ERDC/CERL TR-17-15

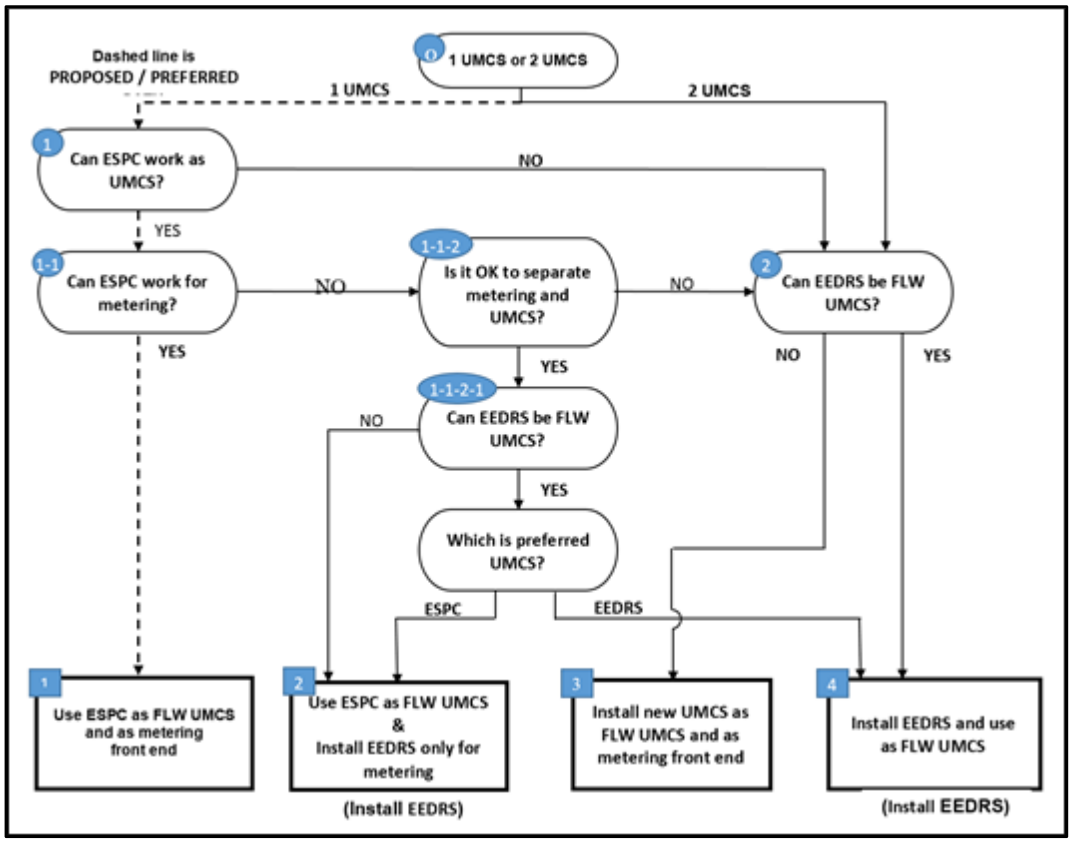
US Army Corps of Engineers®
Engineer Research and Development Center

ERDC
INNOVATIVE SOLUTIONS for a safer, better world

Utility Monitoring and Control System (UMCS) and Utility Metering Plan and Specifications for Fort Leonard Wood, MO

David M. Schwenk, Dave M. Underwood, Joseph Bush, Brian Clark, Tapan Patel, Annette L. Stumpf, and Susan J. Bevelheimer

June 2017



Construction Engineering Research Laboratory

Approved for public release; distribution is unlimited.

The U.S. Army Engineer Research and Development Center (ERDC) solves the nation's toughest engineering and environmental challenges. ERDC develops innovative solutions in civil and military engineering, geospatial sciences, water resources, and environmental sciences for the Army, the Department of Defense, civilian agencies, and our nation's public good. Find out more at www.erdc.usace.army.mil.

To search for other technical reports published by ERDC, visit the ERDC online library at http://acwc.sdp.sirsi.net/client/default.

ERDC/CERL TR-17-15
June 2017

Utility Monitoring and Control System (UMCS) and Utility Metering Plan and Specifications for Fort Leonard Wood, MO

David M. Schwenk, Dave M. Underwood, Joseph Bush, Brian Clark, Tapan Patel, Annette L. Stumpf, and Susan J. Bevelheimer

U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
2902 Newmark Dr.
Champaign, IL 61824

Final Report

Approved for public release; distribution is unlimited.

Prepared for U.S. Army Garrison Fort Leonard Wood, MO

Under MIPR 10768675, “Energy Investigations for Fort Leonard Wood, MO”

Abstract

Fort Leonard Wood, MO, has two separate Utility Monitoring and Control Systems (UMCSs) that remotely monitor and supervise hundreds of building control systems. The garrison is currently considering whether it would best to merge the two existing systems into a single, integrated UMCS. However, coordinating the operation of these separate systems is a significant issue that will affect the garrison's decision on how to move forward. This work reviewed and analyzed the installation's building automation technology, related industry standards, utility metering requirements, and market trends, and made specific recommendations to outline a path forward to configure a single installation-wide UMCS with a front-end that provides DPW access to perform supervisory monitoring and control functions including access to utility metering data.

DISCLAIMER: The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products. All product names and trademarks cited are the property of their respective owners. The findings of this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

DESTROY THIS REPORT WHEN NO LONGER NEEDED. DO NOT RETURN IT TO THE ORIGINATOR.

Executive Summary

Fort Leonard Wood, MO, has two separate Utility Monitoring and Control Systems (UMCSs) that remotely (from on-installation locations) monitor and supervise hundreds of building control systems (BCSs). The garrison is currently considering whether to install a third UMCS dedicated to electrical metering, or to connect all new metering to an existing UMCS. A further consideration is whether the garrison would best be served by merging the two existing systems into a single UMCS, which could then be configured to accommodate utility metering as well, in a single, integrated UMCS.

However, as currently configured, the Fort Leonard Wood UMCS front-ends operate at different levels of functionality. Coordinating the operation of these separate systems is a significant issue that will affect Fort Leonard Wood's decision on how to move forward. This work was undertaken to review and analyze the installation's building automation technology, related industry standards, utility metering requirements, and market trends, and to recommend a path forward that provides a single installation-wide UMCS with a front-end that provides DPW access to perform supervisory monitoring and control functions including access to utility metering data. To that end, this work recommends that Fort Leonard Wood:

1. Select a single UMCS with which to move forward. This work recommends the Honeywell UMCS as the best choice. The existing Government UMCS components should be combined into the Honeywell UMCS, where desirable and applicable; otherwise, the Government UMCS should be allowed to live out its useful life as is, while *new* BCSs are added to the Honeywell UMCS.
2. Continue to specify and procure BCSs in the same competitive procurement manner as done historically, but using the updated Unified Facility Guide Specifications (UFGS) tailored to Fort Leonard Wood as part of this project, i.e., UFGS 23 09 00, UFGS 23 09 13, and UFGS 23 09 23.01. Use UFGS 23 09 93 (HVAC Control Sequences) as specifiers deem appropriate.
3. Integrate future, and (where applicable) existing BCSs into the existing Honeywell UMCS using the updated UMCS UFGS 25 10 10 tailored to Fort Leonard Wood as part of this project.
4. Identify a procurement mechanism to use UFGS 25 10 10 for BCS integration. This can be challenging because it may require providing "sole

source" to Honeywell if the scope of the project is limited to integrating the systems. Where a project, such as Military Construction (MILCON), includes the integration of a BCS and UMCS, the BCS, UFGSs, and UMCS UFGS can be used together and bidders will need to engage with Honeywell to accomplish the integration portion of the project. A non-sole-source path could be taken to continue to expand the Government UMCS, which has the disadvantages described in this report.

5. Consolidate utility metering under a single umbrella by making all future metering part of the selected/adopted UMCS. It is *not* recommended to use a separate UMCS dedicated solely to metering (i.e., do not use an Enterprise Energy Data Reporting Systems [EEDRS] server dedicated to metering). Huntsville should use the Honeywell UMCS to pass metering data to the Meter Data Management System (MDMS).
6. Specify and install all future metering using the requirements defined in UFGS 23 09 13, which were updated and tailored to Fort Leonard Wood as part of this project.
7. Continue to urge Honeywell and the Fort Leonard Wood Network Enterprise Center (NEC) to obtain full UMCS connectivity and to provide the Fort Leonard Wood DPW with a user interface (i.e., Enterprise Buildings Integrator (EBI)/Honeywell Energy Manager [HEM] as described herein).
8. Consider the garrison's ability and means to staff and support a UMCS, both over the near term, and also with the eventual government ownership of the Honeywell UMCS when the Energy Savings Performance Contract (ESPC) period expires in October 2025.
9. Address staffing shortages, in particular recently eliminated DPW UMCS Manager position, which is critically needed to ensure the success of this project, and which should be reinstated.
10. Prepare for possible future transition (from LonWorks, currently used at Fort Leonard Wood) to a different industry-standard communications protocol such as BACnet. Adopting the Honeywell UMCS or any of the other UMCS options presented in this report will allow Fort Leonard Wood to support BACnet or LonWorks.

Contents

Abstract ii

Executive Summary iii

Figures and Tables vii

Preface viii

1 Introduction 1

1.1 Background 1
1.2 Objectives 1
1.3 Approach 2
1.4 Scope 3
1.5 Mode of technology transfer 3

2 Overview: The Challenge 4

3 UMCS – Current 5

3.1 UMCS definitions 5
3.2 Government UMCS 6
3.3 Honeywell UMCS 8

4 Utility Metering - Current 14

4.1 Laclede electric meters 14
4.2 Omega Pipeline gas meters 15
4.3 Honeywell electric and gas meters 15
4.4 Manual electric meters 16

5 Path Forward 17

5.1 Technology considerations 17
5.2 UMCS – options overview. 18
5.3 UMCS – Option 1 (recommended) 21
5.3.1 Summary *21*
5.3.2 Description *21*
5.3.3 Considerations *21*
5.4 UMCS – Option 2 25
5.4.1 Summary *25*
5.4.2 Description *25*
5.5 UMCS – Option 3 29
5.5.1 Summary *29*
5.5.2 Description *29*
5.6 Metering 30
5.7 Contracting 31
5.8 Procurement Options 32
5.9 Staffing 33

5.10 Cybersecurity....36
5.11 Training....36

6 Specifications: Tailored to Fort Leonard Wood....38
6.1 Tailored specifications....38
6.2 UFGS update process....39

7 Scopes: For Project-Specific Energy Conservation Measure....40

Appendix A: National Defense Authorization Act (NDAA 2010) Section 2841....42

Appendix B: Honeywell UMCS/Information Assurance Access Needs (30 March 2016)....43

Appendix C: Honeywell Information Assurance Access (Conference Call Notes)....45

Appendix D: FLW Advanced Metering Installation Status (Conference Call Notes)....49

Appendix E: Fort Leonard Wood Advanced UMCS/Metering Options (for Decision Meeting December 2016)....51

Appendix F: Fort Leonard Wood Advanced Metering Installation Status (Conference Call Notes, December 2016)....55

Appendix G: UMCS Staffing....60

Appendix H: HVAC Controls Summary of Work....68

Appendix I: ECM Scope - FPT (Test Procedures)....78

Appendix J: Electric Metering – Products....146

Appendix K: UFGS – 23 09 00 (Tailored to Fort Leonard Wood): Instrumentation and Control for HVAC....155

Appendix L: Insert: UFGS - 23 09 13 (Tailored to Fort Leonard Wood): Instrumentation & Control Devices for HVAC....193

Appendix M: Insert: UFGS - 23 09 23.01 (tailored to Fort Leonard Wood): LonWorks DDC for HVAC and Other Building Control Systems....253

Appendix N: Insert: UFGS - 23 09 93 (tailored to Fort Leonard Wood): Sequences of Operation for HVAC Control....269

Appendix O: Insert: UFGS - 25 10 10 (tailored to Fort Leonard Wood): Utility Monitoring and Control System (UMCS) Front-End and Integration....317

Acronyms and Abbreviations....346

Report Documentation Page (SF 298)....349

Figures and Tables

Figures

1 Smart server 6
2 Government UMCS 7
3 Honeywell UMCS 9
4 Honeywell EBI opening screen 11
5 Honeywell EBI example screen: “SouthWest” area 11
6 Honeywell EBI example screen: “Building 5074” (Typical clickable radio buttons) 12
7 Honeywell EBI “Building 5074” (Typical clickable radio buttons) 12
8 Honeywell EBI “Building 5074” (Typical AHU) 13
9 Current metering systems 14

Tables

1 Meter type and ownership 14
2 UMCS options 19
3 UMCS Options – Other cost considerations 20
4 Government UMCS support staff estimates (for 226 buildings) 35
5 Unified Facilities Guide Specifications 38
6 Building list and project-specific ECMs (excerpted from Fort Leonard Wood Section 01010) 41

Preface

This study was conducted for the Plans, Analysis, and Integration Office (PAIO) at U.S. Army Garrison Fort Leonard Wood under Military Interdepartmental Purchase Request (MIPR) No. 10768675, "Energy Investigations for Fort Leonard Wood, MO," dated 26 September 2014. The technical monitor was Bryan Parker, Director, Fort Leonard Wood PAIO.

The work was managed and executed by the Engineering Process Branch (CFN) and the Energy Branch (CFE) of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL), Engineer Research and Development Center (ERDC). The CERL project managers were Annette Stumpf and Susan Bevelheimer. Special appreciation is owed to Fort Leonard Wood DPW and other local points of contact along with the Corps Kansas City District for providing information that was invaluable to this work. Several of these individuals include: Alan Simpson, Lee Criswell, Jabe Moore, Jeannie Belew, Paul Schonenberger, Bill McDaniel, Joe Gillardi, Greg Posten, Shelia Collins, Deborah Dowling, Penny Forsythe, Bill McDaniel, and Mark Premont of Fort Leonard Wood; and Kevin Palmer of the Center for Sustainable Solutions. At the time of publication, the Chief of the Engineering Processes Branch was Chuck Schroeder (CEERD-CFN), the Chief of the Energy Branch was Andrew Nelson (CEERD-CFE), the Chief of the Facilities Division was Donald Hicks (CEERD-CF), and the Technical Director for Installations was Kurt Kinnevan (CEERD-CZT). The Deputy Director of ERDC-CERL was Dr. Kirankumar Topudurti and the Director is Dr. Ilker R. Adiguzel.

COL Bryan S. Green was Commander of ERDC, and Dr. David W. Pittman was the Director.

1 Introduction

1.1 Background

Fort Leonard Wood, MO has a great deal of building control system (BCS) infrastructure with microprocessor based direct digital control (DDC) hardware and supporting communications networks. Fort Leonard Wood also has two separate UMCSs, which are used to remotely (from on-installation locations) monitor and supervise hundreds of BCSs. Although the UMCSs have evolved over the years, both are based on industry-standard LonWorks© open-communications protocol technology, and to date, both have served their purposes well. Their sophisticated modern control functions help the garrison to readily access, monitor, and supervise a multitude of subsystems to both save energy and meet the installation's operational needs.

The garrison is currently considering whether to install a third UMCS dedicated to utility metering, or to connect all new metering to an existing UMCS. A further consideration is whether the garrison would best be served by merging the two existing systems into a single UMCS, which could then be configured to accommodate utility metering as well, in a single, integrated UMCS.

However, as currently configured, the Fort Leonard Wood UMCS front-ends operate at different levels of functionality. Coordinating the operation of these separate systems is a significant issue that will affect Fort Leonard Wood's decision on how to move forward. This work was undertaken to review and analyze the installation's building automation technology, related industry standards, utility metering requirements, and market trends, and to recommend a path forward that provides a single installation-wide UMCS with a front-end that provides DPW access to perform supervisory monitoring and control functions including access to utility metering data.

1.2 Objectives

The overall objective of this work was to review and analyze Fort Leonard Wood's building automation technology, related industry standards, utility

metering requirements, and market trends, and to recommend a path forward that provides a single installation-wide UMCS with a front-end that provides DPW access to perform supervisory monitoring and control functions including access to utility metering data. Achieving this broad objective will require an update of the garrison's long-term vision, plans, and specifications.

Specific objectives of this work were to outline a path forward that provides a single installation-wide UMCS that :

- includes a front-end that gives DPW access to perform supervisory monitoring and control functions including access to utility metering data
- supports the DPW and U.S. Army Corps of Engineers (USACE) District's ongoing philosophy of using open/non-proprietary BCS technologies with minimal (or no) sole source procurement
- maintains compatibility with existing infrastructure (as much so as possible), mainly including LonWorks communications protocol technology
- maintains compatibility with DoD UFGS criteria
- supports other, future anticipated technologies such as utility metering, lighting controls, and possible future use of BACnet communication protocol technology
- accommodates a simplified support structure (to minimize additional burdens on Contracting, Staffing/Operations and Maintenance [O&M], etc.).

1.3 Approach

The objectives of this work were completed through the following steps:

1. Site surveys and interviews were conducted to review and analyze the installation's building automation technology and operation.
2. DPW and USACE NWK Specifications and standards were reviewed and analyzed.
3. Existing industry and USACE building automation system standards and specifications were reviewed and analyzed.
4. Draft (preliminary) findings were compiled and presented at Integrated Strategic and Sustainability Plan (ISSP) Quarterly Meetings, through conference calls, and via Dr. Checks.
5. Conclusions were drawn and recommendations made regarding the optimal path forward to achieve a single installation-wide UMCS at Fort Leonard Wood.

1.4 Scope

This project focused specifically on the DPW's awareness of advances in technology, on a review of the current technology, and on the creation of a plan and updated BCS and UMCS specifications at Fort Leonard Wood, MO. Nevertheless, similar analyses could be replicated at other sites by considering the unique aspects of each installation's BCSs and UMCSs, and by modifying specific lines of inquiry, surveys, and interviews to suit their unique aspects.

1.5 Mode of technology transfer

This results of this work will be delivered directly to the Fort Leonard Wood DPW.

2 Overview: The Challenge

Although the Fort Leonard Wood BCS/UMCS infrastructure has served the garrison well, it has some limitations and has evolved to a point where some long-term planning is needed. The primary factors necessitating a plan are that:

1. Fort Leonard Wood has two large, but separate, UMCSs (the "Government" UMCS and the "Honeywell" UMCS). Consideration should be given to merging the two in a single, installation-wide UMCS.
    a. The "Government" UMCS consists of approximately 226 buildings where building-level control systems are procured on a project-by-project basis. The winning bid contractor installs the controls along with a web server to provide graphics pages serving as an operator interface accessible via Universal Resource Locator (URL). Each web server is a separate entity, and is not linked to the other (approximately 226) web servers. The standalone quality of the system makes it impossible tp perform coordinated/global functions from a common interface. Since the web server (and its web pages) is provided by the BCS contractor, and since different contractors structure their graphics differently, these systems have no consistent "look-and-feel" across user interfaces.
    b. The "Honeywell" UMCS consists of approximately 180 buildings (in most cases only a small portion of a building, as further described later) and was procured under a U.S. Department of Energy (DOE) ESPC. In contrast to the Government UMCS, the Honeywell UMCS does have a single front-end user interface software: "EBI." EBI provides a single interface to multiple buildings and can perform global functions from a single interface across such various BCSs as: equipment on/off and occupancy scheduling, management/tracking of alarms, and viewing performance (trend) data from multiple buildings on a common screen display.
2. Evolving technology and new DoD specifications warrant an update to the garrison's BCS specifications including those used by the District to support the garrison.
3. Utility metering (gas, electric, water) is an important capability with high visibility and interest. Currently, a number of different methods are used to read/monitor the various existing meters. There is a need for a single, consistent system that can provide a path forward that grants consistent, ready access to meter data.

3 UMCS – Current

3.1 UMCS definitions

A UMCS is a system consisting of one or more BCSs and a front-end supervisory interface. Each local BCS can perform its primary control functions without relying on the UMCS front-end; however, the BCS does rely on the front-end to perform supervisory functions. The front-end consists of a computer interface, usually remotely located, which provides access through an Internet Protocol (IP) network. It uses UMCS Monitoring and Control (M&C) software, usually with a browser-based user interface, to perform supervisory functions such as:

- graphic display of connected BCSs
- on/off scheduling of equipment and occupancy scheduling
- alarm generation and routing
- collection and storage of performance data (temperatures, equipment status, etc.).

Fort Leonard Wood has an extensive BCS and UMCS infrastructure based on LonWorks© technology, including the use of LonWorks Network Services (LNS©). LonWorks© is a technology based on a standard communications protocol, CEA-709.1, which allows different manufacturers devices (controllers, meters, etc.) to reside on the same communications cable and communicate using the CEA-709.1 protocol. The protocol extends to standard IP-based communications using the CEA-852 protocol. LNS© is a "network operating system" that provides a standard for configuration and management of a control system.

There are two basic UMCS systems at Fort Leonard Wood: Government and Honeywell. There are other less extensive UMCSs, e.g., a Plexus (brand) system, but this work considers only these two principal UMCSs for their significant size and generally predominant usage.

The infrastructure includes hundreds of Echelon (brand) SmartServers* (Figure 1), generally one SmartServer per building, to provide connection

* Note that other devices comparable to the Echelon brand Smart Server are commercially available. Fort Leonard Wood contractors provide the Echelon brand device for consistency.

between the BCS and the IP network. There are two basic SmartServer configurations:

1. As a *Router*, which serves as a (BCS) control protocol router using the CEA-852 protocol to transmit CEA-709.1 data packets over the IP network. This device serves as both a media converter between the building control network (BCN) and the IP network, and as control protocol router (not an IP router) to filter the data that is passed between the BCN and IP network. This is the configuration used in the Honeywell UMCS.
2. As a *Web Server*, which serves up web pages that are accessible via URL. The webpages display control system graphics. SmartServers used by the DPW UMCS are configured as web servers.

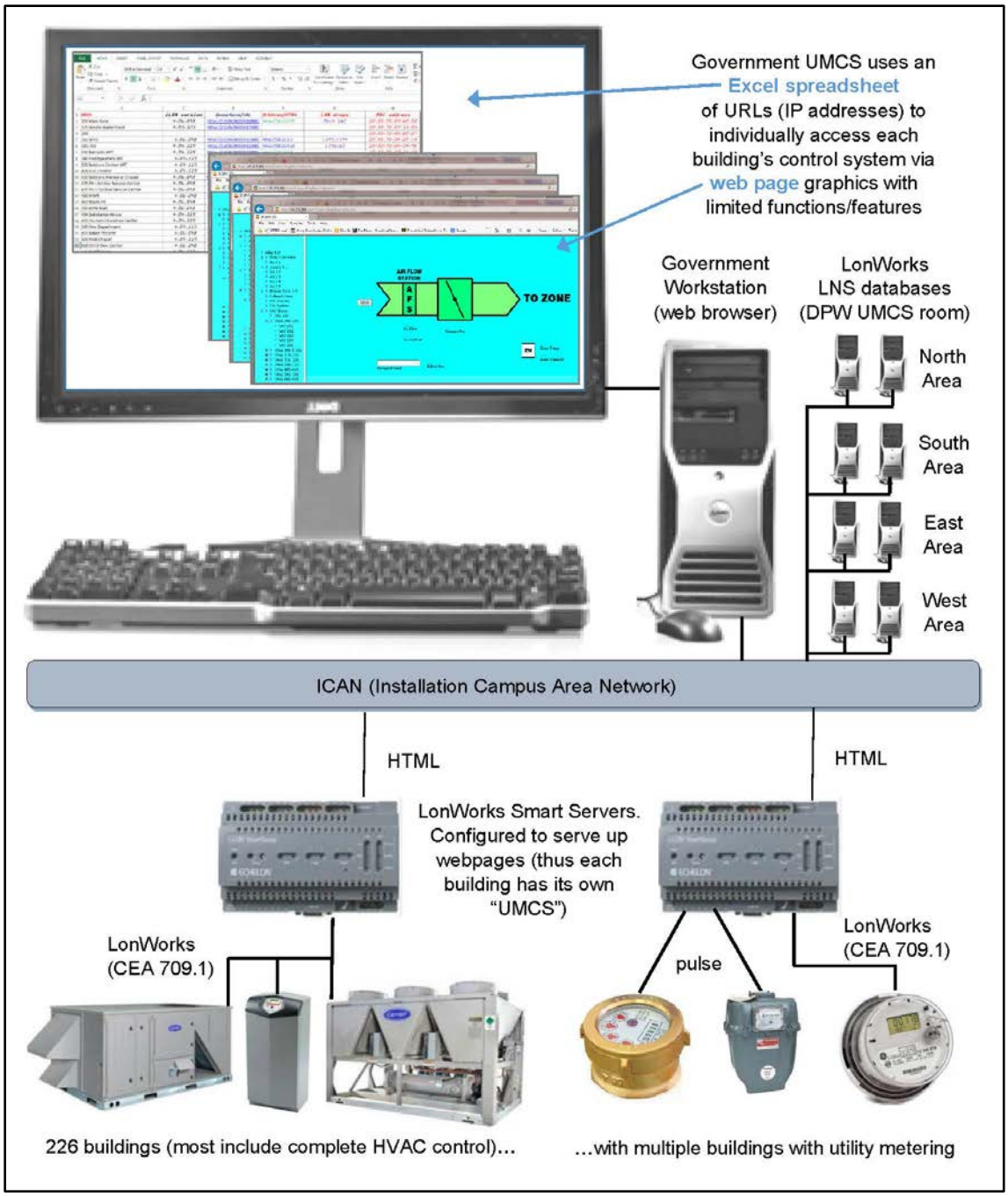
Figure 1. Smart server.

3.2 Government UMCS

Figure 2 shows the Government UMCS, which consists of about 226 buildings. Each building has a LonWorks BCS based on USACE-developed unified guide specifications. Use of the USACE guide specifications provides procurement competition and results in a multi-vendor open protocol system. The BCS in the 226 buildings is used almost exclusively for HVAC control, and for utility metering, but it is presently not used for lighting control or other automation.

Fort Leonard Wood modified the guide specifications to include a requirement for a local web server at each building. The desire to require the building-specific web server was to procure at least a degree of UMCS functionality without actually designating or procuring a complete UMCS front-end at the building level.

Figure 2. Government UMCS.



This approach allowed Fort Leonard Wood to procure local building controls with a degree of UMCS functionality, and to defer procurement of a front-end end supervisory UMCS. The web pages are initially created by the BCS contractor when the BCS is installed. The building-level SmartServers are accessed via URL using a basic/Off the Shelf (OTS) browser. The building automation systems (BAS)/UMCS manager has a

spreadsheet that contains the URL to each of the (226) buildings for ready access to each buildings webpage(s).

The Government UMCS includes a number of LonWorks LNS© databases, two for each of four geographic areas. Subdividing the databases helps Fort Leonard Wood manage the databases; the separate databases allow multiple contractors to work on the system with a reduced chance that more than one contractor will need access to the same database at the same time.

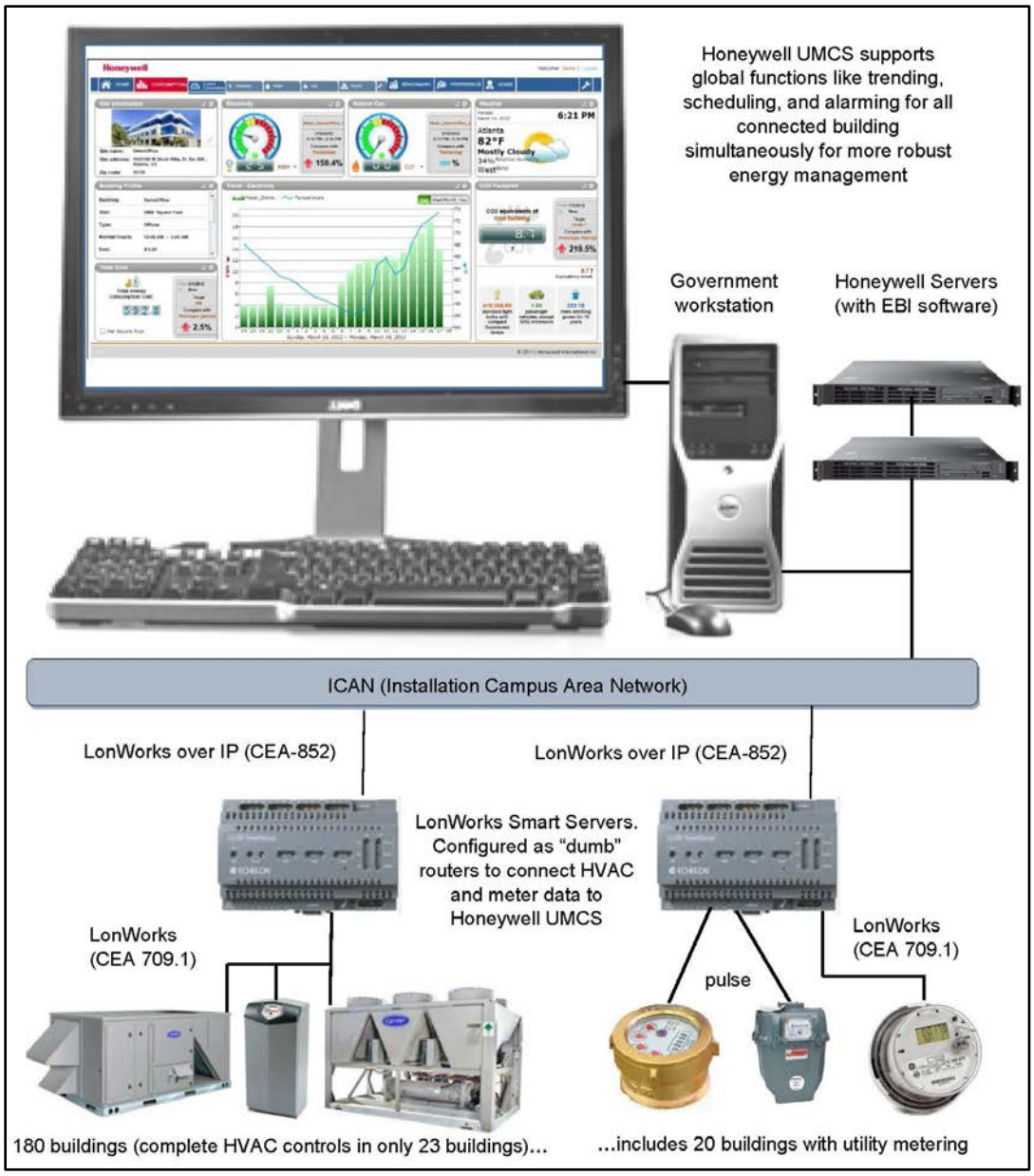
The Government UMCS is not really a single complete UMCS because there is no single coordinated M&C front-end interface. Instead, each building is essentially its own "single building UMCS" that functions as a standalone system; monitoring is done building-by-building via the SmartServer web page(s). As such, the Government UMCS cannot perform global functions. Instead supervisory functions, such as equipment scheduling must be done by accessing each web server individually.

The UMCS also cannot manage/log/track alarms from a single interface. For example, while each web server can issue alarms, the email address to which it sends alarms must be set in in each web server individually. By contrast, if a common interface were available, the email address could be created (or changed) in a single location instead of 200+ times at each of 200+ web servers. Similarly, trend data from two or more different buildings (SmartServers) cannot be readily logged/graphed together. In a consolidated interface, this task could be done by transferring the data to a spreadsheet such as Excel®. As currently configured, Fort Leonard Wood cannot, for example, view all of its buildings meter kWh (at the same time) or perform any HVAC operation; each building's data and interface must be accessed separately.

3.3 Honeywell UMCS

Figure 3 shows the Honeywell UMCS, which consists of about 180 buildings. In this UMCS, each building has a LonWorks BCS although, in some cases, the BCS does not include the entire building. (This is described further below.) Each BCS was installed as part of an ESPC contract. In general, the BCS consists of almost exclusively HVAC controls, although approximately 20 buildings also have Honeywell brand EMON/DMON electric and gas meters integrated into the BCS.

Figure 3. Honeywell UMCS.



The electric meters connect to the TP/FT-10* LonWorks network while the gas meters are picked up by Distech brand controllers that monitor gas meter pulse output signals. The Distech controllers are on the TP/FT-10 network.

* Twisted-Pair/Free Topology (TP/FT)

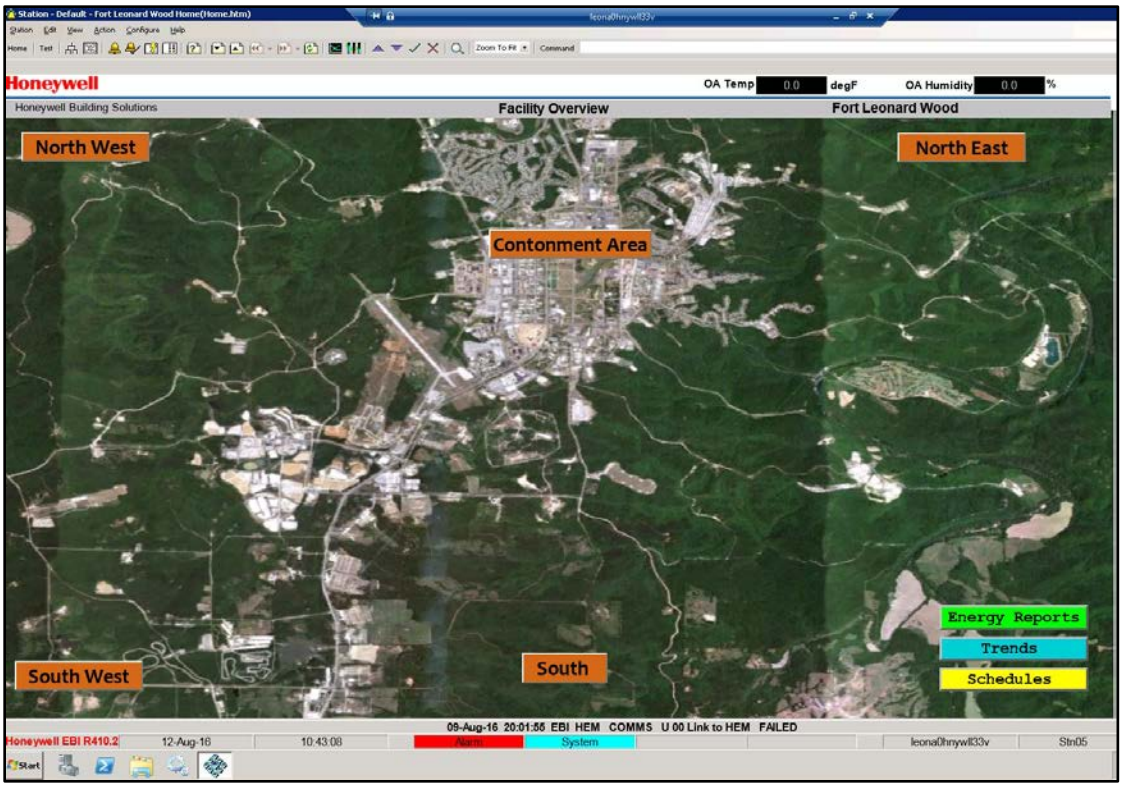
There are several ESPC scopes/contracts for the 180 buildings:

- Scope 1 (106 Buildings): Provide digital controls to enable and disable Air Handling Unit (AHU) supply and return fans, if present, based on occupancy schedules and optimum start/stop software. Push-button override is provided.
- Scope 2 (51 Buildings): Install a 7-day optimum start/stop programmable communicating thermostat with protected schedule and push-button occupant override.
- Scope "Pneu/DDC" (23 Buildings): Convert pneumatic (pneu) control system to LonWorks DDC hardware.
- The Honeywell UMCS meets the requirements of DoD Utility Monitoring Control System UFGS 25 10 10. It uses LNS©-based LonWorks and the front-end includes EBI and HEM software. Figures 4 to 8 show some example Honeywell EBI screens.

The system has an Authorization to Operate (ATO) that expires in 2016, but the NEC is working to have it renewed.

The system has had Installation Campus Area Network (ICAN) connectivity issues. The DPW, NEC, ERDC-CERL, and Honeywell worked to address the problems. Recent reports from Honeywell indicate progress is being made in working with the NEC, but the problems have not been entirely resolved. Appendix B includes a document developed by Honeywell, DPW, CERL, and NEC listing Honeywell Cybersecurity support needs. Additional information in the Cybersecurity section of this report.

Figure 4. Honeywell EBI opening screen.



(note: clicking "South West" button advances to next screen).

Figure 5. Honeywell EBI example screen: "SouthWest" area.

Figure 6. Honeywell EBI example screen: "Building 5074" (Typical clickable radio buttons).

Figure 7. Honeywell EBI "Building 5074" (Typical clickable radio buttons).

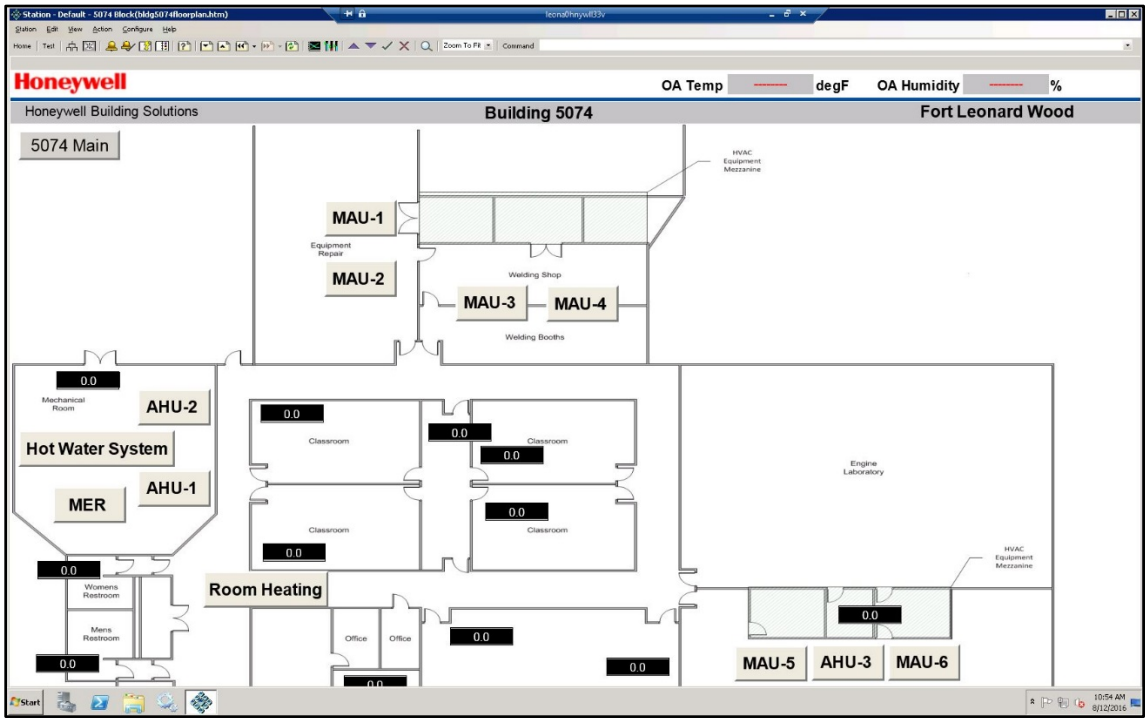
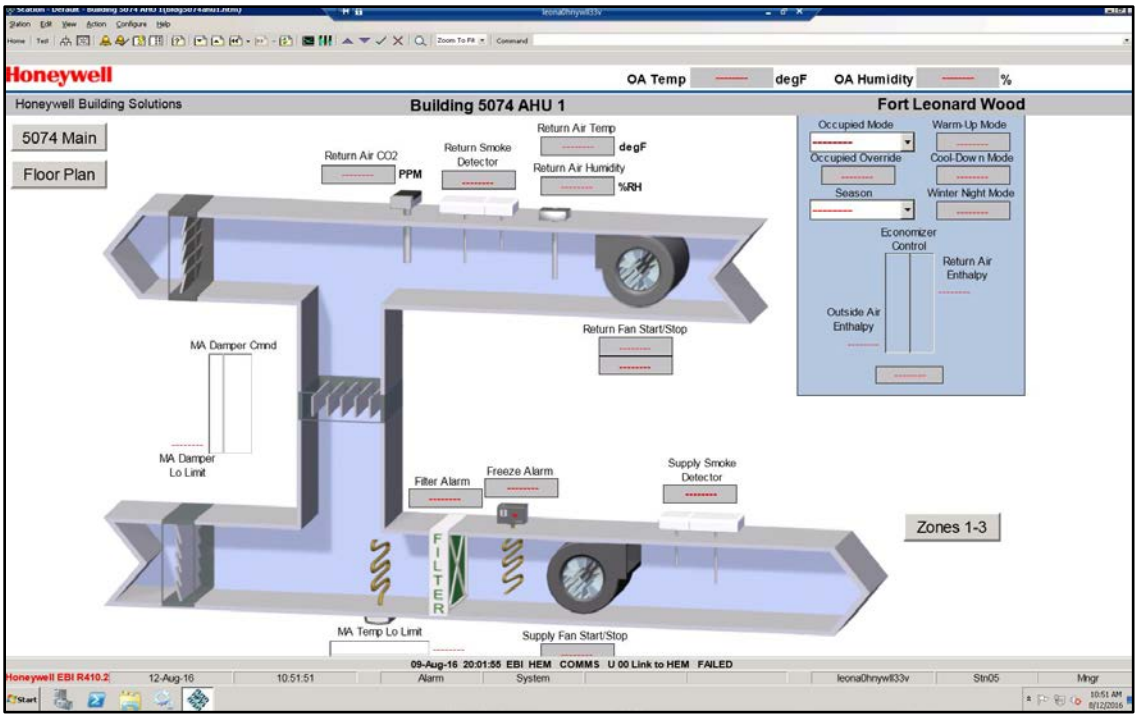


Figure 8. Honeywell EBI "Building 5074" (Typical AHU).



4 Utility Metering - Current

Fort Leonard Wood currently has approximately 1,000 total utility meters. (Note that all meter counts in this report are approximate). Data are collected using five different methods as described in Figure 9. Table 1 lists a breakdown of meter type and ownership, based on available information.

Figure 9. Current metering systems.

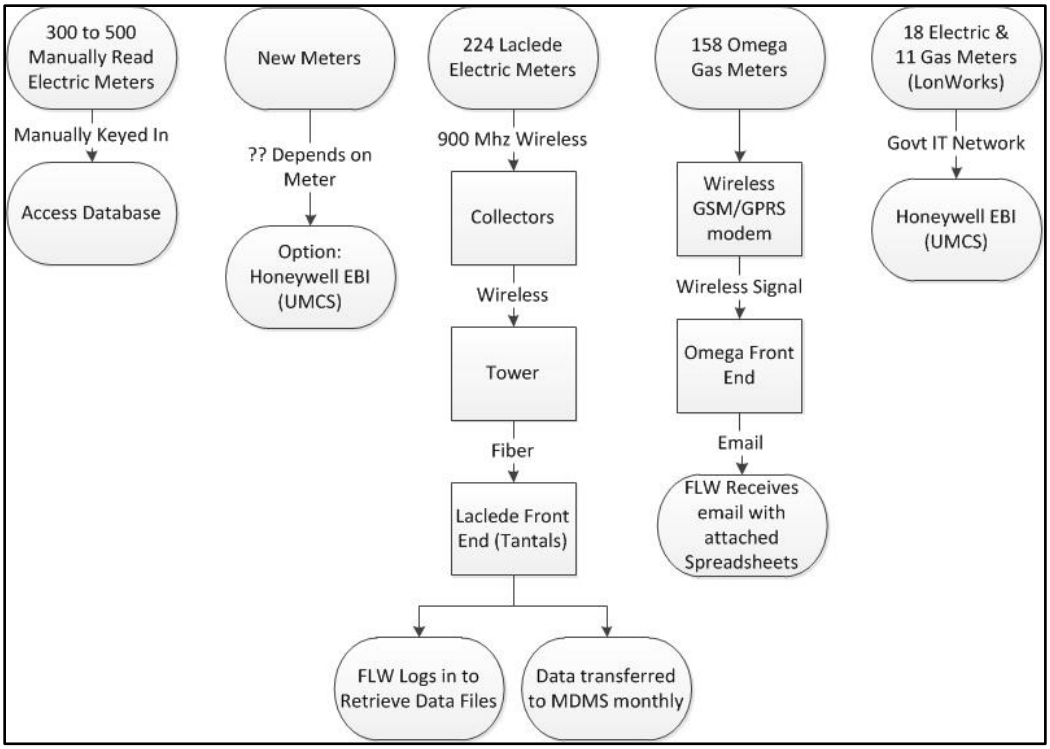


Table 1. Meter type and ownership.

	Electric						Gas				Water	
Type	Networked		Total	Manual		Total	Networked		Total	Manual	Networked	Standard
Count	224	18	242	500	44	544	158	11	169	32	0	12
Ownership	Laclede*	Honeywell		Laclede*	Gov't		Omega*	Honeywell		Omega*		Gov't
*Utility company.												

4.1 Laclede electric meters

Laclede collects data from approximately 224 networked electric meters. Meter data are transmitted via a mesh network on the unlicensed 900 MHz band via collectors to a tower, from where it is transmitted to Laclede's office in Lebanon via fiber. The information is processed from an extensible markup language (XML) schema into Laclede's database called

Tantalas. Fort Leonard Wood can log into this system to view and download data as a text file.

Laclede currently provides all meter data to the MDMS on a monthly basis as bulk data files. MDMS transfers the data to the MDMS website as part of the Army Metering Program (AMP).

An alternate means to monitor these meters via LonWorks BCS would be to add a pulse output. (The meters currently do not have a pulse output.) A Laclede representative expressed the opinion that, to get a pulse output from these smart meters, the current Advanced Metering Infrastructure (AMI) smart module would have to be removed. One problem is that many of these meters have been located at least 30 ft from the building, co-located with power transmission equipment, to meet force protection requirements. Connecting the meter to the BCS would require installing new communication wiring/cabling underground and routing it to the building. This would be both expensive and problematic due to the large number of unmarked underground utilities. It would be more practical to install a separate meter inside the building. Such a meter could be a LonWorks advanced meter connected to the BCS network, or it could provide a pulse output to a LonWorks controller, which in turn is connected to the BCS network.

4.2 Omega Pipeline gas meters

Omega collects data from approximately 158 networked gas meters. The information is transmitted by a wireless Global System for Mobile Communications/General Packet Radio Service (GSM/GPRS) modem to an Omega front-end via an email message that processes the messages into Excel® spreadsheet (*.xlsx) files. Fort Leonard Wood receives these monthly with hourly cumulative cubic feet readings for each meter. (Sometimes several months are combined into a single spreadsheet.) These meters also have a pulse output that could be read by the BCS. This requires a patch cable for the Omega gas meters to transmit the pulse output to a controller on the BCS, which is how Honeywell reads gas meters. With only a few exceptions, all gas meters are located very close to the building and the building has an existing BCS.

4.3 Honeywell electric and gas meters

The Honeywell control systems monitor approximately 11 gas and 18 electric meters via the LonWorks BCS connected to the Honeywell EBI UMCS

front-end. These meters are part of an ESPC project to verify energy savings for the ESPC measurement and verification requirement.

4.4 Manual electric meters

Approximately 300-500 electric meters are not networked. The meters are read manually with the readings keyed into an access database.

Electric meters that are currently read manually would require the addition of pulse output to the existing meter, or the installation of a new meter with either a pulse output or a LonWorks interface. Meters with pulse outputs will require connection to a controller to obtain data using the BCS network. Once meter data are available via the BCS, the meter can be integrated into the UMCS front-end.

5 Path Forward

The proposed path forward is to work to achieve a desired "end state," which includes a single installation-wide UMCS capable of performing supervisory M&C of all BCSs at Fort Leonard Wood. This end state is in keeping with the requirements of National Defense Authorization Act (NDAA) 2010 and 10 U.S. Code (USC) 2867,* and will facilitate cybersecurity as well as system operation.

This work has identified three options to achieve this end state, the primary focus of which is determine "what to do" with the two existing UMCS systems, whether to incorporate them into the new system, to replace them, or simply keep them "as is." The success of the selected option will be determined by its ability to function as the single system of the future, to accommodate subsequent growth, and to sustain the UMCS over time. Therefore, the following discussions of the various options also include consideration of contracting, staffing, and training.

5.1 Technology considerations

An overarching consideration is the future of the existing UMCS and BCS infrastructure at Fort Leonard Wood, which makes extensively use of LonWorks technology. The installation infrastructure has a large installed base of LonWorks controls and the staff has substantial experience and expertise with LonWorks. Nevertheless, LonWorks is one of two communications protocol technologies predominantly used in the HVAC industry, along with BACnet. Although LonWorks is expected to continue to be available and supportable for many years, BACnet seems to have more product development momentum.

Any proposed option must weigh the cost of changing to a new protocol (BACnet) against the risk that the old protocol (LonWorks) will not be supported by the industry at some time in the future. Fortunately, most UMCS M&C software that supports LonWorks, including the existing Honeywell EBI UMCS, also supports BACnet. This fact makes it relatively straightforward to pursue a "middle course," to continue with LonWorks

* 10 USC 2867 is an energy monitoring and utility control system requirement for military construction and military family housing activities calling for adoption of Department-wide, Open Protocol, Energy Monitoring and Utility Control System Specification. The origin of this is NDAA 2010, which added/included this language. See Appendix A to this report.)

as long as practical, but to lay some groundwork for transition to BACnet in the future should this be required.

