SECTION TABLE OF CONTENTS

DIVISION 23 - HEATING, VENTILATING, AND AIR CONDITIONING

SECTION 23 09 23

DIRECT DIGITAL CONTROL FOR HVAC AND OTHER LOCAL BUILDING SYSTEMS

11/08

-- End of Section Table of Contents --

```
**************************************************************************
USACE / NAVFAC / AFCESA / NASA          UFGS-23 09 23 (November 2008)
                                        ----------------------------
Preparing Activity:  USACE              Superseding
                                        UFGS-23 09 23 (April 2006)


              UNIFIED FACILITIES GUIDE SPECIFICATIONS

         References are in agreement with UMRL dated April 2009
**************************************************************************


                          SECTION 23 09 23

   DIRECT DIGITAL CONTROL FOR HVAC AND OTHER LOCAL BUILDING SYSTEMS
                              11/08
```

```
**************************************************************************
              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
```

1.1   REFERENCES

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	(2005) Fundamentals Handbook, I-P Edition
ASHRAE FUN SI	(2005) Fundamentals Handbook, SI Edition

ASME INTERNATIONAL (ASME)

ASME B16.15	(2006) Cast Bronze Threaded Fittings Classes 125 and 250
ASME B16.34	(2004) 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) 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   (2007; AMD 1 2008) National Electrical
                               Code - 2008 Edition

NFPA 90A   (2008) 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 2006) 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   SYSTEM DESCRIPTION

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

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

1.3.1   System Requirements

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

a. 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.
Submit a copy of the LNS database 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. Install the hardware 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. 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. Install and configure hardware 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. Install and configure control hardware 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.

