks of HVAC control system performance by which to measure operation and maintenance effectiveness.

APPENDIX A

QC CHECKLIST

This checklist is not all-inclusive of the requirements of this specification and should not be interpreted as such.

This checklist is for (check one:)

Pre-Construction QC Checklist Submittal (Items 1-5) |____|

Post-Construction QC Checklist Submittal (Items 1-12) |____|

Close-out QC Checklist Submittal (Items 1-19) |____|

Initial each item in the space provided (|____|) verifying that requirement has been met.

Items verified for Pre-Construction, Post-Construction and Closeout QC Checklists Submittal:

- 1 Network bandwidth calculations have been performed, and the backbone type (Ethernet or TP/FT-10) has been determined based on these calculations. |____|
- 2 All DDC Hardware (nodes) are numbered on Control System Schematic Drawings. |____|
- 3 Signal lines on Control System Schematic are labeled with the signal type. |____|
- 4 Local Display Panel (LDP) Locations are shown on Control System Schematic drawings. |____|
- 5 Points Schedule drawings have been sub-divided by device (DDC Hardware), including DDC Hardware node numbers. |____|

Items verified for Post-Construction and Closeout QC Checklist Submittal:

- 6 All DDC Hardware is installed on a TP/FT-10 local control bus. |____|
- 7 All Application Specific Controllers (ASCs) are LonMark certified. |____|
- 8 Communication between DDC Hardware is only via CEA-709.1B using SNVTs. Other protocols and network variables other than SNVTs have not been used. |____|
- 9 Explicit messaging has not been used. |____|
- 10 System Scheduler functionality has been installed for all HVAC systems and default schedules have been configured at each System Scheduler. |____|
- 11 All sequences are performed as specified using DDC Hardware. |____|
- 12 Training schedule and course attendee list has been developed and coordinated with shops and submitted. |____|

QC CHECKLIST

Items verified for Closeout QC Checklists Submittal:

- | | | |
|----|--|------|
| 13 | Final As-built Drawings, including the Points Schedule drawings accurately represent the final installed system. | ____ |
| 14 | LonWorks Network Services (LNS) Database is up-to-date and accurately represents the final installed system. | ____ |
| 15 | LNS Plug-ins have been submitted for all ASCs. | ____ |
| 16 | Programming software has been submitted for all General Purpose Programmable Controllers (GPPCs). | ____ |
| 17 | All software has been licensed to the Government | ____ |
| 18 | O&M Instructions have been completed and submitted. | ____ |
| 19 | Training course has been completed. | ____ |

(QC Representative Signature)

(Date)

-- End of Section --