Typical UMCS and BCS functions include HVAC control and utility metering. Other possible UMCS and BCS interfaces and functions that should be considered for implementation include lighting control, irrigation control, and advanced control strategies in accordance with American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standards 90.1 and 189.1. Note that a related CERL/Fort Leonard Wood effort underway at the installation consists of ASHRAE-defined control schemes including retrofit of existing systems to provide for improved controls strategies such as: duct static pressure reset (DSPR), single zone variable air volume (VAV), low-cost multizone AHU controls conversion to variable volume control, and CO_2 based demand-controlled ventilation (DCV).

5.2 UMCS – options overview.

Three UMCS options are described:

1. **Option 1.** (Recommended Approach) Adopt the existing Honeywell UMCS as the primary Fort Leonard Wood UMCS and begin the integration of all new/future BCS into this UMCS. Integrate existing systems that are part of the current Government UMCS into the Honeywell UMCS as practical to work toward an eventual state of a single installation-wide UMCS using the present Honeywell EBI UMCS as the foundation.
2. **Option 2.** Procure a new Government UMCS to serve as the single installation-wide system of the future and integrate all new/future BCS into the new Government UMCS. Integrate existing systems that are part of the current Government UMCS into the new UMCS as practical, and once the ESPC contract expires, begin to integrate the systems that are currently part of the Honeywell UMCS into the new Government UMCS.
3. **Option 3.** Maintain the status quo. Continue with a separate Honeywell UMCS and Government UMCS (consisting of multiple standalone single building systems), and determine on a case-by-case basis whether new/future BCSs should be integrated into the Honeywell UMCS, or be provided with a web server to become part of the Government UMCS.

Table 2 lists the parameters of each of these three options, side by side, for comparison, and Table 3 lists other cost considerations.

Table 2. UMCS options.

Parameter	Option 1 Honeywell UMCS (existing)	Option 2 New UMCS	Option 3 Government UMCS (existing)
Single UMCS Goal	Yes	Yes – but gradually (due to Honeywell ESPC)	No
Functionality	Excellent	Excellent	Almost acceptable
Time & Cost			
Cost above current cost	$7500 per bldg. integrated.	$7500 per bldg. integrated. Plus new UMCS initial procurement (~$250k)	None
Procurement of this option	Challenging (but MDMS is promising precedent)	OK	Not Applicable (N/A)
Competitive procurement for UMCS system integration (SI)	No.	Possible. But not likely	N/A
SI procurement mechanism	• Sole Source • Huntsville Center, Alabama (HNC) Indefinite Delivery/Indefinite Quantity (IDIQ) contract • ESPC	• Competitive contract • HNC IDIQ contract • ESPC	N/A
Competitive procurement for BCSs	Yes	Yes	Yes
UMCS front-end openness	Honeywell only (possibly someone else at end of ESPC but unlikely)	Other Contractors possible (but unlikely)	N/A
Contracting complexity/challenges	High (but ESPC has been beneficial)	High	Low
Cybersecurity	Has ATO	Will need ATO	No ATO. Tenant system. (for now)
Future/alternate technology support	Good (LonWorks & BACnet)	Good (LonWorks & BACnet)	Good (LonWorks & BACnet)
Utility metering support (MDMS)	Very Good (Need HEM on DPW computers)	Good, but waning	Not possible

Parameter	Option 1 Honeywell UMCS (existing)	Option 2 New UMCS	Option 3 Government UMCS (existing)
Staffing/Technical Support (UMCS)	Structure Exists. SI expertise exists with Honeywell.	Big challenge (Fort Leonard Wood UMCS Manager position recently eliminated). SI expertise not likely in DPW.	Big challenge (Fort Leonard Wood UMCS Manager position recently eliminated). SI expertise not needed.
Staffing/Technical Support (BCS)	Same as existing	Same as existing	Same as existing
Other	Under ESPC contract until October 2025	-	-

Table 3. UMCS Options – Other cost considerations.

Parameter	Option 1 Honeywell UMCS (existing)	Option 2* New UMCS	Option 3 Government UMCS (existing)
Optional Cost: Integrate existing Gov't UMCS bldgs.	$1.7M (226 Gov't UMCS bldgs.)	$1.7M (226 Gov't UMCS bldgs.)	N/A
Optional Cost: Integrate existing Honeywell UMCS bldgs.	$0.0 (180 Honeywell bldgs.)	$0.7M** (180 Honeywell bldgs.)	N/A
Optional Costs TOTAL:	$1.7M (406 bldgs.)	$2.4M (406 bldgs.)	N/A

* Option 2 costs do not include the cost to move Honeywell MDMS metering to New UMCS (~$0.250M); the opportunity to add this cost is available should this option be selected.

**Integration cost is $3,900 per bldg. (compared to $7,500) due to lesser scope per building (there are only simple thermostats and basic start/stop interfaces in many buildings)

In the short-term, this work proposes that Fort Leonard Wood should:

- continue to work with the two existing UMCS systems
- continue to work with Huntsville to use the Honeywell UMCS to meet the MDMS metering requirement
- use the UMCS system integration specification (UFGS 25 10 10) that has been new tailored to Fort Leonard Wood to integrate BCSs into the selected UMCS
- begin to migrate the individual building systems into the selected future UMCS using Fort Leonard Wood-tailored UFGSs (assuming Option 1 or 2)

- use the new DoD UFGS for all new BCS and metering systems (tailored to Fort Leonard Wood) including metering specifications added as part of this project.

Sequencing, various details, and a time frame for these proposed actions need to be defined.

5.3 UMCS – Option 1 (recommended)

5.3.1 Summary

In Option 1, Fort Leonard Wood would adopt the existing Honeywell UMCS as the future single installation-wide UMCS and integrate all future, and at least some existing, BCSs into this UMCS.

5.3.2 Description

If Option 1 is chosen, Fort Leonard Wood would use the Honeywell EBI UMCS as the primary Fort Leonard Wood UMCS. In addition to integrating all new systems to the UMCS (new construction, renovations, retrofits etc.), Fort Leonard Wood should consider merging systems that are part of the existing Government UMCS infrastructure (226 buildings) into the Honeywell UMCS (currently appx 180 buildings). This could entail a concerted integration effort, or an integration of "select" systems while operating the remaining ones independently until they reach end-of-life and are replaced (at which time they would be integrated into the Honeywell UMCS). Depending on contracting limitations and inefficiencies, new systems could either be integrated immediately, or the installation could continue to procure BCSs with local web servers, as they have historically, and operate those systems standalone until a sufficient number are ready to be grouped together for integration.

5.3.3 Considerations

5.3.3.1 Single UMCS goal and functionality

The selection of Option 1 would enable Fort Leonard Wood to take a big step toward creating a single installation-wide UMCS that would provide the benefits of a unified system not currently available with the current Government UMCS. Some of those benefits include:

- a common/single interface for O&M activities

- central control of on/off scheduling of equipment from a single interface/graphic display page
- alarm management/logging/tracking from a single interface/graphic page
- access to trend data from any point/meter from multiple buildings that can be readily logged/graphed together
- potentially, the provision of a common front-end for the existing government BCS systems (approximately 226 buildings) although it may be cost prohibitive to integrate all 226 buildings.

5.3.3.2 Time and cost

Option 1 provides a faster, lower cost path to a single installation-wide system than would Option 2. Option 1 would use existing staff and a defined working infrastructure on both the Honeywell and Government side (i.e., via the ESPC contract relationship), including NEC information assurance (IA) support. The estimated integration cost is $7500 per existing LonWorks building.

5.3.3.3 Procurement of this option

The Honeywell UMCS is part of an existing ESPC contract that does not expire until October 2025. Immediate or near term adoption of the Honeywell UMCS may be contractually challenging as it would require coordination with the requirements in the ESPC contract. At best, a modification to the ESPC or the addition of another contract to augment the ESPC would be required. At worst, mixing ESPC and "normal" buildings may prove to be contractually difficult (or even impossible), but Huntsville efforts and intent to connect MDMS metering (not part of an ESPC) as part of the AMP to the existing Honeywell UMCS suggests that it may be possible to mix contracting mechanisms.

Before proceeding with this option, Fort Leonard Wood would need to determine if it is contractually feasible to adopt the Honeywell UMCS outside the current ESPC contract requirements. If a contract mechanism is not feasible, the installation may be better served by implementing a new UMCS now (Option 2 discussed below), so that the Honeywell UMCS could persist "as is" until the ESPC contract expires October 2025, at which time the Honeywell UMCS becomes government property and could either be integrated into the Option 2 Fort Leonard Wood UMCS, or operated as a separate system as parts are replaced and integrated into the Fort

Leonard Wood UMCS. Caution must be exercised in either case since both Option 1 (Honeywell UMCS) and Option 2 (Fort Leonard Wood UMCS) are potentially subject to the same contractual problems.

5.3.3.4 Competitive procurement/mechanism for UMCS integration

From a technical standpoint, expanding the existing Honeywell UMCS to add new BCS can be fairly straightforward. However, the contracting mechanism to achieve this can be difficult. The installation of BCSs can be performed by non-Honeywell contractors (via MILCON or in-house contract), but integration into the Honeywell front-end would need to be performed by Honeywell. New BCSs can be procured and installed similarly to how they are installed now as "Government UMCSs," without integration, after which multiple Government UMCS buildings may be bundled up and integrated as a group using a mechanism such as ESPC or Huntsville Indefinite Delivery/Indefinite Quantity (IDIQ) through the Huntsville UMCS Mandatory Center of Expertise (MCX).

The compatibility of the existing LonWorks-based government infrastructure will allow the existing government BCS infrastructure (approximately 226 buildings) to be integrated into the Honeywell UMCS. However, it will not be a "plug and play" integration. The systems will have to be added to the Honeywell front-end database; new graphic displays will have to be created; and supervisory functions will have to be configured.

While some of the operational functions of the UMCS under the ESPC may be extended to readily integrate existing buildings to the Honeywell UMCS, this may not be true for all buildings and operational functions; compatible integration may involve a degree of complexity and cost. The cost to integrate all 226 buildings can be significant if not prohibitive — on the order of $1.7 million, or approximately $7500/building. (This estimate factors in some economy of scale, and might be optimistic.) If Option 1 is chosen, Fort Leonard Wood will need to select and prioritize the integration of buildings now part of the current "Government UMCS" into the Honeywell UMCS.

5.3.3.5 Competitive procurement for BCS

The installation, renovation, update, or repair of BCSs can be performed by contractors on a competitive bid basis. The Honeywell UMCS (EBI) supports connectivity to different types of BCSs. It currently uses LNS©-

based LonWorks and can also support BACnet should the garrison decide to use this protocol or to move in this direction in the future.

5.3.3.6 Cybersecurity

The Honeywell UMCS has an ATO on the ICAN. This is a significant time and cost savings benefit. Unfortunately the UMCS is not currently accessible over the ICAN. This is discussed more below in paragraph 5.10 Cybersecurity.

5.3.3.7 Future/alternate technology support

The existing Honeywell UMCS can support BACnet communications protocol technology should the garrison decide to use this protocol or move this direction in the future. EBI is BTL*-listed as a BACnet Advanced Workstation (B-AWS) as called for in UFGS 25 10 10 Guide Specification.

5.3.3.8 Utility metering support

The Honeywell UMCS can support the AMP metering requirement and pass Fort Leonard Wood meter data to MDMS. The meter data obtained locally by the Honeywell UMCS can be processed and analyzed by the UMCS HEM software where HEM software data processing capability is superior to data remotely accessed from the MDMS website. Using the Honeywell UMCS and *not* an EEDRS server dedicated to only perform metering (as is usually done as part of MDMS metering installations) will result in one less server to maintain/support. It is therefore preferable to connect the meters to the Honeywell UMCS instead of an EEDRS server. Fort Leonard Wood should insist that meter data be accessible to the installation via HEM. Adding subsequent/future MDMS and non-MDMS meters can be a challenging task. The need to add meters can be recurring and frequent. This can cause a need for frequent contract modifications, which may be impractical unless a more elegant contracting solution can be identified.

5.3.3.9 Staffing

Honeywell currently has a full-time staff member on site as part of an existing ESPC contract. The contracted staff person is referred to as the Technical Resource Manager (TRM). The TRM performs multiple

* BACnet Testing Laboratories

roles/duties including UMCS Operator and at least some of UMCS Manager duties. The Honeywell TRM is familiar with the Fort Leonard Wood infrastructure, HVAC systems, personnel, policies, and procedures. The TRM is a very valuable and needed asset to help support the UMCS since Fort Leonard Wood otherwise has little UMCS support due to government in-house staffing limitations. Adoption of the Honeywell UMCS can reduce the overall Fort Leonard Wood UMCS management workload if the TRM absorbs at least some of the UMCS Operator and manager duties performed by the Government UMCS manager. Note that Fort Leonard Wood will still need a UMCS Manager to perform duties that only a government employee can do.

5.3.3.10 Technical support

If the Honeywell UMCS is adopted, Honeywell should provide day-to-day operation of the UMCS, and it should also provide DPW Energy Branch and Tsay/Ferguson-Williams (TFW)* with access to the EBI and HEM graphics/interface. Consideration should be given to the degree of access that should be given to DPW and TFW operators, e.g., full edit/override capability versus display/read only, particularly with regards to the systems that Honeywell is responsible for ("owns") under the ESPC. It may be necessary to delineate duties to distinguish responsibilities of Honeywell, DPW, and TFW. This may entail modification of the TFW contract. Appendix G includes a list and basic description of duties.

5.4 UMCS – Option 2

5.4.1 Summary

In Option 2, Fort Leonard Wood would procure a new Government UMCS to serve as the single installation-wide system of the future and integrate all new/future BCS into the new Government UMCS.

5.4.2 Description

If Option 2 is chosen, Fort Leonard Wood would procure a new UMCS as the primary installation UMCS. As with Option 1 described above, in addition to integrating all new systems to the UMCS (new construction, renovations, retrofits etc.), Fort Leonard Wood would consider merging systems that are part of the existing Government UMCS infrastructure (226

* Maintenance services contractor at Fort Leonard Wood, MO.

buildings) into the new UMCS. This could entail a concerted integration effort, or an integration of "select" systems while operating the remaining ones independently until they reach end-of-life and are replaced (at which time they would be integrated into the Honeywell UMCS). However, initial procurement of the UMCS would likely include the integration of several existing facilities to provide for a sufficiently substantial UMCS.

Depending on contracting limitations and inefficiencies, new systems could either be integrated immediately or Fort Leonard Wood could continue to procure BCSs with local web servers, as they have historically, and operate those systems as standalones until a sufficient number are ready to be grouped together for integration. (Integration of individual or small groups of buildings is likely more practical under Option 2 than Option 1, however.) It is recommended that Fort Leonard Wood consider this option as an alternative to (the recommended) Option 1 if it is not feasible to adopt the Honeywell UMCS. Much of the motivation, time, cost, and effort to procure a new UMCS would duplicate the current Honeywell UMCS so this option may be less efficient than Option 1. Should a new UMCS be desired, it should be purchased using UFGS 25 10 10 specification and should consider two tailoring options:

1. **Tailoring option "LNS©-based LonWorks."** This would be equivalent to the existing Honeywell UMCS.
2. **Tailoring option: "Niagara Framework."** Niagara Framework is a set of hardware and software specifications for building and utility control licensed to multiple vendors. It is a popular well-packaged technology consisting of front-end (M&C) software, web-based clients, field level control hardware, and engineering tools. While the Niagara Framework is not recognized by any standards body and does not use an open licensing model, it is sufficiently well-supported by multiple HVAC vendors to be considered a de-facto Open Standard. It supports LonWorks, BACnet, and other protocols at the BCS level.

5.4.2.1 Considerations

5.4.2.1.1 Single UMCS goal and functionality

This aspect of Option 2 is essentially identical to Option 1. Option 2 can absorb the buildings currently connected to the Honeywell UMCS, but not until year 2025, which suggests that the path to a single UMCS would be slower for Option 2 than for Option 1.

5.4.2.1.2 Time and cost

The primary concern with Option 2 is the new UMCS initial procurement, which can be on the order of $250k, including the UMCS front-end procurement costs (time investment and purchase) and IA-related costs, most notably for an ATO, which the Option 1 system already has. Much of the time, cost, and effort to adopt and support a new (Option 2) UMCS would duplicate the current Honeywell UMCS (Option 1), which would require government contracting and technical support, oversight, and management to continue both the use of the Honeywell ESPC and the similar, but separate, support for a new "Option 2" UMCS.

5.4.2.1.3 Procurement of this option

A contracting mechanism and funding to procure this new UMCS would need to be identified. ESPC is a possibility and Huntsville has UMCS procurement options with their IDIQ contracts.

5.4.2.1.4 Competitive Procurement for integration (UMCS)

From a technical standpoint, open protocol requirements make expanding the UMCS to add new BCSs fairly straightforward. However, the integration must be done by the UMCS contractor unless the Government trains a Government employee. The "Niagara Framework" tailoring option could result in more possibilities for competitively procuring integration; however, this is generally discouraged it can be problematic in practice to have multiple different integrators. Also, the only known Niagara Framework contractor in the Fort Leonard Wood area is Honeywell. Niagara may be supported by multiple contractors since it is not restricted to using one specific support contractor for a given geographic region (as are some UMCS and BCS manufacturers). This condition provides leverage for price competition and the potential for switching UMCS contractors in the event this becomes necessary.

5.4.2.1.5 Competitive procurement for BCS

The installation, renovation, update, or repair of BCSs can be performed by contractors on a competitive bid basis. Either tailoring option (LNS© LonWorks or Niagara Framework) provides for open competition for BCS procurement.

5.4.2.1.6 Existing systems integration

The existing Government UMCS/BCS infrastructure (approximately 226 buildings) can be absorbed into a new UMCS (either LNS© or Niagara) due to compatibility of the existing LonWorks-based government infrastructure, but it would not be plug and play as there would be time and expense involved largely in pulling Government UMCS points into the front-end database and creating graphic displays. The cost for integrating 226 buildings can be significant if not prohibitive, on the order of $1.7 million at an approximate cost of $7500 per building.

The existing Honeywell UMCS would remain a separate system at least until the ESPC contract expires (October 2025). At this point, the Honeywell UMCS becomes government property and Fort Leonard Wood will need to identify a way to support the existing Honeywell systems, e.g., by integrating these systems into the new UMCS. This suggests that Option 2 (procuring a new UMCS now) could become problematic in the future, and that it may be better to deal with the ownership issue now rather than later, i.e., adopt Honeywell now rather than risk not having the resources to support/maintain it later.

5.4.2.1.7 Cybersecurity

The new UMCS would need an ATO. This is a significant challenge and can be very time consuming and expensive.

5.4.2.1.8 Future/alternate technology support

An LNS©-based UMCS can typically also accommodate BACnet. The UMCS UFGS 25 10 10 can be used to specify either LonWorks or BACnet should the garrison decide to use the BACnet protocol or move this direction later.

5.4.2.1.9 Utility metering support

MDMS meters can (technically) be integrated into (or through) a new UMCS, but USACE Huntsville Center (HNC) is moving forward (more quickly than originally indicated) with installing but the MDMS. Therefore meter installation will likely precede purchase of a new UMCS system and all future utility meters can (technically) be accommodated. An initial contract (via HNC) to add the FY17 meters seems plausible. Adding subsequent/future MDMS and non-MDMS meters can be a challenging task. The need to add meters can be recurring and frequent. This can cause a

need for frequent contract modifications, which may be impractical unless a more elegant contracting solution can be identified.

5.4.2.1.10 Staffing and technical support

Staffing a new UMCS could be challenging, especially if it is to be operated by the DPW since the Fort Leonard Wood UMCS Manager position was recently eliminated. The Option 2 UMCS procurement might need to include requirements for the UMCS contractor to provide day-to-day operation of the UMCS while also providing DPW Energy Branch and TFW with access to the M&C software graphics/interface. Honeywell already provides support for their UMCS under the ESPC contract, so Option 2 may result in duplicated support by a new contractor. Alternatively, if Honeywell is awarded the Option 2 contract, much of the support elements (i.e., Staffing) will already be in place. Consideration should be given to the degree of DPW and TFW Operator access to the Option 2 UMCS, such as full edit/override capability versus display/read only. Delineation of duties might be necessary to distinguish responsibilities of the UMCS contractor, DPW, and TFW. This may entail modification of the TFW contract. Appendix G includes a list and basic description of duties.

5.5 UMCS – Option 3

5.5.1 Summary

In Option 3, Fort Leonard Wood would continue “as is” with two systems, the Government UMCS and Honeywell UMCS.

5.5.2 Description

If Option 3 is chosen, the installation will continue to use and support two separate UMCSs, the Honeywell UMCS and the Government UMCS. Note that the Government UMCS uses many individual Smart Servers (web servers) per building, which does not really constitute a true installation-wide UMCS.

Although this is the least expensive and easiest option, Option 3 does not provided progress toward creating a single, installation-wide UMCS so it is the least desirable option and is not recommended—for several reasons.

The Government UMCS is operating under the auspices of the NEC while the Honeywell UMCS has an ATO. There is some risk in operating under

the auspices of NEC as they may impose future requirements (such as insisting on an official ATO for the Government UMCS) resulting in added cost and risk of disconnection of the Government UMCS from the NEC network until an ATO is achieved.

Option 3 will require a transition when the Honeywell UMCS ESPC contract expires in October 2025, at which time the Honeywell UMCS becomes government property. To prepare of this, Fort Leonard Wood will need to either adopt Option 1 in year 2025 or implement staffing (see Sections 5.3.3.3 and 5.4.2.1.6 and Appendix G), to internally support/staff the Honeywell UMCS.

BCS procurement remains open competition. The expectation is that each BCS will be procured similarly to how they are currently procured and the Government UMCS will continue to grow.

The Government UMCS "model" will be the same if/when BACnet systems are installed. Similar to the existing LonWorks-based Government UMCS, a BACnet BCS can be installed and connected to a web server with remote access to each individual BACnet building via URL.

5.6 Metering

Fort Leonard Wood will benefit from consolidating their meters to provide real-time useful access to metered data. There are two possible strategies for consolidating the meters at Fort Leonard Wood: (1) connect the meters to an MDMS EEDRS server, or (2) connect the meters to a UMCS, which can then transfer data to MDMS. Chapter 4, "Utility Metering - Current" discusses options/strategies for using existing metering hardware under each meter type.

The "Fort Leonard Wood advanced metering installation status conference call notes," version 2 (Appendix D) further discusses use of the Honeywell UMCS as an MDMS interface. During the writing of this report, new information became available suggesting that an EEDRS was in fact going to be installed. This resulted in a meeting including conference call participants. Before the meeting "Fort Leonard Wood UMCS/Metering Options" (Appendix E) were presented for consideration. Appendix F includes meeting minutes.

The primary decision under discussion was whether Fort Leonard Wood wishes to pursue a single installation-wide UMCS (metering option matrix), and whether the EEDRS could become this single UMCS. Given that the Fort Leonard Wood Honeywell ESPC EBI/HEM system software will be upgraded to match the configuration currently being tested for EEDRS, the general consensus was that, if the open concerns can be addressed, it would make the most sense for Fort Leonard Wood to adopt the ESPC EBI system (Option 1) as the single front-end for UMCS and Metering.

The primary concerns from the Metering side appear to be: (1) the need to document an agreement for the system to operate on the Fort Leonard Wood ICAN, and (2) the need to address system administration responsibilities for the system. More general concerns to address are: (1) how to handle adding meters and building controls to the ESPC contractually, (2) how to break down the maintenance responsibilities, and (3) how to fund the necessary work to obtain a site ATO for the system. It was also decided that MDMS meters should be put on the Honeywell system only if UMCS Option 1 is selected. If UMCS Option 2 is selected, Fort Leonard Wood should try to convince HNC to wait until Fort Leonard Wood procures the Option 2 UMCS.

Metering hardware should be specified/procured such that electric meters provide LonWorks communications output to the BCS network. Gas and water meters should provide LonWorks or pulse output. (Pulse output is the much more commercially available option.) Appendix J includes Points Schedules for these electric, gas, and water interface options. The gas or water meter pulse output can be connected to a control device that accepts pulse; the device then provides a LonWorks communications output to the BCS network. CERL-developed UFGS 23 09 13 includes these metering requirements specifically for Fort Leonard Wood. Use of the UFGS should be accompanied by corresponding "Points Schedules," which further define the input/output (I/O) including specific data variables to be made available to the communications network and thus the UMCS (and MDMS).

5.7 Contracting

The time, effort, and expertise needed to issue and execute a contract, in combination with procurement regulations and restrictions can make contracting in the government procurement environment a challenging task. The pertinent restriction in this case is the potential need for sole source

procurement for a UMCS, which involves three contract-related support actions:

1. UMCS initial procurement.
2. UMCS Expansion. Adding new BCSs into the front-end subsequent to the initial procurement of the UMCS.
3. UMCS Maintenance/Support. Providing ongoing operation, maintenance, and support for the UMCS. Sufficient in-house support/staffing may not be available to adequately support the UMCS (refer to "Staffing"), so contracted support is likely needed.

5.8 Procurement options

The initial procurement of a new UMCS or adoption of the Honeywell UMCS, along with subsequent UMCS expansion and support will require contract actions. The existing Honeywell UMCS was initially procured through an ESPC contract that has been expanded through ESPC contract modifications. Prior ESPC contracting success at Fort Leonard Wood (and Fort Hood, TX) suggests that this approach may successfully continue. An ESPC can be used to absorb the approximately 226 "Government UMCS" buildings or a subset of these. Adding future BCSs (constructed later) is a greater challenge. Ideally, each would be added to the UMCS as the BCS is initially installed, but this may not be practical. Due to open competition procurement rules, new BCSs are likely to be installed by a contractor other than Honeywell. Then, integrating/connecting the BCS to the UMCS will require a (potentially sole source procurement) contract with Honeywell.

The possible options for integrating BCSs into the Honeywell UMCS are:

1. **Existing BCS.** One option to integrate BCSs into the Honeywell UMCS is to use an ESPC to absorb all (approximately) 226 existing government BCS into the Honeywell UMCS, or to absorb only a more manageable or affordable subset of these. This approach would be consistent with the way Fort Leonard Wood currently procures BCSs, in which each MILCON or in-house project includes a requirement for a web server (Echelon Smart Server) with limited UMCS functionality (mainly web pages as a graphical user interface [GUI]) in every building. This Smart Server approach functions as a temporary UMCS while awaiting interface to a real UMCS such as the Honeywell. An alternate contracting mechanism to absorb existing BCSs into the Honeywell EBI is an IDIQ contract such as HNC's "UMCS IV Unrestricted" contract vehicle, which expires August 2017, but can be extended once used.

2. **New BCS.** Similar to option described in Section 5.3.3.4, it would be possible to let new/future BCSs accumulate, perhaps five or 10 of them, then use an ESPC or HNC IDIQ to integrate them. The HNC IDIQ procurement process (according to the HNC UMCS Technical Deputy) calls for competitive procurement among the multiple contractors (Honeywell, Johnson Controls, Schneider Electric, etc.). To ensure that the new BCSs are all compatible, the installation may need to pursue sole source procurement or carefully crafted requirements making it clear to all competitors/bidders the need for requisite skills, staff, and capabilities to provide integration into an existing UMCS of single manufacturer (i.e., Honeywell).
3. **New BCS acquired by issuing *separate* contracts (UFGS) for each new BCS *and* for Integration.** This method suggests that the integration contract would need to be a sole source procurement to the current UMCS contractor (i.e., Honeywell), or carefully crafted requirements making it clear to all competitors/bidders the need for requisite skills, staff, and capabilities to provide integration into an existing UMCS of single manufacturer (i.e., Honeywell).
4. **New BCS acquired by issuing *a single* contract (UFGS) for each new BCS *and* integration.** This method would likely force the (General) contractor to subcontract to Honeywell to accomplish the integration. Requirements (and scope verbiage) for the UMCS system integration would need to be developed. Inherent to this approach is that the supplier of the current UMCS (i.e., Honeywell) may have a competitive bidding advantage.
5. **New or existing BCS.** Fort Leonard Wood could hire and train its own in-house System Integrator, either a federal employee, or possibly an individual procured via a Services contract. There would some risk involved in relying on a single person. However, support provided by a "company" would likely have reserve staff to provide services. This approach would also not work well with the current ESPC as Honeywell is contractually responsible for the UMCS.

5.9 Staffing

Staffing is a serious concern and Fort Lenard Wood needs to take this into account in their decision on how to move forward. Currently staff support for the Government UMCS is provided through DPW and TFW contractor. The Honeywell UMCS also has staff support provided through the ESPC contract with Honeywell.

The success of a UMCS depends on its proper use, management, maintenance, and growth. Historically, Army installations do not customarily

provide this type of support. The maintenance staff within the DPW, who are already overburdened with responsibilities, generally have insufficient Information Technology (IT) expertise and insufficient controls expertise. Often there are no dedicated operators for the system, and no single individual at the garrison who is truly responsible for the UMCS (i.e., who has the authority or job description to manage the UMCS). The garrison DPW (O&M) have traditionally managed to "squeak by" doing what they can and leaving much undone.

As described in the Appendix G and summarized here, there are six "roles" that must be filled at the garrison for the UMCS/BCS to succeed.

1. **UMCS Manager**: This role manages all aspects of the UMCS. The UMCS Manager is the individual at the garrison with the responsibility and authority to make local decisions concerning the UMCS, including planning, project prioritization and system operation. At Fort Leonard Wood, the Energy Manager provides general guidance and oversight, but this role is otherwise filled by Lee Criswell. For the Honeywell UMCS, this role is filled by Jabe Moore, the TRM.
2. **UMCS Administrator.** This role provides the necessary IT expertise to the DPW in support of the UMCS, performs IT management for the UMCS, and coordinates UMCS IT issues with NEC. At Fort Leonard Wood, this role is filled by Lee Criswell. For the Honeywell UMCS, this role is filled by Jabe Moore, the TRM.
3. **Technical Expert.** This role provides expertise on the technology related to the control system and the implementation of this technology at the garrison. The key responsibilities for this role are the review of project submittals (designs, as-built drawings, etc.) and participation in control system acceptance. At Fort Leonard Wood, this role is filled by Lee Criswell and Roger Smith although Roger has since moved to a different position. Mr. Criswell is assisted by the Fort Leonard Wood Design Branch and by NWK. For the ,Honeywell UMCS this role is filled by Jabe Moore, the TRM.
4. **System Integrator.** This role performs the actual integration of BCSs into the UMCS. This service will might be obtained as part of the BCS project procurement or by the UMCS Contractor (discussed in Section 5.7, "Contracting") so this role does not necessarily correspond to a position that must be filled at the garrison. At Fort Leonard Wood, this role is filled by the BCS contractor with oversight from Lee Criswell. For the Honeywell UMCS, this role is filled by Jabe Moore, the TRM.
5. **Controls Technician.** This role provides control system maintenance expertise and support to DPW O&M staff. At Fort Leonard Wood, this role is

filled by the TFW maintenance contractor with oversight from Lee Criswell. For the Honeywell UMCS, this role is filled by Jabe Moore, the TRM.

6. **UMCS Operator.** The purpose of this role is to use the UMCS to monitor and control the connected BCSs. The UMCS Operator provides remote troubleshooting and diagnostic support. The Operator can also adjust schedules, set up trending, configure demand limiting, and otherwise take advantage of the power and capabilities of the UMCS in support of the garrison. At Fort Leonard Wood, this role is filled by Lee Criswell. For the Honeywell UMCS, this role is filled by Jabe Moore, the TRM.

Each of the above roles does not necessarily correspond to a single full-time staffed position. In some cases, one individual can fulfill more than one role; in other ,cases multiple individuals will be required for each role. For example, the UMCS Administrator and Technical Expert may be the same individual, but the garrison will likely require more than one System Operator. Fort Leonard Wood's historical commitment to BASs has resulted in an environment for UMCS and BCS success. Critical parts and pieces of the necessary roles have been filled even in the absence of sufficient staffing. A byproduct of this commitment to the UMCS is that a high level of in-house expertise has dwindled with staff reassignments, even though at least some expertise does remain.

Table 4 lists support staff requirements for the Government UMCS. For each role/duty, the table shows annual hours (ann. hrs) and the full-time equivalent (FTE) ratio based on an 1800 hour work year. These are rough estimates, intended to provide perspective, using an informal spreadsheet tool developed by CERL as part of a prior project for the U.S. Army Installation Management Command (IMCOM).

Table 4. Government UMCS support staff estimates (for 226 buildings).

System	Staff (person)	UMCS Mgmt ann. Hrs (FTE)	UMCS Admin ann. hrs (FTE)	Tech Expert ann. hrs (FTE)	Controls Tech ann. hrs (FTE)	UMCS Operator ann. hrs (FTE)	Total ann. hrs (FTE)
Gov't UMCS (226 bldgs.)	DPW(Criswell)	1239 (0.69)	830 (0.46)	192 (0.11)	0 (0)	360 (0.2)	2621 (1.46)
	TFW (Multiple)	0 (0)	0 (0)	0 (0)	2744 (1.52)	9199 (5.31)	11943 (6.83)

The data in Table 4 along with the (above) description of how the staffing roles are currently filled suggest that DPW staffing is inadequate to support the 226 Government UMCS buildings. Lee Criswell performs the bulk if not all of the first three listed staff roles (UMCS Manager, UMCS Admin, and Tech Expert) while TFW performs none of these tasks. Mr. Criswell also performs some UMCS Operator duties; potentially 20% of his time is spent as an operator. This equates to approximately 1.5 FTE positions. Consequently it is unlikely Mr. Criswell can keep up with the demands of his position(s). Based on CERL's experience with other garrisons, he is not alone in this challenge. It is not unusual for Army UMCS support staff to be overburdened due to the expansive, complex, and detailed nature of a UMCS. Other DPW staff are involved with the UMCS, but the table focuses on Mr. Criswell as his involvement and responsibilities far outweigh others.

5.10 Cybersecurity

The Fort Leonard Wood Network Enterprise Center (NEC) provides access to the ICAN. The Government UMCS has minimal access requirements since a basic web server is used in each building. However, the Honeywell UMCS requires NEC server space in a NEC server facility. Access and use requirements are strict, as expected the help ensure IA.

Although the Honeywell UMCS has an ATO, access and interface requirements have not been met. Honeywell, NEC, and CERL had multiple discussions and emails regarding Honeywell access and worked out a series of Honeywell needs/requirements (Appendix B). Appendix C includes a sample telephone conversation record of discussion along with a related email further documenting the cybersecurity challenge.

As of November 2016, Honeywell UMCS still did not have connectivity to the ICAN. Over the course of several months leading up to November 2016, multiple service requests had been issued and Honeywell and NEC continue to work on the obtaining connectivity.

5.11 Training

Training, which is critical due to the complex and evolving nature of building automation technology, falls into two basic categories:

1. **UMCS Use and Operation.** This can potentially be provided by the Honeywell TRM under terms of the ESPC contract. Basic HVAC systems

training could be beneficial for an operator not versed in HVAC, such as courses offered by University of Wisconsin. HVAC control systems training could be beneficial. More advance training might include Honeywell-specific training, which includes classroom and web-based training. Course offerings are listed and described at: https://hbsmicrosites.honeywell.com/Documents/HBS_CustomerTraining_Catalog.pdf

2. **UMCS Management and Design.** The evolving nature of UMCS and BCSs technology necessitates training to keep current on changes in the technology, including many technical and administrative details such as:
   a. The availability of and various types of instrumentation/sensors.
   b. New and sometimes complex HVAC control sequences.
   c. Communications network regulations and policies.
   d. Evolving industry standards.
   e. Army/DoD policies, etc.

   The Huntsville Learning Center 1-week long Proponent Sponsored Engineer Corps Training (PROSPECT) course 340 “HVAC Control Systems: Design 7 Quality Verification” is one good source of technical and standards information.

6 Specifications: Tailored to Fort Leonard Wood

Fort Leonard Wood has historically used the USACE LonWorks-based specifications; the DPW has maintained a working version based on UFGS-15951 that contains both BCS and UMCS requirements. Within the past few years, USACE/DoD has updated the UMCS and BCS-related UFGS so that, instead of a single specification, there are now four 23-09-xx series UFGSs related to BCSs. This subcategorization of the UFGS is in accordance with Construction Specifications Institute (CSI) standards. Table 5 lists the four (new) UFGSs along with the UMCS 25 10 10 specification. Note that UFGS 23 09 00 is the overarching 23-series specification, with three subelement specifications.

Table 5. Unified Facilities Guide Specifications.

UFGS	Title	Description
UFGS 25 10 10	Utility Monitoring & Control System (UMCS) Front-End and Integration	For procuring a new UMCS or integrating into an existing UMCS
UFGS 23 09 00	Instrumentation and Control for HVAC	"Top level" DDC specification with general, schedule, submittal, Performance Verification Test (PVT), and training requirements
UFGS 23 09 23.01	LonWorks DDC for HVAC & Other Local Controls	DDC Hardware (controller) specifications and common protocol requirements (also covers SmartServer/web server device)
UFGS 23 09 13	Instrumentation and Control Devices for HVAC	Sensor, actuator, and instrumentation specifications
UFGS 23 09 93	Sequences of Operation for HVAC Control	Requirements for various HVAC system types

6.1 Tailored specifications

The five UFGS for Fort Leonard Wood (Table 5) were tailored by CERL in coordination with NWK and the Fort Leonard Wood Design Branch and DPW. The effort focused on UFGS 25 10 10, UFGS 23 09 00, UFGS-23 09 23.01, and UFGS-23 09 13 (Appendices K, L, N, and O). Requirements for water, gas, and electric metering were included after being modified from their respective (complete) UFGS and melded into UFGS-23 09 13. The intent is to use these UFGS in all new construction, major renovation, and HVAC controls retrofit projects including both MILCON and in-house projects. UFGS 25 10 10 tailoring is based on using the Honeywell UMCS; its focus is therefore on system integration. UFGS 25 01 10 inherently supports a UMCS that can accommodate the possible future use of BACnet technology.

6.2 UFGS update process

Successful use of the new specifications requires periodic updates and coordination between NWK and DPW. This was discussed during a conference call in which NWK suggested that Sue Amato (Specifications Specialist with the Tech Division) be the keeper of the master Specs Intact files on behalf of Fort Leonard Wood.

NWK has been doing periodic reviews and providing updates to the Fort Leonard Wood Design Requirements beginning back in July 2011 at the height of the MILCON Build up at Fort Leonard Wood. Project Manager (PM) Robyn Kiefer and Tech Services Specialist Sue Amato were instrumental in kicking off this effort and reviewing all the requirements. Robyn moved from NWK Military Branch to the District's Environmental Division and this effort was then transferred to Bill McDaniel. This effort included development of the *Fort Leonard Wood Design Guide* (June 2013).

NWK has been working with Randy Knutson, DPW Planning Division Construction Coordinator. Randy is the DPW Point of Contact (POC) and all stakeholders submit changes to him for the Fort Leonard Wood Design Guide. The installation stakeholders are: Fire Protection, NEC (Information and Communication Technology)/Anti-Terrorism/Force Protection (ATFP)/Safety along with the DPW Divisions. Once Randy receives changes, he reviews them and notifies Bill McDaniel and/or Sue Amato. If the changes could have a significant impact on the contracts/task orders then Sue makes the necessary edits in the NWK Specifications. The Fort Leonard Wood Design Guide lags somewhat as the changes are sent to the installation stakeholders and a review period is established for comment. Once the period is complete and review comments have been received, then a review conference is set up to acknowledge the necessary changes. NWK controls the ProjNet (DrChecks) and opens and closes the review period. Once all changes are agreed to, the final changes are made to the Design Guide and to the NWK Specifications if not already completed.

7 Scopes: For Project-Specific Energy Conservation Measure

Pacific Northwest National Laboratory (PNNL) issued (unpublished internal) report PNNL-24052, *FINAL REPORT Comprehensive Energy and Water Evaluation at Fort Leonard Wood, MO* (J. T. Woodward et al. 2015) The report described potential energy conservation measures (ECMs) in 38 buildings.

CERL reviewed the PNNL report and identified ECMs related to BAS, categorized the ECMs, and reviewed the ECM list with DPW (Lee Criswell, Alan Simpson, and Jabe Moore) to down-select to 20 candidate buildings. Based on DPW input and site visits to multiple buildings CERL developed scopes for eight buildings to include the following ECMs:

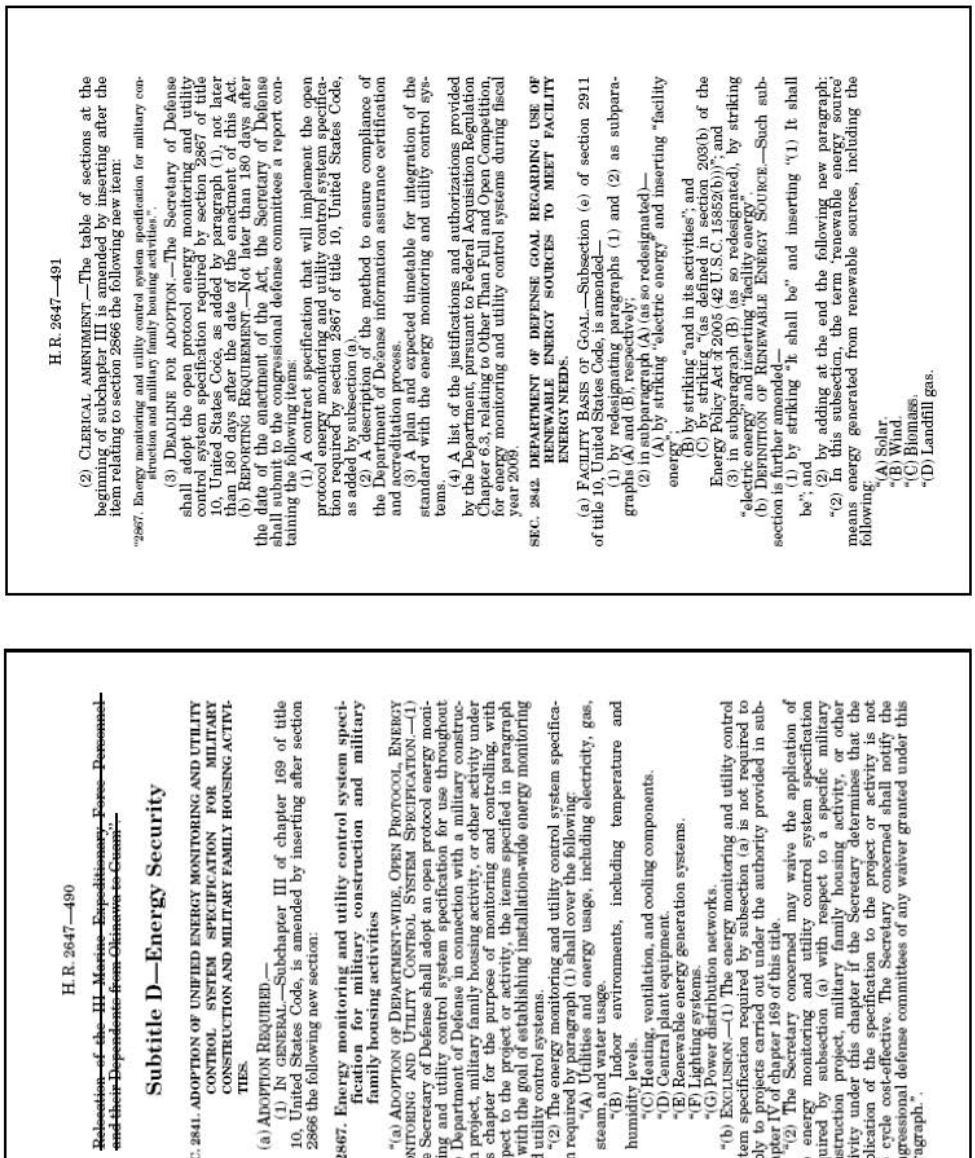
- Single zone to VAV
- DSPR in VAV systems
- DCV using CO_2 sensors
- Multizone-to-VAV control system conversion
- Economizer assessment/repair.

Appendix I contains the scope (Fort Leonard Wood Section 01010 PNNL ECMs) for the buildings and ECMs listed in Table 6. Appendix I also contains functional performance tests (FPTs) for the ECMs to assist Fort Leonard Wood quality verification efforts. Appendix I includes Sample Smart Server graphics, Fort Leonard Wood climatic data, and dry-bulb economizer setpoint information. Appendix I contains sample graphics because the scope requires the contractor to "Provide the graphics pages and control features shown in the attached Fort Leonard Wood Sample Smart Server Graphics pages." Appendix I includes Fort Leonard Wood mean coincident wet bulb (MCWB) data (source: National Climatic Data Center) because it contains MCWB bin data used to determine the dry-bulb economizer setpoint as shown in the psychrometric chart also included in Appendix I. The 71 °F economizer setpoint is an ideal value at an assumed return air condition of 76 °F, 50% relative humidity (RH), and "average" weather conditions. A more practical and conservative value might be a few degrees lower. This is a specifier decision.

Table 6. Building list and project-specific ECMs (excerpted from Fort Leonard Wood Section 01010).

Bldg #	Bldg Name	Bldg Function	Bldg System	Existing Field Controls	UMCS Type	ECM: Single Zone to VAV	ECM: Multizone (MZ) to VAV	ECM: DSPR	ECM: DCV	ECM: Economizer
2100	Grant Hall	Army In-Processing Center (offices, assembly, medical, storage spaces)	AHU-1	Distech EC-FCU-L, VAVs, Circon 452A	iLON Smart Server (Phase I)			X		X
			AHU-2	Distech ECP-510s	iLON Smart Server (Phase II)			X		X
			AHU-3	Distech ECP-410, ECP 510	iLON Smart Server (Phase II)	X			X	X
			AHU-4	Distech ECP-500, ECC-VAVs	iLON Smart Server (Phase II)			X		X
			AHU-8, AHU-9	Distech EC-RTU-L	iLON Smart Server (Phase II)	X			X	X
932, 934, 936, 937, 939	930-series	Army Barracks (dwelling, office and multi-purpose spaces)	AHU-1	Distech ECP-400s/ECL-STAT-RTs	iLON Smart Server		X			
			AHU-2, AHU-3, AHU-4, AHU-5	Distech ECP-500s/ECC-VAV	iLON Smart Server			X		
5295B	Simulator Facility	Army Computer Training (data center/warehouse, offices)	AHU-1	Scheider TAC Xenta 401, 422As, 452As	Honeywell EBI			X		
			AHU-2	Scheider TAC Xenta 401, 422As, 452As	Honeywell EBI		X			
5400	Brown Hall	Army Instructional Training (classes, offices, assembly)	AHU-1, AHU-2	Distech ECP-610s, ECC-VAVs	iLON Smart Server			X		

Appendix A: National Defense Authorization Act (NDAA 2010) Section 2841



H.R. 2647—490

~~Relocation of the III Marine Expeditionary Force Personnel and their Dependents from Okinawa to Guam.~~

Subtitle D—Energy Security

SEC. 2841. ADOPTION OF UNIFIED ENERGY MONITORING AND UTILITY CONTROL SYSTEM SPECIFICATION FOR MILITARY CONSTRUCTION AND MILITARY FAMILY HOUSING ACTIVITIES.

(a) ADOPTION REQUIRED.—
(1) IN GENERAL.—Subchapter III of chapter 169 of title 10, United States Code, is amended by inserting after section 2866 the following new section:

"§ 2867. Energy monitoring and utility control system specification for military construction and military family housing activities

"(a) ADOPTION OF DEPARTMENT-WIDE, OPEN PROTOCOL, ENERGY MONITORING AND UTILITY CONTROL SYSTEM SPECIFICATION.—(1) The Secretary of Defense shall adopt an open protocol energy monitoring and utility control system specification for use throughout the Department of Defense in connection with a military construction project, military family housing activity, or other activity under this chapter for the purpose of monitoring and controlling, with respect to the project or activity, the items specified in paragraph (2) with the goal of establishing installation-wide energy monitoring and utility control systems.

"(2) The energy monitoring and utility control system specification required by paragraph (1) shall cover the following:
"(A) Utilities and energy usage, including electricity, gas, steam, and water usage.
"(B) Indoor environments, including temperature and humidity levels.
"(C) Heating, ventilation, and cooling components.
"(D) Central plant equipment.
"(E) Renewable energy generation systems.
"(F) Lighting systems.
"(G) Power distribution networks.

"(b) EXCLUSION.—(1) The energy monitoring and utility control system specification required by subsection (a) is not required to apply to projects carried out under the authority provided in subchapter IV of chapter 169 of this title.

"(2) The Secretary concerned may waive the application of the energy monitoring and utility control system specification required by subsection (a) with respect to a specific military construction project, military family housing activity, or other activity under this chapter if the Secretary determines that the application of the specification to the project or activity is not life cycle cost-effective. The Secretary concerned shall notify the congressional defense committees of any waiver granted under this paragraph."