1.3.2   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).
*************************************************************************
```

Provide a building control network consisting of a backbone and one or more
local control busses as specified.

1.3.2.1   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 according to the following criteria:

a. The backbone shall be an IP network as specified in Section 25 10 10
 if both of the following conditions are met:

   (1) the Network Bandwidth Calculations for a heavily loaded
   network show that more than 70 percent 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
   percent 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.

1.3.2.2   Control Network Requirements

 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

    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.

1.3.3   Network Bandwidth Usage Calculations

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

    a.   A heavily loaded control network is characterized as one performing

the following activities simultaneously:

    1.   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).

    2.   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.

    3.   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.

    4.   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.

    5.   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.

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

    1.   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).

    2.   Transmitting 50 points to the UMCS in response to polling requests at 5-second intervals.

    3.   Transmitting occupancy commands from the UMCS to every system scheduler sequence in a one-minute interval.

1.4   SUBMITTALS

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.]

a. 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.

b. 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 in hard copy and on CDROM in [AutoCAD][Microstation] format.

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

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

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

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

SD-03 Product Data

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

   Product specific catalog cuts 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) as a Technical Data Package licensed to the project site. Software on CD-ROM and [_____] hard copies of the software user manual for each piece of software provided.

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

   All installed GPPC Application Programs on CD-ROM as a Technical Data Package. Include in the CD-ROM a list or table of contents clearly indicating which application program is associated with each device. Submit [2][_____] copies of the GPPC Application Program's CD-ROM.

XIF files[; G][; G, [_____]]

   External interface files (XIF files) 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 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 as a
Technical Data Package. LNS Plug-ins distributed under a license
shall be licensed to the project site. Submit Plug-ins on
CD-ROM. Submit hard copy manuals, if available, for each plug-in
provided.

SD-05 Design Data

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

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

SD-06 Test Reports

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

   [Four][_____] copies of the Existing Conditions Report.

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

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

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

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

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

   [Four][_____] copies of the PVT Phase Report. 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.

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

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

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. 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, [_____]]

      Deliver training manuals for each trainee on the Course Attendee
      List with [2][_____] additional copies delivered for archival at
      the project site. Deliver [2][_____] copies of the Course
      Attendee List 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.

1.5   QUALITY ASSURANCE

1.5.1   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.

1.5.2   Surge Protection

1.5.2.1   Power-Line Surge Protection

  Protect equipment connected to ac circuits 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.

1.5.2.2   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.
****

  Protect DDC hardware 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.

1.5.3   Input Measurement Accuracy

    Select, install and configure sensors, transmitters and DDC Hardware such
    that the maximum error of the measured value at the SNVT output of the DDC
    hardware is less than 150 percent of the maximum allowable error specified
    for the sensor or instrumentation.

1.5.4   System Modifications

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

1.5.5   Drawings

    The Government will not indicate all offsets, fittings, and accessories
    that may be required on the drawings. Carefully investigate the
    mechanical, electrical, and finish conditions that could affect the work to
    be performed, arrange such work accordingly, and provide all work necessary
    to meet such conditions. 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. Use in the drawings the same abbreviations, symbols,
    nomenclature and identifiers shown. Each control system element on a
    drawing shall be assigned a unique identifier as shown. Deliver the DDC
    Contractor Design Drawings 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.

1.5.6   Draft As-Built Drawings

Update the Contractor Design Drawings with all as-built data and submit as specified.

1.5.7   Final As-Built Drawings

Update the Draft As-Built Drawings with all final as-built data and submit as specified.

1.6   DELIVERY, STORAGE, AND HANDLING

Store products 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.

1.7   PROJECT/SITE CONDITIONS

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 percent relative humidity, noncondensing and humidity conditions outside this range normally encountered at the installed location.

1.8   PROJECT SEQUENCING

TABLE I. PROJECT SEQUENCING lists the 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, 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 (before schedule)	[_____] days 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

1.9   SCHEDULING

****
NOTE: 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

1.9.1   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.

1.9.2   System Scheduler Requirements

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.

    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).

1.9.3   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 determined as follows:

            (a) The output shall be Occupied when the Override Occupancy
            Input is OC_OCCUPIED.

            (b) The output shall be Unoccupied when the Override 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 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.

1.9.4   Air Handler System Scheduling

a. 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

b. 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.

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

d. 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.

1.9.5   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.

1.10   MAINTENANCE

1.10.1   General

  The HVAC control System Operation and Maintenance (O&m) 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 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.

1.10.2   Maintenance 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**
****

  Provide services, materials and equipment 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. Minimize impacts on facility operations.

1.10.2.1   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.

1.10.2.2   Personnel

Use qualified service personnel to accomplish work promptly and satisfactorily. Advise the Government in writing of the name of the designated service representative, and of any changes in personnel.

1.10.2.3   Scheduled Inspections

Perform two inspections 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.

1.10.2.4   Scheduled Work

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

1.10.2.5   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 in accordance with Section 01 78 00 CLOSEOUT SUBMITTALS.

1.10.2.6   Operation

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

verification test.

1.10.2.7   Records and Logs

Keep dated records and logs 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.

1.10.2.8   Work Requests

Record each service call request as received and 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. Submit a record of the
work performed within 5 days after work is accomplished.

PART 2   PRODUCTS

2.1   MATERIALS AND EQUIPMENT

Provide materials and equipment which are standard products of a
manufacturer regularly engaged in the manufacturing of these and similar
products and that 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. 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. DDC Hardware not meeting the two-year field service
requirement will be acceptable provided it has been successfully used 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. Submit
manufacturer's catalog data sheets documenting compliance with product
specifications as specified for each product installed under this
specification.

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.

        d. 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. Provide the weathershield 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. Install weathershields near outside
  air intake ducts such that normal outside air flow does not cause rainwater
  to strike the sensor. Provide weathershields 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 Repeaters

  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 percent 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 percent 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.**

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 percent of the system design operating
pressure. Unless otherwise specified or shown, valve leakage shall meet
FCI 70-2 Class IV leakage rating (0.01 percent 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 percent 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

 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 percent (60 degrees) open position. Valve leakage shall meet
 FCI 70-2 Class VI leakage rating.

2.6.3   Two-Way

 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

 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

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   Chilled-Water, Condenser-Water, and Glycol

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

2.6.7   High-Temperature Water, Hot-Water and Dual Temperature

    a. 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.

    b. 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 percent 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 in accordance with
  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 degreeF 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 percent 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 percent with an
  accuracy of +/- 3 percent. 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 percent 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 percent (non-condensing).
  The sensor shall have a maximum drift of 2 percent. 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 percent. The over pressure
rating shall be a minimum of 150 percent of the highest design pressure of
either input to the sensor. The accuracy shall be +/- 2 percent 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 percent 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)

   a. 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 AMFA 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.

   b. 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.**
****

   c. 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] [_____].

   d. 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 percent over a range of 2.5 to 12.5 m/s 500 to 2,500
fpm.

e. 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 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 percent 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
percent of the pipe inside diameter or 12.5 percent 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 percent 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 +/- 1 percent 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 +/- 2 percent of full flow and a repeatability of +/- 0.5
percent 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 +/- 1 percent of reading for
a minimum turndown ratio of 1:1 through a maximum turndown ratio of 50:1.
Repeatability shall be +/- 0.25 percent of reading. The meter flow sensing
element shall operate over a range suitable for the installed location with
a pressure loss limited to 1 percent 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 +/- 0.8 percent 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 +/- 2 percent 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 percent 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
percent. 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 percent 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 percent 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 percent 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 percent 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 percent error, while the 0.2 class allows 0.2 percent).
****

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

****

Current transducers shall accept an AC current input and shall have an
accuracy of +/- [0.5] [2] percent 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 percent 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 percent 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 percent of full scale in one second and a
linearity of 99 percent 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

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 percent value. Unit measurement
range shall not exceed specified range by more that 50 percent.
Repeatability shall be +/- 2 percent of full scale with an accuracy of +/-
3 percent 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 percent of setting with repeatability of plus or minus 2 percent.

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.
Field verify the ranges for particular applications and adjust the range as
required. [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
percent 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 percent 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 percent 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 percent of full scale and an
   accuracy of +/- 2 percent 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 percent of scale range.
Thermometers shall have a range suitable for the application with an upper
end of the range not to exceed 150 percent 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
percent 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 percent of the
design upper limit. Accuracy shall be +/- 3 percent 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 percent 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

  ****

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 in accordance with
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

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)

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 percent of full
scale, including linearity and hysteresis. The EP shall withstand
pressures at least 150 percent 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 percent 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

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 (*nci*s) 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   EXAMINATION

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

3.2   EXISTING CONDITIONS SURVEY

****
        NOTE: Use the bracketed text for retrofit projects

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 its impact on the Contractor's ability to meet this
specification. For those items considered nonfunctional, 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, define the scheduled need date for connection to existing
equipment.[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.]

3.3   CONTROL SYSTEM INSTALLATION

3.3.1   General Installation Requirements

3.3.1.1   HVAC Control System

The HVAC control system shall be completely installed, tested and ready for
operation. Provide dielectric isolation 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.

3.3.1.2   Device Mounting Criteria

Install all devices in accordance with manufacturer's recommendations and
as specified and shown. Provide control devices, to be installed in piping
and ductwork, 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. Install spare thermowells adjacent to each
thermowell containing a sensor and as shown. Devices located outdoors
shall have a weathershield.

3.3.1.3   Labels and Tags

Key labels and tags to the unique identifiers shown on the As-Built
drawings. Label all enclosures and DDC hardware. All sensors and
actuators in mechanical rooms shall be tagged. Tag airflow measurement
arrays 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, outside of protective enclosures, shall be
engraved plastic and mechanically attached to the enclosure or DDC
Hardware. Labels inside protective enclosures may attached using adhesive,
but shall not be hand written.

3.3.2   DDC Hardware

****

Install DDC hardware 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
[_____].

3.3.3   Local Display Panel (LDP)

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.

3.3.4   Gateways

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.

3.3.5   Network Interface Jack

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,
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. Furnish [one][_____]
interface cable(s).

3.3.6   Room Instrument Mounting

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.