H.R. 2647—491

(2) CLERICAL AMENDMENT.—The table of sections at the beginning of subchapter III is amended by inserting after the item relating to section 2866 the following new item:

"2867. Energy monitoring and utility control system specification for military construction and military family housing activities."

(3) DEADLINE FOR ADOPTION.—The Secretary of Defense shall adopt the open protocol energy monitoring and utility control system specification required by section 2867 of title 10, United States Code, as added by paragraph (1), not later than 180 days after the date of the enactment of this Act.

(b) REPORTING REQUIREMENT.—Not later than 180 days after the date of the enactment of the Act, the Secretary of Defense shall submit to the congressional defense committees a report containing the following items:
(1) A contract specification that will implement the open protocol energy monitoring and utility control system specification required by section 2867 of title 10, United States Code, as added by subsection (a).
(2) A description of the method to ensure compliance of the Department of Defense information assurance certification and accreditation process.
(3) A plan and expected timetable for integration of the standard with the energy monitoring and utility control systems.
(4) A list of the justifications and authorizations provided by the Department, pursuant to Federal Acquisition Regulation Chapter 6.3, relating to Other Than Full and Open Competition, for energy monitoring and utility control systems during fiscal year 2009.

SEC. 2842. DEPARTMENT OF DEFENSE GOAL REGARDING USE OF RENEWABLE ENERGY SOURCES TO MEET FACILITY ENERGY NEEDS.

(a) FACILITY BASIS OF GOAL.—Subsection (e) of section 2911 of title 10, United States Code, is amended—
(1) by redesignating paragraphs (1) and (2) as subparagraphs (A) and (B), respectively;
(2) in subparagraph (A) (as so redesignated)—
(A) by striking "electric energy" and inserting "facility energy";
(B) by striking "and in its activities"; and
(C) by striking "(as defined in section 203(b) of the Energy Policy Act of 2005 (42 U.S.C. 15852(b)))"; and
(3) in subparagraph (B) (as so redesignated), by striking "electric energy" and inserting "facility energy".

(b) DEFINITION OF RENEWABLE ENERGY SOURCE.—Such subsection is further amended—
(1) by striking "It shall be" and inserting "(1) It shall be"; and
(2) by adding at the end the following new paragraph:
"(2) In this subsection, the term 'renewable energy source' means energy generated from renewable sources, including the following:
"(A) Solar.
"(B) Wind.
"(C) Biomass.
"(D) Landfill gas.

National Defense Authorization Act for FY 2010 (NDAA 2010) Section 2841

Appendix B: Honeywell UMCS/Information Assurance Access Needs (30 March 2016)

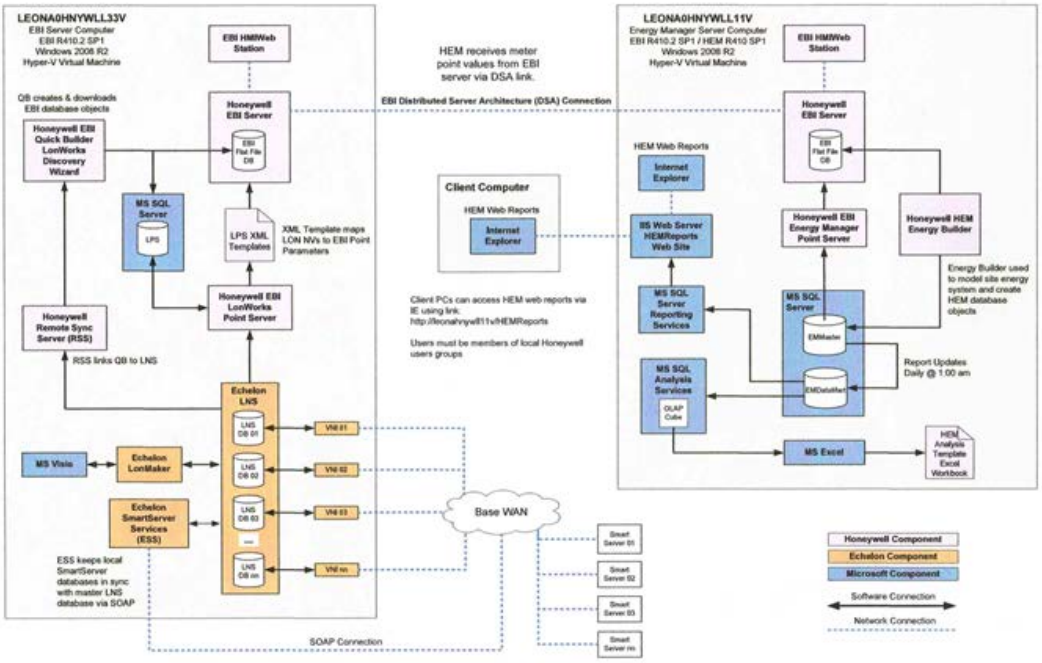
B.1 Background

Honeywell does not have access to the Honeywell EBI/HEM UMCS. Jabe Moore (Honeywell) has expressed the opinion that he does not have everything needed to access the UMCS and that he/we would like NEC's help determining what NEC can provide/help with to afford Honeywell with access. Issues/items are listed below.

1. Honeywell/Jabe Moore needs User access to 11v and 33v servers. "User" means or refers to no access to server configuration, but only access to project software. (11v = LEONA0HNYWLL11V 33V = LEONA0HNYWLL33V). Honeywell needs access to: LonMaker, LonWorks IP Configuration software, Enterprise Building Integrator (EBI), Quick Builder, and other software programs on 33v server, that are necessary for integrating buildings into EBI/LNS©.
2. HEM software web service needs to be fixed. (Unable to access Energy reporting page). Is the web service turned off/disabled? Or maybe the pathing/URL has changed?
3. Need to provide DPW machine access (approximately six personnel) to the Virtual Local Area Network (VLAN) so that DPW can access HEM reports page. Need URL to direct DPW to HEM on 11V server.
4. Need "Station" browser (software) for EBI installed on various DPW machines to provide a user interface to the EBI software. "Station" is the client software.
    a. Also need the ability to use "Station" from a virtual private network (VPN) connection, but believe that resolving the other "station" access issues will address this, too.
5. IP addresses in VLAN use the Dynamic Host Configuration Protocol (DHCP). For the building automation system to function properly they need to be static. It is spelled out this way in our ATO. What do you need from us to change back to static?
6. All ports to which a SmartServer is connected need to be set to 100meg, ½ duplex. Can NEC query the network for Media Access Control (MAC) addresses that start with "00D0"? This would save Lee Criswell and Jabe Moore from having to physically visit approximately 500 buildings.
7. We do not believe the Smart Servers support 802.1x. We would like to discuss with NEC how to handle port authentication without using 802.1x.

8. Is there a response protocol for IT work orders/requests specific to UMCS? Should we define one?

Figure B-1. Honeywell EBI/HEM UMCS Architecture.



Appendix C: Honeywell Information Assurance Access (Conference Call Notes)

Topic: IA for Fort Leonard Wood Utility Monitoring Control System (UMCS)
When: 17 February 2016
Who:
Shelia Collins, FLW NEC Server Support
Lee Criswell: FLW DPW Ops Mech Sec
Dave Schwenk: Corps of Engineers, ERDC-CERL
Joe Bush: Corps of Engineers, ERDC-CERL
Dave Underwood: Corps of Engineers, ERDC-CERL

Background. This is follow-up to discussions and emails with Allen Simpson, Lee Criswell, Deborah Dowling and Jabe Moore. And is an extension of work Lee, Shelia, and others have been doing to support the FLW UMCS SmartServers (i.e., the Government UMCS versus the Honeywell UMCS, where the Honeywell UMCS was discussed today/below).

1. Honeywell access to Honeywell Server/System. **Jabe Moore** (Honeywell, Technical Resource Manager) needs at least a degree of access. We need to determine if it needs to be "SA"* privilege access versus "User" access. It is not totally clear what is the definition of access but prior discussion (via email) with Jabe he said "It does not require an SA to operate EBI/HEM." **Shelia Collins** will discuss Honeywell access with **Deborah Dowling** (FLW NEC) and then (tentatively) test Jabe's needed level of access ("SA" versus "User").
2. DPW web-based access to Honeywell System. Honeywell has offered DPW web-based access to the Honeywell system but has not been able to achieve this. It seems this requires some coordination with NEC. Shelia said she would discuss with Deborah and then Jabe to see if/how this is possible.
3. Fixing the broken IP-852 channels (and configuration of LonPoint Server) are needed to get the Honeywell UMCS system/server working. This requires visiting each SmartServer and a work order to NEC **Matt Henson** (to open a port, I think). This should be dealt with only after item 1 above is resolved. There was some discussion of static vs. dynamic IP addresses. Control systems typically expect static addresses.
4. IE Edge versus IE9. There is a browser compatibility issue where support for IE9 will eventually stop.

* System Administrator (SA)

5. VLAN. Possibility of putting the UMCS system(s) on a Virtual LAN was discussed. This could make things more manageable.

Some acronyms:

EBI = Enterprise Buildings Integrator (software)

HEM = Honeywell Energy Manager (software)

SA = System Administrator

NEC = Network Enterprise Center

****

Follow-up email:

-----Original Message-----
From: Dowling, Deborah J CIV USARMY 106 SIG BDE (US) [mailto:deborah.j.dowling.civ@mail.mil]
Sent: Thursday, February 18, 2016 7:39 AM
To: Schwenk, David M ERD-IL <David.M.Schwenk@usace.army.mil>; Collins, Shelia J CIV USARMY 106 SIG BDE (US) <shelia.j.collins2.civ@mail.mil>; Simpson, Allen W CIV USARMY USAG (US) <allen.w.simpson2.civ@mail.mil>; Criswell, G L (Lee) CIV USARMY USAG (US) <gerald.l.criswell.civ@mail.mil>; Bush, Joseph ERD-IL <Joseph.Bush@usace.army.mil>; Underwood, David ERD-IL <David.M.Underwood@usace.army.mil>
Cc: Stumpf, Annette ERD-IL <Annette.L.Stumpf@usace.army.mil>; Bevelheimer, Susan ERD-IL <Susan.J.Bevelheimer@usace.army.mil>; Landers, Matthew P CIV USARMY 106 SIG BDE (US) <matthew.p.landers.civ@mail.mil>
Subject: RE: FLW UMCS IA

All,

Here is additional background based on the notes that were attached for the meeting held yesterday.

1. Mr. Jabe Moore started experiencing issues with connecting to the Honeywell servers after I had removed his ability to login as the default administrator on the server. I had been attempting to

set the servers to the configuration that had been outlined in the security configuration guide that accompanied the ATO. There was no change to any of the accounts other than the default administrator account on the server. The connection from the application installed on the desktop is at an elevated level and there should be nothing that he cannot do from within the application.

****CERL NOTES: This seems to be a “setup” versus “use” issue. What rights does Honeywell need to run the software? We/Honeywell may not know. Discuss with Jabe? We may need to just try it to determine based on trial and error with Shelia’s help.****

2. If the controllers and servers are configured per the ISEC guidance, DPW should have access to the Honeywell systems. The last time that I had been involved, the Honeywell controllers had not been configured in accordance with the ISEC guidance. Information had been provided to DPW and Mr. Moore on how to configure the controllers.

****CERL NOTES: We assume “Controller” = SmartServer. Can/will Jabe configure the Honeywell controllers/SmartServers? Controllers/SmartServers should not affect DPW access to Honeywell system, but “servers” may. Is Deborah mixing/confusing SmartServer webpage service with access to the Honeywell server serving of webpages?****

3. The broken IP-852 channels had to do with 802.1x being enabled on the network. Both Mr. Moore and DPW were notified in advance of the changes occurring and what it would entail to be able to connect to the devices after the port changes were made. During the upgrade to the switches to enable the 802.1x, the decision was made to create a VLAN and segregate the controllers, per the ISEC guidance and ATO. The Network Division has worked with DPW in correcting their connection issues. Mr. Moore was provided the same information as DPW was.

****CERL NOTES: (802.1x = port security.) Not clear what this means or where we/FLW are at with this. Jabe had once said they needed to re-enter IP addresses into the SmartServers to fix this. Is there a configuration server issue?****

4. The version of Internet Explorer will be in alignment of what is approved on the new ATO. Currently, a POA&M has been submitted by USACE to remain on the 2008r2 platform until testing can be completed on the 2012r2 platform and the new ATO can be granted. From what I understand, EBI will have to be upgraded on the 2012r2 platform. The POA&M has been approved for the Honeywell to continue to operate until December 2016. A copy of the POA&M will need to be forwarded to the Cybersecurity Division for our records.

****CERL NOTES: POA&AM = plan of action and milestones (i.e., a get well plan). Does EBI need to be upgraded? Can EBI be upgraded? By who/at what cost? How to get there from here? Who/how does a copy of the POA&M get forwarded to the Cybersecurity Division for their records?****

5. The controllers are in a separate VLAN per the ISEC configuration guidance and the approved ATO for the Honeywell systems.

****CERL NOTES: OK/good. ****

END OF NOTES

Appendix D: FLW Advanced Metering Installation Status (Conference Call Notes)

(Blue highlight = Update with Allen Simpson input email 3/14/16)

Topic: FLW advanced metering installation status
When: 8 March 2016
Who:
Bill Hood, HNC
Dave Schwenk: Corps of Engineers, ERDC-CERL
Joe Bush: Corps of Engineers, ERDC-CERL
Dave Underwood: Corps of Engineers, ERDC-CERL

Background: CERL has been tasked with helping FLW plan for existing and future UMCS and metering. These notes extend/elaborate on some of the things we discussed during the conference call.

Summary: It appears the direction we are going will be to install new meters in buildings, connect them to the Smart Servers, run the data through Honeywell's EBI (because it has an ATO), and let Honeywell transfer the meter data onto MDMS.

1. Bill indicated that the metering plan is to have 100-200 new advanced electric meters installed and connected to MDMS (via Honeywell UMCS) but this would likely not start until FY17.
2. Bill, along with Fred Abbitt (HNC) in separate email, suggests connecting to MDMS via the Honeywell UMCS. Bill indicated connection via the Honeywell UMCS is beneficial in large part because Honeywell has an ATO. We had previously discussed "sharing" meter data between MDMS and (any other FLW) UMCS via the SmartServers (using IP output from this device). Instead, the approach using the Honeywell UMCS, where all meters would be connected to Honeywell (likely via SmartServers) would basically require that Honeywell transfer meter data via SQL database to MDMS. This approach would eliminate the need for an EEDRS server (which is simply "another" UMCS dedicated to metering) at FLW.
3. Meter connection to the Honeywell UMCS suggests the possible need for a contractual arrangement with Honeywell where Honeywell would provide MDMS with access to meter data via the SQL database. FLW currently has ESPC contracts with Honeywell but we assume HNC will use their contracting mechanism to obtain Honeywell services, in the event a contract is necessary. Bill Hood suggested access to meter data via SQL could be trivial. This needs to be explored.

Allen suggestion: I would believe we could modify an existing Honeywell ESPC contract to provide payment for this service, but we probably should use the contract administered by our local MICC. I suggest this contract because it is the one under which Honeywell provided the existing EBI/UMCS and metering. The Huntsville-Corps contract I have with Honeywell does not include these services in its scope.

4. Would a Honeywell/MDMS metering contract involve FLW interests/needs? For example, would the MDMS scope/requirements include graphic display development in Honeywell EBI/HEM for access/viewing by FLW, or is the scope going to only call for meter data to simply pass through to MDMS via SQL. Perhaps FLW does not need a graphic display because the data will be available via MDMS.
5. MDMS currently gets some metering data from Fort Leonard Wood where Laclede data is processed and sent by Laclede to the MDMS server once a month, which then makes it accessible to MDMS. There have been concerns about the accuracy of this data. It seems Laclede provides this data gratis and this arrangement may not last. It seems the current method of MDMS accessing Laclede data should be phased out with the new approach where MDMS accesses data via the Honeywell UMCS.
6. The existing Honeywell ATO covers only the Honeywell system and the devices (SmartServers) and thus meters connected to it. There has been prior discussion about including the existing DPW meters & SmartServers under the (Honeywell) ATO. We should consider if and how to go about this. This may entail connecting the existing government SmartServers to the Honeywell system.
7. IMCOM policy is that they will not provide funding for obtaining ATOs. Thus using the existing Honeywell ATO is appealing.

Allen input: CAUTION AHEAD. If IMCOM policy is that they will not provide funding for ATOs, then how will the Gov't. be expected to continue providing the services once our ESPC contract expires? I ask because at the conclusion of the ESPC contract the Honeywell system reverts to Government ownership and operation. It would then be our responsibility to keep the ATO current.

8. New meters should be installed carefully taking into account lessons learned. The Laclede meters were installed on transformers, which are a minimum of 30 ft from a building (a force protection requirement) making them "unusable"(due to inaccessibility) by the advanced metering program. Future meters should be installed in/at the buildings. We need to define other metering requirements necessary for success.

Appendix E: Fort Leonard Wood Advanced UMCS/Metering Options (for Decision Meeting December 2016)

Fort Leonard Wood UMCS/Metering Options
19 December 2016

Table E-1 lists five options Fort Leonard Wood has for obtaining the necessary functionality for UMCS and Metering.

Figure E-1 shows the UMCS/EEDRS decision flow chart. Decisions and end states are described below.

Table E-1. Fort Leonard Wood UMCS/metering options.

		FUNCTIONALITY NEEDED		
		ESPC UMCS	FLW UMCS	METER REPORTING
OPTIONS	CURRENT	ESPC EBI	MANY STAND-ALONE SYSTEMS	NONE
	OPTION A	ESPC EBI		
	OPTION B	ESPC EBI		NEW EEDRS
	OPTION C-1	ESPC EBI	NEW UMCS (FLW PROCURED)	
	OPTION C-2	ESPC EBI	NEW UMCS (PROCURED AS EEDRS)	
	OPTION D	ESPC EBI	NEW UMCS	NEW EEDRS

Decision -1: Is it OK to have MORE than 2 UMCS?

There is likely no debate that three systems is not the correct approach, thus eliminating Option D.

Decision 0: 1 UMCS or 2 UMCS OK?

- Assumptions:
  - Any UMCS will cost Fort Leonard Wood money to O&M. This may be more or less for different system types, but it is non-zero for any system.

    - There is an impact on usability when having multiple systems, and the DPW will have to know both, have accreditation credentials for both, and will be unable to look at the entire system (both systems) at one time.
- Factors Affecting the Decision
    - Fort Leonard Wood has an ESPC until 2025, and is "stuck" with the Honeywell EBI system provided under the ESPC. Unless they buy-out the ESPC or otherwise determine they can discount it as counting as a UMCS, a decision to have a single UMCS means using the existing ESPC system.
    - At least one of the systems selected must be able to report meter data to MDMS.
    - Can the ESPC contract accommodate using the EBI system as the installation-wide UMCS?
    - Fort Leonard Wood DPW has expressed a STRONG desire for a SINGLE UMCS.
- Decision Options: Fort Leonard Wood can make one of two determinations here:
    - Try for 1 UMCS
    - Try for 2 UMCS

Decision 1: Can ESPC EBI System work for the Fort Leonard Wood UMCS?

- Technical capability: YES.
- Contract: Our current belief based on input from Fort Leonard Wood is that the answer is YES.
- Other: Are there other factors (maintenance etc.) to consider?
- This appears to be primarily a question of whether the ESPC contract can support.
- If YES, go to decision 1-1. If NO then a single UMCS is not practical, go to decision 2.

Decision 1-1: Can ESPC EBI system work for metering?

- Technical capability: Based on the EBI system being the same revision as the EEDRS EBI, this should be YES.
- Contract: Our current belief based on input from Fort Leonard Wood is that the answer is YES.
- Other: Are there other factors (maintenance etc.) to consider?
- IF YES, go to End State 1. If NO then a single UMCS is not practical, go to decision 1-1-2.

End State 1: Use the ESPC EBI system as both the installation-wide UMCS and the Metering Front-End.

Decision 1-1-2: Is it OK to have the metering and Fort Leonard Wood UMCS functions separate?

- If NO go to Decision 2. If Yes then go to decision 1-1-2-1

Decision 1-1-2-1: Can EEDRS be the Fort Leonard Wood UMCS (Note that this is the same question as in Decision 2)

- If NO go to END STATE 2. If Yes then go to decision 1-1-2-1-1

Decision 1-1-2-1-1: Which is preferred as the Fort Leonard Wood UMCS

- If ESPC EBI go to END STATE 2. If EEDRS go to END STATE 4

End State 2: Use the ESPC EBI system as installation-wide UMCS and install a new EEDRS for metering ONLY.

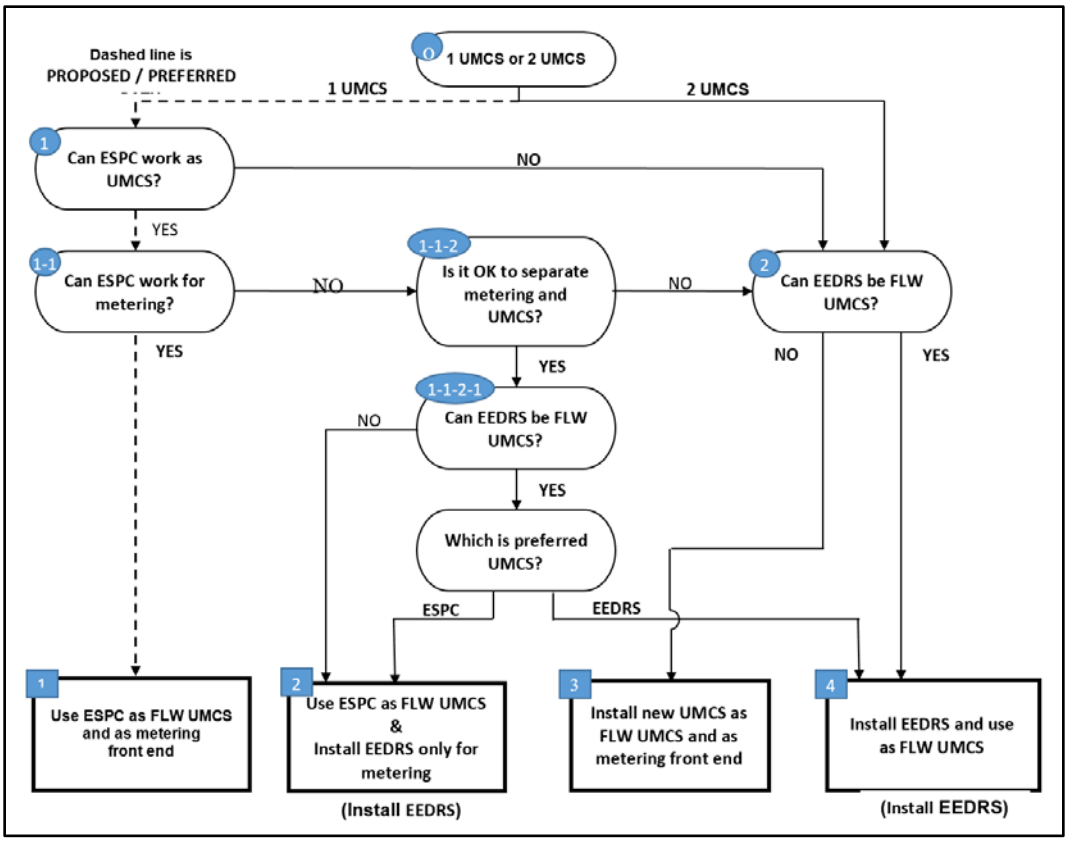
Decision 2: Can EEDRS function as the Fort Leonard Wood UMCS?

- If YES go to END STATE 4. If NO go to END STATE 3

End State 3: Install a new UMCS (NOT EEDRS) and use it for the UMCS and for Metering. **(included for completeness… we should never end up here, though)** (Continue to operate the ESPC EBI system separately)

End State 4: Install an EEDRS and use is as the installation-wide UMCS as well. (Continue to operate the ESPC EBI system separately)

Figure E-1. UMCS/EEDRS flow chart.



Appendix F: Fort Leonard Wood Advanced Metering Installation Status (Conference Call Notes, December 2016)

Meeting Minutes/Notes
Fort Leonard Wood UMCS/EEDRS
(ver: 23 December 2016)

1. Conference call & meeting at CERL: 20 December 2016
2. Participants:

Huntsville/AMP: Bill Hood, Fred Abbitt, Jim Workman
MDMS: Christian Roberson
Fort Leonard Wood: Allen Simpson, Jeannie Belew, Paul Schonenberger, Shelia Collins (NEC), Deborah Dowling (NEC), Joe Gillardi, Lee Criswell
Spectrum Solutions, Inc. (SSI): Jim Whitt, Kevin Kechler
CERL: Dave Schwenk, Joe Bush, Brian Clark, Dave Underwood, Annette Stumpf, Sue Bevelheimer, Dale Herron, Heather Fitzhenry

3. Summary
   a. Given that the Fort Leonard Wood Honeywell ESPC EBI/HEM system software will be upgraded to match the configuration currently being tested for EEDRS, the general consensus was that if the open concerns (question list is below) can be addressed it would make the most sense for Fort Leonard Wood to adopt the ESPC EBI system as their single front-end for UMCS and Metering purposes. The primary concerns from the Metering side appear to be a) the need to document an agreement for the system to operate on the Fort Leonard Wood ICAN and b) the need to address system administration responsibilities for the system. More general concerns to address are a) how to handle adding meters and building controls to the ESPC contractually, b) what will be the breakdown of maintenance responsibilities and c) how will the necessary work to obtain a site ATO for the system be funded.
   b. The group determined that the next step is to develop a list of questions/concerns for Allen to take to Honeywell to address. This should provide sufficient information to determine the feasibility of using the ESPC EBI system as the single Fort Leonard Wood UMCS/Metering system.
   c. There was some brief discussion about what the AMP can and cannot (will and will not) pay for. This is something that will need more definition – and it is likely that discussions with the AMP

Program Manager and/or the Assistant Chief of Staff for Installation Management (ACSIM) will be needed. The potential savings of using the ESPC EBI system are significant, but AMP may be unable to use metering funding for anything other than EEDRS ... Joe Bush volunteered to try and convince AMP and/or ACSIM that it would be worthwhile to consider changing this policy to avoid the waste of government funds. If the issue is ACSIM rules that limit the ways in which AMP can use metering funds, it would be best to approach ACSIM in coordination/cooperation with the AMP PM to see if they can modify these rules.

4. Question/Action Item Due Out List in support of the 1 UMCS approach. Some items are for Allen to ask Honeywell, others are more general or need to be answered by the group, but the group needs to reach consensus before Allen approaches Honeywell:
   a. The Fort Leonard Wood Security Evaluation Visit (SEV) report lists 2 high risk items related to using the Honeywell ESPC EBI system to meet the AMP metering requirements:
      b. "The ISSM is currently accepting the risk for allowing the ESPC system to operate on the network, although it was installed using the EEDRS ATO. It was installed and configured in accordance with (IAW) the EEDRS SCG and implementation guidelines. If the ISSM transitions to another site, the potential exists for the incoming ISSM to reject the risk acceptance and remove the system from the network until such time as a legitimate ATO is achieved for the system implemented at the site." **Possible resolution**: The relationship between DPW and NEC (especially ISSM, Ms. Dowling) has been "above average" (per the SEV) but it could be beneficial to create a Tenant Security Plan (TSA) agreement/arrangement between DPW and NEC to help ensure ongoing management of the computers/servers. A good start point might be the "Honeywell UMCS/IA Access Needs" document created this past fiscal year (FY) by Honeywell, NEC, DPW and CERL. It is attached to these minutes. There is already a service level agreement (SLA) between NEC and DPW that should be considered/referred to in development of and TSP.
      c. "The NEC SA is currently performing all administration (patching and updating) of the ESPC system, because the contractor employed to perform those tasks by Honeywell does not meet the minimum DoD/Army security requirements for System access." **Possible resolution**: The Fort Leonard Wood ESPC onsite Honeywell "Technical Resource

Manager" (Jabe Moore) is actively engaged in obtaining SA designation.

d. How to contractually structure/use the Honeywell ESPC EBI system to meet AMP metering requirements given that the EBI is owned by Honeywell (until 2025) and its use/access is governed/restricted by the ESPC contract. **Possible resolution**: Roll the AMP requirements into an ESPC contract (where the guaranteed energy savings requirement might be difficult) or a separate contract mechanism potentially as a sole source procurement action (Less than ideal, but Allen suggested this was possible). This is not a question for Honeywell, but for the Feds involved with this project.
e. In the event the Honeywell will be used to meet AMP metering requirements, we will need to know the expected date that Honeywell EBI R500 system will receive its type certification. **Possible resolution**: Ben Murray verbally told CERL/DPW it was expected April 2017.
f. Honeywell reported to CERL that Honeywell is obligated to upgrade the existing Fort Leonard Wood EBI to EBI 500 in accordance with the ESPC contract support requirements. For planning purposes we would need to know when this can occur.
g. What support does Honeywell need to meet AMP metering requirements.
h. eMASS and Form 1144 need to be updated. Existing eMASS profile needs to be updated to help convert the Honeywell EBI 500 "Type" accreditation to a "Site" accreditation. **Possible resolution**: Fred Abbitt is facilitating/attending to these items.
i. Existing Honeywell ESPC EBI system does not have connectivity and Honeywell and NEC have bene working to resolve this based on the attached "Honeywell UMCS/IA Access Needs" document. **Possible resolution**: Allen should schedule and host a conference call with NEC, Honeywell, and CERL every 2 weeks to review connectivity status. CERL can provide a call-in number if necessary (Joe and Annette have ones that can be used).
j. Bill Hood is setting up a follow-up conference call (appx 31 January) to review status of these items.

5. Other notes:
   a. Joe Bush stepped through the flowchart during the meeting. The big question seems to be whether Fort Leonard Wood can pursue the single UMCS approach or if they will need to adopt two UMCSs.
   b. A key point or decision factor is that the existing Honeywell EBI 410 system will lose its ATO on 31 Dec. It can be extended tempo-

rarily, per Fred Abbitt. The system needs an operating system update in order for the EBI to remain on the network beyond 31 Dec. Fred is dealing with this. He/we need an SES to sign the exception memo. Then, in separate discussion (between Honeywell and Allen Simpson, and yet another separate discussion between CERL and Honeywell) Honeywell has said they plan to upgrade the existing Fort Leonard Wood Honeywell from EBI R-410 to new Honeywell EBI 500. Statement from Ben Murray (Honeywell Technical Services Manager) original installer of the existing system at Fort Leonard Wood:

> The ATO reaccreditation is for type certification of Honeywell EBI R500 and Energy Manager R500 and a specific set of Echelon and Honeywell field devices. It is targeted at the Army EEDRS (Enterprise Energy Data Reporting System) use case and not specifically for Fort Leonard Wood. However, it would be applicable to the energy monitoring EBI system at FLW so long as it is substantially the same as when I originally installed it.

c. Fred Abbitt outlined a path forward where the Honeywell EBI could be used as the single Fort Leonard Wood UMCS to include AMP metering. This leads to the question/action item list above.
d. With the Fort Leonard Wood EBI 500 updated to the accredited version, the Fort Leonard Wood Honeywell EBI can serve as both a UMCS and MDMS metering platform.
e. When will Honeywell deploy the new EBI 500? Honeywell told CERL in prior discussion that it should be “Type” accredited in April 2017.
f. Site accreditation tasks need to be addressed.
g. Who will manage the new EBI 500? DPW has an SLA with NEC where NEC has historically been providing all services needed to support the Honeywell EBI. The expectation is that this will continue per Allen Simpson.
h. Honeywell (Jabe Moore) is working on obtaining System Administrator (SA) privileges. This entails completing training courses that Allen Simpson said he is in the process of doing.
i. Existing EEDRS gateway at Fort Leonard Wood. Need Ports, Protocols and Services (PPS). Fort Leonard Wood host MDMS URL: 140.153.165.114
j. The Government needs to be conscientious in monitoring and understanding Honeywell pricing, especially in the case of sole source procurement.
k. Building Point Of Common connection (BPOC) (SmartServer) sharing. Paul Schonenberger asked if it was possible for a single BPOC to share meter data with two different systems (i.e., an

EEDRS and a UMCS). If Fort Leonard Wood finds it must proceed with both an EEDRS and a UMCS it would be beneficial if the existing UMCS could access the meter connected to the Smart Server. We had discussed this possibility

AMP = Army Metering Program
BPOC = Building point of connection (an older term) used to describe SmartServer
EBI = Enterprise Buildings Integrator (software). Provides building-level (HVAC) graphics.
ESPC = Energy Saving Performance Contract
HEM = Honeywell Energy Manager (software)
ISSM = Information Systems Security Manager

Appendix G: UMCS Staffing

NOTE: This appendix is intended to provide insight for UMCS/BCS staffing and support. It was excerpted from an informal report written by CERL for IMCOM. The original IMCOM version was slightly to address Fort Leonard Wood situation but has not been rigorously edited. The **"***UMCS Staffing Matrix*" table (excerpted from a spreadsheet) was edited to include 226 BCSs to replicate Fort Leonard Wood's Government UMCS.

G.1 Overview and summary

There are several roles that need to be filled and multiple tasks performed to support a UMCS and the associated BCSs. The various roles and tasks are not new requirements - they were always needed to properly support a UMCS - this is a formalization of those requirements. The roles and tasks lead to the definition of staffing requirements fundamental to the success of a UMCS where the staffing requirements are a function of the size and growth rate of the UMCS. 26 basic tasks are listed/described here along with six related roles including; UMCS Manager, UMCS Administrator, Technical Expert, System Integrator, Controls Technician, and UMCS Operator. In some cases one individual can fulfill more than one role. For example, the UMCS Administrator and Technical Expert may be the same individual. With the exception of the UMCS Manager, these roles can be filled with contracted personnel. The UMCS Manager must be able to represent and commit the Government, however, so must be a federal employee.

G.2 Background

The success of a UMCS system depends on it being properly used, managed, maintained and grown. Historically, Army installations are not accustomed to providing this type of support – often there is insufficient controls expertise among maintenance staff who are stretched too thin, generally insufficient IT expertise within the DPW, no dedicated operators for the system, and no individual at the garrison who is truly responsible for the UMCS in that one individual does not have the authority or job description to manage the UMCS. The garrison DPW (O&M) have traditionally managed to "squeak by" doing what they can and leaving much undone.

G.3 UMCS support roles

Each UMCS/BCS support role listed here is not necessarily a full-time staffed position. With the exception of the UMCS Manager, these roles can be filled with contracted personnel (and this is essentially the model used by Fort Leonard Wood). The UMCS Manager must be able to represent and commit the Government, however, so must be a federal employee. In practice it likely makes sense to combine the UMCS Administrator and Technical Expert roles. Staffing requirements are a function of the size and growth rate of the UMCS and are discussed later. UMCS support roles include:

1. UMCS Manager: This role is responsible for managing all aspects of the UMCS and is the individual at the garrison with the responsibility and authority to make local decisions concerning the UMCS, including planning, project prioritization and system operation. Historically, if and when this role has been filled, it has typically been filled by the DPW Energy Manager, but this individual ordinarily does not have the time, designated responsibility or authority to do so effectively. This can easily be a full-time position at most garrisons (smaller garrisons may be able to do with a part-time position) and should be someone with a supervisory level position. Key responsibilities include:
   a. Developing, documenting and maintaining UMCS policies and procedures,
   b. Planning and programming (in the business sense) for the UMCS,
   c. Championing the UMCS to garrison leadership to secure funding and support,
   d. Managing the other UMCS roles.
2. UMCS Administrator: This role provides the necessary IT expertise to the DPW in support of the UMCS, performs IT management for the UMCS and coordinates UMCS IT issues with NEC. The role of managing the IT related aspects of the system is one of the biggest challenges facing a UMCS at most garrisons due in large part to IA requirements. Note that the NEC is not ordinarily responsible for the UMCS so the DPW has to manage it themselves or pay NEC to do so.
3. Technical Expert: This role provides expertise on the technology (LonWorks for example) and the implementation of this technology at the garrison. The key responsibilities for this role are the review of project submittals (designs, as-built drawings, etc.) and participation in control system acceptance. Garrisons will have an ongoing need for someone who has ex-

pertise in UMCS technology - specifically the protocol, networking and database management requirements of the UMCS - to assist the garrison with preparation for job specifications, review of designs and participating in system testing and acceptance.

4. System Integrator: This role performs the actual integration of BCSs into the UMCS to expand the UMCS. This service will generally be obtained as part of the BCS project, so this role does not correspond to a position that must be filled at the garrison.
5. Controls Technician: This role provides controls expertise and support to DPW O&M staff. Initially this might best consist of contract personnel in the form of dedicated controls technicians who provide direct O&M support along with on the job training to the DPW O&M staff. While this role will be filled via contract personnel who already have controls expertise, this role should transition to O&M staff as they become trained. This basic approach has been used successfully by Fort Hood. As mentioned previously a UMCS is only useful when connected to building controls systems – but these systems must themselves be functioning properly for the UMCS to provide benefit. Most garrisons do not have sufficient controls expertise "in-house" to effectively manage their building controls. Controls Technicians hired on a short-term basis (a few years) can work with the O&M staff on controls issues while also providing "on the job" training to allow the garrison to obtain the controls expertise it needs. Retaining a single controls technician long-term will provide ongoing support and training to ensure that the garrison can maintain its level of controls expertise.
6. UMCS Operator: The purpose of this role is take advantage of the power and capabilities of the UMCS. The UMCS Operator uses the UMCS to monitor and control the connected BCSs. The UMCS Operator provides remote troubleshooting and diagnostic support. The Operator can also adjust schedules, set up trending and configure demand limiting to support the changing needs of the garrison. To be effective, the UMCS must have operators using it. Some sites currently do this e.g., the Pentagon, but most operate the UMCS on a sporadic basis relying on the O&M staff to use it. Staffing the UMCS with operators on a full-time basis allows pro-active use of the UMCS to address issues, while also assuring that the system remains functional and useful. Initially fewer operators are needed, but in the long-term the goal should be to have the UMCS staffed 24/7.
7. UMCS Support Tasks. Table G-1 lists 26 tasks associated with the support of a UMCS. Each task includes additional information describing the task including an indication as to whether or not a contractor can perform the task.

Table G-1. Tasks necessary to support a UMCS.

Task #	Can a Ctr Do This?	Task	Description
1	Y	Integrate BCS & LNS© into UMCS	Including: - Merge databases - Fix building addressing - Create graphics, trends, alarms, etc. - Install 852 router (request IP drop) We assume that MCA pays for system integration, so although there is System Integrator (SI) involvement in this role/task, no labor time is included/shown in the Roles Matrix for the SI.
2	Y	Review BCS submittals (during construction)	Review of submittals during construction: - contractor design drawings - device data sheets - as-builts (esp. Points Schedule and LNS© Database).
3	Y	Review BCS proposals (prior to award)	Review proposals from contractors. (Note there may be a possible conflict/issue with contractors reviewing contractors.)
4	Y	Review BCS designs	Review project designs and RFPs (prior to announcement). Note there is possible concern/conflict with contractor review of RFP they are going to bid on.
5	N	BCS "document" approvals	-Actual approval of all the reviews for the BCS (submittal, proposal, design). -Keeping the authority to approve with a Gov't person gives some relief from issues of contractors review of these documents.
6	Y	IT: hardware admin	Computer hardware management and procurement.
7	Y	IT: OS admin	Operating system and standard software (including office automation and standard server packages like SQL and Internet Information Services [IIS]) management and upgrades, etc.
8	Y	IT: application administration	Admin of the M&C software, network configuration tool software, Plug-ins, programming software, etc.
9	Y	UMCS policies/procedures (System Integration Methodology, etc.)	Development and updates to policies and procedures such as: - System integration methodology (SIM) - database management scheme/plan - system operation policies - etc. Includes lots of IA and IT related items. We assume that MCA pays for system integration, so although there is System Integrator (SI) involvement in this role/task, no labor time is included/shown in the Roles Matrix for the SI.
10	Y	LNS© database (DB) mgmt/coord	Management of database issues such as: - database/server distribution (how many, what breakdown, etc.) - database storage and backup - database management for building contractors (esp. for return/warranty work).
11	N	UMCS planning (decisions)	UMCS Master Planning such as: - building integration priorities - system operation parameters (schedules, demand limiting, etc.) - workload planning and work distribution.
12	N	UMCS champion (funding etc.)	Secure funding, promote system, monitor use of system and address issues. The time/effort associated with this role/task is difficult to estimate and likely differs/varies in large part as a function of system size.

Task #	Can a Ctr Do This?	Task	Description
13	N	UMCS contract support	-Determine contract needs (personnel, etc.) and monitor contractors. -This is only for the contracts necessary to fill the "recurring" roles (not new building contracts, not integration contracts). In other words the contracts needed to get people. -The time estimate assumes only a couple of contracts (per year).
14	Y	Alarm management (alarm receipt)	-Handle incoming alarms (keep alarm log from filling up). -The expectation/estimation is 15 minutes/week/bldg.
15	Y	Work order generation	Generate work orders.
16	Y	UMCS ongoing configuration	Tweak/add graphic pages, set up trends, alarming, scheduling. Change reports, demand limiting.
17	Y	UMCS system "browsing"	-Use GUI to scan through systems for problems. -Monitor overrides. -Check schedules -etc. There is no fixed time allotment/estimation associated with these tasks.
18	Y	UMCS trouble call receipt	-Receive trouble calls from building occupants (via phone). -The time/effort associated with this role/task is difficult to estimate, but is assumed to be 10 min per call and one call per week per building.
19	Y	UMCS remote diagnostics	Remotely diagnose/repair problems in building controls.
20	Y	BCS testing/Cx	Participate and assist with building testing. -The time/effort associated with this role/task is difficult to estimate, but is assumed to be 20 min per issue and one issue per week per building.
21	N	BCS Acceptance	Determine acceptability of building controls. "Sign off" on building controls (with the caveat that the building acceptance process must account for the need for BCS acceptance).
22	Y	Interface with NEC	-Talk/coordinate with NEC -We assume that MCA pays for system integration, so although there is System Integrator (SI) involvement in this role/task, no labor time is included/shown in the Roles Matrix for the SI.
23	N	Be the boss	-Manage other roles (supervise contracts and government employees filling the other "new" roles defined here). -The time/effort associated with this role/task is difficult to estimate, but is assumed to be 8 hr/year/person.
24	Y	HVAC mechanical & BCS equip work	-Assist with diagnostics, troubleshooting maintenance and repair of control equipment and related mechanical equipment. - The time/effort associated with this role/task is difficult to estimate, but is assumed that each controls technician spends 80% of their time supporting 5 HVAC techs.
25	Y	Train (or get training for) HVAC Techs	-Provide training (either directly or indirectly) to bring HVAC Techs "up to speed" on controls with a goal of making them able to do control tech work. - The time/effort associated with this role/task is difficult to estimate, but is assumed that HVAC techs get 40 hrs/year of training, Controls techs train in pairs of HVAC techs so provide 20 hr/year of training per HVAC tech.
26	Y	Maintain IT Certification	Take classes/tests as needed to maintain ability to be a System Administrator.

8. UMCS support staffing
   a. The categories/cells shown in Table G-2 include:
      (1) -Roles: The roles that need to be performed/supported. An individual can perform more than one role. Note that we are redefining roles here. This is not an attempt to match up, say "UMCS Admin"

with specific tasks. Instead, this list of tasks defines the UMCS Admin role.

(2) -Item number: sequential numbering of items listed in the matrix.

(3) -Ctr: Can this task be done by a contractor?

(4) -Task: Short description of the task.

(5) -Startup? Is there a "startup" cost associated with the task? Startup costs include the development of documents, procedures and processes for example. Startup costs are not quantified here.

(6) -Time Category: Each task includes an estimate of the amount of time required to support/perform the task. Some tasks are estimated differently than others and therefore have different time category units. These include:

(a) hours/year

(b) hours/new building per year

i. hours/year per existing building

ii. hours/year per person managed

iii. hours/year per HVAC Tech

9. UMCS Staff Organization within the DPW

a. A glance at the roles and responsibilities for the UMCS Manager indicates that it requires a greater level of responsibility and authority than the Energy Manager (whom it is often confused with).

b. For a medium sized UMCS, the UMCS has a support staff consisting of:

(1) UMCS Manager

(2) UMCS Administrator (part-time FTE)

(3) Technical Expert (part-time FTE)

(4) UMCS Operators (perhaps five or more FTE)

(5) System Integrator (or more likely, contract responsibility for the System Integrator)

(6) Controls Technicians (two to five or more FTE)

(7) (This works out to approximately a dozen FTEs, not counting the System Integrator.)

c. The UMCS Manager must be able to influence other divisions within the DPW:

(1) Engineering Division to ensure:

(a) UMCS requirements are in design documents (in house and out of house)

(b) Project submittals meet UMCS requirements

(c) QA and commissioning procedures adequately check for UMCS requirements

(2) O&M Division to coordinate UMCS use and maintenance with O&M staff. This interaction is absolutely critical and its lack is one of the big stumbling blocks with many UMCS implementations. There is likely coordination with the service order process in the O&M division as well.

(3) Master Planning Division to champion projects that make best use of the UMCS

(4) Environmental Division to coordinate efforts to meet energy goals.

10. As the person responsible for the UMCS, the UMCS Manager has authority to accept or reject BCS and UMCS project submittals and other work.
11. The UMCS Manager must be able to work with NEC and should be at a sufficient level to interact directly with decision makers in the NEC. Because of their responsibility for contract approvals and the ability to commit the Government, as well as their interaction with other DPW and NEC staff, the UMCS Manager must be a Government position.
12. The UMCS Manager must be given responsibility for and authority over the UMCS, including related garrison processes (such as O&M and design standards for controls). Ideally, the UMCS Manager would be at a Division Chief level to facilitate interactions with other Division Chiefs in the DPW; however, staffing levels do not appear to justify a Division Chief position and creation of a new Branch is recommended. Placing the UMCS Manager directly under the Director of DPW helps ensure that the UMCS Manager can influence the other Divisions within the DPW without regard to answering to a particular Division Chief.

Table G-2. UMCS Staffing Matrix (for UMCS with 226 buildings).

#	Ctr?	Tasks	Time Category	UMCS Manager	UMCS Admin	Tech Expert	SI	Controls Tech	UMCS Operator
1	Y	Integrate BCS & LNS into UMCS	hours/new building per year		2.00		X		
2	Y	Review BCS submittals (during contruction)	hours/new building per year	4.00		5.00		2.00	
3	Y	Review BCS proposals (prior to award)	hours/new building per year	4.00		5.00		2.00	
4	Y	Review BCS designs	hours/new building per year	4.00		4.00		3.00	
5	N	BCS "document" approvals	hours/new building per year	4.00					
6	Y	IT stuff - hardware admin	hours/year		50.0				50.0
7	Y	IT stuff - OS admin	hours/year		100.0				
8	Y	IT stuff - application admin	hours/year	20.0	180.0				
9	Y	UMCS policies/procedures (SIM etc)	hours/year	12.0	24.0	12.0	/		
10	Y	LNS DB mgmt/coord	hours/year per existing building		1.0				
			hours/new building per year		3.0				
			hours/year	20.0	80.0				
11	N	UMCS planning (decisions)	hours/new building per year	2.0					
			hours/year	80.0					
12	N	UMCS champion (funding etc)	hours/year per existing building	2.0					
			hours/year	200.0					
13	N	UMCS (not BCS) COTR	hours/year	120.0					
14	Y	Alarm management (alarm receipt)	hours/year per existing building						13.0
			hours/year						40.0
15	Y	Work order generation	hours/year per existing building						5.0
16	Y	UMCS ongoing configuration	hours/year per existing building						1.0
			hours/new building per year						4.0
17	Y	UMCS system "browsing"	undetermined (as time permits)					/	X
18	Y	UMCS trouble call receipt	hours/year per existing building						9.0
			hours/new building per year						2.0
19	Y	UMCS remote diagnostics	hours/year per existing building					4.5	13.5
			hours/new building per year					1.0	3.0
20	Y	BCS testing/Cx	hours/new building per year	1.0		4.0		11.0	
21	N	BCS Acceptance	hours/new building per year	4.0					
22	Y	Interface with DOIM	hours/new building per year		4.0		/		
			hours/year		40.0				
23	N	Be the boss	hours/new building per year	2.0					
			hours/year per person managed	8.0					
24	Y	HVAC mechanical & BCS equip work	hours/year per HVAC Tech					320.0	
25	Y	Train (or get training for) HVAC Techs	hours/year per HVAC Tech	1.0				20.0	
26	Y	Maintain IT Certification	hours/year		40.0		/		
			Total Hours/Year	**1239**	**830**	**192**		**2743.8**	**9559**
			Decimal FTE Positions	0.69	0.46	0.11		1.52	5.31

Number of Existing Buildings:	226	
Number of New per year	10	
Number of HVAC Techs:	4.52	(calculated: 1 per 50 buildings)
Person-hours per year	1800	

Appendix H: HVAC Controls Summary of Work

JOB TITLE: POC:
W0RK ORDER # POC PHONE:
DRAWING # Construction (DBA Wages) or Service (SCA Wages):

SECTION 01010

HVAC CONTROLS SUMMARY OF WORK

1 DESCRIPTION OF WORK:

1.1 Work to be Done: The work consists of furnishing all plant, labor, equipment, supplies, and materials, and performing all work in accordance with these specifications and drawings as indicated at Fort Leonard Wood, Missouri.

1.2 Location: The site of the proposed work is in the Cantonment Area of the Fort Leonard Wood Military Reservation, Fort Leonard Wood, Missouri.

2 PRINCIPAL FEATURES:

The work to be performed will include, but not be limited to, the following principal features:

2.1 Reprogram existing controls in 8 buildings for energy conservation and economizer improvement purposes

2.2 Energy conservation measures include duct static pressure reset, conversion of multi-zone or single-zone handlers to variable air volume units, and demand-controlled ventilation

2.3 Installation, programming, and commissioning of two new programmable controllers

2.4 Modification of existing front-end controls graphics to support the new sequences

2.5 Testing, adjusting, and balancing (TAB) of select economizers

3 SEQUENCE OF WORK:

The area concerned in this project is Government owned and will be in use during the course of this project.

4 SCHEDULING:

4.1 The Contractor shall schedule all activity at the job site through the DPW Contract Inspection Branch a minimum of 24 hours in advance of work.

4.2 Contractor shall schedule his working hours to coincide with the working hours of the military reservation. Normal working hours of the reservation are 7:30 a.m. to 4:00 p.m., Monday thru Friday, legal public holidays exempted. The Contractor shall not perform work on the reservations beyond the aforementioned working hours without the written approval of the Contracting Officer.

4.3 If the Contractor, for his convenience, desires to perform work during other than normal working hours or on other than normal workdays, he shall notify the Contracting Officer and the Directorate of Public Works Inspection Branch at least 72 hours in advance. The Contractor shall not perform work beyond the normal working hours or normal workdays without written approval of the Contracting Officer and the DPW Inspection Branch approval. The Contractor shall reimburse the Government for any additional expense occasioned the Government thereby, such as, but not limited to, overtime pay for Government inspectors, utilities service, etc.

4.4 The Contractor shall complete all work on this contract by within (120) days after issue of delivery order by Contracting Officer (delete this sentence if this project goes to DOC) Time extensions due to adverse weather or material lead time, must be received in writing prior to scheduled completion date.

4.5 If the Contractor intends to perform the project work using subcontractors the Contractor shall include a liquidated damages provision in each subcontract providing that if the construction completion period exceeds the calendar days allotted, a minimum cost of $54.00 liquidated damages will be assessed per calendar day to each subcontractor.

JOB TITLE: POC:
W0RK ORDER # POC PHONE:
DRAWING # Construction (DBA Wages) or Service (SCA Wages):

5 UTILITY INTERRUPTIONS:

Coordinate with the Contracting Officer, DPW Contract Inspection Branch, and the user for any utility work that interrupts service to the facility, any area outside the facility, or any real property facility. Establish a schedule of interruptions listing starting and ending times of disconnection 48 hours prior to interruption.

6 FIELD MEASUREMENTS:

The Contractor shall verify all measurements at the project site and shall be responsible for all dimensions, fittings, and the proper installation of all materials and equipment specified

7 PERMITS:

The Contractor shall be responsible for obtaining permits for each worksite.

7.1 Digging: A digging permit is required prior to ANY earthwork operations. The DPW Contract Inspection Branch will assist the Contractor in obtaining this free permit.

7.2 Land Disturbance: A land disturbance permit is required for any projects that disturb one (1) acre or more. Land disturbance is defined as any activity that disturbs the roots of vegetation such as clearing, grubbing and grading. The Contractor shall apply for the permit from the Missouri Department of Natural Resources (MODNR), after the FLW Environmental Office has approved the permit application. MODNR by law may take up to 180 days to review and issue a permit. Copy of the permit shall be forwarded to the DPW Environmental Office. The Contractor shall not begin land disturbance operations until they have received and complied with the MODNR permit. MODNR charges a fee for the permits.

7.3 Hot Work Permit: The Contractor shall obtain a written "Hot Work Permit" (DA Form 5383-R) prior to commencing all hot work outside an approved shop area. Permits will be issued by the FLW Fire & Emergency Services at Fire Station #1, Bldg. 580, Phone: (573) 596-0883. The Contractor shall be liable for any fire loss to Government property attributable to negligence on the part of the Contractor, including failure to comply with fire prevention measures prescribed by terms of this contract. The Inspection Branch will assist the Contractor in obtaining this free permit

7.4 Confined Space Permit: The Contractor shall obtain a written "Confined Space Permit" prior to commencing all confined space activity above and/or below ground. Title 29 CFR 1910.146 OSHA (Confined Space Entry) and FLW Regulation 385-7 sets forth the definition of confined spaces and establishes responsibility and procedures for protection of personnel that shall be entering, work in, and existing confines space. If a permit is required the Contractor shall contact the FLW Fire Department, Fire Station #1, Assistant Chief of Operations, Bldg 580, Phone: (573) 596-0883 prior to, and after the permit required entry is conducted. The Contractor shall keep the permit copy within the work area until all workers have been accounted for after completion of the workday. The Inspection Branch will assist the Contractor in obtaining this free permit.

8 SAFETY REQUIRMENTS:

8.1 General Safety: During progress of work, the Contractor shall protect all personnel, whether Government or civilian, from any and all safety hazards caused by the construction operations. The contractor shall follow all Federal, State and local laws in accordance with 29 CFR 1910 (General Industries Standards), and 29 CFR 1926 (Construction Standards).

8.2 Fire Prevention: The current version of FLW Regulation 420-2 "Post Fire Regulations" is by this reference made a part of this solicitation and resultant contract. The Contractor's operation shall conform to all applicable portions of this document. All personnel entering on duty as Contractor's employees shall be instructed in the fire prevention program of the Post and shall be advised of the requirement of the Post Fire Regulations as they pertain to this particular contract.

8.3 Traffic Control: Contractor shall provide all temporary signs and markers as necessary to maintain safety in the worksite. All signs shall conform to the latest edition of the Manual of Uniform Control Devices (MUTCD) and shall be coordinated with, and approved by, DPW Inspection Branch. Contractor shall ensure road user movement is inhibited as little as practical.

9 SPECIAL REQUIREMENTS:

JOB TITLE: POC:
W0RK ORDER # POC PHONE:
DRAWING # Construction (DBA Wages) or Service (SCA Wages):

9.1 Use of Fire Hydrants – The temporary use of fire hydrants as sources of water is not authorized without prior approval by the Fire Department, 596-0886. Fire hydrant connections shall include an approved backflow preventer. Use of backflow preventers must comply with Missouri Department of Natural Resources, Division 60, Public Drinking Water Program, Chapter 11 – Backflow Prevention, Title 10CSR60-11. Government furnished backflow preventers shall be utilized and are available at Bldg. 1601, Water Treatment Plant on a first come basis. The Contractor shall be required to sign a hand receipt prior to obtaining a backflow preventer. The Contractor shall be accountable to return the checked out backflow preventer equipment undamaged and as soon as possible. The contractor shall furnish and use an approved fire plug wrench to open and close the hydrant. Pipe wrenches shall not be used. When the hydrant is not being used it shall be shut off. When the need for the hydrant is finished, the hydrant shall be shut off, the temporary connection and backflow preventer shall be removed, the fire hydrant caps shall be replaced and the Fire Department shall be notified that the hydrant will no longer be used.

9.2 Dust Walls - Provide tightly sealed dust curtains to prevent dust from either demolition or construction work from spreading to other parts of the facility. Temporary enclosures materials must be of noncombustible panels, flame-resistant tarpaulins, or approved materials of equivalent fire-retardant characteristics. All other fabrics or plastic films used shall be certified as conforming to the requirements of Test Method 2 contained in NFPA 701, Standard Methods of Fire Tests for Flame Propagation of Textiles and Films.

9.3 Building Number – Contractor shall provide a facility number sign with the street address included. Display in a prominent location near the entrance of the job site. Sign numbers shall be white, minimum of 4" tall on brown background, Bold Helvetica style. Sign shall be mounted 7' from ground to bottom of sign and shall be maintained in a legible condition from start of actual work on site to final acceptance.

10 SECURITY:

10.1 In unoccupied facilities, the Contractor shall be responsible for the security of the facility; i.e., all exterior doors shall be locked, windows closed and locked, etc.

10.2 The Contractor shall not be on site without prior notification to the DPW Contract Inspection Branch.

10.3 Contractor personnel shall have valid civilian ID's.

11 APPLICABLE PUBLICATIONS/REFERENCES:

The publications referenced herein after shall be the most recent at the time of solicitation, unless otherwise specified at the beginning of each Specification Section under paragraph 1. APPLICABLE PUBLICATIONS and or REFERENCES.

12 WORKSITE HOUSEKEEPING:

12.1 The Contractor shall remove all trash and disposal material from the worksite before the end of each day, to the extent it is consistent with standard construction practices on Government work sites. The Contractor shall take all possible precautions to maintain the work site, at all times, in a condition that will prevent damage or injury to person or property, Government or otherwise. The above precautions shall include protection from weather conditions. The Contractor shall be responsible for all damages caused by the negligent acts or omissions of his employees, sub-contractors, or agents during Contract performance.

12.2 Materials to be used within 1 week of delivery and scrap material to be used as work progresses shall not be required to be in screened area. However, all such items shall be placed in an orderly manner (i.e. dirt, rock, etc., in piles and stackable items such as pipe, brick, lumber, etc., stacked off the ground on pallets in an orderly manner).

12.3 Grass and weeds at work/storage site shall be kept at a height of 4"or less. Work site/storage site shall be policed for trash and disposal material a minimum of once per day.

12.4 All trailer and material storage sites shall have an identification board/sign, with company and job name on it, i.e. ABC Construction – ABC building complex. Signs shall meet the following criteria: min 3' X 3' max of 4' X 8' in size, 3" high legible print, and be approved by DPW Inspection Branch.

13 RESPONSIBLITY FOR DAMAGE

JOB TITLE: POC:
W0RK ORDER # POC PHONE:
DRAWING # Construction (DBA Wages) or Service (SCA Wages):

13.1 Damage to Personal Property: The Contractor shall be solely responsible for all damage to Government and occupant personal property caused by the Contractors' personnel, subcontractors, his agents, or by the performance of his work.

13.2 Damage by Negligence: Damage resulting in gas leaks, electrical outages, loss of heat during cold weather, water leaks, unsecured facilities, weather damage, or oil/hazardous waste spills shall be responded to by the Contractor within 2 hours and repaired within one workday. If the Contractor fails to comply with these requirements, the Government reserves the right to repair the damage and charge the cost to the Contractor. Contractor shall protect all areas through which he will be transporting demolition debris or construction materials. Any damaged turf, sidewalks, roads, vegetation, site amenities, etc, shall be replaced or repaired by the Contractor prior to final Contract closeout.

14 DISPOSAL OF MATERIALS:

All materials removed and not reused or designated as salvage material in this project shall become the property of the Contractor, unless otherwise specified, and shall be the Contractor's responsibility for lawful disposal.

14.1 The Contractor may use the Fort Leonard Wood Compost area for the disposal of wood chips, leaves, and grass clippings generated by this project.

14.2 All other wastes generated during Contractor operations shall be disposed of off post by the Contractor at his/her expense.

14.2.1 The disposal of demolition waste is regulated by the Missouri Department of Natural Resources under Chapter 260, Revised Statutes of Missouri and 10 Code of State Regulations Chapter 80-4. Such waste, in types and quantities established by the Department, shall be taken to a demolition landfill or a sanitary landfill off of the Installation for disposal. The Contractor shall provide any information requested by the landfill operator to complete forms required by the Missouri Department of Natural Resources or other Government-required landfill records.

14.2.2 Wastes classified as hazardous wastes under the Resource Conservation and Recovery Act shall be disposed of off the installation, unless otherwise specified in this contract. No hazardous waste shall be disposed of without prior review of the disposal documents, and the approval of the Contracting Officer and the Directorate of Public Works Environmental Coordinator, or his designated representative. The Contractor shall provide an original copy of the disposal document from the approved EPA or State permitted disposal facility for each shipment of hazardous waste generated in this project to the Contracting Officers Representative.

15 ACCESS AND GENERAL PROTECTION/SECURITY POLICY AND PROCEDURES:

15.1 All Contractor and sub-contractor personnel performing tasks on this SOW shall comply with all applicable installation, facility and area commander installation/facility access and local security policies and procedures which will be provided to the Contractor by a Government representative upon written request to the Contracting Officer. Contractor shall provide all information required for background checks to meet installation access requirements as performed by the installation Provost Marshal Office, Director of Emergency Services or Security Office. Requesting Contractor shall submit request for installation pass to the KO at https://vcc1.icmvcc.com/im3500/. There is no charge to the Contractor for this pass. Contractor personnel shall comply with all personal identity verification requirements as directed by DoD, HQDA and/or local policy. In addition to the changes otherwise authorized by the changes clause of the base contract to this task order, should the Force Protection Condition (FPCON) at any facility or installation change, the Government may require changes in Contractor security matters or processes.

15.1.1 In the event that the automated system at https://jkodirect.jten.mil is not available (e.g., server problems), Level I AT Awareness Training can be provided by a qualified instructor. However, if the training is not completed online, the Level I AT Awareness Instructor qualification must be coordinated with the Installation Antiterrorism Officer (or Installation Security equivalent) and the resultant name(s) of approved instructors shall be provided to the KO.

15.2 Antiterrorism (AT) Level I Training: All contractor and sub-contractor employees requiring access to Army installations, facilities and controlled access areas shall complete AT Level I awareness training available at

JOB TITLE: POC:
W0RK ORDER # POC PHONE:
DRAWING # Construction (DBA Wages) or Service (SCA Wages):

https://jkodirect.jten.mil.Users need to enroll in "Course #JS-US007-14" to receive credit for the training within 10 calendar days of contract award; or for new employees within 10 working days of beginning performance on this contract. Contractor shall submit certificates of completion for all personnel to the KO within five calendar days of completion of the training. There is no charge to the Contractor for this training. The burden to complete this training is approximately 1-hour per employee.

15.3 iWatch Training: Within 10 calendar days of contract award and within 10 calendar days of new Contractor employees commencing work on this contract, all Contractor and sub-contractor employees shall review the FLW Directorate of Emergency Services (DES) web link for iWatch training located at http://www.wood.army.mil/LEC/iWatch/iWatch.htm. This locally developed training will inform employees of the types of behavior to watch for and how to report suspicious activity. Suspicious activity shall be reported to the KO. There is no charge to the Contractor for this review. The burden to complete this training is approximately 20-minutes per employee.

15.4 OPSEC Standard Operating Procedure/Plan (SOP): The KO will ensure the contractor (after selected) is aware of the MSCoE OPSEC Plan and is in compliance with the MSCoE OPSEC Plan during contract performance

15.5 OPSEC Training: New contractor employees must complete Level I OPSEC training within 30 calendar days of their reporting for duty in accordance with AR 530-1. All contractors shall complete annual OPSEC Awareness training if the contract duration is longer than 30-days. MSCoE OPSEC Officer will provide training. Coordination of training shall be through Rick Bowser, (573)563-2402. Proof of training, including a detailed listing of attendees, shall be provided to the KO. A nominal fee shall be charged to the Contractor for this training equal to 1-hour of Government time. The burden to complete this training is approximately 1-hour per training evolution. There are no restrictions to number of attendees in a given training evolution.

15.5.1 All costs associated with employee training and review must be included in the CLIN prices bid/offered for the underlying requirement. No other payments are authorized.

15.5.2 Contractor shall reimburse the Government for classroom OPSEC training. The established fee is $30 per face-to-face training session conducted. Contractor personnel may all attend the same training session; however, in the event of new hires, additional session(s) shall be required. Contractor shall submit payment to the US Treasury, Attention: Budget Officer, MSCoE G-8, 14000 MSCoE Loop, Ste 335, Fort Leonard Wood, MO 65473.

JOB TITLE: POC:
W0RK ORDER # POC PHONE:
DRAWING # Construction (DBA Wages) or Service (SCA Wages):

16 BUILDING LIST:

Energy Conservation Measures (ECMs) required for each building system as part of this scope are identified with an "X"

Bldg #	Bldg Name	Bldg Function	Bldg System	Existing Field Controls	Existing LDP	UMCS Type	ECM1: SZ to VAV	ECM2: MZ to VAV	ECM3: DSPR	ECM4: DCV	ECM5: Econo Assess
2100	Grant Hall	Army In-Processing Center (offices, assembly, medical, storage spaces)	AHU-1	Distech EC-FCU-L, VAVs, Circon 452A	None	iLON Smart Server (Phase I)			X		X
			AHU-2	Distech ECP-510s	None	iLON Smart Server (Phase II)			X		X
			AHU-3	Distech ECP- 410, ECP 510	EC-Display	iLON Smart Server (Phase II)	X			X	X
			AHU-4	Distech ECP-500, ECC-VAVs	EC-Display	iLON Smart Server (Phase II)			X		X
			AHU-8, AHU-9	Distech EC-RTU-L	EC-Display	iLON Smart Server (Phase II)	X			X	X
932, 934, 936, 937, 939	930-series	Army Barracks (dwelling, office and multi-purpose spaces)	AHU-1	Distech ECP-400s/ ECL-STAT-RTs	EC-Display	iLON Smart Server		X			
			AHU-2, AHU-3 AHU-4, AHU-5	Distech ECP-500s/ ECC-VAV	EC-Display	iLON Smart Server			X		
5295B	Simulator Facility	Army Computer Training (data center/wareh ouse, offices)	AHU-1	Scheider TAC Xenta 401, 422As, 452As	None	Honeywell EBI			X		
			AHU-2	Scheider TAC Xenta 401, 422As, 452As	None	Honeywell EBI		X			
5400	Brown Hall	Army Instructional Training (classes, offices, assembly)	AHU-1, AHU-2	Distech ECP-610s, ECC-VAVs	EC-Display	iLON Smart Server			X		

17 GENERAL CONTRACT REQUIREMENTS

Either reference a tailored UFGS 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC as the source for all general contract requirements and include in the attachments or list the applicable requirements below for this scope of work (eg, project sequencing, submittals required, existing conditions survey, etc). For now it's assumed the UFGS will the referenced and included.

17.1 Adhere to the attached UFGS 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC for project sequencing, quality control, training, and general submittal requirements.

17.2 Use the below table of FLW POCs for submittal routing and coordination with site work including existing conditions survey, equipment downtime, construction, testing, and training in accordance with the attached UFGS 23 09 00.

Primary POC:	Alternate POC:
Project Manager (Government Approval):	Project Engineer (Government Approval):

JOB TITLE: POC:
W0RK ORDER # POC PHONE:
DRAWING # Construction (DBA Wages) or Service (SCA Wages):

Alternate POC: FLW Energy Manager (Government Approval):	Alternate POC: Operations & Maintenance Lead (Government Approval):
Alternate POC: UMCS Operator/Programmer:	

17.3 Provide performance verification testing (PVT) procedures and execution as required in UFGS 23 09 00. Use the attached functional performance test sheet templates or integrate tasks from these sheets into contractor-provided PVT procedures forms. Contractor shall not conduct PVT until the government provides written acceptance of PVT procedures submitted and government witness of PVT is indicated per the attached UFGS 23 09 00.

17.4 For HVAC control tasks below, contractor shall have a minimum of 3 years' experience working with the field and supervisory controllers described. TAB contractor must be AABC, NEBB, or TABB certified.

18 SEQUENCE OF OPERATION REQUIREMENTS

New content has been added to the UFGS 23 09 93 SEQUENCES OF OPERATION FOR HVAC CONTROL tailored for Fort Leonard Wood that includes requirements for VAV Multi-zone units, duct static pressure reset, and demand-controlled ventilation. References to the UFGS are used below with additional info added for building-specific requirements.

18.1 Adjust occupancy modes and zone control features to match UFGS 23 09 93 SEQUENCES OF OPERATION FOR HVAC CONTROL. Configure/adjust zone thermostats for 70F and 76F heating and cooling temperature set points, respectively, and a 1.5F occupant adjust range.

18.2 Convert CV single zone (SZ) air handling units to VAV using zone temperature-based VFD control per the requirements in UFGS 23 09 93 section 3.2.4. Include the supply air temperature set point reset requirements from section 3.2.4.6.

18.3 Convert CV multi-zone (MZ) air handling units to VAV using zone temperature-based VFD control per the requirements in UFGS 23 09 93 SEQUENCES OF OPERATION FOR HVAC CONTROL section 3.2.7 (without hot deck bypass) and 3.2.8 (with hot deck bypass).

18.4 Duct Static Pressure Reset (DSPR)

18.4.1 Program air handlers to reset duct static pressure set point based on critical damper position and using a set point offset and fixed rate change per the requirements in UFGS 23 09 93 SEQUENCES OF OPERATION FOR HVAC CONTROL section 3.2.9.6.1.1.

18.4.2 Exclude zones identified in the attached as builts or during site assessments as exclusively serving bathroom, corridor, or storage spaces from the DSPR sequence. Provide front-end DWPR graphics functionality matching the format of the attached sample UMCS graphics to include display requirements on AHU screens for critical damper zone/position and summary zone tables with selections for excluding zones from DSPR logic.

18.4.3 Program a minimum VFD speed based on motor manufacturer requirements. If the motor manufacturer does not specify a minimum VFD speed, initially configure at 25%.

18.5 DCV

JOB TITLE: POC:
W0RK ORDER # POC PHONE:
DRAWING # Construction (DBA Wages) or Service (SCA Wages):

18.5.1 Use the CO2-based control reset range criteria and sequences of operation described in UFGS 23 09 93 by system type to adjust VAV box, single zone economizer, multi-zone economizer, and VAV AHU economizer flow requirements based on zone CO2 readings.

18.6 For each ECM, perform TAB at the economizer to correlate damper position to design (and lower reset range for DCV) minimum outside air flow for 20%, 50%, 75%, and 100% VFD speeds. Perform the ASHRAE 62.1 Ventilation Rate Procedure calculations described in UFGS 23 09 93 to determine lower minimum outside air reset ranges based on SF only. Use TAB data to adjust economizer minimum damper position set points.

18.7 Economizer Assessments:

Based on field observations economizer dampers at Grant Hall air handlers are being commanded closed during occupied operation. The below requirements for functional testing will indicate which modes/sequences trigger improper economizer operation and help coordinate FLW adjustment of existing control logic for improved economizer operation.

18.7.1 Complete the Air-Side Economizer form as part of the attached Functional Performance Test Sheets set for each economizer system. Perform functional testing by temporary overriding economizer controls, examining existing logic block sequences, and evaluating performance responses and trends.

18.7.2 Provide written recommendations to the government for improved economizer operations and any permanent logic changes performed on site.

19 VFD REQUIREMENTS

Either reference 26 29 23 VARIABLE FREQUENCY DRIVE SYSTEMS UNDER 600 VOLTS as the source for all VFD requirements and include in the attachments or list the applicable requirements below for this scope of work. For now it's assumed the UFGS will be referenced and included

19.1 Provide new VFDs sized to match existing nameplate motor requirements and equivalent to or exceeding the features (including but not limited to cabinet style, control capabilities, display options, and efficiencies) of existing ABB VFDs in corresponding buildings. Reuse existing motors. Replace existing belts with synchronous (cogged) belts.

19.2 Provide VFDs and related appurtenances to meet the sequence of operations for each required ECM for the following air handling equipment:

Bldg #	Bldg System	Fan Type	Fan Motor Nameplate Size	Physical Fan Location	Field Controller Output Availability?
2100	AHU-3	Supply Fan	7.5 HP	Room 424	Yes
		Return Fan	5 HP (estimated)	Room 424	Yes
	AHU-8	Supply Fan	5 HP	Room 337	No (see section 21)
	AHU-9	Supply Fan	5 HP	Room 337	No (see section 21)
932	AHU-1	Supply Fan	7.5 HP	1st Floor Mech Rm	Yes
934	AHU-1	Supply Fan	7.5 HP	1st Floor Mech Rm	Yes
936	AHU-1	Supply Fan	7.5 HP	1st Floor Mech Rm	Yes
937	AHU-1	Supply Fan	7.5 HP	1st Floor Mech Rm	Yes
939	AHU-1	Supply Fan	7.5 HP	1st Floor Mech Rm	Yes
5295B	AHU-2	Supply Fan	20 HP	Mech Room	No (see section 21)

19.3 Provide VFDs that meet all requirements of UFGS 26 29 23 VARIABLE FREQUENCY DRIVE SYSTEMS UNDER 600 VOLTS.

19.4 Integrate all submittal, testing, and training requirements from UFGS 26 29 23 into the overall project sequencing and requirements as defined in UFGS 23 09 00.

JOB TITLE: POC:
W0RK ORDER # POC PHONE:
DRAWING # Construction (DBA Wages) or Service (SCA Wages):

19.5 Use the attached annotated as-builts as requirement for VFD cabinet mounting locations. Where no location is specified on the as-builts, adhere to VFD manufacturer's installation requirements. Either air handler or wall-mounting is acceptable provided that all other requirements are met and the VFD is not directly in the outside, return, or supply air stream.

20 INSTRUMENTATION REQUIREMENTS

New content has been added to the UFGS 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC tailored for Fort Leonard Wood that includes requirements for new HVAC control sensors and actuators. References to the UFGS are used below with additional info added for building-specific requirements.

20.1 Provide all sensors and instrumentation required to support the above sequence of operation. All new input and output hardware must meet the corresponding requirements in UFGS 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC

20.2 CV to VAV

20.2.1 Air flow stations are not required at each OA duct but shall be reused where existing.

20.3 DSPR

20.3.1 Use existing duct static pressure sensors, verify condition and location on the drawings for preexisting conditions report.

20.3.2 Evaluate condition of at least 20% of the VAV box terminal units for the preexisting conditions report to verify overall functionality of VAV flow sensors and damper actuators.

20.4 DCV

20.4.1 CO2 sensors shall meet the accuracy and operational criteria given in UFGS 23 09 13 section 2.7.5.

20.4.2 Install CO2 sensors for multiple zone systems on non-adjustable wall mounts 60" above the floor and within 6' horizontal feet of an active return grill on the same system. CO2 sensors for single zone systems may be installed in return duct using manufacturer mounting criteria. Raceways are not permitted.

20.4.3 Calibrate existing and new CO2 sensors used as part of this scope's sequence of operation and measure ambient CO2 to establish DCV baseline conditions.

20.4.4 Provide CO2 sensors and related appurtenances to meet the sequence of operations for each required ECM for the following air handling equipment:

Bldg #	Bldg System	Room Number	Zone Type	High (Design) Min OA	Low (Reset) Min OA	CO2 Sensor Quantity Required	Field Controller Input Availability?
2100	AHU-3	FTU-13, 14	Assembly	770 CFM	0.1 CFM/SF	2	Yes
	AHU-8	302	Auditorium	1200 CFM	0.1 CFM/SF	1	No (see section 21)
	AHU-9	302	Auditorium	1200 CFM	0.1 CFM/SF	1	No (see section 21)

21 HVAC CONTROLLER REQUIREMENTS

Either reference UFGS 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS tailored for Fort Leonard and include in the attachments or list the applicable requirements below for this scope of work. References to the UFGS are used below with additional info added for building-specific requirements.

21.1 Reuse existing DDC controllers. Prior to contract award, contractor shall be responsible for confirming that existing DDC controllers have the capability and capacity for the required sequence of operation, VFD, and instrumentation changes. When these changes require new controllers, contractor shall purchase, install, and commission new DDC controllers per the attached UFGS 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS and FLW DDC Points Schedules.

JOB TITLE: POC:
W0RK ORDER # POC PHONE:
DRAWING # Construction (DBA Wages) or Service (SCA Wages):

21.2 Provide, install, program (with existing logic augmented by required ECM sequences), and commission new programmable controllers for the following systems with known capacity or operational issues:

Bldg #	Bldg System	Controller to Remove	Existing Controller to Match	Input/ Output Needs	Inputs Quantity Needed	Output Quantity Needed
2100	AHU-1	Circon UHC-300	Distech ECP-610	Transfer Circon logic/bindings to new controller	2 (universal)	12 (universal)
5259B	AHU-2	(none)	TAC Xenta 452A	Capacity for DSP input and VFD speed output	1 (analog)	1 (analog)

21.3 In addition to the requirements in UFGS 23 09 23.01, provide DDC controllers that match or exceed the HVAC controls features of existing DDC devices for each corresponding building and use hand-of-auto switches and analog dials for all device outputs.

21.4 Reconfigure existing local display panels (LDPs) to provide the monitor and override capabilities described in the attached FLW DDC Points Schedules.

22 UMCS REQUIREMENTS

These buildings currently use iLON Smart Servers at each building for standalone UMCS monitoring and control capabilities. This scope requires graphics changes to provide new view/configuration features for the required sequences of operation and conform buildings to the FLW M&C standard. Include edited screenshots of existing Smart Server graphics to identify the look and functionality required for this scope. Later integration into a central front-end can be accomplished using UFGS 25 10 10.

22.1 Provide the point naming convention, trending, and alarm features shown in the attached FLW DDC Points Schedules.

22.2 Provide the graphics pages and control features shown in the attached FLW Sample Smart Server Graphics pages.

23 ATTACHMENTS

23.1 UFGS 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC

23.2 UFGS 23 09 93 SEQUENCES OF OPERATION FOR HVAC CONTROL

23.3 UFGS 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC

23.4 UFGS 26 29 23 VARIABLE FREQUENCY DRIVE SYSTEMS UNDER 600 VOLTS

23.5 UFGS 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS

23.6 FLW DDC Points Schedules

23.7 FLW Sample UMCS Smart Server Graphics

23.8 Functional Performance Test Sheets

23.9 HVAC and HVAC Control As-Builts

2100: 2010 HVAC Controls Retrofit (23 sheets)

900-series: 2010 HVAC Controls Retrofit (49 sheets)

5295B: 2012 HVAC Controls Retrofit (7 sheets)

5400: 2014 HVAC Controls Retrofit (32 sheets)

Appendix I: ECM Scope - FPT (Test Procedures)

I.1 Test procedure: Air handling unit setpoint reset strategies

This functional testing guidance is designed to aid in developing test procedures for a specific project by describing the steps involved in testing a particular system. The guidance should be adapted as necessary to address the configuration and performance requirements of the system being tested. Additionally, codes may require specific testing procedures that may not be addressed in this document. All tests based on this guidance should be reviewed carefully to ensure that they are complete and appropriate.

I.1.1 Overview

The objective of testing both the static pressure and discharge air temperature reset control strategies is two-fold:

- To ensure the individual reset strategies function as intended; and
- To minimize negative interaction between the two reset strategies.

The intent of these control strategies is to reduce air handler capacity in ways that improve energy efficiency. During cooling mode, raising supply air temperature increases the number of hours the outdoor economizer can operate and reduces terminal reheat. On direct expansion air handlers it reduces compressor lift, improving energy efficiency. On air handlers with hydronic cooling coils it allows the chilled water temperature to be increased, which increases chiller efficiency. However, when the supply air temperature is raised at a given condition, the fan speed will increase to compensate.

Resetting duct static pressure keeps the duct static pressure only as high as is needed to satisfy the neediest zone, which saves fan energy. The static pressure and discharge air temperature reset control strategies compete for capacity control, and can have adverse interactions with each other and may not deliver the level of control or energy savings expected from the individual reset strategies. Common interactions are listed in the following table.

Table I-1. Common interactions.

Control Issue	Decrease in Zone Loads	Reset Strategy Action	Interaction
Zones with similar loads	VAV box damper modulates closed	Lower static pressure setpoint Increase discharge air temperature setpoint	Increased discharge air temperature will drive VAV box damper open, driving static pressure back up. Supply fan may operate like constant volume system.
Same control parameters (for example, VAV box damper position)	VAV box damper modulates closed	Lower static pressure setpoint Increase discharge air temperature setpoint	Lower air flow and increased discharge air temperature will drive VAV box damper open. Open damper position will then cause static pressure setpoint to increase and discharge air temperature setpoint to decrease, driving static pressure back up. System control may become unstable.

The following procedures will assist with:

- Ensuring all system prefunctional checklists are complete prior to executing system tests
- Verifying static pressure reset control strategy operates as intended
- Verifying discharge air temperature reset control strategy operates as intended
- Evaluating interaction between the two reset strategies

I.1.2 System description

A central air handling and distribution system typically includes a wide array of individual components, subsystems, or related systems, including: supply fan, variable frequency drives or inlet guide vanes to vary air flow, distribution ducts, VAV boxes, central heating, cooling, and pumping systems, control valves, temperature and pressure sensors, and safeties/interlocks.

Many AHUs vary the amount of air delivered to the space being served depending on zone loads. Typically as the primary air damper within individual VAV boxes modulate to meet the respective zone loads, the total amount of air delivered by the supply fan changes to either maintain a specific static pressure within the duct or discharge pressure within the supply fan. Often, the controlling static pressure setpoint (duct or discharge) is automatically reset up or down based on zone loads to minimize supply fan energy and still ensure proper air flow through the VAV boxes.

I.1.3 DSPR control

One option is to reset static pressure setpoint based zone cooling demand. The two most common parameters available from the VAV box controller that can be used to determine zone cooling demand are VAV box damper position and cooling loop output. VAV box damper position, if available

from the VAV box controller, may be the actual damper signal for modulating actuators or an estimated position based on timing of open/close signals if floating actuators are used. In contrast, the cooling loop output is the actual output value used to calculate the intermediate air flow rate value that the VAV box is trying to achieve to satisfy zone temperature setpoint. Using VAV box damper position as an example, as zone loads are satisfied and VAV box dampers begin to shut, the static pressure setpoint will be lowered until a particular number of VAV box dampers are at a predetermined position. The reverse is true when zone loads increase and VAV box dampers begin to open up to cool the space. This control strategy requires that the system has full DDC control and feedback on VAV box damper position or cooling loop output. If DSPR control is being employed based on zone cooling demand , the location of the static pressure sensor is less critical than in a fixed setpoint application and may be located as far out in the system as possible. A good rule of thumb would be to install the pressure sensor 3/4 the way down a main distribution duct to ensure the system will still operate correctly should the reset control logic fail, as it would in the loss of the network controller. Note that individual sensors should be installed in each major branch coming off the main supply duct.

I.1.4 Discharge air temperature reset control

Another common control strategy is to reset the discharge air temperature (DAT) setpoint for an AHU. The intent of the control strategy is to adjust the DAT up and down to satisfy actual loads within the spaces served more effectively. This control strategy has the potential to minimize the heating, cooling, pumping and reheat energy associated with the conditioned air delivered to each zone during less-than-design operating conditions. However, supply fan energy may increase if a VAV box damper opens more to satisfy the load with warmer DAT from the central AHU. Common variables used for resetting DAT include, but not limited to:

1. Outdoor air temperature
2. VAV box damper position
3. Deviation from zone temperature setpoint
4. Cooling demand.

Note, however, that resetting the DAT upward can impede the AHU's ability to dehumidify the air and may not be appropriate where tight humidity control is required. Examples of the common control strategies are provided below.

I.1.4.1 Outdoor air temperature

A common reset control strategy is to raise DAT setpoint when outdoor air is cold and lower the setpoint when it is warm. A typical reset schedule may be 65°F DAT @ 45°F OAT and 55°F DAT @ 60°F. This control strategy is very effective if all zones have similar loads and are dependent on outdoor air temperature – like west-facing perimeter zones with the same lighting/equipment/occupancy loads. However, this strategy could be problematic if certain zones require cooling regardless of outdoor air temperature. For example zones with high internal gains or general interior zones in large buildings. Resetting the DAT upward may cause critical zones to overheat and result in comfort issues.

I.1.4.2 VAV box damper position

An alternate reset control strategy is to adjust DAT based on VAV box damper position, if available from the VAV box controller. This signal may be the actual damper signal for modulating actuators or an estimated position based on timing of open/close signals if floating actuators are used. As zone loads decrease and primary air dampers begin to close, the DAT is reset upward incrementally until one or more dampers reach a predetermined position. As zone loads increase and primary air dampers modulate open, the DAT is then reset downward incrementally until all of the dampers reach a predetermined position. The advantage of this control strategy is that DAT setpoint is continually adjusted based on actual zone loads. However, this method may cause control instability or comfort problems if the static pressure reset control strategy is also based on VAV box damper position. Refer to the *Reset Strategy Interactions* section below for an example.

In addition, either all or selected VAV boxes must be polled to execute the sequence. If the building has numerous VAV boxes and all boxes are polled, then the amount of data being transferred across the network can severely limit the speed or capacity the DDC system. If only selected boxes are polled, then extreme care must be taken when selecting the boxes to ensure comfort problems in non-selected zones are not created.

I.1.4.3 Deviation from zone temperature setpoint

Another common reset control strategy is to adjust DAT based on how far actual zone temperature is away from setpoint. As zone loads decrease and

actual zone temperature begins to drop below setpoint, the DAT is reset upward incrementally once a predetermined temperature deviation is reached. As zone loads increase and actual zone temperature begins to rise above setpoint, the DAT is reset downward incrementally once a predetermined temperature deviation is reached. One advantage of this control strategy is that DAT setpoint is based on actual zone loads, but it may not be very effective if the zone temperature control loops for each VAV box keeps the respective zone under control before the reset control loop has a chance to be enabled.

For example, the zone temperature control loop will modulate the primary air damper and reheat valve as zone loads raise and fall, respectively, to meet zone temperature setpoint. If this control loop is tuned properly, zone temperature should be fairly steady and may never reach the deviation from setpoint necessary to trigger the DAT reset control strategy, unless zone loads exceed the cooling or heating capacity of the VAV box. One possible strategy would be to make the reset deviation tighter than the zone temperature loop, or allow the reset loop to execute faster than the zone temperature loop, so that resetting of the DAT occurs first and then the primary air damper and reheat valve will modulate as necessary to maintain zone temperature.

Another disadvantage is that either all or selected VAV boxes must be polled to execute the reset sequence. If the building has numerous VAV boxes and all boxes are polled, then the amount of data being transferred across the network can severely limit the speed or capacity the DDC system. If only selected boxes are polled, then extreme care must be taken when selecting the boxes to ensure comfort problems in non-selected zones are not created.

I.1.4.4 Cooling demand

A more effective reset control strategy is to adjust DAT based on the actual cooling demand for the respective zones being polled, as determined by the zone temperature control loop output signal. The control strategy is best described by the following example. Assume a single zone temperature loop output ranges between 0 and 200, with the output range of 0 to 100 modulating the reheat valve from full open to fully closed (at minimum air flow) and the output range of 100 to 200 modulating the primary air damper from minimum to maximum cooling air flow. The DAT reset control loop would start to lower the air temperature incrementally toward

the air temperature low limit to maintain the polled zone temperature loop output value at 125 as zone loads increased. Then, as zone loads decrease, raise the DAT setpoint incrementally toward the air temperature high limit to maintain the zone temperature loop output value at around 75.

The advantage of this control strategy is that DAT setpoint is truly based on actual zone loads, and will have the least negative interaction with the static pressure reset strategy. But again, the primary disadvantage is that either all or selected VAV boxes must be polled to execute the reset sequence. If the building has numerous VAV boxes and all boxes are polled, then the amount of data being transferred across the network may limit the speed or capacity the DDC system. If only selected boxes are polled, then extreme care must be taken when selecting the boxes to ensure comfort problems are not created.

I.1.5 Reset strategy Interactions

Unfortunately, the static pressure and DAT reset control strategies can have adverse interactions with each other and may not deliver the level of control or energy savings expected from the individual reset strategies. For example, raising the DAT setpoint will tend to cause a VAV box damper to modulate open because warmer air is trying to satisfy the loads within the zone served. This in turn will cause the static pressure setpoint to be raised, increasing fan energy. This is best illustrated through an example:

> The zone cooling loads begin to decrease and all VAV dampers begin to close. The static pressure reset strategy will tend to lower the static pressure setpoint and the supply fan will start to slow down to meet the new setpoint. At the same time, however, the reduced zone loads would also tend to cause the discharge air temperature to be reset upward. This will cause the VAV box damper to open since warmer air is being used to satisfy zone loads, requiring more air to be delivered to the zone. As the dampers begin to open, the static pressure reset control loop will start to increase the static pressure setpoint and more air will be delivered to each zone. As zone loads increase, this sequence is reversed, but the bottom line is that the central air handling unit will tend to operate like a constant volume system rather than a variable air volume system, with the air flow control benefits being negated.

Another possible negative interaction may occur if both reset strategies are based on the same parameter, for example VAV box damper position. This is best illustrated through the following example:

> As the load within a zone increases, the zone temperature control loop will drive the damper open. If damper position exceeds the limit set for each control strategy, this may cause both the discharge air temperature setpoint to be lowered and the duct static pressure to be increased at the same time (depending on how frequently each control loop is executed). As a result, more air flow at much lower temperature will be delivered, potentially overcooling the space. This in turn would cause the damper to modulate closed, and the reset strategies would then cause the temperature and pressure setpoints to swing in the other direction. Under some ambient conditions, the oscillation between overcooling and under-cooling may persist for extended periods of time, resulting in comfort and control issues.

To optimize system operation, it may be beneficial to evaluate which control strategy will generate the best reduction in energy use under different atmospheric conditions and building loads and modify control sequences as necessary. For example the heating, cooling, and reheat benefits associated with resetting DAT may far outweigh increased supply fan energy usage during winter and swing seasons, whereas static pressure reset may be optimal during warmer atmospheric conditions. Note that this assumes that the AHU serves VAV boxes with reheat and the VAV boxes provide zonal heating. If the system were served by fan-powered VAV boxes or perimeter fin tube heating, the temperature reset during winter may not be as effective as static pressure reset. An energy simulation may be necessary to determine which control strategy achieves the best energy performance and when each strategy should be implemented. Additional suggestions for minimizing negative interactions are found in Section 5. Note that any changes to design sequence of operations should always be approved by the engineer of record. Also many local code requirements have adopted standard ASHRAE 90.1-1999 and 2001, which requires a static pressure reset control strategy. There may be a potential code compliance issue if the static pressure reset is not implemented all of the time.

I.1.6 Sample tests

The following tests were not created based on this test guidance but serve as a sample of similar tests. These are available at www.ftguide.org/ftct/testdir.htm.

- Cooling AHU Functional Test. ID#: 289
- Large Packaged Rooftop DX Unit Test. ID#: 302.

Test Procedure Outline

1. Preparation

1.1 Create a test form

1.2 Determine acceptance criteria

1.3 Provide instructions/precautions

1.4 Specify test participants and roles/responsibilities

2. General Air Handling and Distribution System Inspection

2.1 Review all prefunctional checklists for completeness

3. Static Pressure Reset Test Procedures

3.1 Verify static pressure high limit setpoint

3.2 Verify static pressure low limit setpoint

3.3 Return system to normal operation

4. Discharge Air Temperature Reset Test Procedures

4.1 Verify DAT high limit setpoint

4.2 Verify DAT low limit setpoint

4.3 Return system to normal operation

5. Identifying Control Strategy Interactions

5.1 Trend reset control strategies

5.2 Consider modifying control strategy to minimize negative interaction

Test Procedure

1. Preparation

1.1 **Create a test form.** Testing will be easier if the test procedure is thought through and documented before conducting the test. Developing a test form will assist in data collection and subsequent evaluation.

1.2 **Determine acceptance criteria.** Both the discharge temperature setpoint and duct static pressure setpoint should be reset between their minimum and maximum setpoint values based on the respective control variable (i.e., outdoor air temperature, damper position, cooling load, etc.) and the system should meet these setpoints without excessive hunting. In addition, interaction between the two reset strategies should be evaluated through trending, resulting in modified sequences if the control strategies begin to "fight" each other.

Note: "Without excessive hunting" signifies that after a moderate perturbation the controlled variable (duct static pressure) comes into and remains within the control deadband within four cycles (one cycle is one over shoot and one undershoot).

1.3 **Provide instructions/precautions.** If performing the tests while the building is partially occupied or the systems are operating temporarily to provide space conditioning, bear in mind that the test procedures may potentially impact zone comfort. If a test fails, the source of the failure should be identified and conveyed to the proper authority. The system will be retested once the repairs are complete.

1.4 **Specify participants and roles/responsibilities.** The testing guidance provided in this document can assist in verifying proper system performance in both new construction and existing building applications. The following people may need to participate in the testing process. Refer to the Functional Testing Basics section of the Functional Test Guide for a description of the general roles and responsibilities of the participants. These roles and responsibilities should be customized based on actual project requirements.

New Construction Project	Existing Building Project
Commissioning Provider	Commissioning Provider
Mechanical Contractor	Building Operating Staff
Control Contractor	Controls Contractor

2. General Air Handling and Distribution System Inspection

2.1 **Review all prefunctional checklists for completeness.** Prior to performing any functional tests, the commissioning pre-start, startup, and prefunctional checklists should be completed, as well as applicable manufacturer's pre-start and startup recommendations. Prefunctional checklists include, but are not limited to, the following:

- Supply fan spins in the right direction and is free of unusual noise and vibration.
- Supply fan belt tension, alignment, and condition is okay (if applicable).
- Duct installation associated with the AHU being tested is complete. If interior duct liner is used, the exposed ends are properly sealed.
- All terminal units associated with the AHU being tested have been functionally tested and are capable of serving normal operating loads.
- Respective heating, cooling, and pumping systems associated with the AHU being tested have been functionally tested and are capable of serving operating loads.
- Water and air systems have been balanced per design.
- All control sensors (i.e., temperature, pressure, etc.) have been installed and calibrated.
- All safeties and interlocks have been tested and are operational.
- All sequence of operations have been programmed per design.

3. Duct Static Pressure Reset Test Procedures

3.1 **Verify static pressure high limit setpoint.** Before testing the static pressure reset strategy, disable the DAT reset to eliminate any interaction between the two control strategies (interaction will be handled separately). Regardless of the static pressure reset control strategy employed (duct or discharge), drive all of the VAV box dampers fully open by either commanding each damper to full cooling or by lowering zone temperature setpoint to 15°F below current space conditions. Both will simulate a cooling load on the space and result in the VAV boxes being driven to full cooling positions. As the primary air dampers open, duct static pressure should drop and the controlling static pressure setpoint should reset upward incrementally until the high limit is reached.

Check the following:

3.1.1 Static pressure setpoint does not exceed high limit value.

3.1.2 Supply fan ramps up close to full speed (or the speed reported by the balancer as necessary to meet design flow).

3.1.3 Static pressure reported in the BAS meets setpoint without excessive hunting.

3.2 **Verify static pressure low limit setpoint.** Continuing from above, drive all of the VAV box dampers to minimum flow position by either commanding each damper to minimum damper position or by raising zone temperature setpoint to 15°F above current space conditions. Note that some VAV boxes may be programmed to increase air flow above the minimum flow setting to satisfy a maximum heating load. If raising space temperature setpoint to drive the VAV boxes to minimum flow position, first verify that maximum heating flow setpoint is the same as the minimum flow value. Adjust system setpoints as necessary. As the primary air dampers close, duct static pressure should increase and the controlling static pressure setpoint should reset downward incrementally until the static pressure low limit is reached, or all zones are satisfied.

Check the following:

3.2.1 Static pressure setpoint does not exceed low limit value.

3.2.2 Supply fan should ramp down.

3.2.3 Supply fan Variable Frequency Drive (VFD) speed should not drop below minimum speed recommended by VFD, fan, or motor manufacturers. Minimum speed can range between 10 Hz and 20 Hz, depending on the type of fan installed. Centrifugal fans can typically operate at the lower end of the range whereas axial fans may require higher minimum speeds.

3.2.4 Measured static pressure meets setpoint without excessive hunting.

3.3 **Return system to normal operation.** Return system to normal operating conditions by removing all overrides and adjusting all setpoints to values specified in the design sequence of operations.

4. Discharge Air Temperature Reset Test Procedures

4.1 **Verify DAT high limit setpoint.** Before testing the DAT reset strategy, disable the static pressure reset to eliminate any interaction between the two control strategies (interaction will be handled separately). The way to simulate a low load condition to trigger the DAT reset control strategy depends on the specific control strategy employed. Test procedures for each control strategy are outlined below.

Outdoor Air – Overwrite the outdoor air temperature value to be at the low-end of the reset schedule.

Damper Position – Either command VAV box dampers to a minimum position or adjust zone temperature setpoint to 5°F above actual zone temperature.

Deviation from Setpoint – Adjust zone temperature setpoint as necessary so that the deviation from setpoint is adequate to trigger the control sequence.

Cooling Demand – Adjust zone temperature setpoint to 5°F above actual zone temperature.

These steps will simulate a decrease in zone cooling loads, which should result in resetting the DAT upward incrementally until the high limit is reached.

Check the following:

4.1.1 DAT setpoint does not exceed high limit value.

4.1.2 DAT meets setpoint without excessive hunting.

4.2 **Verify discharge air temperature low limit setpoint.** Continuing from above, the procedure to simulate a high load condition for each control strategy is outlined below.

Outdoor Air – Overwrite the outdoor air temperature value to be at the high-end of the reset schedule.

Damper Position – Either command VAV box dampers to a maximum position or adjust zone temperature setpoint to 5°F below actual zone temperature.

Deviation from Setpoint – Adjust zone temperature setpoint as necessary so that the deviation from setpoint is adequate to trigger the control sequence.

Cooling Demand – Adjust zone temperature setpoint to 5°F below actual zone temperature.