3.3.7   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.

3.3.8   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][_____]. 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.

3.3.9   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.

3.3.10   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.

3.3.11   Averaging Temperature Sensing Elements

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

3.3.12   Air Flow Measurement Arrays (AFMA))

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].

3.3.13   Duct Static Pressure Sensors

The duct static pressure sensing tap shall be located at 75 percent to 100
percent 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.

3.3.14   Relative Humidity Sensors

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

3.3.15   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.

3.3.16   Dampers

3.3.16.1   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.

3.3.16.2   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.

3.3.17   Valves

3.3.17.1   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.

3.3.17.2   Butterfly Valves

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

3.3.18   Local Gauges for Actuators

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

3.3.19   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 in accordance with 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.]

3.3.20   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.

3.3.21   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.

3.3.22   Pneumatic Lines

   a. Install pneumatic lines 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.

   b. Install all tubes and tube bundles, exposed to view, 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.

   c. 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.

3.3.22.1   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.

3.3.22.2   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.

3.3.22.3   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.

3.3.22.4   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.

3.3.22.5   Connection to Ductwork

Connections to sensing elements in ductwork shall be plastic tubing.

3.3.22.6   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.

3.3.22.7   Tubing Connection to Actuators

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

3.3.23   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.**
****

Mount the air compressor assembly on vibration eliminators, in accordance with ASME BPVC SEC VIII D1 for tank clearance. Connect the air line to the tank with a flexible pipe connector. Install compressed air station specialties 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. Provide foundations and housekeeping pads 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].

3.4   HVAC SYSTEMS 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).**
****

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   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).
****

3.4.2.1   All-Air Small Package Unitary System

****
NOTE: For heating-only or cooling-only systems,

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).

3.4.2.2   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 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

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

        (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

SECTION 23 09 23 Page 68

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.]

3.4.2.3   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. EEdit the Control Logic Diagram and Points Schedule to indicate which reset method is to 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.**
****

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].

3.4.2.4   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 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

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.

3.4.2.5   Single Zone with Heating and 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) 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 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.**
****

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.

3.4.2.6   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 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.**
****

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 percent 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 percent relative humidity, at which point the humidifier valve shall be fully closed. When this loop is disabled, the humidifier valve shall be closed.

3.4.2.7   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 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.**
****

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 follow 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.

3.4.2.8   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 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.
****

    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 follow 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.

3.4.2.9   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 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.**
****

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 percent
>   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 percent
     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.]

3.4.3   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).**
****

3.4.3.1   Zone Temperature Control – Cooling-Only VAV Box

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.

3.4.3.2   Zone Temperature Control – VAV Box with Reheat

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.

3.4.3.3   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.**
****

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.

3.4.3.4   Perimeter Radiation Control Sequence

****

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.

3.4.3.5   Unit Heater and Cabinet Unit Heater

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.

3.4.3.6   Gas-Fired Infrared Heater

**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.**
****

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.

3.4.3.7   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.
****

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.

3.4.4   Operation for Hydronic Systems

3.4.4.1   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.
****

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.

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.

3.4.4.2   Heating Hot Water From Single-Building Boiler

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.

3.4.4.3   Dual-Temperature System

****
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.
****

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 (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 degreesF.

(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.]

3.4.4.4   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.
****

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. Proofs 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

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. 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

Perform the following startup tests for each control system to ensure that
the described control system components are installed and functioning in
accordance with this specification.

   a.   General: 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;

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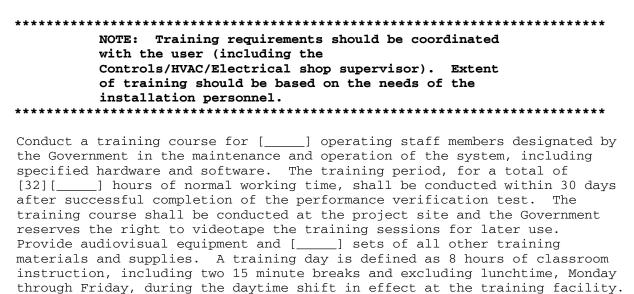   NOTE: If the specification has been edited to
         include M&C Software (from Section 25 10 10),
         include the requirement to inspect M&C Clients to
         make sure they display shutdown conditions.
****

      (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.

d. Test Report: Upon completion of the Start-Up Test, 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 in accordance with this specification, and is ready for the
Performance Verification Test (PVT).

3.7   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.
****

Conduct a training course 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.
Provide audiovisual equipment and [_____] sets of all other training
materials and supplies. 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.

3.7.1   Training Documentation

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

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.

3.7.2   Training Course Content

For guidance in planning the required instruction, 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.

3.8   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.
****

3.8.1   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.

3.8.2   PVT Execution

Demonstrate compliance of the control system with the contract documents.
Using test plans and procedures approved by the Government, 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 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.

3.8.3   PVT Report

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.

3.9   APPENDIX A

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.

<u>QC CHECKLIST</u>
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 --