These steps will simulate an increase in zone cooling loads, which should result in resetting the DAT downward incrementally until the low limit is reached.

Check the following:

4.2.1 DAT setpoint does not exceed low limit value.

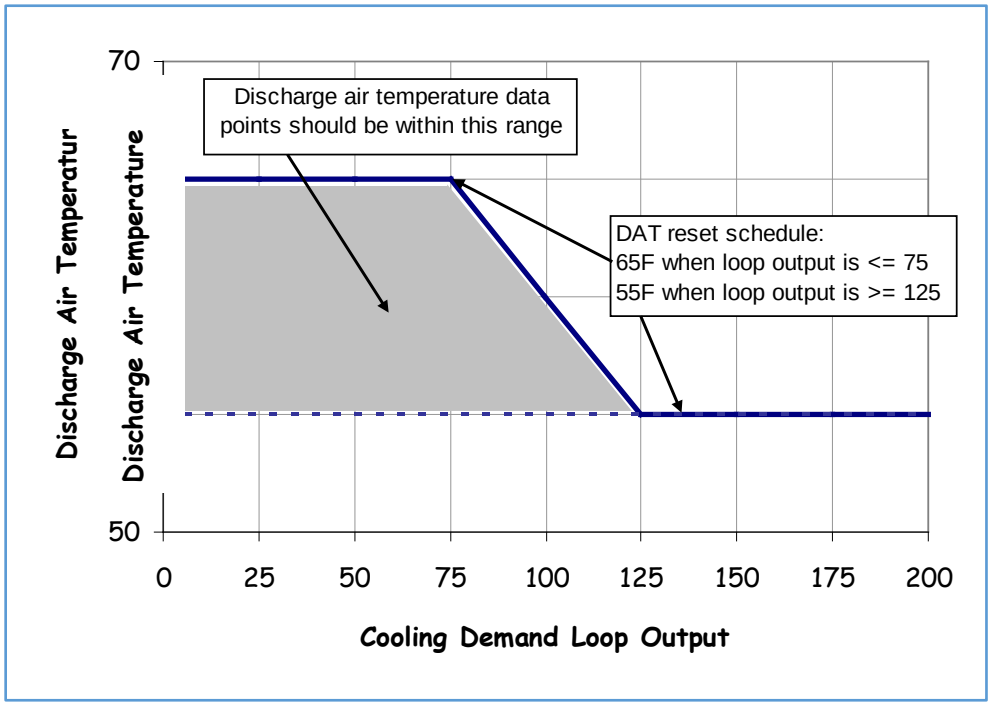
4.2.2 Measured DAT meets setpoint without excessive hunting.

4.3 **Return system to normal operation.** Return system to normal operating conditions by removing all overrides and adjusting all setpoints to values specified in design sequence of operations.

5. Identifying Control Strategy Interactions

5.1 **Trend reset control strategies.** As discussed in the Reset Strategy Interactions section, it is not unusual for these two reset strategies to counteract one another and result in unstable control. The best way to determine if individual reset control strategies are working properly under normal operating conditions and to identify possible negative interactions between the static pressure and DAT resets is through trend analysis of all polled terminal boxes for a given air handler. A trend sample rate of no more than 5 minutes is necessary to detect operational problems like hunting and excessive cycling. Typically the independent variable (for example, VAV box damper position for static pressure reset or zone temperature control loop output for DAT reset) is plotted along the X-axis and the control variable (static pressure or DAT setpoint) is plotted on the Y-axis. Figure I-1 illustrates what the plot may look like to verify correct operation of a DAT reset control strategy.

Figure I-1. Example Discharge Air Temperature Trend Plot



Another trend plot that can assist in identifying reset interactions is the actual speed of the supply fan (assuming the supply fan is controlled by a VFD) over time. If the supply fan speed remains fairly constant (especially if zone loads are known to vary) or seems to be constantly fluctuating, then the two reset strategies may be fighting each other.

5.2 **Consider modifying control strategy to minimize negative interaction.** To minimize negative interaction between the DAT reset and static pressure reset strategies, one option is to enable the DAT reset strategy and disable the static pressure reset strategy (i.e., maintain fixed static pressure setpoint) when atmospheric conditions are colder, and disable the DAT reset strategy (i.e., maintain fixed DAT setpoint) and enable the static pressure reset strategy when atmospheric conditions are warmer.

- **Colder Conditions:** The intent is to minimize the amount of simultaneous heating and cooling during the winter, avoid overcooling internal zones that may not have reheat capability, and maximize energy savings in both the chilled and hot water plants. While true that supply fan energy savings will be sacrificed, the energy saved at the central plant should far outweigh the lost fan energy savings. Note that fan energy usage can be minimized if the fixed static pressure setpoint is as low as possible to satisfy all zones. Experimentation may be required to determine the optimum static pressure setpoint.
- **Warmer Conditions:** Holding a constant DAT during warmer weather will improve space temperature and humidity control and allow for maximum supply fan energy savings as zone loads vary and VAV dampers modulate.

A method for implementing such a control strategy is to have two independent control loops that become enabled and disabled based on outside air temperature. A reasonable outdoor air temperature for a changeover between control strategies may range between 70°F and 75°F. In this range, the economizer will be able to offset more chiller load at the higher DAT setpoint during cooler ambient conditions. Above this range, the economizer provides minimal benefit, most zones will probably not require any reheat, and humidity control will be improved by maintaining a fixed DAT setpoint. It may take some experimentation to determine the optimum outside air temperature changeover point.

I.1.7 Functional performance test air-side economizer

Date:

Building Name:				Testing Agent:	
Address					
				Assisted by:	
Phone:					
Equipment Name					
Manufacturer					
ECM No.		ECM Name:		New/Retrofit:	

Unit ID	AHU ID	Size (tons)	Zone
1			
2			
3			
4			

Documentation. Installation and user's manuals on site (Y/N)?_____

Installation. Note any anomalies about the installations.

_____

_____

Space and Outside Air (OSA) temperature sensors have been calibrated ***and*** OSA sensor located in open air, shaded, but not enclosed (where there may be heat buildup from the sun).
(Y/N)?_____

Control Sequence Tests

	Unit 1	Unit 2	Unit 3	Unit 4
General Information				
1. What is current space temperature setpoint? Cooling:				
(enter: occupied/unoccupied) Heating:				
2. Economizer characteristics:				
Sensor type: DB = dry-bulb, dH = enthalpy				
Integrated: (Y/N)				

	Unit 1	Unit 2	Unit 3	Unit 4
Controls: PK = packaged only, **EMS*** = all control by EMS, **PK+** = settings by package; enabled by EMS:				
Dampers: How many positions is the damper system capable of, including when OFF (step positions: closed, minimum and full open)? Enter two, three or infinite.				
3. What type of building pressure relief is there? (FL = fixed link to OSA damper, BD = barometric RA damper, EF = exhaust fan)				
4. What are the current economizer setpoints (changeo-ver temperatures)?				
(If OSA is below this, econ. will open) Package setting:				
(PK+ types will have both settings) EMS enable pt.:				

Mode 1. Test Damper Position in AHU OFF Status

1. Turn unit OFF.

		Unit 1	Unit 2	Unit 3	Unit 4
2. Are dampers completely shut?	OSA:				
	Relief:				
3. Is return damper at maximum open?					
Does the system comply in this mode?					

Mode 2. Test Damper Position With AHU in ON Status; Compressor (or coil valve) and Econ. OFF

1. Turn cooling setpoint to 85 °F.
2. Turn heating setpoint to 60 °F.
3. Turn unit ON.

		Unit 1	Unit 2	Unit 3	Unit 4
4. Are dampers at a minimum?	OSA:				
	Relief:				
5. Is return air damper at maximum open?					
6. NO in either of the above two questions denotes non-compliance. ***Does the system comply in this mode?***					

* Energy Management System (EMS)

	Unit 1	Unit 2	Unit 3	Unit 4

Mode 3. Test Dampers in First Stage of Cooling (Econ. ON, Compressor or coil valve ON or OFF)

1. Adjust economizer setpoint or EMS OSA temperature values so economizer will turn on if cooling is called for.

   For **DB economizers,** OSA temp. must be, or be simulated to read by keyboard edit in EMS, below the economizer setpoint and above any discharge air (DA) low limit (usually ~55°F if used). If OSA is too hot or too cold and there is no EMS system, use a wet rag or hair blower on OSA sensor **OR** come back at a time when OSA is appropriate, **OR** use jumper method of testing, **OR** use "canned" automatic testing sequence in unit, if any. The last two methods give only a partial assurance that the economizer is functioning. For **enthalpy type economizers**, locate the enthalpy of the space air and the OSA on a psychometric chart. Simulate conditions for either so that the OSA has less enthalpy than the inside air or use alternate methods above.

Describe method used:

2. Adjust cooling setpoint or space temp. until setpoint is 1°F *below* space temp. for integrated economizers (deadband + 1° for integrated types). Record:
3. Cooling set point: _____ _____ _____ _____
4. OSA temperatures (actual or simulated, circle): DB: _____ _____ _____ _____

   (for enthalpy types) Wet bulb: _____ _____ _____ _____
5. Space temperature (actual or simulated, circle): DB: _____ _____ _____ _____

   (for enthalpy types) Wet bulb: _____ _____ _____ _____
6. Do dampers open properly?
   Full open for dry-bulb econ., partial for enthalpy type. If OSA: _____ _____ _____ _____

   OSA is below a functioning DA low limit, OSA damper will not be full open. Integrated economizers may not open full or at all in cold weather) Relief: _____ _____ _____ _____
7. Is return air damper closing proportionately? _____ _____ _____ _____
8. Any **NO** answers in the above two questions denote noncompliance.
   Does the system comply in this mode? _____ _____ _____ _____

Mode 4. Test if Economizer Is Integrated (Economizer ON, Compressor [or Coil Valve] ON)

1. Continuing from Mode 3, did compressor come on? (It is best if it does not) _____ _____ _____ _____
2. If compressor does not come on, lower cooling setpoint 2° at a time (or raise space temp.) until compressor comes on. (circle action taken) _____ _____ _____ _____
3. What is the temp. of the changed parameter? _____ _____ _____ _____
4. Do dampers stay open and not at min.? OSA: _____ _____ _____ _____

   (If Yes, its integrated) Relief: _____ _____ _____ _____

   Is RA proportionately closed? RA: _____ _____ _____ _____

	Unit 1	Unit 2	Unit 3	Unit 4
5. Any **NO** answers in the last question denote noncompliance. ***Does the system comply in this mode?***				

Mode 5. Test if Dampers Go to Minimum When OSA is Above Economizer Setpoint

	Unit 1	Unit 2	Unit 3	Unit 4
1. Return economizer settings to original, if changed.				
2. For DB type, lower econ. setpoint or heat up OSA sensor, or simulate OSA in EMS, until the OSA is 1°F above the economizer setpoint or changeover temperature. For enthalpy types, change conditions so that the space enthalpy on the psychometric chart is *lower* than the OSA enthalpy. If dampers do not close, increase OSA temp. until they do.				
3. Do dampers close to minimum? OSA:				
Relief:				
4. Does the RA damper open to maximum?				
5. What are the OSA temperatures being used to cause damper closure (this may be a real or simulated value)? DB:				
(for enthalpy types) Wet bulb:				
6. Is the OSA DB temperature being used, within 2° of what the economizer setpoint said it should be? (use psychometric chart and manufacturers' specs for enthalpy types)				
7. For DB types, is this OSA temperature between 2-5°F below space temp. setpoint? (the economizer should be set so it will open only below an OSA temp. of between 2-5°F below space setpoint)				
8. Any NO answers in the above five questions denote noncompliance. Does the system comply in this mode?				

Mode 6. Test if Dampers Go to Min. When Mixed Air Temp. (MAT) is Below Min. Setting

	Unit 1	Unit 2	Unit 3	Unit 4
1. Cool down MAT sensor, or simulate MAT in EMS, until it is below the MAT setting. (~45-55°F)				
2. Do dampers close to minimum? OSA:				
Relief:				
3. Does the RA damper open full?				
4. What is the MAT temperature being used to cause damper closure (this may be a real or an EMS simulated value)?				
5. Is the MAT temperature being used within 2° of what the specs say the setpoint temperature should be?				
6. Any **NO** answers in the above three denote noncompliance. ***Does the system comply in this mode?***				

	Unit 1	Unit 2	Unit 3	Unit 4

Restore all adjustments to their original settings, unless desired as a permanent change. Make a permanent mark on any economizer local controllers showing where the appropriate setting should be. Y/N _____

Abbreviations: SA = supply air, RA = return air, DA = discharge air, OSA = outside air, EMS = energy management system

I.1.8 Test procedure: Demand-controlled ventilation

This functional testing guidance is designed to aid in developing test procedures for a specific project by describing the steps involved in testing. The guidance should be adapted as necessary to address the control sequences, configuration, and performance requirements of the particular system being tested. Additionally, codes may require specific testing procedures that may not be addressed in this document. All tests based on this guidance should be reviewed carefully to ensure that they are complete and appropriate.

I.1.8.1 Overview

A DCV control strategy adjusts the quantity of outdoor ventilation air supplied to a zone by a central AHU based on the ventilation rate required to provide adequate indoor air quality. A significant amount of heating and cooling energy can be saved by supplying just enough ventilation air to satisfy zone load requirements. The objective of testing the DCV control strategy is to ensure that outdoor ventilation air is adjusted as necessary to meet zone loads as they vary with time. The following procedures will assist with:

- Ensuring all system prefunctional checklists are complete prior to executing system tests
- Verifying DCV control strategy operates as intended for both constant and VAV zones and air handling systems
- Verifying zone minimum ventilation air requirements are met under varying operating conditions
- Verifying that zone DCV control strategy interacts with zone terminal units and AHUs' economizer control sequence correctly

I.1.8.2 Control strategy considerations

The amount of outdoor air that must be included in the supply air stream is generally determined by a combination of varying and non-varying factors.

I.1.8.3 Non-varying requirements:

- Make-up requirements for direct exhaust from the zone(s) served
- Design excess air for building pressurization
- Amount of air necessary to dilute non-occupant sources of contaminants (i.e., glues, solvents, cleaning solutions, carpeting, fabrics and materials, office equipment, water vapor and other particulates)

I.1.8.4 Varying requirements:

- Amount of air necessary to dilute occupant-based contaminants like bio-effluents (i.e., body odors)

I.1.8.5 Non-varying outdoor air requirements

For most building types, the amount of outdoor air necessary for exhaust make-up and design excess air for building pressurization are fixed values that do not vary over time. The off-gassing from materials like carpets, fabrics, adhesives, and furnishings will initially be very high when the building is new, but typically decrease to a much lower steady-state (i.e., fixed) emission rate over time as the building ages. In addition, odors and contaminants from cleaning products and solvents, office equipment and materials, or off-gassing from new products (merchandise in a retail store for example), may not vary over time and require a constant volume of outdoor air to maintain adequate indoor air quality. The sum of these three variables will set the *base minimum* ventilation requirement for the system. Note however, if the quantity of direct exhaust air exceeds the design, non-occupant pollutant air flow rate, it will not be necessary to introduce any additional ventilation air into the supply air other than the amount needed to offset the air exhausted from the building.

I.1.8.6 Varying outdoor air requirements

The amount of air necessary to dilute occupant-based contaminants varies with the number of occupants and their activity levels. The total *design minimum* ventilation rate is the sum of the *base minimum* ventilation rate

(described above) and the occupant-based ventilation requirements. The *base minimum* ventilation rate is typically about 20% to 30% of total *design minimum* ventilation. Most building codes and standards require that minimum ventilation flow rate be adequate to satisfy a design occupant load and typically refer to meeting ASHRAE Standard 62.1-2004 requirements. However, design occupant load is rarely achieved under normal building operation. Hence, buildings tend to be over-ventilated, which wastes a significant amount of energy over time. In response, DCV is becoming more widely accepted across the HVAC industry because it varies the amount of outdoor air provided depending on demand within the building.

I.1.8.7 Demand for ventilation in zones

It is exceedingly difficult, if not impossible, to directly measure the demand for outdoor air. Some control strategies may vary ventilation air flow rate based on whether particular zones are occupied via occupancy sensors. If various zones are unoccupied, the ventilation rate can be reduced. Once the zone is occupied, the ventilation rate would most likely be increased to design ventilation air flow requirements regardless of whether the zone is at design occupancy. This control strategy can be effective but it is not optimum since the ventilation air flow rate is not varied based on actual demand with the respective zones.

The most common parameter used to estimate actual demand is the concentration of carbon dioxide (CO_2) within respective zones. CO_2 is generated by humans at varying rates based on age, diet, and physical activity. When the ventilation rate per occupant is low, the concentration of contaminant gases and particulates, as well as CO_2, begin to build up within the space. Although carbon dioxide is not considered a contaminant at the concentration levels typically found in most buildings, a high CO_2 concentration indicates insufficient ventilation. And since the concentration of CO_2 gas is easily measured, it can be used to vary the ventilation rate to maintain acceptable indoor air quality.

I.1.8.8 Appropriate CO_2 setpoints

Building codes and standards typically require that a specific outdoor ventilation air flow rate (in cubic feet per minute (CFM)/person) be provided to a building based on the occupancy category of the zone(s) being served.

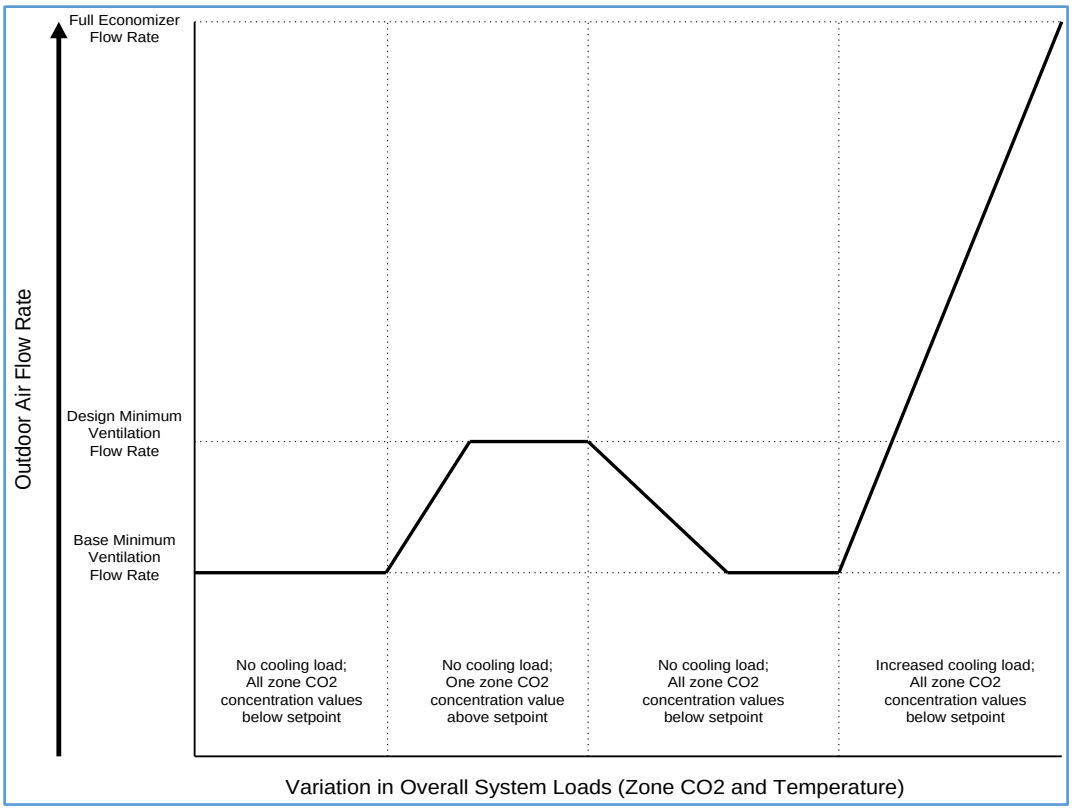
For example, ASHRAE Standard 62.1-2004 stipulates an overall ventilation rate of 17 CFM/person for an office environment to dilute both occupant-based human bio-effluents and non-occupant-based contaminants generated within the space. The mass balance method outlined in Appendix C of ASHRAE Standard 62.1-2004 demonstrates that a steady-state CO_2 concentration of approximately 700 parts-per-million (PPM) above the concentration in the outdoor air (typically ranging between 300 PPM and 500 PPM), is equivalent to a ventilation rate of approximately 15 CFM/person. To be conservative and account for variations among people and activity levels, maintaining an absolute CO_2 concentration setpoint ranging between 900 PPM and 1100 PPM within the zones served by each AHU will provide adequate ventilation for the typical office. Refer to Appendix C of ASHRAE Standard 62.1-2004 for a detailed derivation and rationale for minimum ventilation requirements based on CO_2 concentration. Additional analysis may be necessary to ensure adequate indoor air quality as well as satisfy applicable codes and standards if the activity level, ventilation rate, or outdoor CO_2 concentration for a specific project is different than the mass balance calculation outlined in Appendix C of ASHRAE Standard 62.1-2004.

I.1.8.9 Constant volume system considerations

A demand-based ventilation control strategy can be applied to both constant volume and VAV air handling systems. In a constant volume application, the outdoor air dampers are typically modulated between the *base minimum* and *design minimum* ventilation flow rates to maintain a CO_2 concentration setpoint, which is a fairly simple control strategy to implement.

Note that the economizer control loop will interact with the DCV control loop. Whichever control loop is calling for the highest amount of outdoor air should take precedence. For example if the economizer loop is driving the outdoor air dampers open to provide free cooling, the dampers should not close because zone CO_2 concentrations are below setpoint. In contrast, the outdoor air dampers should be driven toward the *design minimum* ventilation flow rate if any zone CO_2 concentration exceeds setpoint even if free cooling is neither available nor needed (i.e., economizer is locked out or the economizer loop output signal is zero). This control strategy is illustrated in Figure I-2.

Figure I-2. Outdoor Air Damper Control with Demand-controlled Ventilation



I.1.8.10 Variable air volume system considerations

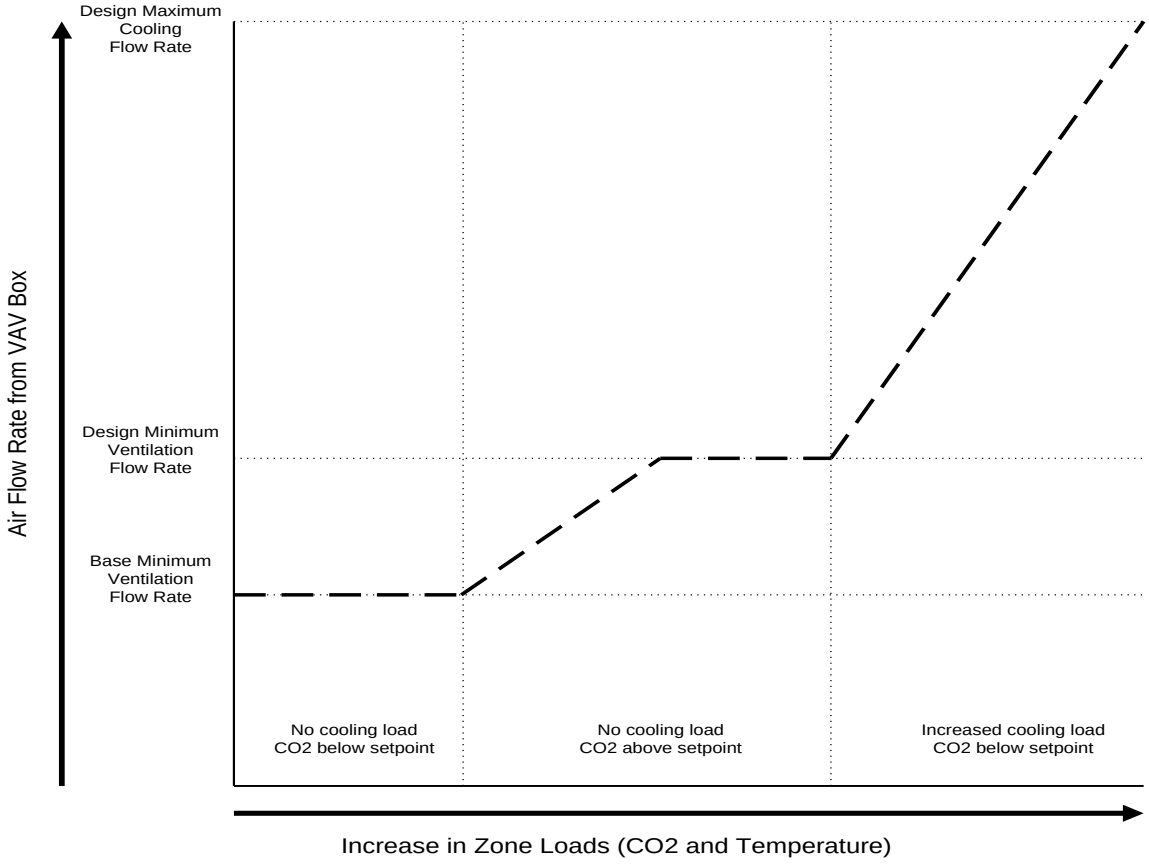
In a VAV system, the minimum air flow rate delivered by an individual VAV box to its respective zone is typically based on providing adequate ventilation for the occupants within that zone. The overall minimum outdoor air flow rate added to the supply air stream at the central AHU is determined by the ventilation requirements of all the zones served. Hence as building occupancy varies within each zone, the individual VAV box damper as well as the central AHU outdoor air damper can be adjusted to satisfy ventilation requirements based on CO_2 concentration.

I.1.8.11 VAV box control

When the CO_2 concentration for an individual zone is below setpoint, the minimum ventilation flow rate setpoint for that VAV box is reset to its *base minimum* ventilation flow rate value. As occupancy increases and the CO_2 concentration within the zone begins to rise above setpoint, the minimum ventilation flow rate setpoint is reset upwards toward its *design minimum* ventilation flow rate value to satisfy the CO_2 setpoint.

Note that CO_2 concentration only impacts the minimum ventilation flow rate setpoint for the VAV box. Actual flow rate delivered by the VAV box to the zone will be controlled based on maintaining zone temperature set-point. Typical VAV box control is illustrated in Figure I-3. Also keep in mind that the *base minimum* ventilation flow rate value for a VAV box is dependent on the minimum flow rate to which the particular VAV box can be controlled, as well as any specific operating requirements. For example, the minimum air flow rate necessary for an electric reheat element to become and remain enabled may exceed the minimum flow determined by the DCV control loop. In this case, the CO_2 control loop output may be overridden if the zone is calling for heat.

Figure I-3. VAV box control with demand-controlled ventilation.



I.1.8.12 AHU Outside air damper control

Control of the outdoor air damper in a VAV system is very similar to that of a constant volume system. The outdoor minimum ventilation setpoint is at the *base minimum* ventilation flow rate value until one VAV box is at its *design minimum* ventilation flow rate value and zone CO_2 concentration

continues to rise. At this point, the outdoor air ventilation setpoint will be reset upwards toward the *design minimum* ventilation flow rate value and the outdoor air damper will modulate open.

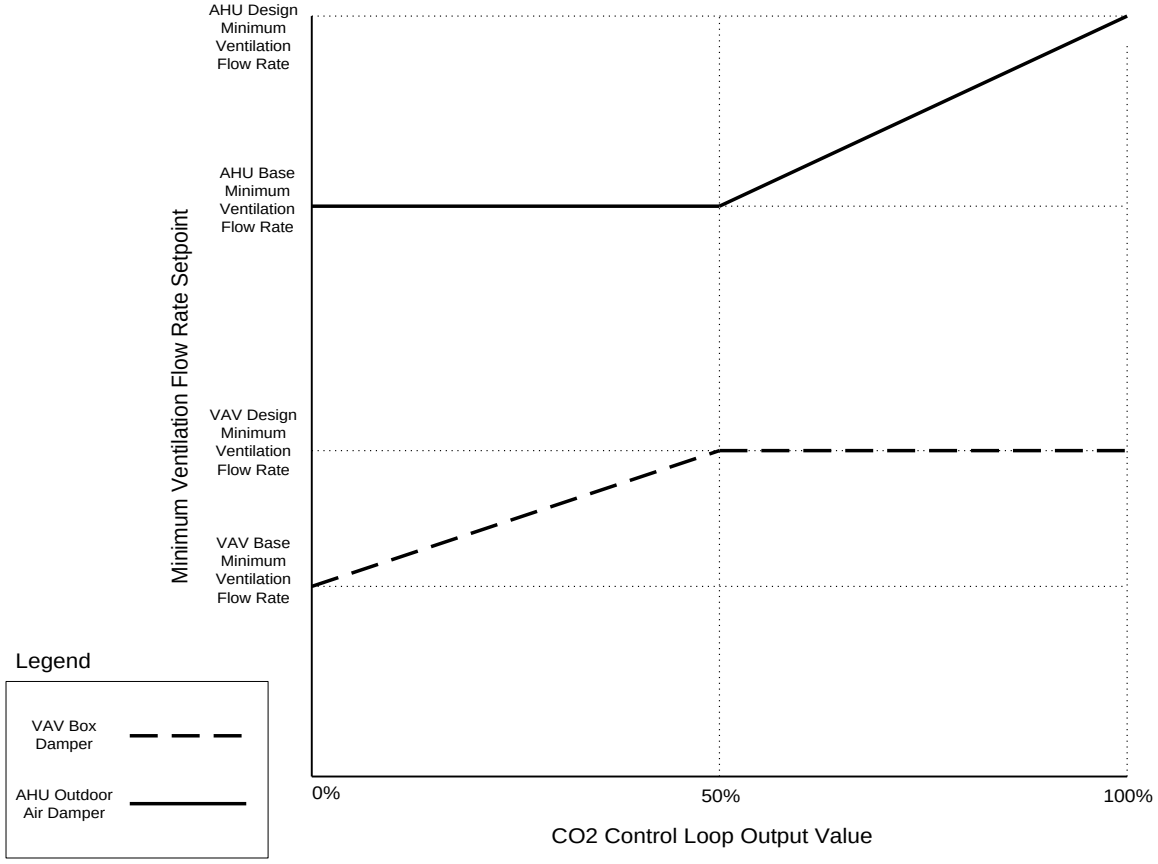
As with a constant volume system, CO_2 concentration only impacts the minimum ventilation flow rate. The economizer control loop takes precedence over the DCV control loop (refer to **Error! Reference source not found.**). However, resetting the minimum damper position in a VAV system is significantly more complicated than in a constant volume system depending on the actual control strategy employed to regulate outdoor air intake (common control strategies include fan tracking, flow tracking, direct flow measurement, mixed plenum pressure, injection fan, and energy balance method). Due to the increased complexity of the control sequences, some designers may opt for just controlling the VAV box and leave the minimum ventilation setpoint for the air handler fixed at the *design minimum* value.

An example operating sequence for controlling both the VAV box and outdoor air damper in a VAV system is illustrated below.

> The minimum ventilation flow rate setpoint for each VAV box is at its respective *VAV base minimum* ventilation flow rate value when zone CO_2 concentration is below setpoint. The minimum outdoor ventilation flow rate setpoint for the central air handling unit is at the *AHU base minimum* ventilation flow rate value when **ALL** zone CO_2 concentrations are below setpoint. As an individual zone CO_2 concentration increases above setpoint, the minimum ventilation flow rate setpoint for that VAV box is reset linearly from the *VAV base minimum* to *VAV design minimum* ventilation flow rate value as the CO_2 control loop output value ranges between 0% and 50%. The minimum outdoor ventilation flow rate setpoint at the central air handling unit remains at the *AHU base minimum* ventilation flow rate value. If the CO_2 control loop output value for **ANY** zone exceeds 50%, the minimum outdoor ventilation flow rate setpoint is reset linearly from the *AHU base minimum* to *AHU design minimum* ventilation flow rate value as the CO_2 control loop output value ranges between 50% and 100%.

The control strategy is graphically represented in Figure I-4.

Figure I-4. VAV box and AHU outdoor air damper control.



I.1.8.13 Sensor location

Regardless of system type, location of the CO_2 sensor can significantly impact overall control and system performance. Examples of the common locations are provided below.

- **Return Air CO_2 Measurement.** A common strategy is to install a single CO_2 sensor in the return air stream of the AHU. This method can be effective if the unit is serving large open spaces where concentration levels are uniform across the entire zone – for example large office spaces, theaters, lecture halls, classrooms, or churches. It will be less effective if the unit serves multiple spaces, especially if some are enclosed with the potential for temporary high occupancy loads (i.e., conference rooms, lunch rooms, assembly areas, etc.). The reason is that transient CO_2 concentration in these zones may exceed safe limits, but the ventilation rate might not be adjusted if total return air concentration is below setpoint (due to dilution from other over-ventilated zones). This method is also ineffective at controlling minimum ventilation rates at the zone level in VAV applications.

- **Critical Zone(s) CO_2 Measurement.** An alternate method is to install CO_2 sensors in all of the critical zones served by the central AHU. The critical zone(s) can be any enclosed space with the potential for temporary high occupancy loads. The local sensor(s) will ensure that the ventilation rate is adjusted as necessary to meet the requirements of the zone with the highest concentration, and the general return air sensor can be used to set overall minimum ventilation rates or control VAV boxes serving "open areas," especially if the building is in partial use during unoccupied periods. This method will be more expensive since additional sensors, wiring, and control points must be installed. In addition, the control sequences will require additional programming, but will yield better indoor air quality. This is the recommended control option for multizone constant volume systems and VAV air handling systems.

I.1.9 Test conditions

The test can be performed under any condition. Care should be taken when verifying economizer interaction if the outdoor air temperature is below freezing. Ensure the freezestat or similar safety/interlock is functioning correctly to protect the AHU during the test. The test can be performed regardless of building occupancy.

I.1.10 Test equipment

The following equipment may be necessary to conduct this test procedure.

- Cylinder with a known concentration of CO_2 to calibrate sensor
- Air flow measurement device (Shortridge, anemometer, etc.)
- Digital temperature measurement device

Test Procedure Outline

Preparation

1.1 Create a test form

1.2 Determine acceptance criteria

1.3 Provide instructions/precautions

1.4 Specify test participants and roles/responsibilities

General System Inspection

2.1 Review all prefunctional checklists for completeness

DCV Test Procedures – Constant Volume Systems

3.1 Verify base minimum outdoor air ventilation flow rate

3.2 Verify design minimum outdoor air ventilation flow rate

3.3 Verify economizer interaction

3.4 Return system to normal

DCV Test Procedures – Variable Air Volume Systems

4.1 Verify base minimum VAV box ventilation flow rate

4.2 Verify design minimum VAV box ventilation flow rate

4.3 Verify base minimum AHU outdoor air ventilation flow rate at reduced supply fan speed

4.4 Verify base minimum AHU outdoor air ventilation flow rate at full supply fan speed

4.5 Verify design minimum AHU outdoor air ventilation flow rate at reduced supply fan speed

4.6 Verify design minimum AHU outdoor air ventilation flow rate at full supply fan speed

4.7 Verify economizer interaction

4.8 Return system to normal

Test Procedure

1. Preparation

1.1 **Create a test form.** Testing will be easier if the test procedure is thought through and documented before conducting the test. Developing a test form will assist in data collection and subsequent evaluation, as well as allow less experienced staff to execute the test.

1.2 **Determine acceptance criteria.** In a constant volume system, the outdoor air minimum ventilation setpoint should be reset between the base minimum and design minimum ventilation flow rate values to maintain CO_2 concentration setpoint. For VAV systems, each VAV box minimum ventilation setpoint should be reset between its respective base minimum and design minimum ventilation flow rate values to maintain zone CO_2 concentration setpoint. In addition, the outdoor air minimum ventilation setpoint may also be reset between the base minimum and design minimum ventilation flow rate values based on the zone with the highest CO_2 concentration. All measured flow rates should be within ±10%* of setpoint. Flow measurements can be made by many methods including but not limited to duct traverse, measuring air velocity across intake, reading measurements from installed flow meters (if factory or field calibrated), or using a hand-held flow device like a hot-wire anemometer.

1.3 **Provide instructions/precautions.** If performing the test during subfreezing atmospheric conditions, ensure proper care is taken to prevent freezing of the coil(s) when verifying economizer interaction. Be sure to have an emergency "exit" strategy in place should the test need to be aborted prior to completion. If a test fails, the source of the failure should be identified and conveyed to the proper authority. The system should be retested once the repairs are complete.

1.4 **Specify participants and roles/responsibilities.** The testing guidance provided in this document can assist in verifying proper system performance in both new construction and existing building applications. At a minimum, the following people should participate in the testing process. Refer to the Functional Testing Basics section of the Functional Test Guide for a description of the general role and responsibility of the respective participant throughout the testing process. The

* note the 10% value is from California Title 24 acceptance testing requirements

roles and responsibilities should be customized based on actual project requirements.

New Construction Project	Existing Building Project
Commissioning Provider	Commissioning Provider
Mechanical Contractor	Building Operating Staff
Control Contractor	Controls Contractor

2. General System Inspection

2.1 **Review all prefunctional checklists for completeness.** Prior to performing any functional tests, the commissioning pre-start, startup, and prefunctional checklists should be completed, as well as applicable manufacturer pre-start and startup recommendations.

Prefunctional checklists include, but are not limited to, the following:

- CO_2 sensor(s) has either calibration certificate from the manufacturer or is field calibrated
- Sensor(s) is installed per the location specified on the plans
- All AHU(s) being tested have been functionally tested and are capable of serving normal operating loads
- All terminal unit(s) being tested have been functionally tested and are capable of serving normal operating loads
- Air system has been balanced per design
- All safeties and interlocks have been tested and are operational
- All sequence of operations are programmed per design

3. DCV Test Procedures – Constant Volume Systems

3.1 **Verify base minimum outdoor air ventilation flow rate.** Prior to performing the test, disable the economizer control loop to prevent unwanted interaction. Simulate a low CO_2 concentration by raising the setpoint for all CO_2 sensors significantly above the zone CO_2 level.

Check the following:

3.1.1 The outdoor air damper modulates to the base minimum damper position as determined when the air handling system was balanced.

3.1.2 The measured outdoor air ventilation rate is within ±10% of the specified value.

3.2 **Verify design minimum outdoor air ventilation flow rate.** Continuing from step 3.1, leave the economizer control loop disabled. Simulate a high CO_2 concentration by lowering the setpoint for one of the CO_2 sensors significantly below the zone CO_2 level.

Check the following:

3.2.1 The outdoor air damper modulates to the design minimum damper position as determined when the air handling system was balanced.

3.2.2 The measured outdoor air ventilation rate is within ±10% of the specified value.

3.3 **Verify economizer interaction.** Simulate a low CO_2 concentration by raising the setpoint for all carbon dioxide sensors installed well above the zone CO_2 level. Re-enable the economizer control loop and adjust the economizer lockout setpoint as necessary depending on the control strategy used so that the economizer will not become disabled during the test. For dry-bulb or enthalpy single-point changeover strategy, raise the economizer lockout setpoint significantly above current outdoor air conditions. For dry-bulb or enthalpy differential changeover strategy, raise the measured return air condition value significantly above current outdoor air conditions. Simulate a call for cooling by lowering the cooling control loop setpoint (typically DAT) or, if applicable, the independent economizer control loop setpoint (which is typically based on mixed air temperature) to 50°F.

Check the following:

3.3.1 The outdoor air damper starts from the base minimum damper position as determined when the air handling system was balanced.

3.3.2 The outdoor air damper modulates toward a full open position (refer to **Error! Reference source not found.**).

3.4 **Return system to normal.** Once all tests are complete, return all control parameters back to original setpoints and conditions per the design sequence of operations.

4. DCV Test Procedures – Variable Air Volume Systems

4.1 **Verify base minimum VAV box ventilation flow rate.** Simulate a low CO_2 concentration by raising the setpoint for each CO_2 sensors significantly above the zone CO_2 level. To simulate a low cooling load without enabling reheat, adjust zone cooling temperature setpoint 5°F above current space temperature and zone heating temperature setpoint (if applicable) 5°F below current space temperature.

Keep in mind that each VAV box must be tested individually. Hence, this step must be repeated until all VAV boxes that are employing DCV have been tested.

Check the following:

4.1.1 The VAV box damper modulates to the base minimum damper position as determined when the air handling system was balanced.

4.1.2 The measured VAV box flow rate is within ±10% of the specified value.

4.2 **Verify design minimum VAV box ventilation flow rate.** Continuing from step 4.1, keep the zone cooling temperature setpoint 5°F above and zone heating temperature setpoint (if applicable) 5°F below current space temperature. Simulate a high CO_2 concentration by lowering the setpoint for each CO_2 sensors significantly below the zone CO_2 level. Again, this step must be repeated until all VAV boxes that are being controlled have been tested.

Check the following:

4.2.1 The VAV box damper modulates to the design minimum damper position as determined when the air handling system was balanced.

4.2.2 The measured VAV box flow rate is within ±10% of the specified value.

4.3 **Verify base minimum AHU outdoor air ventilation flow rate at reduced supply fan speed.** Release all of the zone temperature setpoint changes. Command all VAV box dampers being controlled by CO_2 to their respective base minimum ventilation flow setpoints and command all non-controlled VAV boxes to their respective minimum damper positions. This should simulate a low cooling load and allow

the supply fan speed to slow down. Simulate a low CO_2 concentration by raising the setpoint for all CO_2 sensors significantly above the zone CO_2 level.

Check the following:

4.3.1 Supply fan speed slows down toward minimum speed.

4.3.2 The measured outdoor air ventilation rate is within ±10% of the specified base minimum ventilation flow rate value.

4.4 **Verify base minimum AHU outdoor air ventilation flow rate at full supply fan speed.** Continuing from step 4.3, leave CO_2 setpoint significantly above the zone CO_2 level. Command all VAV box dampers (those controlled and not controlled by CO_2) to their respective maximum ventilation flow setpoints. This should simulate a full cooling load and allow the supply fan speed to increase.

Check the following:

4.4.1 Supply fan speed increases to full speed.

4.4.2 The measured outdoor air ventilation rate is within ±10% of the specified *base minimum* ventilation flow rate value.

4.5 **Verify design minimum AHU outdoor air ventilation flow rate at reduced supply fan speed.** Command all VAV box dampers being controlled by CO_2 to their respective design minimum ventilation flow setpoints and command all non-controlled VAV boxes to their respective minimum damper positions. This should simulate a low cooling load and allow the supply fan speed to slow down. Simulate a high CO_2 concentration in one zone by lowering the respective CO_2 setpoint significantly below the zone CO_2 level.

Check the following:

4.5.1 Supply fan speed slows down toward minimum speed.

4.5.2 The measured outdoor air ventilation rate is within ±10% of the specified design minimum ventilation flow rate value.

4.6 **Verify design minimum AHU outdoor air ventilation flow rate at full supply fan speed.** Continuing from step 4.5, leave CO_2 setpoint for the selected zone significantly below the zone CO_2 level to simulate a high CO_2 concentration. Command all VAV box dampers (those controlled and not controlled by CO_2) to their respective maximum ventilation flow setpoints. This should simulate a full cooling load and allow the supply fan speed to increase.

Check the following:

4.6.1 Supply fan speed increases to full speed.

4.6.2 The measured outdoor air ventilation rate is within ±10% of the specified design minimum ventilation flow rate value.

4.7 **Verify economizer interaction.** Simulate a low CO_2 concentration by raising the setpoint for all CO_2 sensors significantly above the zone CO_2 level. Re-enable the economizer control loop and adjust the economizer lockout setpoint as necessary depending on the control strategy used so that the economizer will not become disabled during the test. For dry-bulb or enthalpy single-point changeover strategy, raise the economizer lockout setpoint significantly above current outdoor air conditions. For dry-bulb or enthalpy differential changeover strategy, raise the measured return air condition value significantly above current outdoor air conditions. Simulate a call for cooling by lowering the cooling control loop setpoint (typically DAT) or, if applicable, the independent economizer control loop setpoint (which is typically based on mixed air temperature) to 50°F.

Check the following:

4.7.1 The outdoor air damper starts from the base minimum damper position as determined when the air handling system was balanced.

4.7.2 The outdoor air damper modulates toward a full open position (refer to **Error! Reference source not found.**).

4.8 **Return system to normal.** Once all tests are complete, return all control parameters back to original setpoints and conditions per the design sequence of operations.

I.1.11 Checklist to evaluate economizers for potential operating problems

Instructions: Evaluate your system for each of the items listed below to determine its susceptibility to economizer related operating problems. Include the recommended measures based on the results of the evaluation in the testing program for the system. Consult the appropriate section of *Chapter 9 Economizer and Mixing Section* for additional information on any of the topics. If you are using this in the electronic version, the hyperlinks will take you to the related section of the Guide, assuming it is available on your computer. When you click on the link, it will open the chapter in a separate window and put you at a location in the document that contains the related information associated with the hyperlink. You will also notice that the task bar at the bottom of your screen has buttons for both of the documents (as well as any other Word documents that you might have open). To return to this checklist, simply click on the button associated with it in the task bar at the bottom of your screen or in the Windows drop down menu.

Date(s) of Evaluation:

_____

Evaluator:

_____

Item Number	Requirement	Initial and Date when Complete
Dampers, Actuators, and Linkage Systems		
1	**Is there an independent minimum outdoor air damper?** **Yes -** This is generally the best situation because it will allow the minimum outdoor airflow rate to be set and regulated independently from the economizer related maximum outdoor air function. ***Follow-up and Recommendations:*** Include functional testing in the Commissioning plan targeted at ensuring that the minimum outdoor air damper is set up properly to achieve the design intent for the system. **No -** Lack of an independent minimum outdoor air damper can lead to economizer related operating problems. The two most likely issues are: • The minimum flow is much higher than required because of the non-linear relationship between flow and damper stroke causing excessive energy consumption. • Low or no minimum outdoor airflow into the building causes indoor air quality problems and/or problems with pressure relationships. ***Follow-up and Recommendations:*** *Design Phase* - Recommend that the design team address the issue by providing a regulated, independent minimum outdoor air damper. Include functional testing in the Commissioning Plan targeted at ensuring that the proper minimum outdoor	

Item Number	Requirement	Initial and Date when Complete
	air flow rate is set and maintained for the system. *Construction Phase* - Recommend that the outdoor air damper section be modified to provide a regulated, independent minimum outdoor air damper. *Retrocommissioning* - Consider modifying the existing minimum outdoor air damper assembly to provide an independent minimum outdoor air damper. Where this is not practical or possible, add a minimum outdoor air flow limit to the economizer control signal. Functionally test to ensure that the required minimum outdoor air flow is delivered.	
2	**Check damper sizing.** There are several approaches possible. *Check based on size relative to the duct or louver they are associated with.* If the dampers are the same size as the duct, plenum or intake louver they are associated with, then they probably are oversized. *Check based on nominal face velocity.* Proceed as follows. *Document the system design flow rate.* Unit rated capacity _____ cfm *Document the maximum outdoor air damper size and calculate the area.* Height_____ ft Width _____ ft Area = Height x Width _____ sq ft *Note the damper blade type (check the appropriate item)* Flat late _____ Airfoil _____ *Calculate the nominal damper face velocity* Face velocity = Flow rate ÷ Area _____ fpm For airfoil dampers in typical systems, velocities through the damper section in the range of 2,000 - 3,000 fpm are typically required to generate a pressure drop that provides a satisfactory alpha ratio and reasonable control. For flat plate dampers, the range is more like 1,500 - 2,000 fpm. **Based on the preceding rules of thumb, do the dampers appear to be sized properly?** **Yes -** No additional effort is required at this time. ***Follow-up and Recommendations:*** *Design phase* - Include documentation of damper sizing in project control submittal requirements.	

Item Number	Requirement	Initial and Date when Complete
	Construction phase or Retrocommissioning - Investigate further if subsequent functional testing indicates problems that can be related to damper sizing issues. **No** - Improper sizing can lead to a variety of operational problems including poor mixing and non-linear performance. In turn, these issues can lead to energy waste, nuisance freezestat trips, and premature component failure. ***Follow-up and Recommendations:*** *Design phase* - Request that the design team address damper sizing and related issues either directly or by including specific delegation of the responsibility to the control contractor. Require documentation of damper sizing in the project control submittals. *Construction phase* - Request that the control contractor document damper sizing and/or modify the damper sections as required to achieve the necessary level of mixing and linearity. Coordinate with the project designer to obtain an understanding of their design intent in this regard. Include functional testing designed to identify damper sizing issues early on such as the Temperature Traverse Test and the flow linearity test. *Retrocommissioning* - Do further calculations to investigate the damper sizing requirements. Perform functional testing designed to identify damper sizing issues such as the Temperature Traverse Test and the flow linearity test. Modify damper sections as necessary to achieve the desired level of performance.	
3	**A. Are the return and maximum outdoor air damper sections similar in size and arrangement?** **B. Are the dampers oriented in a manner that will promote mixing?** **C. Are the blades rotations set up in a manner that will promote mixing?** **Yes to all three items** - No additional effort is required at this time. ***Follow-up and Recommendations:*** *Design phase* - Include shop drawing requirements for installation details for all dampers as a part of the control system submittal.	

Item Number	Requirement	Initial and Date when Complete
	Construction phase or Retrocommissioning - Investigate further if subsequent functional testing indicates problems that can be related to damper configuration issues. **No to any one item** - Improper configuration can lead to a variety of operational problems poor mixing. In turn, these issues can lead to energy waste and nuisance freezestat trips. ***Follow-up and Recommendations:*** *Design Phase* - Recommend that the design team include details on the contract documents describing the arrangement of all mixing dampers including blade orientation and rotation, damper arrangements, and blank-off plate locations and requirements or specifically delegate this responsibility to the control contractor via the specifications. Include shop drawing requirements for installation details for all dampers as a part of the control system submittal. *Construction phase* - If the dampers are already installed, then, other than for blade rotation, it is usually best to wait to modify or reconfigure the damper sections based on the results of functional testing. If blade rotation is an issue, recommend that the dampers be reoriented so that the blade rotation promotes mixing. This is easier (less costly) if you can catch the problem before the actuators are installed and piped. Perform functional testing designed to identify damper configuration issues such as the Temperature Traverse Test and the flow linearity test. Modify damper sections or install baffling as necessary to achieve the desired level of performance. *Retrocommissioning* - Reorient the dampers to correct any blade rotation problems. Perform functional testing designed to identify damper configuration issues such as the Temperature Traverse Test and the flow linearity test. Modify damper sections or install baffling as necessary to achieve the desired level of performance.	
System Turn-Down (Variable Flow Systems Only)		
1	**If the system is required to operate at different flow rates, either because it is a VAV system or a system equipped with a multi-speed motor, then evaluate its turn down ratio using one of the following three techniques.**	

Item Number	Requirement	Initial and Date when Complete
	Method 1 - Turn-down ratio for systems with several different operating flow rates. A = Rated flow at maximum speed ___ cfm B = Lowest rated flow ___ cfm Turn-down ratio = A ÷ B ___ *Method 2* - Turn-down ratio for VAV systems with a terminal unit schedule stating maximum and minimum flows and no zone level scheduling.* A = Maximum rated flow = AHU's rated cfm ___ cfm B = Minimum flow = Sum of minimum flow rates for all units served by the AHU _____ cfm Turn-down ratio = A ÷ B ___ *Method 3* - Turn-down ratio for VAV systems with a terminal unit schedule stating maximum and minimum flows and with zone level scheduling. A = Maximum rated flow = AHU's rated cfm	

* Zone level scheduling is a technique that uses a schedule to control the terminal equipment on a VAV system. If the area served by the terminal equipment is unoccupied, then the terminal unit damper is driven closed. The central system then backs down due to the normal fan volume control system responding to this reduction in flow. The central system is shut down when none of the zones it serves are in the occupied mode. Night set back and set up routines return the terminal equipment to the occupied cycle on a temporary basis if necessary to hold unoccupied space temperatures within some temperature range.

In system level scheduling, the central system is shut down if all of the zones it serves are unoccupied, but unoccupied zones continue to operate based on their current set points and never reduce their flow below the terminal unit minimum flow settings. The technique has the advantage of saving energy by eliminating the minimum flow associated with unoccupied zones. But, it generally means the system will have a higher turn down ratio since in theory, it may have to run to serve only one terminal unit operating at its minimum flow. Usually, this is impractical so the controlling software is arranged to schedule terminal units in blocks with the smallest block size being determined by the turn down capability of the system.

Item Number	Requirement	Initial and Date when Complete
	___ cfm B = Minimum flow = Sum of minimum flows for the smallest group of terminal units that can run in an occupied mode with all of the others in an unoccupied mode. ___ cfm Turn-down ratio = A ÷ B ___ **Is the turn-down ratio greater than 2:1?** **No** - No additional effort is required at this time. ***Follow-up and Recommendations:*** *Design phase* - None *Construction phase or Retrocommissioning* - Investigate further if subsequent functional testing or trending indicates operating problems that can be related to performance at low percentages of design flow. **Yes** - Variable flow systems with high turn-down ratios may have difficulty operating at low percentages of design flow (high turn-down ratio), especially if the dampers are marginally sized at design flow. ***Follow-up and Recommendations:*** *Design phase* - Investigate alternatives that allow the system to perform better at low flow rates. *Construction phase* - Include functional tests such as the High Turn-Down Test in the commissioning plan to verify system performance at low percentages of design flow. *Retrocommissioning* - Perform functional tests such as the High Turn-Down Test to identify either the limiting flow condition where damper performance has degraded to the point where the economizer function is no longer reliable or confirm economizer reliability at the lowest flow rate routinely seen by the system. Coordinate with the operating staff to identify operating options or control modifications that will provide reliable system performance at the required operating conditions.	
Mixing conditions		
1	**Is there sufficient distance between the mixing plenum and**	

Item Number	Requirement	Initial and Date when Complete
	the freezestat and/or first coil with a potential for freezing to allow mixing to occur? **Yes-** No additional effort is required at this time. ***Follow-up and Recommendations:*** *Design phase* - None *Construction phase* - Monitor construction to verify that the spacing incorporated in the design is maintained in the actual installation. Consider including a test procedure such as the Temperature Traverse Test in the functional testing plan to document and verify the mixing performance. *Retrocommissioning* - Consider including a test procedure such as the Temperature Traverse Test in the functional testing plan to document and verify the performance. **No -** Insufficient distance for mixing to occur can cause operating difficulties with the economizer system that can prevent it from achieving its design intent. ***Follow-up and Recommendations:*** *Design phase* - Investigate alternatives that allow the system to provide better mixing conditions. Air blenders are one option if sufficient distance cannot be provided. *Construction phase* - Monitor construction to verify that the spacing or other mixing features incorporated in the design is implemented in the actual installation. Consider including test procedures such as the Temperature Traverse Test in the functional testing plan to document and verify the performance. *Retrocommissioning* - Perform a test procedure such as the Temperature Traverse Test to identify the magnitude of the problem. Based on the test results, evaluate retrofit options that could help address any issues identified.	
Sensors and Control		

Item Number	Requirement	Initial and Date when Complete
1	**Have the temperature sensing elements associated with the economizer function (Typically, the mixed air sensor and freezestat) been located and arranged in a manner that ensures they will reflect the true conditions in the mixed air plenum?** **Yes-** No additional effort is required at this time. ***Follow-up and Recommendations:*** *Design phase* - None *Construction phase* - Monitor construction to verify that the requirements of the design are reflected in the actual installation. *Retrocommissioning* - Consider including a test procedure such as a Temperature Traverse Test in the functional testing plan to document and verify that the sensing elements reflect the true mixed air plenum conditions. **No** - Poorly located and arranged sensing elements can cause numerous problems with the operation of the economizer cycle and related safety functions. ***Follow-up and Recommendations:*** *Design phase* - Request that the designers provide guidance on the contract documents regarding requirements for the installation and location of the sensing elements. *Construction phase* - Monitor construction to verify that the sensor installation reflects the requirements of the design. Consider including test procedures such as a Temperature Traverse Test in the functional testing plan to document and verify the performance. *Retrocommissioning* - Perform a test procedure such as a Temperature Traverse Test to identify the magnitude of the problem. Based on the test results, modify the sensor installation as required to achieve satisfactory performance.	
2	**A. Does the design include appropriate controls and interlocks to enable and disable the economizer function as appropriate for the ambient conditions, system operating conditions, and safety requirements?** **B. Are the set points for these interlocks clearly defined on the documents and appropriate for the project local?** **Yes to all** - No additional effort is required at this time. ***Follow-up and Recommendations:*** *Design phase* - None	

Item Number	Requirement	Initial and Date when Complete
	Construction phase or Retrocommissioning - Include functional tests like the Ambient Interlock Test to verify proper functionality. **No to any one item** - Improperly set or missing interlocks can lead to operational problems and energy waste. ***Follow-up and Recommendations:*** *Design phase* - Request that the designers provide guidance on the contract documents regarding interlock requirements and settings. *Construction phase* - Include functional tests like the Ambient Interlock Test to verify proper functionality. *Retrocommissioning* - Evaluate the existing system to determine interlock requirements and appropriate settings. Implement any necessary changes and perform a functional test like the Ambient Interlock Test to verify proper functionality.	
3	**If the system does not have an independent mixed air controller or control loop, is it provided with a mixed air low limit control loop?** **Yes** - No additional effort is required at this time. ***Follow-up and Recommendations:*** *Design phase* - None *Construction phase or Retrocommissioning* - Include functional tests like the Mixed Air Low Limit Test to verify proper functionality. **No** - Systems with economizers that are controlled by a condition downstream of the mixed air plenum can be difficult to start in subfreezing winter weather. ***Follow-up and Recommendations:*** *Design phase* - Request that the designer's include a mixed air low limit sequence in the control requirements for the project. *Construction phase and Retrocommissioning* - Include functional tests like the Mixed Air Low Limit Test to verify proper functionality.	
4	**Does the control sequence and design of the air handling system adequately address the building pressure control requirements generated by operating on an economizer cycle?** **Yes** - No additional effort is required at this time. ***Follow-up and Recommendations:*** *Design phase* - None	

Item Number	Requirement	Initial and Date when Complete
	Construction phase or Retrocommissioning - Include functional tests like the D:\REPORTS_Project\HPCBS\E-5\2.2.1\8 - Economizer and Mixing Section.doc - MixedAirLoLimitTest targeted at verifying the integrated performance of the building pressure control system with the economizer system as necessary to meet the design intent for the project. **No –** The extra air brought in by an economizer cycle that slightly pressurizes a building can provide significant benefits in terms of energy conservation and comfort. Failing to address building pressure control requirements can cause significant operating problems. ***Follow-up and Recommendations:*** *Design phase* - Request that the designer's include a building pressure control sequence in the control requirements for the project. *Construction phase* - Include functional tests like the D:\REPORTS_Project\HPCBS\E-5\2.2.1\8 - Economizer and Mixing Section.doc - MixedAirLoLimitTest targeted at verifying the integrated performance of the building pressure control system with the economizer system as necessary to meet the design intent for the project. *Retrocommissioning* - Include functional tests targeted at identifying the impact of the economizer cycle on building pressure with the economizer system in various operating modes. On high-rises, large buildings or buildings that are part of an interconnected complex, consider performing the Building Pressurization Test to evaluate the pressurization needs of the building and the impact the economizer cycle can have on addressing it.	
5	**Has the control of the economizer dampers been fully integrated with the control of the other heat transfer elements in the system?** **Yes** - No additional effort is required at this time. ***Follow-up and Recommendations:*** *Design phase* - Request that the design team include appropriate alarms and smart alarms to annunciate problems with the economizer system and its integrated performance with the other air handling system control functions.	

Item Number	Requirement	Initial and Date when Complete
	Construction phase or Retrocommissioning - Include functional tests like the D:\REPORTS_Project\HPCBS\E-5\2.2.1\8 - Economizer and Mixing Section.doc - MixedAirLoLimitTest targeted at verifying the integrated performance of the economizer system with the other heat transfer elements in the air handling system as necessary to meet the design intent for the project. **No -** Failure to fully integrate the economizer function with the operation of the other heat transfer elements in the air handling system can result in energy waste that is difficult to address directly. ***Follow-up and Recommendations:*** *Design phase* - Request that the designer include a building pressure control sequence in the control requirements for the project. *Construction phase* - Include functional tests like the D:\REPORTS_Project\HPCBS\E-5\2.2.1\8 - Economizer and Mixing Section.doc - MixedAirLoLimitTest targeted at verifying the integrated performance of the building pressure control system with the economizer system as necessary to meet the design intent for the project. *Retrocommissioning* - Include functional tests like the D:\REPORTS_Project\HPCBS\E-5\2.2.1\8 - Economizer and Mixing Section.doc - MixedAirLoLimitTest targeted at identifying the impact of the economizer cycle on building pressure with the economizer system in various operating modes. On high-rises, large buildings or buildings that are part of an interconnected complex, consider performing the Building Pressurization Test to evaluate the pressurization needs of the building and the impact the economizer cycle can have on addressing it.	

Item Number	Requirement	Initial and Date when Complete
Comments: _____ _____ _____ _____ _____ _____ _____ _____ _____ _____ _____		

I.1.12 VFD VAV fan application

Constant Static Pressure Application

Project: _____ Date: _____
Address: _____

Commissioning Participants:
Commissioning agent: _____ of _____
EMS Operator: _____ of _____
VFD technician: _____ of _____
HVAC technician: _____ of _____
Owner's rep.: _____ of _____

Air handler ID: ___. ___ Supply fan (SF) hp: ___ CFM: ___ RPM ___ SP ___
___ Return fan (RF) hp: ___ CFM: ___ RPM ___ SP ___
VFD brand and model:
_____

The following functional performance test is for a VFD controlling a VAV air handler to a **constant** duct static pressure (SP). ***A check-mark denotes acceptance or compliance.***

I. Design Intent and Documentation Verification

___ Review the design documents and the specifications.
___ Verify that the VFD ___ description, __ specifications, __ technical and troubleshooting guide and the installation, __ programming record and ___balance report are on site.
From the design documents determine: Location of static pressure sensor:
_____
Nearest duct fitting upstream (fitting and distance): _____
Nearest duct fitting downstream: _____
Control strategy for the return fan: _____
_____

II. VFD Installation

Static Pressure Sensor

Linear Position

Location of sensor in % of the distance from fan to terminal box: _____
Normally, the sensor should be located 2/3 to 3/4 the distance from the fan to the terminal box of the most restrictive branch.

____**Complies?**

Pressure Reading Reliability

Nearest duct fitting upstream (fitting and distance): _____
Nearest duct fitting down-
stream:_____

The SP sensor controlling the VFD must be located so as to properly sense the static pressure in the duct without being adversely affected by changes in flow from duct fittings. This ideally requires the sensor to be at least 10 duct diameters downstream and five duct diameters upstream from any duct takeoff or elbow fittings.

___**Complies?**

Pressure Offset (Po)

Duct static pressure fan is being controlled to: _____in. H_20 [A].

Pressure rise across supply fan at design conditions (from balance report summary): _____in. H_20 [B]. Pressure offset, Po, [A]/[B]: _____.

Optimally, Po should be 0.3 or less for the VFD and fan to be able to respond to small pressure changes and realize adequate energy savings. If Po is greater than 0.4, the duct SP sensor is probably located too close to the fan.

___**Complies?**

Balancing to Lowest Pressure

Review the HVAC balance report and verify that according to the report, the system was balanced so the VFD controls to the lowest possible duct static pressure (that is, a capacity test was performed). The controlling duct static pressure from balance reports is _____in. H_20. The corresponding VFD frequency or fan RPM from the balance report is: supply fan (SF):_____, return fan (RF):_____. Refer to the end of this test for details of the capacity test.

___**Balanced to lowest static?** (this is further verified by #2 under Section IV)

Turn-Down Ratio

What is the minimum Hz the VFD will take the fan to? _____
What is the reason for any limitations?_____

General Issues

___ Verify that any power quality mitigation measures required from the specifications have been completed.

___ Verify that any inlet vanes or outlet dampers on the fan have been removed or permanently held full open.

___ Verify verbally that the acceleration and deceleration ramp time of the VFD is between one and four minutes.
Actual ramp time: up _____min. down _____min. (too short of ramp times will result in "hunting" and excess modulation by the VFD, typical ramp times are 1 to 4 minutes)

___ Verify that the lower frequency limit is 0, unless explained.

___ Verify that the VFD has been integrated into the EMS as per specification.

___ Verify that the EMS monitors the duct static pressure or that an in-line "T" in the static pressure hose is extended to near the VFD, from which a magnehelic static pressure reading can be made during testing.

III. Functional Performance Test

This test is not intended to verify that the VAV system is functioning properly, but rather that the VFD is functioning properly.

1. **Boxes Partially Open (intermediate CFM).** If current conditions are such, that the system is not expected to be in full cooling, nor be at the minimum flow condition:
   a. Read the frequency output of the VFDs and record in Table 1 in the "Boxes Partially Open" column for both the supply fan (SF) and return fan (RF) if applicable.
   b. Read the duct static pressure and record in the same column.

   If the conditions are not in an "intermediate" position, change all space temperature set points to 4 degrees below the actual temperature in the space, to simulate an approaching of thermostat satisfaction and take readings.

2. **Boxes to Maximum Open (Full Cooling).** Using the (EMS) or other means, change all the space temperature setpoints to at least 10 degrees below the current space temperature so that the entire HVAC system supplied from this fan is in full cooling in all zones and *all* terminal boxes are open to their maximum "stops."

   a. Measure or read the duct static pressure controlling the VFD and record in the "Open to Max. Stop" column in Table 1.
   b. Read the frequency output of the VFDs and record in Table 1.

3. **Boxes to Minimum Positions.** Change all space temperature set points to be equal to the actual space temperatures to simulate a satisfied condition, driving the boxes to their minimum.
   a. Take the frequency and static pressure readings and record in Column D.

IV. Analysis

A Design static pressure_____ Design freq. (Hz): SF _____ RF _____ Design RPM: SF_____ RF _____ SP being controlled to now _____	**B** **Terminal Boxes Open to Max. Stop**	**C** **Boxes Partially Open**	**D** **Boxes Closed to Min. Stop**
	SF | RF	**SF | RF**	**SF | RF**
VFD frequency. or RPM	|	|	|

Static pressure during VFD test			
Static pressure during capacity test		(from Testing, Adjusting and Balancing [TAB] report data form)	

1. Fractional variance of SF design frequency or RPM to full open, 1-(B/A): _____. If the full open SF frequency or RPM is more than 5% less than the design value (assuming the design and actual static are equal), all boxes may not be driven full open. Investigate as appropriate.
___**Less than 5% variance?**

2. The SP with full open boxes (B) should be significantly less than the SP during the partially loaded conditions and should be within 0.15 inches SP of the SP from the capacity test. If the VFD SP is greater than the capacity test SP, all boxes may not be fully open. If the SPs are not close to each other, the TAB data may be inaccurate. Compliance basically verifies that a capacity test was completed.
___**Complies?**

3.___**Is the SP in (C) and (D) within 10% of the what it is being controlled to in (A)?**

4.___**The min. turn-down ratio (from Section II) should be close to (freq. D/B) Y/N?**

5.___**Return fan RPMs or frequencies track well with changes in SF RPM, accounting for changes in OSA quantities and relief strategy?**

6. Static pressure (SP) readings at the last two conditions should remain within 5% of each other. If the there is more than a 5% variance, the sensor may be unstable, possibly from being too close to duct fittings.
___**Less than 5% variance?**

___**Collaborative Trending:** If the variance is greater than 5% and if the Pressure Reading Reliability location does not comply, from Section III, trending (monitoring) the SP against terminal unit damper position or SF flow is recommended to confidently verify stability. The SP should remain constant (+/- 5%) regardless of damper position or flow.. SP trended? _____
___**Complies?** (sensor is stable)

7.___**For the frequency or RPM readings in Table 1, are the values in Col. B > C > D?**

V. Training

___The training specified in the design incentive agreement has been completed.

Required Capacity Test

To insure that energy use is minimized, the HVAC system must be balanced at design conditions at the lowest possible static pressure possible. This requires that the lowest possible static pressure (SP) be found at the sensor that will allow full design flow at the terminal units (TUs) most difficult to satisfy. This system minimum SP found is what the VFD should control to. This is accomplished by changing the temperature setpoint for all zones to 55F, causing all TUs to be calling for full cooling. Each TU's airflow is then measured against the design flow. The TU that is receiving the lowest fraction of design is identified. The current SP at the controlling sensor is noted. A calculation is made, giving the SP required at the sensor to allow the identified most critical TU box to meet its design flow. The equation is $SP_2 = SP_1 \times Q_2^2/Q_1^2$. Where Q_1 = actual or fraction of design flow during capacity test. Q_2 = design flow or 1.0 if using fractions. SP_1 = SP at sensor. SP_2 = SP to control to. It is noted that if all boxes were calling for full cooling simultaneously, the fan could not maintain the new SP_2 value, due to diversity fan size reduction having been made by the design engineer.

Parties required for VFD site commissioning work

Commissioning agent To witness and record the tests.

EMS Operator To drive boxes open and shut by changing the set points, etc.

VFD technician To use the keypad to verify the ramp time. (unless verified at startup, which is recommended). Sequencing the keypad to display ramp time could be done by the commissioning agent, alone after reviewing the VFD technical manual.

HVAC technician To apply magnehelic gages to the pressure tap to measure duct static, if not monitored by EMS.

I.1.13 Standard commissioning procedure for variable frequency motor drives

BUILDING NAME: _____ **APPLICATION #:** _____

BUILDING ADDRESS: _____

_____

_____

NAME & FIRM OF PERSON(S) DOING TEST: _____

DATE(S) OF TEST: _____

General Notes:

1. This is a generic test procedure for variable frequency drives (VFDs). If the complexity, configuration, or other aspects of a specific project require substitute tests or additional tests, explain on the comments sheets, and attach the additional test procedures and field data. Attach all relevant functional performance verification sheets, and always attach the final signed and dated procedure certification page.
2. In all test sections, circle or otherwise highlight any responses that indicate deficiencies (i.e., responses that do not meet the criteria for acceptance). Acceptance requires correction and retest of all deficiencies, as defined in each test section under "Criteria for Acceptance" or "Acceptance." Attach all retest data sheets. Complete the Deficiency Report Form for all deficiencies.
3. This Commissioning Procedure does not address fire and life safety or basic equipment safety controls.
4. To ensure that this Commissioning Procedure will not damage any equipment or affect any equipment warranties, have the equipment manufacturer's representative review all test procedures prior to execution.

NAMEPLATE DATA (from equipment nameplates, as recorded in field):

Criteria for Acceptance: Nameplate data must be in accordance with approved submittals.

DESCRIPTION	DRIVE # (Pump or Fan Symbol)					
Serves What Equipment (Describe)?						
Drive Manufacturer						
Drive Model #						
Drive Serial #						
Motor Manufacturer						
Motor Model #						
Motor Rated Horsepower Motor Rated Voltage/Phase Motor Rated Full Load Amps Motor Rated Frequency, Hz						
Drive Rated Horsepower Drive Rated Voltage/Phase Drive Rated Full Load Amps Drive Rated Frequency, Hz						

COMMENTS ON NAMEPLATE ITEMS (add more sheets if needed):

ITEM # UNIT # COMMENT

_____ _____ _____

_____ _____ _____

_____ _____ _____

_____ _____ _____

_____ _____ _____

INSTALLATION VERIFICATION:

Instructions: Under each unit write "Y" for yes, "N" for no, "NA" for not applicable, or a number to refer to any needed comments. If other information is requested such as voltage or frequency, write the appropriate values.

Criteria for Acceptance: All items in this section require answers of "Y" (or "NA," where relevant) except where other criteria are noted.

Test Equipment: Use of a true RMS multimeter is highly recommended for all VFD electrical measurements. Multimeters that are not true RMS often give confusing and/or erroneous data when measuring waveforms that are not pure sine wave.

Meter Manufacturer: _____ Model #: _____ True RMS? ___

___

Caution: Only qualified personnel familiar with the operation of the installed drives and motors, and the hazards involved, should adjust, operate, test, and/or service the equipment. The commissioning agent should become familiar with the installation, operation, and maintenance manuals prior to starting commissioning work. Failure to observe proper safety precautions could result in damage to equipment, severe bodily injury, and/or loss of life.

DESCRIPTION	DRIVE #					
1. Manufacturer's startup sheet completed and attached.						
2. Drive & motor environment clean.						
3. Adequate drive & motor access for ventilation and maintenance.						
4. No unusual noise or vibration.						
5. No disconnects installed between VFD & motor without shut-down interlock to VFD.						

DESCRIPTION	DRIVE #					
6. Shut-down interlocks between VFD & motor verified to be operational.						
7. Separate conduit for incoming power and outgoing motor leads.						
8. No power factor correction capacitors connected to motor.						
9. Shaft rotation correct, normal operation.						
10. If equipped with bypass, note bypass starter overload heater size. Acceptance: properly sized for motor.						
11. Shaft rotation correct, bypass operation [1]						
12. Verify bypass switch starts & operates equipment [1]						
13. Maximum Hertz setting[2] Acceptance: per footnote.						
14. Minimum Hertz setting[3, 4] Acceptance: per footnote.						
15. Does motor have oil sleeve bearings?[5] Acceptance: per footnote.						
16. Is there an isolation transformer or line reactor in the drive circuit? Acceptance: Must be installed if required by drive manufacturer or designer.						
17. O&M manual on site.						

Notes To Table:

[1] Note that testing of the drive bypass switch will drive the driven equipment at full speed. First verify with building operator that this will not damage equipment, ductwork, piping, etc. due to excessive flow or pressure.

[2] The maximum frequency setpoint should not be higher than the motor full speed rating without approval by the user. Inform the user that such operation may affect the motor life, and that they should verify with the motor manufacturer's representative that the driven motor is rated for such operation.

[3] Operation of the driven motor at less than 25% of the motor full speed rating may cause the motor to run with inadequate cooling. Inform the user that such operation may affect the motor life, and that they should verify with the motor manufacturer's representative that the driven motor is rated for such operation. Note that the minimum speed may be set at either the drive or at the EMS.

[4] If the driven motor is to operate at less than 50% of its nameplate speed, the thermal overload protection may not properly protect the motor. The motor may overheat due to the reduction in

ventilation at reduced speed even though it is operating at well less than its rated full load current. A thermally responsive overload protection device that responds to actual motor winding temperature may be required in this case. Advise the installer to check this requirement with the motor manufacturer's representative.

[5] For motors that are equipped with oil sleeve bearings, operation of the driven motor at less than 50% of the motor full speed rating may cause the bearings to receive inadequate lubrication. Inform the user that such operation may affect the motor life, and that they should verify with the motor manufacturer's representative that the driven motor is rated for such operation.

COMMENTS ON INSTALLATION VERIFICATION CHECKLIST ITEMS (add more sheets if needed):

ITEM #	UNIT #	COMMENT

FUNCTIONAL PERFORMANCE VERIFICATION:

The following sections are a series of field tests that are intended to verify that the variable frequency motor drives operate as they were intended to operate by the manufacturer and designer. If the field observation does not correspond to the intended design operation, write a comment number that refers to an explanatory comment in the comments section or on attached comments sheets. If a test does not apply, write "NA" for not applicable. If you were not able to complete a test, write "ND" for not done, and explain in a comment.

Full Capacity Test: Perform the following tests and measurements by forcing the system to its maximum capacity (e.g., full flow). Verify that the drive maintains the system at setpoint.

Criteria for Acceptance: As noted under specific test items. Note: Imbalance (current or voltage) is defined as largest phase difference from the average, divided by the average.

DRIVE #						
19. Controlled variable setpoint & units of measurement (static pressure, ˚F, etc.). Acceptance: Setpoint must be as low as possible, consistent with proper system operation. 20. Measured controlled variable full capacity value. Acceptance: Must be within -15% to +10% of setpoint.						
21. Maximum Hertz setting. Acceptance: <65 Hz 22. Measured Hertz. Acceptance: Must be within ±10% of maximum setting.						
23. Measured amps into drive. Acceptance: Average must be no more than 5% above rated motor full load amps	/ /	/ /	/ /	/ /	/ /	/ /
24. Measured amps into motor. Acceptance: Current imbalance between phases must be <2%	/ /	/ /	/ /	/ /	/ /	/ /
25. Measured volts into drive. Acceptance: Average must be within ±10% of rating.	/ /	/ /	/ /	/ /	/ /	/ /
26. Measured volts into motor.	/ /	/ /	/ /	/ /	/ /	/ /
27. Voltage imbalance into drive <2%? Acceptance: Must be <2%.						
28. Voltage imbalance into motor <2%? Acceptance: Must be <2%.						

Flying Start Test: Perform this test only if the drive is equipped with a flying start function. This test verifies that the drive is able to start to a spinning load, without undergoing nuisance trips. With the equipment running, momentarily interrupt power to the drive and restore power before the driven equipment comes to a complete stop. Alternative Test: If it is not possible to interrupt power to the drive, use the drive controls to turn it off momentarily, and then turn it back on before the driven equipment comes to a complete stop. Use this alternative only if it is impossible to interrupt power **to** the drive.

Caution: In some cases, this test has resulted in damage to the VFD because of faulty VFD components. Inform the building operator of this possibility, and get permission to perform the test before starting.

DRIVE #						

29. Did the drive restart & match the spinning load without tripping any safeties? Acceptance: Drive must restart & match load without trips.						
30.						

Normal Operation Test: Monitor or measure kW or Amp input to the drive, and trend EMS VFD output signal and controlled variable input signal (static pressure, ˚F, etc.) for at least 24 hours to document speed modulation under normal operation. If drive is not observed to modulate to less than 50% of full speed, force the flow control devices to minimum positions by changing setpoints, control signal, etc. as needed. Attach annotated graphs of monitored data to this test sheet. If using an energy management system (EMS) to verify drive operation, record the following values, and then attach annotated trend-logs. Test 1 must be at a control signal of between 60 and 75%, and test 2 must be at a control signal of between 30 and 50% of full speed.

Criteria for Acceptance: As noted under specific test items.

DRIVE #						
31. Test 1: control speed signal, % of maximum signal (60 - 75%) 32. Divide answer to #31 by 100% and cube the result. 33. VFD input amps at same time as #31 34. Fractional Current: Divide the avg. VFD input amps (#33) by the avg. max running amps into the motor (#24). 35. Calculate the correspondence between the fractional current and the cube of the control signal: (#34 - #32)/#32. Acceptance: The calculated correspondence must be within ±20%.	/ /	/ /	/ /	/ /	/ /	/ /
36. Test 2: control speed signal, % of maximum signal (30 -50%) 37. Divide answer to #36 by 100% and cube the result. 38. VFD input amps at same time as #36 39. Fractional Current: Divide the avg. VFD input amps (#38) by the avg. max running amps into the motor (#24). 40. Calculate the correspondence between the fractional current and the cube of the control signal: (#39 - #37)/#37. Acceptance: The calculated correspondence must be within ±20%.	/ /	/ /	/ /	/ /	/ /	/ /
41. Was VFD observed to modulate to <60% of full speed under normal (non-forced) operation? If not, comment below on likely reasons. Note if this is to be considered a deficiency. Recommend seasonal retesting if appropriate.						

COMMENTS ON FUNCTIONAL PERFORMANCE VERIFICATION ITEMS:

ITEM #	UNIT #	COMMENT

I certify that the data and test results as recorded herein are accurate.

Signature, Commissioning Agent Date

Firm Name (Area Code) Phone Number

file:vfdqas1.pro

I.1.14 Economizer bin data

FORT LEONARD WOOD MO WMO No. 724457

Dry-Bulb Temperature Hours For An Average Year (Sheet 5 of 5)

Period of Record = 1967 to 1996

Annual Totals

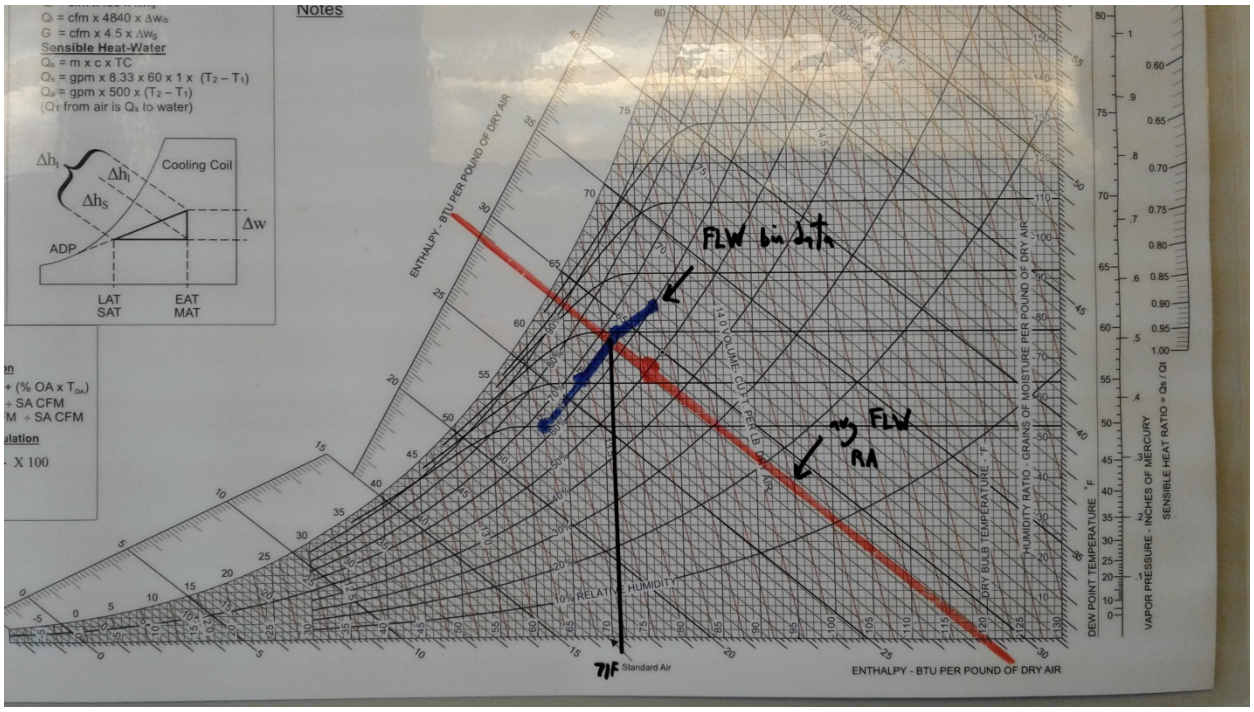
Temperature Range (°F)	Hour Group (LST) 01 To 08	09 To 16	17 To 00	Total Obs	MCWB (°F)
105 / 109		1	0	1	72.9
100 / 104		6	2	8	75.7
95 / 99		27	10	37	75.5
90 / 94		107	40	146	75.0
85 / 89	4	212	105	321	72.9
80 / 84	41	296	195	532	69.9
75 / 79	155	292	274	721	66.9
70 / 74	320	275	296	891	64.0
65 / 69	356	242	276	874	59.7
60 / 64	318	221	244	782	54.9
55 / 59	268	195	225	688	50.3
50 / 54	233	178	208	619	45.7
45 / 49	213	171	205	589	41.5
40 / 44	206	174	207	588	37.4
35 / 39	212	164	187	563	33.2
30 / 34	210	145	180	535	29.0
25 / 29	145	86	109	340	24.4
20 / 24	93	58	72	223	19.7
15 / 19	64	35	42	141	15.1
10 / 14	35	19	22	77	10.4
5 / 9	24	9	11	44	5.8
0 / 4	14	5	6	25	1.0
-5 / -1	6	1	2	9	-3.4
-10 / -6	3	1	1	5	-7.4
-15 / -11	0	0	0	0	-12.5
-20 / -16	0			0	-15.0

Caution: This summary reflects the typical distribution of temperature in a typical year. It does not reflect the typical moisture distribution. Because wet bulb temperatures are averaged, this summary understates the annual moisture load. For accurate moisture load data, see the long-term humidity summary and the ventilation and infiltration load pages in this manual.

Source: National Climatic Data Center

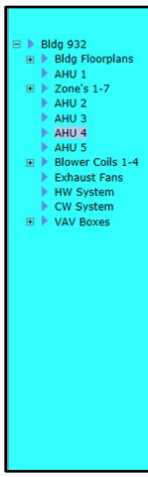
I.1.15 ECM Scope – Economizer psychrometric chart: High limit setting.

Figure I-5. Economizer psychrometric chart: high limit setting.



I.1.16 ECM Scope - Example graphic display screens for Smart Servers (quantity: 12)

Figure I-6. Example Graphic Display Screens for DSPR.



Zone	Temp	Temp SP	CO2	Flow	Flow SP	Valve %	Damper %	Part of DSPR?
1	70.1F	72F	440 ppm	1105 CFM	1200 CFM	15%	74%	Included
2	72.2F	72F	560 ppm	814 CFM	850CFM	0%	89%	Included
3	74.8F	73.5F	555 ppm	1450 CFM	1500 CFM	0%	92%	Included
4	72.7F	74F	344 ppm	255 CFM	275 CFM	29%	45%	Excluded
5	73.0F	72.5F	750 ppm	1504 CFM	1475 CFM	0%	100%	Included
6	76.7F	75F	459 ppm	467 CFM	450 CFM	0%	80%	Excluded
7	74.7F	75F	600 ppm	990 CFM	1000 CFM	0%	20%	Included

Figure I-7. Example Graphic Display Screens for DSPR (typical AHU).

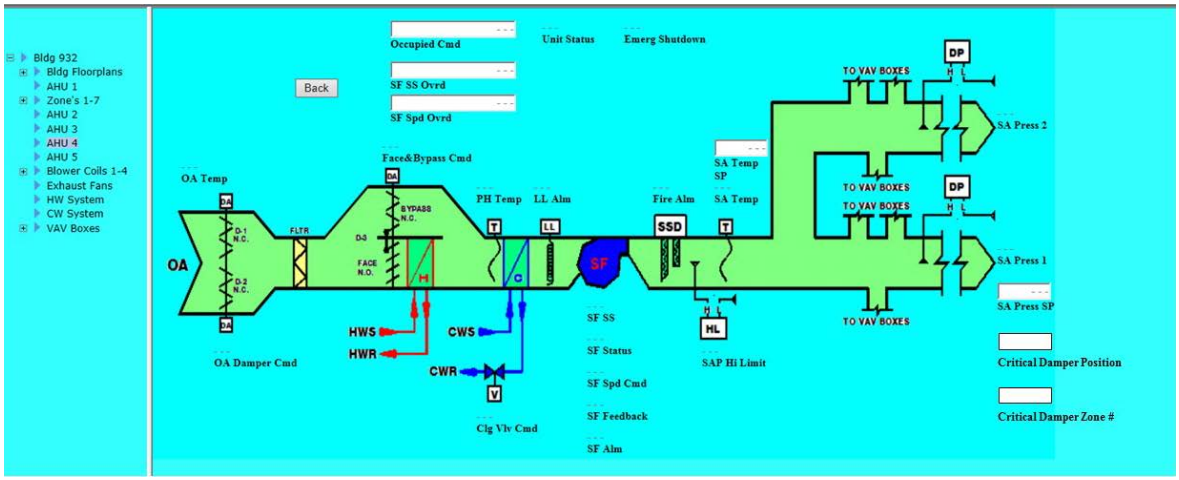


Figure I-8. Example Graphic Display: Bldg. 932, AHU-1.

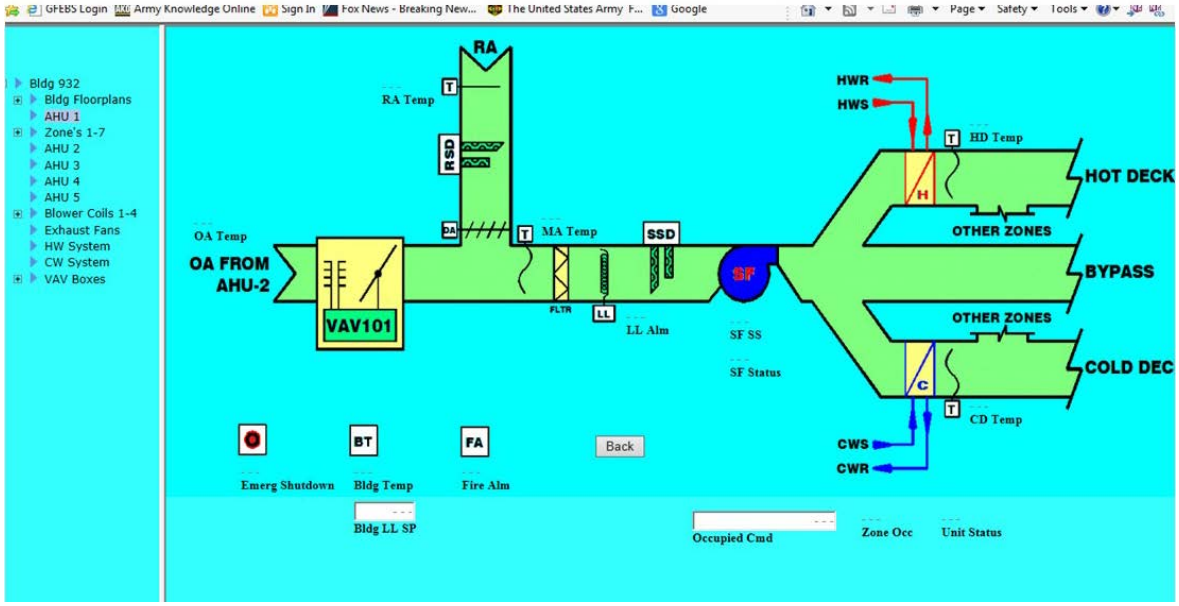


Figure I-9. Example Graphic Display: Bldg. 932, AHU-1, Zone 1.

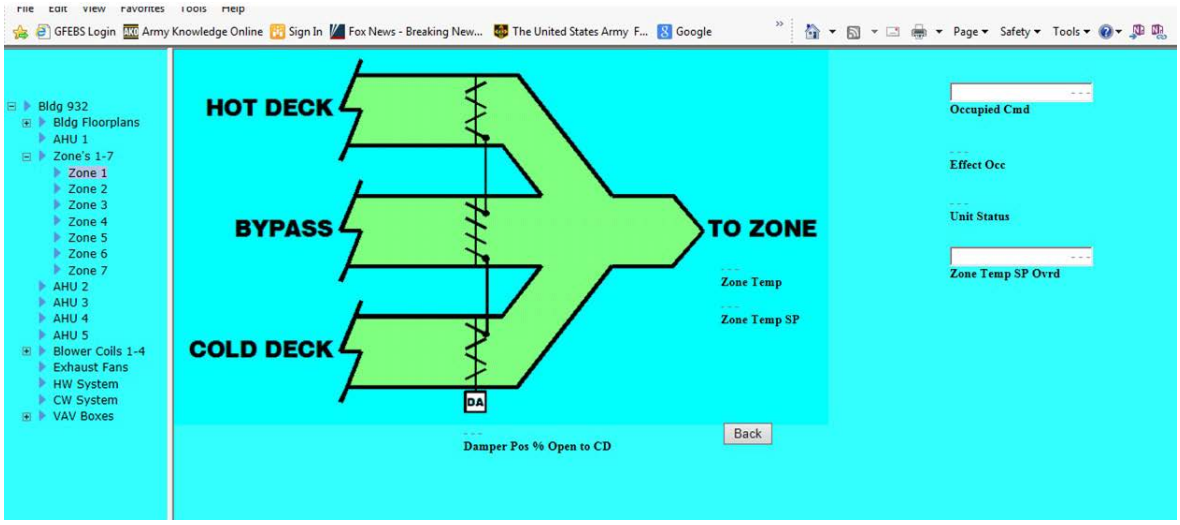


Figure I-10. Example Graphic Display: Bldg. 932, AHU-1, Zone 7.

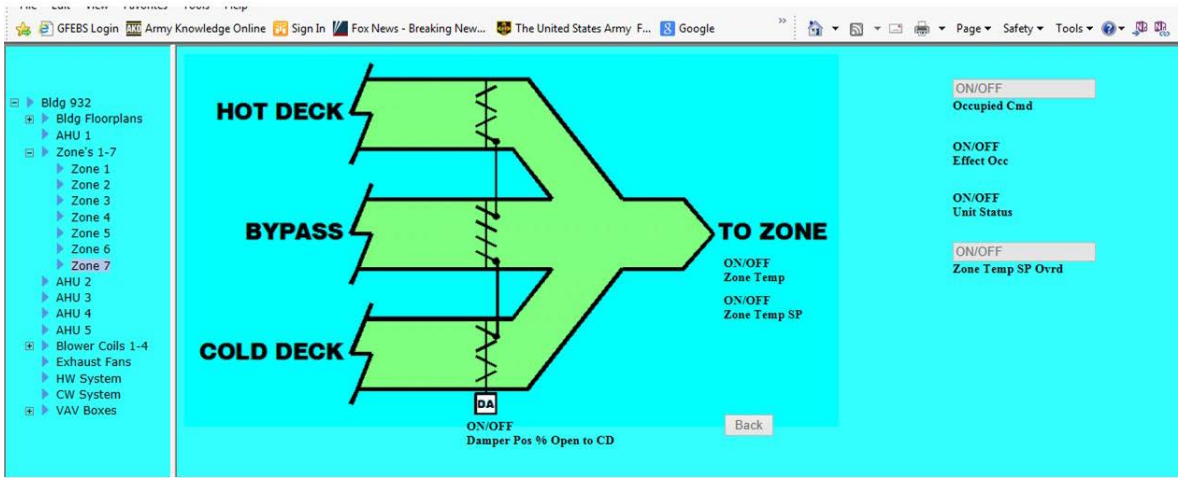


Figure I-11. Example Graphic Display: Bldg. 932, AHU-2.

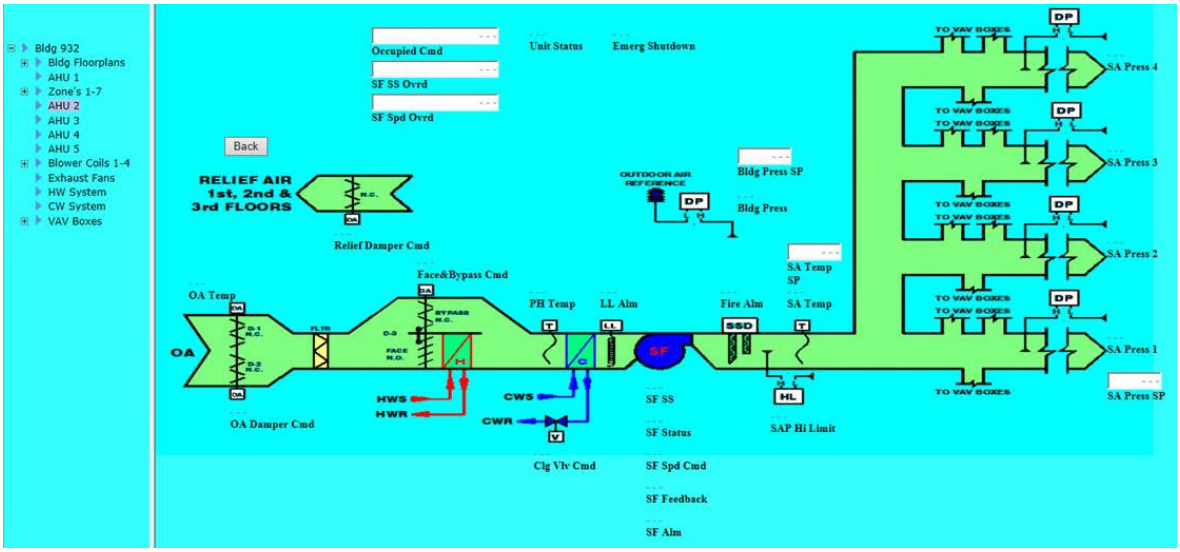


Figure I-12. Example Graphic Display: Bldg. 932, AHU-3.

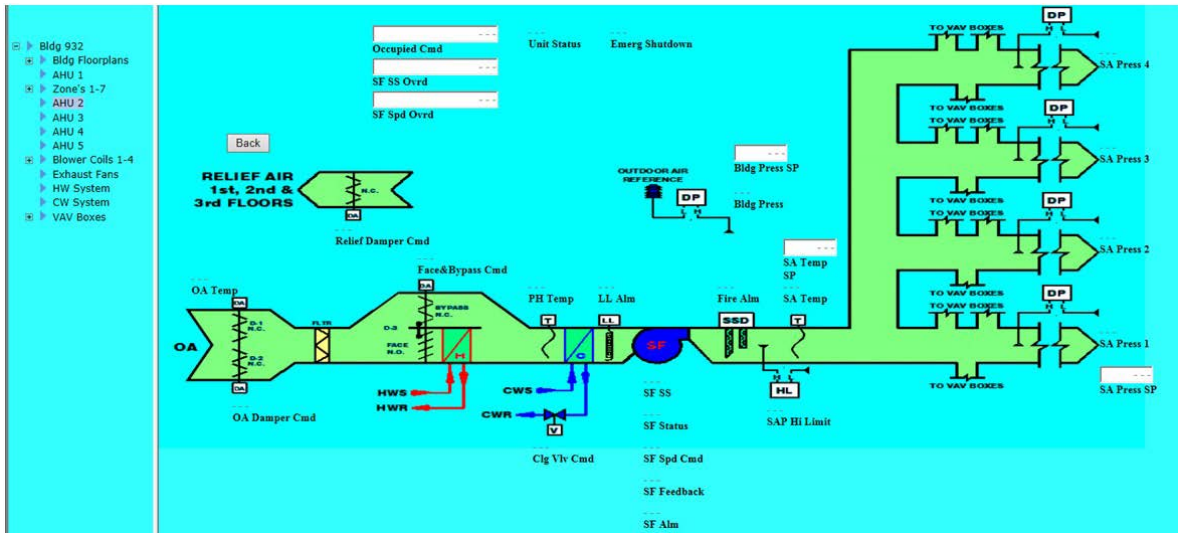


Figure I-13. Example Graphic Display: Bldg. 932, AHU-4/5.

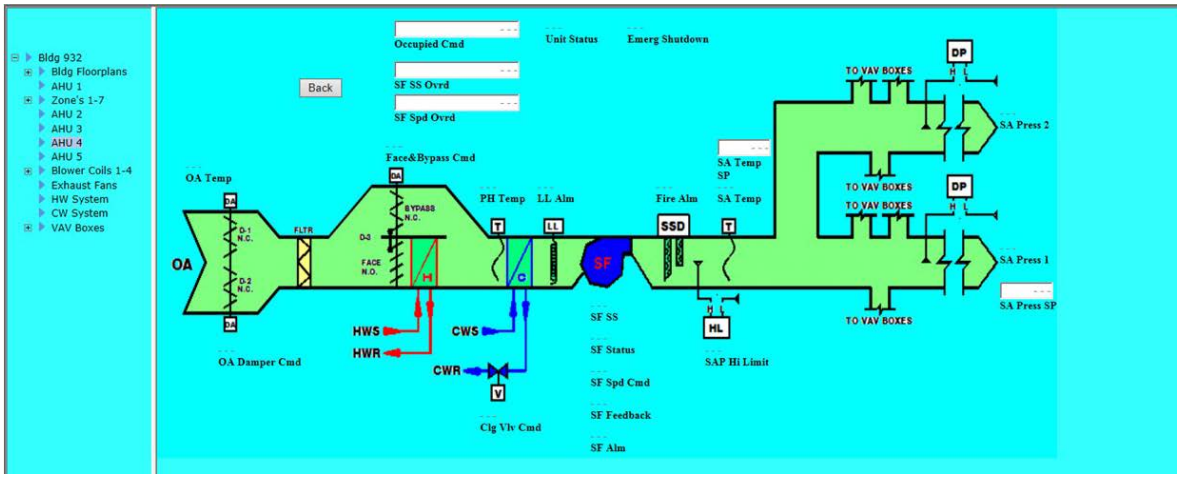


Figure I-14. Example Graphic Display: Bldg. 932, VAV box 101.

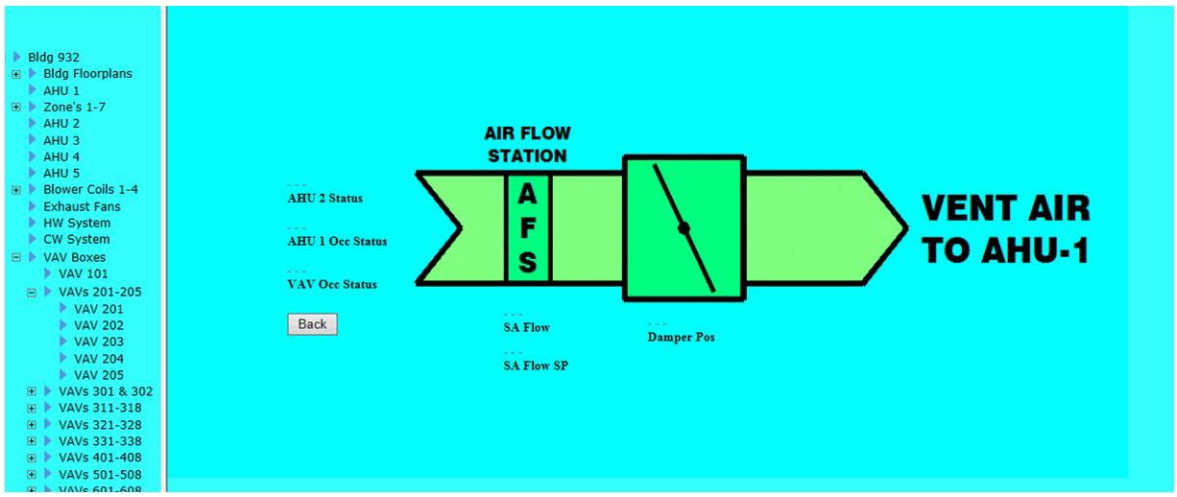


Figure I-15. Example Graphic Display: Bldg. 932, VAV box 201.

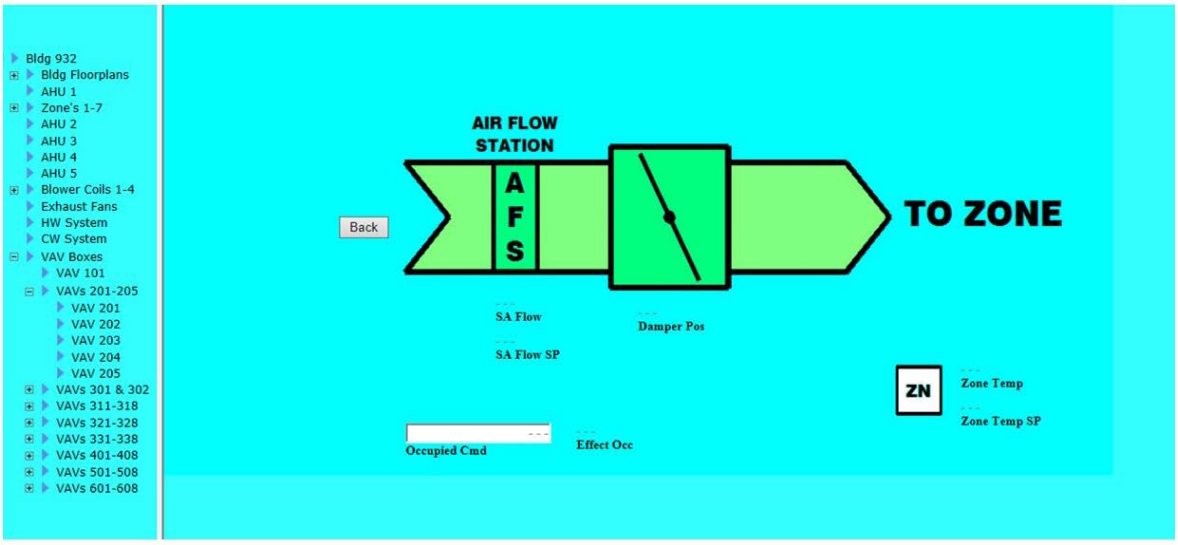


Figure I-16. Example Graphic Display: Bldg. 932, VAV box 301.

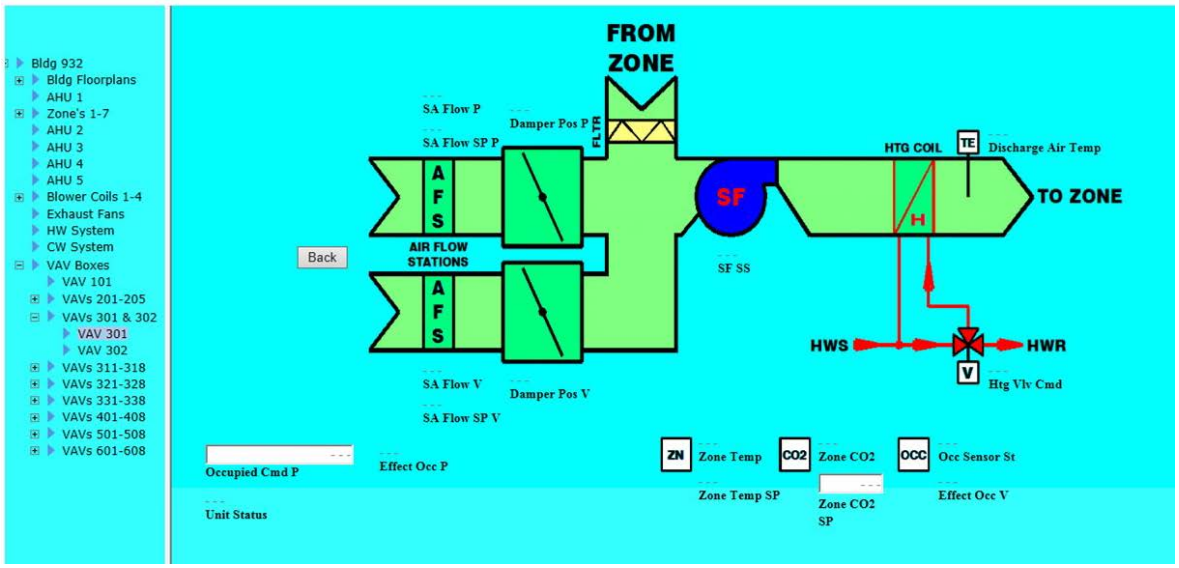
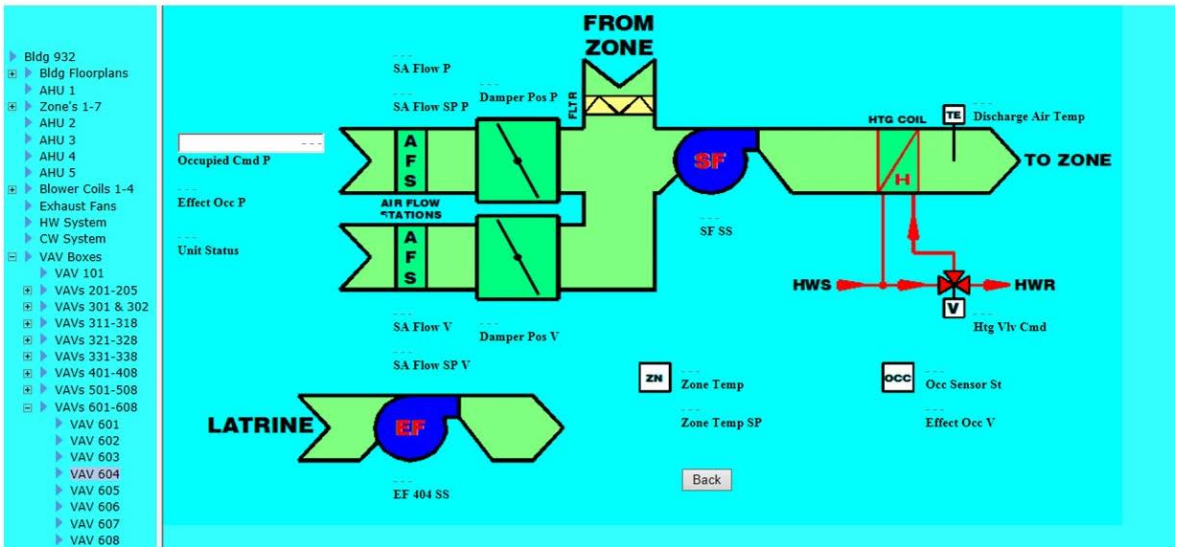


Figure I-17. Example Graphic Display: Bldg. 932, VAV box 604.



Appendix J: Electric Metering – Products

J.1 Overview

At least three LonWorks compatible electric meters appear to provide sufficient functionality to meet UMCS monitoring requirements for Fort Leonard Wood. The list is not exhaustive and is not an endorsement. Other meters may be acceptable:

- Wattnode Plus for LonWorks (by Continental control systems)
- MeasureLogic 310
- Emon.

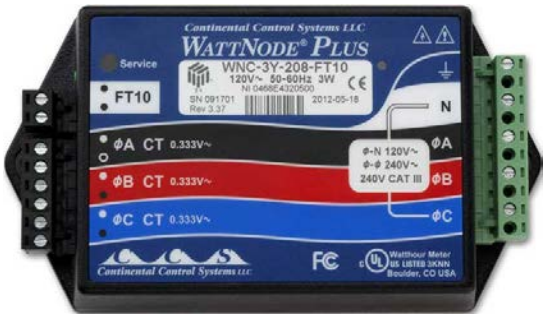
In general all meters surveyed, appear to meet the various voltage, amperage, and phase/conductor arrangement needs of typical metering applications. Product features/functions of concern, where there may be shortcomings and designers/specifiers need to be careful include; communications protocol offered, recorded values (some display parameters that are not recorded), including pulse output(s) as well as digital communications. Modbus is much more prevalent than LonTalk. Many products appear to be intended as standalone systems, with characteristics such as proprietary communications and dedicated proprietary monitoring software. Four mounting configurations offered by various vendors include Panel, DIN,* socket, and surface (in a panel/enclosure). Prices referenced below do not include Current Transducers.

J.2 Wattnode

Continental Control Systems offers several models of electric power meters, all referred to as "WattNodes." They range from a basic kWh meter with a pulse output to the Wattnote LonWorks Power Meter with a logger that monitors and records (logs to memory) all values specified in UFGS 23 09 13. Wattnodes seem to be intended for submetering and UMCS monitoring applications as compared to some vendors' products that are more oriented to standalone/dedicated metering systems.

* DIN: Deutsches Institut für Normung [the German national standards organization].

Figure J-1. Typical Wattnode.



J.3 Various Wattnodes

- WattNode BACnet — is a multi-function kilowatt-hour (kWh) energy and power (kW) meter that communicates with BACnet MS/TP over an EIA RS-485 network, measures 1, 2, or 3 phases with voltages from 120 to 600 VAC and 5 to 6,000 amps in delta and wye configurations.
- WattNode Modbus — is a multi-function kilowatt-hour (kWh) energy and power (kW) meter that communicates over an EIA RS-485 network, measures 1, 2, or 3 phases with voltages from 120 to 600 VAC and 5 to 6,000 amps in delta and wye configurations.
- WattNode Plus for LonWorks — The WattNode Plus multi-function meter measures 27 electric power related quantities: power (kW), energy consumption (kWh), voltage, current, power factor, frequency, demand, peak demand and time of peak demand. Individual phase measurements are available for most measurements. The WattNode Plus for LonWorks communicates over a TP/FT10 twisted-pair network.
- WattNode Logger for LonWorks — is a multi-function kilowatt-hour (kWh) energy and power meter that communicates on a LonWorks network, and can log 24,000+ measurement records in non-volatile memory. The WattNode Logger meter measures 1, 2, or 3 phases with voltages from 120 to 600 volts alternating current VAC and 5 to 6,000 amps in delta (phase to phase) and wye (phase to neutral) configurations.
- Advanced Pulse WattNode — is a true RMS AC watt-hour transducer with pulse output (solid state relay closure) proportional to kWh consumed. The WattNode provides accurate measurement at low cost to meet your needs for submetering, energy management, and performance contracting applications.
- LCD Display for Pulse Output WattNodes — These LCD displays connect to Pulse Output WattNodes to display energy (watthours) and/or power (watts).

Fort Leonard Wood is currently focused on two options for electric metering, a pulse output and LonWorks-based communications with a UMCS. Therefore some detailed features are documented here:

J.4 Wattnode pulse

- **Pulse output:** Compatible with EMSs and data loggers.
- **Nominal 0.5% accuracy (see manual for details)**
- **Small size:** Can be installed in existing service panels or junction boxes.
- **Bidirectional metering:** Net metering for PV (photovoltaic) solar and wind power generation with only one meter.
- **Advanced metering design:** Enables metering of inverters and VFDs.
- Safe CTs (current transformers), output 0.333 VAC at rated current.
  - Split core CTs for quick installation
  - Solid core CTs are less expensive and prevent tampering
  - Custom and standard Bus Bar sized CTs
- **Line powered:** No external supply required.
- **Detachable terminal blocks:** Easy to install and remove.
- **UL, cUL Listed:** Designed and tested for safety and use throughout North America.
- **CE Mark:** Can be installed throughout the EU.
- The optional LCD display module remotely displays energy in Wh, kWh, or MWh; or power in W or kW
- **Small form factor** for easy installation inside most electrical panels, see a sample installation diagram
- **Assembled in USA**, qualified under the Buy American provision in the American Recovery and Reinvestment Act of 2009 (ARRA).
- **Five year warranty**

J.5 WattNode LonWorks power meter w/logger

- Quantities Logged:
  - Date and Time
  - Net Energy (A, B, C and Sum) (kWh)
  - Reactive Energy (Sum)
  - Positive Energy (Sum)
  - Real and Reactive Power (A, B, C and Sum)
  - Voltage, Current and Power Factor (A, B, C)
  - Demand (kW)

- Features:
  - Logging intervals from 1 minute to 12 hours, allows logging up to 250 days of 15-minute data
  - Supports LonWorks TP/FT-10 free topology twisted-pair network using Echelon's® LonTalk® (ANSI/CEA-709.1-B-2002) network protocol.
  - LonMark 3.4 Certified
  - Small form factor for easy installation inside most electrical panels
  - Pluggable screw terminals for easy wiring
  - 0.5% nominal accuracy (see manual for details)
  - True RMS power even with leading or lagging power factor and chopped or distorted waveforms
  - Monitors variable speed drives, pumps, and motors
  - Safe CTs (current transformers), output 0.333 VAC at rated current.
    * Split core CTs for quick installation
    * Solid core CTs are less expensive and prevent tampering
    * Custom and standard Bus Bar sized CTs

J.6 MeasureLogic

This meter appears to meet the current DoD draft electric meter specification. Current list price from Engenuity ranges from $293 to $885. It is currently listed as unavailable on the Engenuity web site but is still on the MeasureLogic site.

Figure J-2. MeasureLogic 310 Electric Meter.

- Line powered single-/three-phase energy submeter with auto-topology detection
- Class 0.5 Energy Meter** (ANSI C12.20) - "Revenue grade"

- Bidirectional for renewable systems (Net metering)
- Interfaces with “safe” mV and RopeCTs
- Embedded Ethernet connectivity - Modbus/TCP, BACnet/IP,
- SNMP or DNP 3.00
- RS-485 connectivity - Modbus Remote Terminal Unit (RTU) or BAC-net MS/TP
- Communications setting via dual in-line package (DIP) switches for Modbus RTU
- LonWorks FT-10 communications
- 2 digital status/counter inputs OR digital outputs - optional
- Color coded, pluggable connectivity
- Compact DIN rail design
- User configurable using DTS Config software
- User-definable Modbus register area
- Compatible with PowerStudio Energy Management Software
- SunSpec Alliance certified
- Designed and Manufactured in the USA. Complies with the
- Buy American Provisions of ARRA Section 1605

J.7 Emon

Emon offers five versions of meter with a variety of characteristics. Key features include:

- Modbus, LonTalk (except the D2 model), BACnet, and EZ7
- Pulse output for both Watt-hour and VAR-hour or phase loss
- Data logging of kWh and kVARh 15min interval for 72 days
- ANSI C12.20 accuracy (+-0.2% from 1% to 100% of rated load)

For the most part these meters meet the current DoD draft electric meter specification except they do not record various parameters (such as each phase voltage and amperage) required by the UFGS.

J.8 Other electric meters

ABB offers a variety of electric meters, all with pulse output. Communications protocols include Modbus and a proprietary protocol; EQ bus. Communication with other systems can be obtained through an ABB gateway. They offer three series of meters, the C, B, and A. Both the B and A series appear to have logging capabilities. All are DIN rail mountable.

Schneider Electric has a variety of electric meters. Communications offered is Modbus serial, networking (via Modbus) is accomplished via various gateways offered.

Leviton offers five versions of commercial power meters. Communications protocol options include Modbus and BACnet-IP. The three more advanced versions record all parameters listed in the UFGS 23 09 13. Data Storage is limited to "last reading." Accuracy meets C 12.20 accuracy (stated as 0.5% in product brochure for the 4000 and 4100 series models).

J.9 Gas and water meter – products

Gas and water meters, unlike electric meters, do not tend to be available with an industry-standard communications protocol output. A pulse output is common, where this pulse can be monitored by a digital control device that provides an industry-standard communications protocol output available to the BCS communication network and thus a UMCS.

J.10 Electric meter "Points Schedule"

(For a meter directly connected to the LonWorks network)

Table J-1. Electric meter "Points Schedule."

ELECTRIC METER

											ALARMING			PRIMARY POINT INFORMATION		OVERRIDES		
FUNCTION	NAME	DESCRIPTION	DDC HARDWARE ID	SETTING (WITH UNITS)	RANGE (WITH UNITS)	IO TYPE	CONFIG. TYPE	M&C VIEW AND OVRD	LDP VIEW AND OVRD	TREND REQ'D	ALARM CONDITION	ALARM PRIORITY	M&C ROUTING	SNVT NAME	SNVT TYPE	SNVT NAME	SNVT TYPE	CONFIGURATION INFORMATION
REQUIRED POINTS	PWR-TOT	REAL POWER (TOTAL)	< >		0 - < > WATTS			V		X					SNVT_power_f			
	KWH-TOT	TOTAL kWh (TOTAL ENERGY)	< >		0 - < > kWh			V		X					SNVT_elec_kwh_l			
	PWR-DEMAND-PEAK	HISTORICAL PEAK DEMAND POWER	< >		0 - < > WATTS			V		X					SNVT_power_f			
	PWR-DEMAND	DEMAND POWER	< >		0 - < > WATTS			V		X	[__][~]	[INFO][CRIT][~]			<SNVT_power_f>			
	VOLT-A	RMS VOLTAGE FOR PHASE A	< >		0 - < > VOLTS RMS	<AI>		V		X	VOLT-A < [0.9*NOMINAL]	[INFO][CRIT]			SNVT_volts_f			
	VOLT-B	RMS VOLTAGE FOR PHASE B	< >		0 - < > VOLTS RMS	<AI>		V		X	VOLT-B < [0.9*NOMINAL]	[INFO][CRIT]			SNVT_volts_f			
	VOLT-C	RMS VOLTAGE FOR PHASE C	< >		0 - < > VOLTS RMS	<AI>		V		X	VOLT-C < [0.9*NOMINAL]	[INFO][CRIT]			SNVT_volts_f			
	AMP-A	RMS CURRENT FOR PHASE A	< >		0 - < > AMPS RMS	<AI>		V		X					SNVT_amp_f			
	AMP-B	RMS CURRENT FOR PHASE B	< >		0 - < > AMPS RMS	<AI>		V		X					SNVT_amp_f			
	AMP-C	RMS CURRENT FOR PHASE C	< >		0 - < > AMPS RMS	<AI>		V		X					SNVT_amp_f			
	HZ-AVG	AVERAGE LINE FREQUENCY	< >		0 - < > HZ			V		X					SNVT_freq_f			
OPTIONAL POINTS	PWR-A	REAL POWER FOR PHASE A	< >		0 - < > WATTS			[~]		X					<SNVT_power_f>			
	PWR-B	REAL POWER FOR PHASE B	< >		0 - < > WATTS			[~]		X					<SNVT_power_f>			
	PWR-C	REAL POWER FOR PHASE C	< >		0 - < > WATTS			[~]		X					<SNVT_power_f>			
	HZ-A	FREQUENCY FOR PHASE A	< >		0 - < > HZ			[~]		X					SNVT_freq_f			
	HZ-B	FREQUENCY FOR PHASE B	< >		0 - < > HZ			[~]		X					SNVT_freq_f			
	HZ-C	FREQUENCY FOR PHASE C	< >		0 - < > HZ			[~]		X					SNVT_freq_f			
	KVA-TOT	TOTAL kVA	< >		0 - < > kVA			[~]	[~]	X					SNVT_power_f			
	KVA-A	kVA FOR PHASE A	< >		0 - < > kVA			[~]		X					SNVT_power_f			
	KVA-B	kVA FOR PHASE B	< >		0 - < > kVA			[~]		X					SNVT_power_f			
	KVA-C	kVA FOR PHASE C	< >		0 - < > kVA			[~]		X					SNVT_power_f			
	KVAR-TOT	TOTAL REACTIVE POWER	< >		0 - < > kVA			[~]		X					SNVT_power_f			
	KVAR-A	REACTIVE POWER FOR PHASE A	< >		0 - < > kVA			[~]		X					SNVT_power_f			
	KVAR-B	REACTIVE POWER FOR PHASE B	< >		0 - < > kVA			[~]		X					SNVT_power_f			
	KVAR-C	REACTIVE POWER FOR PHASE C	< >		0 - < > kVA			[~]		X					SNVT_power_f			
	KVARH-TOT	TOTAL kVARh (TOTAL REACTIVE ENERGY)	< >		0 - < > kVAh			[~]		X					SNVT_elec_kwh_l			
	KVARH-A	kVARh (TOTAL REACTIVE ENERGY) FOR PHASE A	< >		0 - < > kVAh			[~]		X					SNVT_elec_kwh_l			
	KVARH-B	kVARh (TOTAL REACTIVE ENERGY) FOR PHASE B	< >		0 - < > kVAh			[~]		X					SNVT_elec_kwh_l			
	KVARH-C	kVARh (TOTAL REACTIVE ENERGY) FOR PHASE C	< >		0 - < > kVAh			[~]		X					SNVT_elec_kwh_l			
	PF-AVG	AVERAGE POWER FACTOR	< >		-1 TO 1			[~]		X					SNVT_pwr_fact_f			
	PF-A	POWER FACTOR FOR PHASE A	< >		-1 TO 1			[~]		X					SNVT_pwr_fact_f			
	PF-B	POWER FACTOR FOR PHASE B	< >		-1 TO 1			[~]		X					SNVT_pwr_fact_f			
	PF-C	POWER FACTOR FOR PHASE C	< >		-1 TO 1			[~]		X					SNVT_pwr_fact_f			

Notes:

1) THE CONTRACTOR SHALL COMPLETE THE POINTS SCHEDULE AS INDICATED IN THE SPECIFICATION AND IN ACCORDANCE WITH THE POINTS SCHEDULE INSTRUCTIONS DRAWING.
2) UNIT MANUFACTURERS PROOFS AND SAFETIES: THE CONTRACTOR SHALL SHOW EACH PROOF AND SAFETY AS A SEPARATE ROW.
3) UNIT STATUS: SERVES AS A MONITORED POINT AT THE M&C SOFTWARE (FRONT-END) AND AS A HEATING/COOLING REQUEST TO THE BOILER, HEAT EXCHANGER, AND/OR CHILLER SERVING THIS SYSTEM.

THIS NOTE IS USED ONLY FOR LNS LONWORKS (NO NIAGARA)

6) DDC HW IF FOR DEVICE CONTAINING SIMPLE SCHEDULER OBJECT (OR SYSTEM SCHEDULER SEQUENCE OF OPERATIONS) FOR THIS SYSTEM: <____>

J.12 Water meter "Points Schedule"

(For a LonWorks device to be connected to a water meter pulse output)

Table J-2. Water meter "Points Schedule."

WATER METER

FUNCTION	NAME	DESCRIPTION	DDC HARDWARE ID	SETTING (WITH UNITS)	RANGE (WITH UNITS)	IO TYPE	CONFIG. TYPE	M&C VIEW AND OVRD	LOP VIEW AND OVRD	TREND REQ'D	ALARMING: ALARM CONDITION	ALARMING: ALARM PRIORITY	ALARMING: M&C ROUTING	PRIMARY POINT INFORMATION: SNVT NAME	PRIMARY POINT INFORMATION: SNVT TYPE	OVERRIDES: SNVT NAME	OVERRIDES: SNVT TYPE	CONFIGURATION INFORMATION
Flow	WATER-F	FLOW RATE	<___>		0 - <___> [CU FT/ MIN][CFM] [GPM]	<PULSE><BP>		V		X	<EXCESSIVE FLOW>	CRIT			SNVT_flow_f			
	WATER-F-TOT	TOTAL WATER FLOW	<___>		0 - <___> [CU FT] [GAL]	<PULSE><BP>		V							SNVT_vol_f			

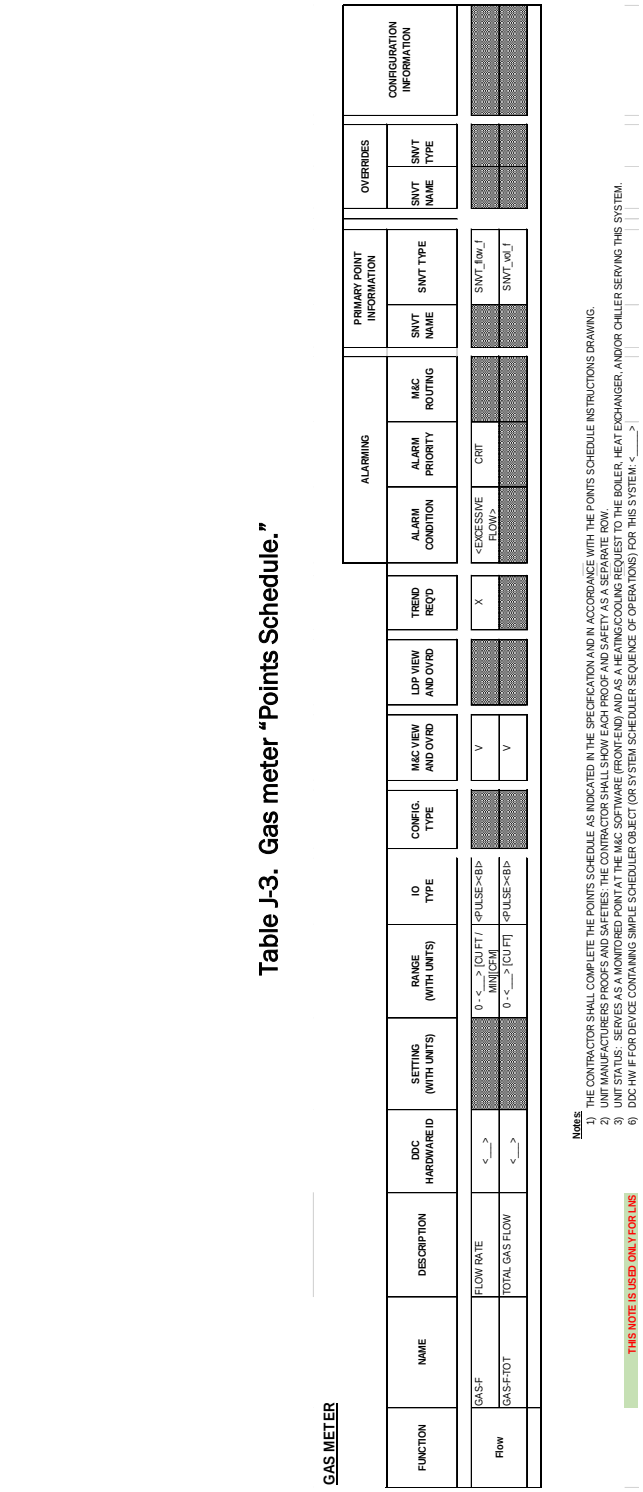
Notes:

1) THE CONTRACTOR SHALL COMPLETE THE POINTS SCHEDULE AS INDICATED IN THE SPECIFICATION AND IN ACCORDANCE WITH THE POINTS SCHEDULE INSTRUCTIONS DRAWING.
2) UNIT MANUFACTURERS PROOFS AND SAFETIES: THE CONTRACTOR SHALL SHOW EACH PROOF AND SAFETY AS A SEPARATE ROW.
3) UNIT STATUS: SERVES AS A MONITORED POINT AT THE M&C SOFTWARE (FRONT-END) AND AS A HEATING/COOLING REQUEST TO THE BOILER, HEAT EXCHANGER, AND/OR CHILLER SERVING THIS SYSTEM.
6) DDC HW IF FOR DEVICE CONTAINING SIMPLE SCHEDULER OBJECT (OR SYSTEM SCHEDULER SEQUENCE OF OPERATIONS) FOR THIS SYSTEM: <___>

THIS NOTE IS USED ONLY FOR LNS

J.14 Gas meter "points Schedule"

(For a LonWorks device to be connected to a gas meter pulse output)



GAS METER

Table J-3. Gas meter "Points Schedule."

FUNCTION	NAME	DESCRIPTION	DDC HARDWARE ID	SETTING (WITH UNITS)	RANGE (WITH UNITS)	IO TYPE	CONFIG. TYPE	M&C VIEW AND OVRD	LDP VIEW AND OVRD	TREND REQ'D	ALARMING			PRIMARY POINT INFORMATION		OVERRIDES		CONFIGURATION INFORMATION
											ALARM CONDITION	ALARM PRIORITY	M&C ROUTING	SNVT NAME	SNVT TYPE	SNVT NAME	SNVT TYPE	
Flow	GAS-F	FLOW RATE	<___>		0 - <___> [CU FT / MIN][CFM]	<PULSE><BI>		V		X	<EXCESSIVE FLOW>	CRIT			SNVT_flow_f			
	GAS-F-TOT	TOTAL GAS FLOW	<___>		0 - <___> [CU FT]	<PULSE><BI>		V							SNVT_vol_f			

Notes:
1) THE CONTRACTOR SHALL COMPLETE THE POINTS SCHEDULE AS INDICATED IN THE SPECIFICATION AND IN ACCORDANCE WITH THE POINTS SCHEDULE INSTRUCTIONS DRAWING.
2) UNIT MANUFACTURERS PROOFS AND SAFETIES: THE CONTRACTOR SHALL SHOW EACH PROOF AND SAFETY AS A SEPARATE ROW.
3) UNIT STATUS: SERVES AS A MONITORED POINT AT THE M&C SOFTWARE (FRONT-END) AND AS A HEATING/COOLING REQUEST TO THE BOILER, HEAT EXCHANGER, AND/OR CHILLER SERVING THIS SYSTEM.
6) DDC HW IF FOR DEVICE CONTAINING SIMPLE SCHEDULER OBJECT (OR SYSTEM SCHEDULER SEQUENCE OF OPERATIONS) FOR THIS SYSTEM: <___>

THIS NOTE IS USED ONLY FOR LNS

Appendix K: UFGS – 23 09 00 (Tailored to Fort Leonard Wood): Instrumentation and Control for HVAC

SECTION TABLE OF CONTENTS

DIVISION 23 - HEATING, VENTILATING, AND AIR CONDITIONING (HVAC)

SECTION 23 09 00

INSTRUMENTATION AND CONTROL FOR HVAC

11/15

PART 1 GENERAL

1.1 SUMMARY
1.1.1 System Requirements
1.1.2 End to End Accuracy
1.1.3 Verification of Dimensions
1.1.4 Drawings
1.2 RELATED SECTIONS
1.3 REFERENCES
1.4 DEFINITIONS
1.4.1 Alarm Generation
1.4.2 Application Generic Controller (AGC)
1.4.3 Application Specific Controller (ASC)
1.4.4 Binary
1.4.5 Binding
1.4.6 Building Control Network (BCN)
1.4.7 Building Point of Connection (BPOC)
1.4.8 Channel
1.4.9 Commandable
1.4.10 Configurable
1.4.11 Configuration Property
1.4.12 Control Logic Diagram
1.4.13 Digital Controller
1.4.14 Direct Digital Control (DDC)
1.4.15 Domain
1.4.16 Explicit Messaging
1.4.17 External Interface File (XIF)
1.4.18 Field Point of Connection (FPOC)
1.4.19 Functional Profile
1.4.20 Gateway
1.4.21 General Purpose Programmable Controller (GPPC)
1.4.22 IEEE 802.3 Ethernet
1.4.23 Internet Protocol (IP, TCP/IP, UDP/IP)
1.4.24 Input/Output (I/O)
1.4.25 I/O Expansion Unit
1.4.26 IP subnet
1.4.27 Local-Area Network (LAN)
1.4.28 Local Display Panels (LDPs)
1.4.29 LonMark
1.4.30 LonMark International
1.4.31 LonMark Interoperability Association
1.4.32 LonMark Object
1.4.33 LonWorks
1.4.34 LonWorks Network Services (LNS)
1.4.35 LonWorks Network Services (LNS) Plug-in
1.4.36 MAC Address

1.4.37 Monitoring and Control (M&C) Software
1.4.38 Network Variable
1.4.39 Network Configuration Tool
1.4.40 Node
1.4.41 Node Address
1.4.42 Node ID
1.4.43 Operator Configurable
1.4.44 Override
1.4.45 Performance Verification Test (PVT)
1.4.46 Polling
1.4.47 Points
1.4.48 Program ID
1.4.49 Proportional, Integral, and Derivative (PID) Control Loop
1.4.50 Repeater
1.4.51 Router
1.4.52 Segment
1.4.53 Service Pin
1.4.54 Standard Configuration Property Type (SCPT)
1.4.55 Standard Network Variable Type (SNVT)
1.4.56 Subnet
1.4.57 TP/FT-10
1.4.58 TP/XF-1250
1.4.59 User-defined Configuration Property Type (UCPT)
1.4.60 User-defined Network Variable Type (UNVT)
1.4.61 UMCS
1.4.62 UMCS NETWORK
1.5 PROJECT SEQUENCING
1.6 SUBMITTALS
1.7 DATA PACKAGE AND SUBMITTAL REQUIREMENTS
1.8 SOFTWARE FOR DDC HARDWARE AND GATEWAYS
1.8.1 Programming Software
1.8.2 Controller Application Programs
1.8.3 LNS Plug-Ins
1.8.4 Certificate of Networthiness Documentation
1.9 QUALITY CONTROL CHECKLISTS
1.9.1 Pre-Construction Quality Control (QC) Checklist
1.9.2 Post-Construction Quality Control (QC) Checklist
1.9.3 Closeout Quality Control (QC) Checklist
1.10 CERTIFICATES
1.10.1 Electric Meters
1.10.2 Welder's Qualifications for Installation of Gas Meters

PART 2 PRODUCTS

2.1 GENERAL PRODUCT REQUIREMENTS
2.2 PRODUCT DATA
2.2.1 XIF Files
2.3 OPERATION ENVIRONMENT
2.4 Wireless Capability
2.5 ENCLOSURES
2.5.1 Outdoors
2.5.2 Mechanical and Electrical Rooms
2.5.3 Other Locations
2.6 WIRE AND CABLE
2.6.1 Terminal Blocks
2.6.2 Control Wiring for Binary Signals
2.6.3 Control Wiring for Analog Signals
2.6.4 Power Wiring for Control Devices
2.6.5 Transformers

```
PART 3   EXECUTION

  3.1   EXISTING CONDITIONS
    3.1.1   Existing Conditions Survey
    3.1.2   Existing Equipment Downtime
    3.1.3   Existing Control System Devices
  3.2   INSTALLATION
    3.2.1   Dielectric Isolation
    3.2.2   Penetrations in Building Exterior
    3.2.3   Device Mounting Criteria
    3.2.4   Labels and Tags
    3.2.5   SURGE PROTECTION
      3.2.5.1   Power-Line Surge Protection
      3.2.5.2   Surge Protection for Transmitter and Control Wiring
    3.2.6   Basic Cybersecurity Requirements
      3.2.6.1   Passwords
      3.2.6.2   Wireless Capability
      3.2.6.3   IP Network Physical Security
  3.3   DRAWINGS AND CALCULATIONS
    3.3.1   Drawing Index and Legend
    3.3.2   Thermostat and Occupancy Sensor Schedule
    3.3.3   Valve Schedule
    3.3.4   Damper Schedule
    3.3.5   Project Summary Equipment Schedule
    3.3.6   Equipment Schedule
    3.3.7   Occupancy Schedule
    3.3.8   DDC Hardware Schedule
      3.3.8.1   DDC Hardware Identifier
      3.3.8.2   HVAC System
      3.3.8.3   Network Address
      3.3.8.4   Unique Node ID
    3.3.9   Points Schedule
      3.3.9.1   Point Name
      3.3.9.2   Description
      3.3.9.3   DDC Hardware Identifier
      3.3.9.4   Settings
      3.3.9.5   Range
      3.3.9.6   Input or Output (I/O) Type
      3.3.9.7   Primary Point Information: SNVT Name
      3.3.9.8   Primary Point Information: SNVT Type
      3.3.9.9   Override Information (SNVT Name and Type)
      3.3.9.10   Configuration Information
    3.3.10   Riser Diagram
    3.3.11   Control System Schematics
    3.3.12   Sequences of Operation Including Control Logic Diagrams
    3.3.13   Controller, Motor Starter and Relay Wiring Diagram
  3.4   CONTROLLER TUNING
  3.5   START-UP
    3.5.1   Start-Up Test
      3.5.1.1   Systems Check
        3.5.1.1.1   Step 1 - System Inspection
        3.5.1.1.2   Step 2 - Calibration Accuracy Check
        3.5.1.1.3   Step 3 - Actuator Range Check
      3.5.1.2   Weather Dependent Test
    3.5.2   Start-Up Testing Report
    3.5.3   Draft LNS Database
  3.6   PERFORMANCE VERIFICATION TEST (PVT)
    3.6.1   PVT Procedures
```

3.6.1.1 Sensor Accuracy Checks
3.6.1.2 Temporary Trending Hardware
3.6.1.3 Endurance Test
3.6.1.4 PVT Equipment List
3.6.2 PVT Execution
3.6.3 PVT Report
3.6.4 Final LNS Database
3.7 OPERATION AND MAINTENANCE (O&M) INSTRUCTIONS
3.8 MAINTENANCE AND SERVICE
3.8.1 Description of Work
3.8.2 Personnel
3.8.3 Scheduled Inspections
3.8.4 Scheduled Work
3.8.5 Emergency Service
3.8.6 Operation
3.8.7 Records and Logs
3.8.8 Work Requests
3.8.9 System Modifications
3.9 TRAINING
3.9.1 Training Documentation
3.9.2 Training Course Content

ATTACHMENTS:

QC Checklist for LNS-Based LonWorks Systems

QC CHECKLIST FOR LNS-BASED LONWORKS SYSTEMS

-- End of Section Table of Contents --

SECTION 23 09 00

INSTRUMENTATION AND CONTROL FOR HVAC
11/15

PART 1 GENERAL

1.1 SUMMARY

Provide a complete Direct Digital Control (DDC) system, except for the Front End which is specified in Section 25 10 10 UTILITY MONITORING AND CONTROL (UMCS) FRONT END AND INTEGRATION, suitable for the control of the heating, ventilating and air conditioning (HVAC) and other building-level systems as indicated and shown and in accordance with Section 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC, Section 23 09 93 SEQUENCES OF OPERATION FOR HVAC CONTROL, Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS and other referenced Sections.

1.1.1 System Requirements

Provide systems meeting the requirements this Section and other Sections referenced by this Section, and which have the following characteristics:

a. The system implements the control sequences of operation shown in the Contract Drawings using DDC hardware to control mechanical and electrical equipment

b. The system meet the requirements of this specification as a stand-alone system and does not require connection to any other system.

c. Control sequences reside in DDC hardware in the building. The building control network is not dependent upon connection to a Utility Monitoring and Control System (UMCS) Front End or to any other system for performance of control sequences. To the greatest extent practical, the hardware performs control sequences without reliance on the building network.

d. The hardware is installed such that individual control equipment can be replaced by similar control equipment from other equipment manufacturers with no loss of system functionality.

e. All necessary documentation, configuration information, programming tools, programs, drivers, and other software are licensed to and otherwise remain with the United States Army and Fort Leonard Wood Directorate of Public Works 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, Vendor or Manufacturer. Provide the most recent versions of all computer software provided under this specification delivered as a Technical Data Package unless stated otherwise. Provide the user manuals for all software delivered for this project.

f. Sufficient documentation and data, including rights to documentation and data, are provided 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, Vendor or Manufacturer.

g. Hardware is installed and configured such that the Government or their agents are able to perform repair, replacement, and upgrades of individual hardware without further interaction with the Contractor, Vendor or Manufacturer.

1.1.2 End to End Accuracy

Select products, install and configure the system such that the maximum error of a measured value as read from the DDC Hardware over the network is less than the maximum allowable error specified for the sensor or instrumentation.

1.1.3 Verification of Dimensions

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.

1.1.4 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.

1.2 RELATED SECTIONS

Related work specified elsewhere:

a. Section 23 03 00.00 20 UTILITY MONITORING AND CONTROL SYSTEMS (UMCS) FRONT END AND INTEGRATION

b. Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS

c. Section 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC

d. Section 23 09 93 SEQUENCES OF OPERATIONS FOR HVAC CONTROLS

e. Section 25 08 10 UTILITY MONITORING AND CONTROL SYSTEMS TESTING

f. Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEMS (UMCS) FRONT END AND INTEGRATION

g. Section 01 91 00.15 TOTAL BUILDING COMMISSIONING

1.3 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.

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

ASHRAE FUN IP (2013; Addenda and Corrigendum 2013)

Fundamentals Handbook, I-P Edition

ASME INTERNATIONAL (ASME)

ASME B31.8	(2014; Supplement 2014) Gas Transmission and Distribution Piping Systems

CONSUMER ELECTRONICS ASSOCIATION (CEA)

CEA-709.1-D	(2014) Control Network Protocol Specification
CEA-709.3	(1999; R 2004) Free-Topology Twisted-Pair Channel Specification

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE C62.41	(1991; R 1995) Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA 250	(2014) Enclosures for Electrical Equipment (1000 Volts Maximum)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2017) National Electrical Code
NFPA 90A	(2015) Standard for the Installation of Air Conditioning and Ventilating Systems

UNDERWRITERS LABORATORIES (UL)

UL 5085-3	(2006; Reprint Nov 20121) Low Voltage Transformers - Part 3: Class 2 and Class 3 Transformers

1.4 DEFINITIONS

The following list of definitions includes terms used in Sections referenced by this Section and are included here for completeness.

The definitions contained in this Section may disagree with how terms are defined or used in other documents, including documents referenced by this Section. The definitions included here are the authoritative definitions for this Section and all Sections referenced by this Section.

1.4.1 Alarm Generation

Alarm Generation is the monitoring of a value, comparison of the value to alarm conditions and the creation of an alarm when the conditions set for the alarm are met. Note that this does NOT include delivery of the alarm to the final destination (such as a user interface) - see paragraph ALARM ROUTING in Section 25 10 10 UTILITY MONITORING AND CONTROL SYSTEM (UMCS) FRONT END AND INTEGRATION.

1.4.2 Application Generic Controller (AGC)

A device that is furnished with a (limited) pre-established application that also has the capability of being programmed. Further, the ProgramID and XIF file of the device are fixed. The programming capability of an AGC may be less flexible than that of a General Purpose Programmable Controller (GPPC).

1.4.3 Application Specific Controller (ASC)

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.

1.4.4 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'.

1.4.5 Binding

The act of establishing communications between CEA-709.1-D devices by associating the output of a device to the input of another so that information is automatically (and regularly) sent.

1.4.6 Building Control Network (BCN)

The network connecting all DDC Hardware within a building (or specific group of buildings).

1.4.7 Building Point of Connection (BPOC)

A FPOC for a Building Control System. (This term is being phased out of use in preference for FPOC but is still used in some specifications and criteria. When it was used, it typically referred to a piece of control hardware. The current FPOC definition typically refers instead to IT hardware.)

1.4.8 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.

1.4.9 Commandable

See Overridable.

1.4.10 Configurable

A property, setting, or value is configurable if it can be changed via hardware settings on the device, via the use of engineering software or over the control network from the front end, and is retained through (after) loss of power.

1.4.11 Configuration Property

Controller parameter used by the application which is usually set during installation/testing and seldom changed. For example, the P and I settings of a P-I control loop. Also see paragraph STANDARD CONFIGURATION PROPERTY TYPE (SCPT).

1.4.12 Control Logic Diagram

A graphical representation of control logic for multiple processes that make up a system.

1.4.13 Digital Controller

An electronic controller, usually with internal programming logic and digital and analog input/output capability, which performs control functions.

1.4.14 Direct Digital Control (DDC)

Digital controllers performing control logic. Usually the controller directly senses physical values, makes control decisions with internal programs, and outputs control signals to directly operate switches, valves, dampers, and motor controllers.

1.4.15 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.) See also Node Address.

1.4.16 Explicit Messaging

A non-standard and often vendor (application) specific 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.

1.4.17 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.

1.4.18 Field Point of Connection (FPOC)

The FPOC is the point of connection between the UMCS IP Network and the field control network (either an IP network, a non-IP network, or a combination of both). The hardware at this location which provides the connection is generally an IT device such as a switch, IP router, or firewall.

In general, the term "FPOC Location" means the place where this connection occurs, and "FPOC Hardware" means the device that provides the connection. Sometimes the term "FPOC" is used to mean either and its actual meaning (i.e. location or hardware) is determined by the context in which it is used.

1.4.19 Functional Profile

A standard description, defined by LonMark, of one or more LonMark Objects used to classify and certify devices.

1.4.20 Gateway

A device that translates from one protocol application data format to another. Devices that change only the transport mechanism of the protocol - "translating" from TP/FT-10 to Ethernet/IP or from BACnet MS/TP to BACnet over IP for example - are not gateways as the underlying data format does not change. Gateways are also called Communications Bridges or Protocol Translators.

1.4.21 General Purpose Programmable Controller (GPPC)

Unlike an ASC or AGC, a GPPC is not furnished with a fixed application program and does not have a fixed ProgramID or XIF file. A GPPC can be (re-) programmed, usually using vendor-supplied software. When a change to the program affects the external interface (and the XIF file) the ProgramID will change.

1.4.22 IEEE 802.3 Ethernet

A family of local-area-network technologies providing high-speed networking features over various media, typically Cat 5, 5e or Cat 6 twisted pair copper or fiber optic cable.

1.4.23 Internet Protocol (IP, TCP/IP, UDP/IP)

A communication method, the most common use is the World Wide Web. At the lowest level, it is based on Internet Protocol (IP), a method for conveying and routing packets of information over various LAN media. Two common protocols using IP are User Datagram Protocol (UDP) and Transmission Control Protocol (TCP). UDP conveys information to well-known "sockets" without confirmation of receipt. TCP establishes connections, also known as "sessions", which have end-to-end confirmation and guaranteed sequence of delivery.

1.4.24 Input/Output (I/O)

Physical inputs and outputs to and from a device, although the term sometimes describes network or "virtual" inputs or outputs. See also "Points".

1.4.25 I/O Expansion Unit

An I/O expansion unit provides additional point capacity to a digital controller

1.4.26 IP subnet

A group of devices which share a defined range IP addresses. Devices on a common IP subnet can share data (including broadcasts) directly without the need for the traffic to traverse an IP router.

1.4.27 Local-Area Network (LAN)

A communication network that spans a limited geographic area and uses the

same basic communication technology throughout.

1.4.28 Local Display Panels (LDPs)

A DDC Hardware with a display and navigation buttons, and must provide display and adjustment of points as shown on the Points Schedule and as indicated.

1.4.29 LonMark

See paragraph LONMARK INTERNATIONAL. Also, a certification issued by LonMark International to CEA-709.1-D devices.

1.4.30 LonMark International

Standards committee consisting of numerous independent product developers, system integrators and end users dedicated to determining and maintaining the interoperability guidelines for LonWorks. Maintains guidelines for the interoperability of CEA-709.1-D devices and issues the LonMark Certification for CEA-709.1-D devices.

1.4.31 LonMark Interoperability Association

See paragraph LONMARK INTERNATIONAL.

1.4.32 LonMark Object

A collection of network variables, configuration properties, and associated behavior defined by LonMark International and described by a Functional Profile. It defines how information is exchanged between devices on a network (inputs from and outputs to the network).

1.4.33 LonWorks

The term used to refer to the overall technology related to the CEA-709.1-D protocol (sometimes called "LonTalk"), including the protocol itself, network management, interoperability guidelines and products.

1.4.34 LonWorks Network Services (LNS)

A network management and database standard for CEA-709.1-D devices.

1.4.35 LonWorks Network Services (LNS) Plug-in

Software which runs in an LNS compatible software tool, typically a network configuration tool. Device configuration plug-ins provide a user friendly method to edit a device's configuration properties.

1.4.36 MAC Address

Media Access Control address. The physical device address that identifies a device on a Local Area Network.

1.4.37 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.

1.4.38 Network Variable

See paragraph STANDARD NETWORK VARIABLE TYPE (SNVT).

1.4.39 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).

1.4.40 Node

A device that communicates using the CEA-709.1-D protocol and is connected to a CEA-709.1-D network.

1.4.41 Node Address

The logical address of a node on the network, consisting of a Domain number, Subnet number and Node number. Note that the "Node number" portion of the address is the number assigned to the device during installation and is unique within a subnet. This is not the factory-set unique Node ID (see Node ID).

1.4.42 Node ID

A unique 48-bit identifier assigned (at the factory) to each CEA-709.1-D device. Sometimes called the Neuron ID.

1.4.43 Operator Configurable

For LNS LonWorks systems, Operator Configurable is defined the same as Configurable. See paragraph CONFIGURABLE.

1.4.44 Override

Changing the value of a point outside of the normal sequence of operation where the change has priority over the sequence and where there is a mechanism for releasing the change such that the point returns to the normal value. Overrides persist until released or overridden at the same or higher priority but are not required to persist through a loss of power.

1.4.45 Performance Verification Test (PVT)

The procedure for determining if the installed BAS meets design criteria prior to final acceptance. The PVT is performed after installation, testing, and balancing of mechanical systems. Typically the PVT is performed by the Contractor in the presence of the Government.

1.4.46 Polling

A device periodically requesting data from another device.

1.4.47 Points

Physical and virtual inputs and outputs. See also paragraph INPUT/OUTPUT (I/O).

1.4.48 Program ID

An identifier (number) stored in the device that identifies the node manufacturer, functionality of device (application & sequence), transceiver used, and the intended device usage.

1.4.49 Proportional, Integral, and Derivative (PID) Control Loop

Three parameters used to control modulating equipment to maintain a setpoint. Derivative control is often not required for HVAC systems (leaving "PI" control).

1.4.50 Repeater

A device that connects two control network segments and retransmits all information received on one side onto the other.

1.4.51 Router

A device that connects two channels and controls traffic between the two by retransmitting signals received from one side onto the other based on the signal destination. Routers are used to subdivide a control network and to control bandwidth usage.

1.4.52 Segment

A 'single' section of a control network that contains no repeaters or routers. There is generally a limit on the number of devices on a segment, and this limit 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.

1.4.53 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.

1.4.54 Standard Configuration Property Type (SCPT)

Pronounced skip-it. A standard format type (maintained by LonMark International) for Configuration Properties.

1.4.55 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.

1.4.56 Subnet

Consists of a logical grouping of up to 127 nodes, where the logical grouping is defined by node addressing. Each subnet is assigned a number which is unique within the Domain. See also paragraph NODE ADDRESS.

1.4.57 TP/FT-10

A Free Topology Twisted Pair network defined by CEA-709.3. This is the most common media type for a CEA-709.1-D control network.

1.4.58 TP/XF-1250

A high speed (1.25 Mbps) twisted pair, doubly-terminated bus network defined by the LonMark Interoperability Guidelines. This media is typically used only as a backbone media to connect multiple TP/FT-10 networks.

1.4.59 User-defined Configuration Property Type (UCPT)

Pronounced u-keep-it. A Configuration Property format type that is defined by the device manufacturer.

1.4.60 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.

1.4.61 UMCS

UMCS stands for Utility Monitoring and Control System. The term refers to all components by which a project site monitors, manages, and controls real-time operation of HVAC and other building systems. These components include the UMCS "front-end" and all field building control systems connected to the front-end. The front-end consists of Monitoring and Control Software (user interface software), browser-based user interfaces and network infrastructure.

The network infrastructure (the "UMCS Network"), is an IP network connecting multiple building or facility control networks to the Monitoring and Control Software.

1.4.62 UMCS NETWORK

The UMCS Network connects multiple building or facility control networks to the Monitoring and Control Software.

1.5 PROJECT SEQUENCING

TABLE I: PROJECT SEQUENCING lists the sequencing of submittals as specified in paragraph SUBMITTALS (denoted by an 'S' in the 'TYPE' column) and activities as specified in PART 3 EXECUTION (denoted by an 'E' in the 'TYPE' column). TABLE I does not specify overall project milestone and completion dates[; these dates are specified in the contract documents][_____].

a. Sequencing for Submittals: The sequencing specified for submittals is the deadline by which the submittal must 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 will 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
1	S	Existing Conditions Report	
2	S	DDC Contractor Design Drawings	
3	S	Manufacturer's Product Data	
4	S	Pre-construction QC Checklist	
5	E	Install Building Control System	AAO #1 thru #4
6	E	Start-Up and Start-Up Testing	ACO #5
7	S	Post-Construction QC Checklist	ACO #6
8	S	Programming Software Configuration Software XIF Files LNS Plug-Ins	ACO #6
9	S	Draft As-Built Drawings Draft LNS Database	ACO #6
10	S	Start-Up Testing Report	ACO #6
11	S	PVT Procedures	before schedule start of #12 and AAO #10
12	E	Execute PVT	AAO #9 and #11
13	S	PVT Report	ACO #12
14	S	Meter Certificate of Accuracy	ACO #13

TABLE I. PROJECT SEQUENCING			
ITEM #	TYPE	DESCRIPTION	SEQUENCING (START OF ACTIVITY OR DEADLINE
15	S	Controller Application Programs Controller Configuration Settings Final LNS Database	AAO #14
16	S	Final As-Built Drawings	AAO #14
17	S	O&M Instructions	AAO #16
18	S	Training Documentation	AAO #10 and before scheduled start of #19
19	E	Training	AAO #17 and #18
20	S	Closeout QC Checklist	ACO #19

1.6 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government. [Submit items designated with a "G,DO" concurrently in a "system submittal" to permit simultaneous review of functionally interrelated items. Omission of a required item from the package may result in disapproval of the submittal. Unless noted in the submittal review comments, disapproval of any element within the package will require a re-submittal of the entire system package.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

DDC Contractor Design Drawings; G, DO

DDC Contractor Design Drawings as a single complete package: 2 hard copies and 2 copies on CDROM. Submit hardcopy drawings on ISO A1 34 by 22 inches sheets, and electronic drawings in PDF and in Microstation format. In addition, submit electronic drawings in editable Excel format for all drawings that are tabular, including but not limited to the Point Schedule and Equipment Schedule.

Draft As-Built Drawings; G, DO

Draft As-Built Drawings as a single complete package: 2 hard copies and 2 copies on CDROM. Submit hardcopy drawings on ISO A1 34 by 22 inches sheets, and electronic drawings in PDF and in Microstation format. In addition, submit electronic drawings in editable Excel format for all drawings that are tabular, including but not limited to the Point Schedule and Equipment Schedule.

Final As-Built Drawings; G, DO

Final As-Built Drawings as a single complete package: 2 hard copies and 2 copies on CDROM. Submit hardcopy drawings on ISO A1 34 by 22 inches sheets, and electronic drawings in PDF and in Microstation format. In addition, submit electronic drawings in editable Excel format for all drawings that are tabular, including but not limited to the Point Schedule and Equipment Schedule.

SD-03 Product Data

Certificate of Networthiness Documentation; G, RO

Submit Certificate of Networthiness Documentation in PDF format on CD-ROM.

Programming Software; G, RO

Submit Programming Software on CD-ROM as a Technical Data Package. Submit 2 hard copies of the software user manual for each piece of software.

Controller Application Programs; G, RO

Submit Controller Application Programs on CD-ROM as a Technical Data Package. Include on the CD-ROM a list or table of contents clearly indicating which application program is associated with each device. Submit 2 copies of the Controller Application Programs CD-ROM.

Manufacturer's Product Data; G, DO

Submit Manufacturer's Product Data on CD-ROM.

XIF files; G, RO

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

Draft LNS Database; G, RO

Submit two copies of the fully commissioned, valid draft LNS Database (including all LNS credits) as a Technical Data Package. Submit each copy on a CD-ROM and clearly mark the CD-ROM identifying it as the LNS Database for the work covered under this specification and with the date of the most recent database modification.

Final LNS Database; G, RO

Submit two copies of the fully commissioned, valid as-built LNS

Database (including all LNS credits) for the complete control network provided under this specification as a Technical Data Package. Submit each copy on CD-ROM and clearly mark the CD-ROM 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-ins; G, RO

Submit LNS Plug-ins on CD-ROM as a Technical Data Package. Include on the CD-ROM a list or table of contents clearly indicating which files are associated with each device.

SD-06 Test Reports

Existing Conditions Report; G, RO.

Four copies of the Existing Conditions Report.

Start-Up Testing Report; G, RO

PVT Procedures; G, RO

PVT Report; G, RO

Four copies of the PVT Report. The PVT Report may be submitted as a Technical Data Package.

Pre-Construction Quality Control (QC) Checklist; G, RO

Four copies of the Pre-Construction QC Checklist.

Post-Construction Quality Control (QC) Checklist; G, RO

Four copies of the Post-Construction QC Checklist.

SD-07 Certificates

Welder's Identification Symbols; G, RO

Welder's Qualifications For Installation of Gas Meters; G, RO

Certificates of Accuracy; G, RO

SD-10 Operation and Maintenance Data

Operation and Maintenance (O&M) Instructions; G, RO

Submit 2 copies of the Operation and Maintenance Instructions, indexed and in booklet form. The Operation and Maintenance Instructions may be submitted as a Technical Data Package.

Training Documentation; G, RO

Submit hardcopy training manuals and all training materials on CD-ROM. Provide one hardcopy manual for each trainee on the Course Attendee List and 2 additional copies for archive at the project site. Provide 2 copies of the Course Attendee List with the archival copies. Training Documentation may be submitted as a

Technical Data Package.

SD-11 Closeout Submittals

Enclosure Keys; G, RO

Password Summary Report; G, RO

Provide Two hardcopies of the Password Summary Report, each copy in its own sealed envelope.

Closeout Quality Control (QC) Checklist; G, RO

Four copies of the Closeout QC Checklist.

1.7 DATA PACKAGE AND SUBMITTAL REQUIREMENTS

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 must be delivered strictly in accordance with the CONTRACT CLAUSES and in accordance with the Contract Data Requirements List, DD Form 1423. Data delivered must 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 must contain no proprietary information and be delivered with unrestricted rights.

1.8 SOFTWARE FOR DDC HARDWARE AND GATEWAYS

Provide all software related to the programming and configuration of DDC Hardware and Gateways as indicated. License all Software to the project site. The term "controller" as used in these requirements means both DDC Hardware and Gateways.

1.8.1 Programming Software

For each type of General Purpose Programmable Controller (GPPC), provide the programming software in accordance with Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.

1.8.2 Controller Application Programs

For each General Purpose Programmable Controller (GPPC), provide copies of the application program as source code compatible with the programming software for that GPPC in accordance with Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS. For each Application Generic Controller (AGC), provide copies of the application program as source code compatible with the programming and configuration tool LNS plug-in for that AGC in accordance with Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.

1.8.3 LNS Plug-Ins

Provide LNS Plug-ins in accordance with Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS for each Application Specific Controller and each Application Generic Controller.

For LNS Plug-ins distributed under a license, license the Plug-In to the project site. Submit hard copy manuals, if available, for each plug-in provided as part of the LNS- Plug-Ins submittal.

1.8.4 Certificate of Networthiness Documentation

For all software provided, provide documentation that an Enterprise Certificate of Networthiness exists, that a Limited Certificate of Networthiness for the project site exists, or provide a completed Certificate of Networthiness "Application Checklist".

1.9 QUALITY CONTROL CHECKLISTS

The QC Checklist for LNS-Based LonWorks Systems in APPENDIX A of this Section must be completed by the Contractor's Chief Quality Control (QC) Representative and submitted as indicated. The QC Representative must verify each item indicated and initial in the space provided to indicate that the requirement has been met. The QC Representative must sign and date the Checklist prior to submission to the Government.

1.9.1 Pre-Construction Quality Control (QC) Checklist

Complete items indicated as Pre-Construction QC Checklist items in the QC Checklist.

1.9.2 Post-Construction Quality Control (QC) Checklist

Complete items indicated as Post-Construction QC Checklist items in the QC Checklist.

1.9.3 Closeout Quality Control (QC) Checklist

Complete items indicated as Closeout QC Checklist items in the QC Checklist.

1.10 CERTIFICATES

1.10.1 Electric Meters

Submit Certificates of Accuracy for each component contributing to the overall meter accuracy, including the meter and all connected Current Transformers, Potential Transformers and Current Switches.

1.10.2 Welder's Qualifications for Installation of Gas Meters

Comply with ASME B31.8. The steel welder shall have a copy of a certified ASME B31.8 qualification test report. Submit each welder's identification symbols, assigned number, or letter, used to identify work of the welder. Affix symbols immediately upon completion of welds. Welders making defective welds after passing a qualification test shall be given a requalification test and, upon failing to pass this test, shall not be permitted to work this contract.

PART 2 PRODUCTS

Provide products meeting the requirements of Section 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC, Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS, and this Section.

2.1 GENERAL PRODUCT REQUIREMENTS

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

2.2 PRODUCT DATA

Provide manufacturer's product data sheets documenting compliance with product specifications for each product provided under Section 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC, Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS, or this Section. Provide product data for all products in a single indexed compendium, organized by product type. For each manufacturer, model and version (revision) of DDC Hardware indicate the type or types of DDC Hardware the product is being provided as in accordance with Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.

2.2.1 XIF Files

Provide External Interface Files (XIF Files) for DDC Hardware in accordance with Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS.

2.3 OPERATION ENVIRONMENT

Unless otherwise specified, provide products 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:

(1) Products installed indoors: Ambient temperatures in the range of 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 -35 to +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.

2.4 Wireless Capability

For products incorporating any wireless capability (including but not limited to radio frequency (RF), infrared and optical), provide products for which wireless capability can be permanently disabled at the device. Optical and infrared capabilities may be disabled via a permanently affixed opaque cover plate.

2.5 ENCLOSURES

Enclosures supplied as an integral (pre-packaged) part of another product are acceptable. Enclosures located in mechanical rooms and outside the building shall not have top penetrations or openings. Provide two Enclosure Keys for each lockable enclosure on a single ring per enclosure with a tag identifying the enclosure the keys operate. Provide enclosures meeting the following minimum requirements:

2.5.1 Outdoors

For enclosures located outdoors, provide enclosures meeting NEMA 250 Type 4 requirements.

2.5.2 Mechanical and Electrical Rooms

For enclosures located in mechanical or electrical rooms, provide enclosures meeting NEMA 250 Type 4 requirements.

2.5.3 Other Locations

For enclosures in other locations including but not limited to occupied spaces, above ceilings, and in plenum returns, provide enclosures meeting NEMA 250 Type 1 requirements.

2.6 WIRE AND CABLE

Provide wire and cable meeting the requirements of NFPA 70 and NFPA 90A in addition to the requirements of this specification and referenced specifications.

2.6.1 Terminal Blocks

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

2.6.2 Control Wiring for Binary Signals

For Control Wiring for Binary Signals, provide 18 AWG copper or thicker wire rated for 300-volt service.

2.6.3 Control Wiring for Analog Signals

For Control Wiring for Analog Signals, provide 18 AWG or thicker, copper, single- or multiple-twisted wire meeting the following requirements:

a. minimum 2 inch lay of twist

b. 100 percent shielded pairs

c. at least 300-volt insulation

d. each pair has a 20 AWG tinned-copper drain wire and individual overall pair insulation

e. cables have an overall aluminum-polyester or tinned-copper cable-shield tape, overall 20 AWG tinned-copper cable drain wire, and overall cable insulation.

2.6.4 Power Wiring for Control Devices

For 24-volt circuits, provide insulated copper 18 AWG or thicker wire rated for 300 VAC service. For 120-volt circuits, provide 14 AWG or thicker stranded copper wire rated for 600-volt service.

2.6.5 Transformers

Provide UL 5085-3 approved transformers. Select transformers sized so that the connected load is no greater than 80 percent of the transformer rated capacity.

PART 3 EXECUTION

3.1 EXISTING CONDITIONS

3.1.1 Existing Conditions Survey

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, document the deficiency in the report including explanation of the deficiencies and 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.

3.1.2 Existing Equipment Downtime

Make written requests and obtain Government approval prior to disconnecting any controls and obtaining equipment downtime.

3.1.3 Existing Control System Devices

Inspect, calibrate, and adjust as necessary to place in proper working order all existing devices which are to be reused.

3.2 INSTALLATION

Fully install and test the control system in accordance Section 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC, Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS, and this Section.

3.2.1 Dielectric Isolation

Provide dielectric isolation where dissimilar metals are used for connection and support. Install control system in a matter that provides clearance for control system maintenance by maintaining access space required to calibrate, remove, repair, or replace control system devices. Install control system such that it does not interfere with the clearance requirements for mechanical and electrical system maintenance.

3.2.2 Penetrations in Building Exterior

Make all penetrations through and mounting holes in the building exterior watertight.

3.2.3 Device Mounting Criteria

Install devices in accordance with the manufacturer's recommendations and as indicated and shown. Provide a weathershield for all devices installed outdoors. Provide clearance for control system maintenance by maintaining access space required to calibrate, remove, repair, or replace control system devices. Provide clearance for mechanical and electrical system maintenance; do not not interfere with the clearance requirements for mechanical and electrical system maintenance.

3.2.4 Labels and Tags

Key all labels and tags to the unique identifiers shown on the As-Built drawings. For labels exterior to protective enclosures provide engraved plastic labels mechanically attached to the enclosure or DDC Hardware. Labels inside protective enclosures may be attached using adhesive, but must not be hand written. For tags, provide plastic or metal tags mechanically attached directly to each device or attached by a metal chain or wire.

a. Label all Enclosures and DDC Hardware.

b. Tag Airflow measurement arrays (AFMA) with flow rate range for signal output range, duct size, and pitot tube AFMA flow coefficient.

c. Tag duct static pressure taps at the location of the pressure tap

3.2.5 SURGE PROTECTION

3.2.5.1 Power-Line Surge Protection

Protect equipment connected to AC circuits to withstand power-line surges in accordance with IEEE C62.41. Do not use fuses for surge protection.

3.2.5.2 Surge Protection for Transmitter and Control Wiring

Protect DDC hardware against or provided DDC hardware capable of withstanding surges induced on control and transmitter wiring installed outdoors and as shown. Protect equipment against the following two waveforms:

a. A waveform with a 10-microsecond rise time, a 1000-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.

3.2.6 Basic Cybersecurity Requirements

3.2.6.1 Passwords

For all devices with a password, change the password from the default password. Do not use the same password for more than one device. Coordinate selection of passwords with the Directorate of Public Works. Provide a Password Summary Report documenting the password for each device and describing the procedure to change the password for each device.

3.2.6.2 Wireless Capability

Unless otherwise indicated, disable wireless capability (including but not limited to radio frequency (RF), infrared and optical) for all devices with wireless capability. Optical and infrared capabilities may be disabled via a permanently affixed opaque cover plate. Password protecting a wireless connections does not meet this requirement; the wireless capability must be disabled.

3.2.6.3 IP Network Physical Security

Install all IP Network media in conduit. Install all IP devices including but not limited to IP-enabled DDC hardware and IP Network Hardware in lockable enclosures.

3.3 DRAWINGS AND CALCULATIONS

Provide drawings in the form and arrangement indicated and shown. Use the same abbreviations, symbols, nomenclature and identifiers shown. Assign a unique identifier as shown to each control system element on a drawing. When packaging drawings, group schedules by system. When space allows, it is permissible to include multiple schedules for the same system on a single sheet. Except for drawings covering all systems, do not put information for different systems on the same sheet.

a. Submit DDC Contractor Design Drawings consisting of each drawing indicated with pre-construction information depicting the intended control system design and plans.

b. Submit Draft As-Built Drawings consisting of each drawing indicated updated with as-built data for the system prior to PVT.

c. Submit Final As-Built Drawings consisting of each drawing indicated updated with all final as-built data.

Sample drawings in electronic format are available via a link in the "Graphical Table of Contents" online at: http://www.wbdg.org/ccb/NAVGRAPH/graphtoc.pdf. These drawings may prove useful in demonstrating expected drawing formatting and example content and are provided for illustrative purposes only. These drawings do not meet the content requirements of this Section.

3.3.1 Drawing Index and Legend

Provide an HVAC Control System Drawing Index showing the name and number of the building, military site, State or other similar designation, and Country. In the Drawing Index, list all Contractor Design Drawings,

including the drawing number, sheet number, drawing title, and computer filename when used. In the Design Drawing Legend, show and describe all symbols, abbreviations and acronyms used on the Design Drawings. Provide a single Index and Legend for the entire drawing package.

3.3.2 Thermostat and Occupancy Sensor Schedule

Provide a thermostat and occupancy sensor schedule containing each thermostat's unique identifier, room identifier and control features and functions as shown. Provide a single thermostat and occupancy sensor schedule for the entire project.

3.3.3 Valve Schedule

Provide a valve schedule containing 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. In the valve schedule include actuator selection data supported by calculations of the force required to move and seal the valve, access and clearance requirements. Provide a single valve schedule for the entire project.

3.3.4 Damper Schedule

Provide a damper schedule containing 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. Include the AMCA 511 maximum leakage rate at the operating static-pressure differential for each damper in the Damper Schedule. Provide a single damper schedule for the entire project.

3.3.5 Project Summary Equipment Schedule

Provide a project summary equipment schedule containing the manufacturer, model number, part number and descriptive name for each control device, hardware and component provided under this specification. Provide a single project equipment schedule for the entire project.

3.3.6 Equipment Schedule

Provide system equipment schedules containing the unique identifier, manufacturer, model number, part number and descriptive name for each control device, hardware and component provided under this specification. Provide a separate equipment schedule for each HVAC system.

3.3.7 Occupancy Schedule

Provide an occupancy schedule drawing containing the same fields as the occupancy schedule Contract Drawing with Contractor updated information. Provide a single occupancy schedule for the entire project.

3.3.8 DDC Hardware Schedule

Provide a single DDC Hardware Schedule for the entire project and including following information for each device.

3.3.8.1 DDC Hardware Identifier

The Unique DDC Hardware Identifier for the device.

3.3.8.2 HVAC System

The system "name" used to identify a specific system (the name used on the system schematic drawing for that system).

3.3.8.3 Network Address

The LonWorks Domain, Subnet and Node address for the device.

3.3.8.4 Unique Node ID

The Unique 48-bit Node ID associated with the device. (Also referred to as the Neuron ID for some devices)

3.3.9 Points Schedule

Provide a Points Schedule in tabular form for each HVAC system, with the indicated columns and with each row representing a hardware point, network point or configuration point in the system.

a. When a Points Schedule was included in the Contract Drawing package, use the same fields as the Contract Drawing with updated information in addition to the indicated fields.

b. When Point Schedules are included in the contract package, items requiring contractor verification or input have been shown in angle brackets ("<" and ">"), such as <___> for a required entry or <value> for a value requiring confirmation. Complete all items in brackets as well as any blank cells. Do not modify values which are not in brackets without approval.

Points Schedule Columns must include:

3.3.9.1 Point Name

The abbreviated name for the point using the indicated naming convention.

3.3.9.2 Description

A brief functional description of the point such as "Supply Air Temperature".

3.3.9.3 DDC Hardware Identifier

The Unique DDC Hardware Identifier shown on the DDC Hardware Schedule and used across all drawings for the DDC Hardware containing the point.

3.3.9.4 Settings

The value and units of any setpoints, configured setpoints, configuration parameters, and settings related to each point.

3.3.9.5 Range

The range of values, including units, associated with the point, including but not limited to a zone temperature setpoint adjustment range, a sensor measurement range, occupancy values for an occupancy input, or the status of a safety.

3.3.9.6 Input or Output (I/O) Type

The type of input or output signal associated with the point. Use the following abbreviations for entries in this column:

a. AI: The value comes from a hardware (physical) Analog Input

b. AO: The value is output as a hardware (physical) Analog Output

c. BI: The value comes from a hardware (physical) Binary Input

d. BO: The value is output as a hardware (physical) Binary Output

e. PULSE: The value comes from a hardware (physical) Pulse Accumulator Input

f. NET-IN: The value is provided from the network (generally from another device). Use this entry only when the value is received from another device as part of scheduling or as part of a sequence of operation, not when the value is received on the network for supervisory functions such as trending, alarming, override or display at a user interface.

g. NET-OUT: The value is provided to another controller over the network. Use this entry only when the value is transmitted to another device as part of scheduling or as part of a sequence of operation, not when the value is transmitted on the network for supervisory functions such as trending, alarming, override or display at a user interface.

3.3.9.7 Primary Point Information: SNVT Name

The name of the SNVT used for the point. Any point that is displayed at the front end or on an LDP, is trended, is used by another device on the network, or has an alarm condition must be documented here.

3.3.9.8 Primary Point Information: SNVT Type

The SNVT type used by the point. Provide this information whenever SNVT Name is required.

3.3.9.9 Override Information (SNVT Name and Type)

For each point requiring an Override, indicate the SNVT Name and SNVT Type of the network variable used for the override.

3.3.9.10 Configuration Information

Indicate the means of configuration associated with each point.

a. Indicate "Plug-In" if the point is configurable via an LNS plug-in.

b. If the point is not configurable through an LNS plug-in, indicate the network variable or configuration property used to configure the

value.

3.3.10 Riser Diagram

The Riser Diagram of the Building Control Network may be in tabular form, and must show all DDC Hardware and all Network Hardware, including network terminators. For each item, provide the unique identifier, common descriptive name, physical sequential order (previous and next device on the network), room identifier and location within room. A single riser diagram must be submitted for the entire system.

3.3.11 Control System Schematics

Provide control system schematics in the same form as the control system schematic Contract Drawing with Contractor updated information. Provide a control system schematic for each HVAC system.

3.3.12 Sequences of Operation Including Control Logic Diagrams

Provide HVAC control system sequence of operation and control logic diagrams in the same format as the Contract Drawings. Within these drawings, refer to devices by their unique identifiers. Submit sequences of operation and control logic diagrams for each HVAC system.

3.3.13 Controller, Motor Starter and Relay Wiring Diagram

Provide controller wiring diagrams as 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. Show necessary jumpers and ground connections and the labels of all conductors. Identify sources of power required for control systems and for packaged equipment control systems back to the panel board circuit breaker number, controller enclosures, magnetic starter, or packaged equipment control circuit. Show each power supply and transformer not integral to a controller, starter, or packaged equipment. Show the connected volt-ampere load and the power supply volt-ampere rating. Provide wiring diagrams for each HVAC system.

3.4 CONTROLLER TUNING

Tune each controller in a manner consistent with that described in the ASHRAE FUN IP and in the manufacturer's instruction manual. Tuning must consist of adjustment of the proportional, integral, and where applicable, the derivative (PID) settings to provide stable closed-loop control. Each loop must 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 must 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 must be steady. With the exception of naturally slow processes such as zone temperature control, the controller must settle out at the new setpoint within five (5) minutes. Set the controller to its correct setpoint and record and submit the final PID configuration settings with the O&M Instructions and on the associated Points Schedule.

3.5 START-UP

3.5.1 Start-Up Test

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

Adjust, calibrate, measure, program, configure, set the time schedules, and otherwise perform all necessary actions to ensure that the systems function as indicated and shown in the sequence of operation and other contract documents.

3.5.1.1 Systems Check

An item-by-item check must be performed for each HVAC system

3.5.1.1.1 Step 1 - System Inspection

With the system in unoccupied mode and with fan hand-off-auto switches in the OFF position, verify that power and main air are available where required and that all output devices are in their failsafe and normal positions. Inspect each local display panel [and each M&C Client] to verify that all displays indicate shutdown conditions.

3.5.1.1.2 Step 2 - Calibration Accuracy Check

Perform a two-point accuracy check of the calibration of each HVAC control system sensing element and transmitter by comparing the value from the test instrument to the network value provided by the DDC Hardware. Use digital indicating test instruments, such as digital thermometers, motor-driven psychrometers, and tachometers. Use test instruments with accuracy at least twice as accurate as the specified sensor accuracy and with calibration traceable to National Institute of Standards and Technology standards. Check one the first check point in the bottom one-third of the sensor range, and the second in the top one-third of the sensor range. Verify that the sensing element-to-DDC readout accuracies at two points are within the specified product accuracy tolerances, and if not recalibrate or replace the device and repeat the calibration check.

3.5.1.1.3 Step 3 - Actuator Range Check

With the system running, apply a signal to each actuator through the DDC Hardware controller. Verify proper operation of the actuators and positioners for all actuated devices and record the signal levels for the extreme positions of each device. Vary the signal over its full range, and verify that the actuators travel from zero stroke to full stroke within the signal range. Where applicable, verify 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. For valve actuators and damper actuators, perform the actuator range check under normal system pressures.

3.5.1.2 Weather Dependent Test

Perform weather dependent test procedures in the appropriate climatic season.

3.5.2 Start-Up Testing Report

Submit 4 copies of the Start-Up Testing Report. The report may be submitted as a Technical Data Package documenting the results of the tests performed and certifying that the system is installed and functioning per this specification, and is ready for the Performance Verification Test (PVT).

3.5.3 Draft LNS Database

Upon completion of the Start-Up Test, submit the Draft LNS Database reflecting the system as installed and configured at the completion of the Start-Up and Start-Up-Testing. The Draft LNS Database must be a complete, fully commissioned LNS database for the complete control network provided under this specification. The Draft LNS database submittal must consist of the entire folder structure of the LNS database (e.g. c:\Lm\DB\{database name}. For versions of LNS which use credits, the provided LNS Database must include all device credits.

3.6 PERFORMANCE VERIFICATION TEST (PVT)

3.6.1 PVT Procedures

Prepare PVT Procedures based on Section 25 08 10 UTILITY MONITORING AND CONTROL SYSTEM TESTING explaining 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. Submit 4 copies of the PVT Procedures. The PVT Procedures may be submitted as a Technical Data Package.

3.6.1.1 Sensor Accuracy Checks

Include a one-point accuracy check of each sensor in the PVT procedures and include overall meter accuracy check as applicable and described.

3.6.1.2 Temporary Trending Hardware

Unless trending capability exists within the building control system or the building control system is connected to a UMCS or other system which can perform trending, temporarily install hardware on the building control network to perform trending during the endurance test as indicated. Remove the temporary hardware at the completion of all commissioning activities.

3.6.1.3 Endurance Test

Include a one-week endurance test as part of the PVT during which the system is operated continuously. Use the existing trending capabilities or the Temporary Trending Hardware as indicated to trend all points shown as requiring a trend on the Point Schedule for the entire endurance test. The PVT must include a methodology to measure and record the network bandwidth usage on each TP/FT-10 channel during the endurance test. Poll all points on the Points Schedule with an alarm condition at 5 minute intervals. Poll all points on the Points Schedule required for trending, overrides or graphical displays at 15 minute intervals. Describe in the PVT Procedure a methodology to measure and trend the network bandwidth usage on all Building Control Network channels, including the backbone, during the endurance test to demonstrate that bandwidth usage is less than 70% on all channels.

3.6.1.4 PVT Equipment List

Include in the PVT procedures a control system performance verification test equipment list that lists the equipment to be used during performance verification testing. For each piece of equipment, include manufacturer name, model number, equipment function, the date of the latest calibration, and the results of the latest calibration

3.6.2 PVT Execution

Demonstrate compliance of the control system with the contract documents. Using test plans and procedures approved by the Government, software capable of reading and writing COV Notification Subscriptions, Notification Class Recipient List Properties, event enrollments, demonstrate all physical and functional requirements of the project. Show, step-by-step, the actions and results demonstrating that the control systems perform in accordance with the sequences of operation. Do not start the performance verification test until after receipt of written permission by the Government, based on Government approval of the PVT Plan and Draft As-Builts and completion of balancing. Do not conduct tests during scheduled seasonal off periods of base heating and cooling systems. If the system experiences any failures during the endurance test portion of the PVT, repair the system repeat the endurance test portion of the PVT until the system operates continuously and without failure for the specified endurance test period.

3.6.3 PVT Report

Prepare and submit a PVT report documenting all tests performed during the PVT and their results. Include all tests in the PVT procedures and any additional tests performed during PVT. Document test failures and repairs conducted with the test results.

3.6.4 Final LNS Database

Submit a Final LNS Database consisting of the complete, fully commissioned LNS database for the complete control network provided under this specification. Provide the entire folder structure of the LNS database (e.g. c:\Lm\DB\{database name}. For versions of LNS which use credits, include all device credits in the provided LNS Database.

3.7 OPERATION AND MAINTENANCE (O&M) INSTRUCTIONS

Provide HVAC control System Operation and Maintenance Instructions which include:

a. "Data Package 3" as indicated in Section 01 78 23 OPERATION AND MAINTENANCE DATA for each piece of control equipment.

b. "Data Package 4" as described in Section 01 78 23 OPERATION AND MAINTENANCE DATA for all air compressors.

c. HVAC control system sequences of operation formatted as indicated.

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 indicated.

f. Routine maintenance checklist. Provide the routine maintenance checklist arranged in a columnar format, where the first column lists all installed devices, the second column states the maintenance activity or that no maintenance required, the third column states the frequency of the maintenance activity, and the fourth column is used for additional comments or reference.

g. Qualified service organization list, including at a minimum company name, contact name and phone number.

h. Start-Up Testing Report.

i. Performance Verification Test (PVT) Procedures and Report.

3.8 MAINTENANCE AND SERVICE

Provide services, materials and equipment as necessary to maintain the entire system in an operational state as indicated for a period of one year after successful completion and acceptance of the Performance Verification Test. Minimize impacts on facility operations.

a. The integration of the system specified in this section into a Utility Monitoring and Control System must not, of itself, void the warranty or otherwise alter the requirement for the one year maintenance and service period. Integration into a UMCS includes but is not limited to establishing communication between devices in the control system and the front end or devices in another system.

b. The changing of configuration properties must not, of itself, void the warranty or otherwise alter the requirement for the one year maintenance and service period.

3.8.1 Description of Work

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

3.8.2 Personnel

Use only service personnel qualified 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.

3.8.3 Scheduled Inspections

Perform two inspections at six-month intervals and provide work required. Perform inspections in June and December. During each inspection perform the indicated tasks:

a. Perform visual checks and operational tests of equipment.

b. Clean control system equipment including interior and exterior surfaces.

c. 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 binary inputs and outputs for proper operation during the first inspection. Randomly check at least 25 percent of the remaining binary inputs and outputs during the second inspection. If more than 20 percent of checked inputs or outputs failed the calibration check during any inspection, check and recalibrate all inputs and outputs during that inspection.

d. Run system software diagnostics and correct diagnosed problems.

e. Resolve any previous outstanding problems.

3.8.4 Scheduled Work

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

3.8.5 Emergency Service

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

3.8.6 Operation

After performing scheduled adjustments and repairs, verify control system operation as demonstrated by the applicable tests of the performance verification test.

3.8.7 Records and Logs

Keep dated records and logs of each task, with cumulative records for each major component, and for the complete system chronologically. Maintain a continuous log for all devices, including initial analog span and zero calibration values and digital points. Keep complete logs and provide logs for inspection onsite, demonstrating that planned and systematic adjustments and repairs have been accomplished for the control system.

3.8.8 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.

3.8.9 System Modifications

Submit recommendations for system modification in writing. Do not make system modifications, including operating parameters and control settings, without prior approval of the Government.

3.9 TRAINING

Conduct a training course for 10 operating staff members designated by the Government in the maintenance and operation of the system, including specified hardware and software. Conduct 32 hours of training at the project site within 30 days after successful completion of the performance verification test. The Government reserves the right to make audio and visual recordings (using Government supplied equipment) of the training sessions for later use. Provide audiovisual equipment and other training materials and supplies required to conduct training. 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.

3.9.1 Training Documentation

Prepare training documentation consisting of:

a. Course Attendee List: Develop the list of course attendees in coordination with and signed by the HVAC shop supervisor.

b. Training Manuals: Provide training manuals which include an agenda, defined objectives for each lesson, and a detailed description of the subject matter for each lesson. When presenting portions of the course material by audiovisuals, deliver copies of those audiovisuals as a part of the printed training manuals.

3.9.2 Training Course Content

For guidance in planning the required instruction, assume that attendees will have a high school education, and are familiar with HVAC systems. During the training course, 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 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, and repair procedures. Typical systems and similar systems may be treated as a group, with instruction on the physical layout of one such system. Present the results of the performance verification test and the Start-Up Testing Report as benchmarks of HVAC control system performance by which to measure operation and maintenance effectiveness.

APPENDIX A

QC CHECKLIST FOR LNS-BASED LONWORKS SYSTEMS

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

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

This checklist is for (circle one:)

Pre-Construction QC Checklist Submittal

Post-Construction QC Checklist Submittal

Close-out QC Checklist Submittal

Items verified for Pre-Construction, Post-Construction and Closeout QC Checklist Submittals:

1	All DDC Hardware is numbered on Control System Schematic Drawings.	|____|
2	Signal lines on Control System Schematic are labeled with the signal type.	|____|
3	Local Display Panel (LDP) Locations are shown on Control System Schematic drawings.	|____|

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

4	All sequences are performed as specified using DDC Hardware.	|____|
5	Training schedule and course attendee list has been developed and coordinated with shops and submitted.	|____|
6	All DDC Hardware is installed on a TP/FT-10 Channel.	|____|
7	All Application Specific Controllers (ASCs) are LonMark certified.	|____|
8	Communication between DDC Hardware is only via CEA-709.1-D using SNVTs. Other protocols have not been used. Network variables other than SNVTs have not been used.	|____|
9	Explicit messaging has not been used.	|____|
10	Scheduling is performed in DDC Hardware meeting the Simple Schedule Functional Profile	|____|

Items verified for Closeout QC Checklist Submittal:

QC CHECKLIST FOR LNS-BASED LONWORKS SYSTEMS		
11	Final As-built Drawings, including all Points Schedule drawings, accurately represent the final installed system.	
12	Programming software has been submitted for all programmable controllers.	
13	All software has been licensed to the Government.	
14	O&M Instructions have been completed and submitted.	
15	Training course has been completed.	
16	LonWorks Network Services (LNS) Database is up-to-date and accurately represents the final installed system.	
17	LNS Plug-ins have been submitted for all Application Specific Controllers (ASCs).	
18	Programming software has been submitted for all General Purpose Programmable Controllers (GPPCs) and all Application Generic Controllers (AGCs).	
	_____ _____	
	(QC Representative Signature) (Date)	

-- End of Section --

Appendix L: Insert: UFGS - 23 09 13 (Tailored to Fort Leonard Wood): Instrumentation & Control Devices for HVAC

SECTION TABLE OF CONTENTS

DIVISION 23 - HEATING, VENTILATING, AND AIR CONDITIONING (HVAC)

SECTION 23 09 13

INSTRUMENTATION AND CONTROL DEVICES FOR HVAC

11/15

PART 1 GENERAL

1.1 SUMMARY
1.1.1 Verification of Dimensions
1.1.2 Drawings
1.2 RELATED SECTIONS
1.3 REFERENCES
1.4 SUBMITTALS
1.5 DELIVERY AND STORAGE
1.6 INPUT MEASUREMENT ACCURACY
1.7 SUBCONTRACTOR SPECIAL REQUIREMENTS

PART 2 PRODUCTS

2.1 EQUIPMENT
2.1.1 General Requirements
2.1.2 Operation Environment Requirements
2.1.2.1 Pressure
2.1.2.2 Vibration
2.1.2.3 Temperature
2.1.2.4 Humidity
2.2 WEATHERSHIELDS
2.3 TUBING
2.3.1 Copper
2.3.2 Stainless Steel
2.3.3 Plastic
2.3.4 Polyethylene Tubing
2.4 WIRE AND CABLE
2.4.1 Terminal Blocks
2.4.2 Control Wiring for Binary Signals
2.4.3 Control Wiring for Analog Signals
2.4.4 Power Wiring for Control Devices
2.4.5 Transformers
2.5 AUTOMATIC CONTROL VALVES
2.5.1 Valve Type
2.5.1.1 Liquid Service 150 Degrees F or Less
2.5.1.2 Liquid Service Above 150 Degrees F
2.5.1.3 Steam Service
2.5.2 Valve Flow Coefficient and Flow Characteristic
2.5.2.1 Two-Way Modulating Valves
2.5.2.2 Three-Way Modulating Valves
2.5.3 Two-Position Valves
2.5.4 Globe Valves
2.5.4.1 Liquid Service Not Exceeding 150 Degrees F
2.5.4.2 Liquid Service Not Exceeding 250 Degrees F
2.5.4.3 Hot water service 250 Degrees F and above

2.5.4.4 Steam Service
2.5.5 Ball Valves
2.5.5.1 Liquid Service Not Exceeding 150 Degrees F
2.5.6 Butterfly Valves
2.5.7 Pressure Independent Control Valves (PICV)
2.5.8 Duct-Coil and Terminal-Unit-Coil Valves
2.6 DAMPERS
2.6.1 Damper Assembly
2.6.2 Operating Linkages
2.6.3 Damper Types
2.6.3.1 Flow Control Dampers
2.6.3.2 Mechanical Rooms and Other Utility Space Ventilation Dampers
2.6.3.3 Smoke Dampers
2.7 SENSORS AND INSTRUMENTATION
2.7.1 Analog and Binary Transmitters
2.7.2 Network Transmitters
2.7.3 Temperature Sensors
2.7.3.1 Sensor Accuracy and Stability of Control
2.7.3.1.1 Conditioned Space Temperature
2.7.3.1.2 Unconditioned Space Temperature
2.7.3.1.3 Duct Temperature
2.7.3.1.4 Outside Air Temperature
2.7.3.1.5 High Temperature Hot Water
2.7.3.1.6 Chilled Water
2.7.3.1.7 Dual Temperature Water
2.7.3.1.8 Heating Hot Water
2.7.3.1.9 Condenser Water
2.7.3.2 Transmitter Drift
2.7.3.3 Point Temperature Sensors
2.7.3.4 Temperature Sensor Details
2.7.3.4.1 Room Type
2.7.3.4.2 Duct Probe Type
2.7.3.4.3 Duct Averaging Type
2.7.3.4.4 Pipe Immersion Type
2.7.3.4.5 Outside Air Type
2.7.4 Relative Humidity Sensor
2.7.5 Carbon Dioxide (CO2) Sensors
2.7.6 Differential Pressure Instrumentation
2.7.6.1 Differential Pressure Sensors
2.7.6.2 Differential Pressure Switch
2.7.7 Flow Sensors
2.7.7.1 Airflow Measurement Array (AFMA)
2.7.7.1.1 Airflow Straightener
2.7.7.1.2 Resistance to Airflow
2.7.7.1.3 Outside Air Temperature
2.7.7.1.4 Pitot Tube AFMA
2.7.7.1.5 Electronic AFMA
2.7.7.1.6 Fan Inlet Measurement Devices
2.7.7.2 Insertion Magnetic Flow Meter
2.7.7.3 Flow Switch
2.7.8 Electric Metering
2.7.8.1 Meter Connection Wiring
2.7.8.2 Potential Transformer (PT)
2.7.8.3 Current Transformer
2.7.8.3.1 Current Transformer (CT) Insulation Class
2.7.8.3.2 Current Transformer (CT) Accuracy
2.7.8.3.3 Current Transformer (CT) Secondary Side Output
2.7.8.3.4 Current Transformer (CT) Size
2.7.8.3.5 Current Transformer (CT) Core Type

2.7.8.3.6 Multi-Ratio Current Transformer
2.7.8.4 Current Sensors
2.7.8.5 Electric Meters
2.7.8.5.1 General
2.7.8.5.2 Meter Accuracy
2.7.8.5.3 Certifications and Approvals
2.7.8.5.4 Voltage Requirements
2.7.8.5.5 Current Requirements
2.7.8.5.6 Pulse Input
2.7.8.5.7 Connections
2.7.8.5.8 Meter Output
2.7.8.5.8.1 Communication Protocol
2.7.8.5.8.2 Pulse Output
2.7.8.5.9 Meter Display and Interface
2.7.8.5.10 Trending
2.7.8.5.11 Meter Configuration
2.7.8.5.12 Meter Configuration Software
2.7.9 Gas Metering
2.7.9.1 Gas Pipe, Fittings, Valves, and Regulators
2.7.9.2 Pipe and Fittings
2.7.9.2.1 Aboveground and Within Buildings and Vaults
2.7.9.2.1.1 Pipe
2.7.9.2.1.2 Threaded Fittings
2.7.9.2.1.3 Socket-Welding Fittings
2.7.9.2.1.4 Butt-Welding Fittings
2.7.9.2.1.5 Unions
2.7.9.2.1.6 Flanges and Flanged Fittings
2.7.9.2.2 Risers
2.7.9.2.3 Transition Fittings
2.7.9.2.3.1 Steel to Plastic (PE)
2.7.9.2.3.2 Plastic to Plastic
2.7.9.3 Valves, Aboveground
2.7.9.3.1 Shutoff Valves, Sizes Larger Than 2 Inches
2.7.9.3.2 Shutoff Valves, Sizes 2 Inches and Smaller
2.7.9.3.3 Pressure Regulator
2.7.9.4 Hangers and Supports
2.7.9.5 Welding Filler Metal
2.7.9.6 Pipe-Thread Tape
2.7.9.7 Bolting (Bolts and Nuts)
2.7.9.8 Gaskets
2.7.9.9 Identification for Aboveground Piping (Interior)
2.7.9.10 Gas Meters
2.7.9.10.1 Utility Monitoring and Control (UMCS) Interface
2.7.10 Water Metering
2.7.10.1 Physical and Common Requirements
2.7.10.2 Cold -Water Meters - Displacement Type 5/8-inch x 3/4-inch, 1-inch, 1-1/2-inch, 2-inch Size
2.7.10.3 Cold-Water Meters - Compound Type 2-Inch, 3-Inch, 4-Inch, and 6-Inch Size
2.7.10.4 Cold-Water Meter - Turbine Type 2-Inch Size
2.7.10.5 Cold-Water Meter Strainers 2-Inch, 3-Inch, 4-Inch and 6-Inch Size
2.7.10.6 Utility Monitoring and Control (UMCS) Meter Reading Interfaces
2.7.10.7 Spare Parts List
2.7.11 Steam Meters
2.7.12 Hydronic BTU Meters
2.7.13 pH Sensor
2.7.14 Oxygen Analyzer

2.7.15 Carbon Monoxide Analyzer
2.7.16 Occupancy Sensors
2.7.16.1 Passive Infrared (PIR) Occupancy Sensors
2.7.16.2 Ultrasonic Occupancy Sensors
2.7.16.3 Dual-Technology Occupancy Sensor (PIR and Ultrasonic)
2.7.17 Vibration Switch
2.7.18 Conductivity Sensor
2.7.19 Compressed Air Dew Point Sensor
2.7.20 NOx Monitor
2.7.21 Turbidity Sensor
2.7.22 Chlorine Detector
2.7.23 Floor Mounted Leak Detector
2.7.24 Temperature Switch
2.7.24.1 Duct Mount Temperature Low Limit Safety Switch (Freezestat)
2.7.24.2 Pipe Mount Temperature Limit Switch (Aquastat)
2.7.25 Damper End Switches
2.7.26 Air Quality Sensors
2.8 INDICATING DEVICES
2.8.1 Thermometers
2.8.1.1 Piping System Thermometers
2.8.1.2 Air-Duct Thermometers
2.8.2 Pressure Gauges
2.8.3 Low Differential Pressure Gauges
2.8.4 Pressure Gauges for Pneumatic Controls
2.9 OUTPUT DEVICES
2.9.1 Actuators
2.9.1.1 Valve Actuators
2.9.1.2 Damper Actuators
2.9.1.3 Positive Positioners
2.9.1.4 Electric Actuators
2.9.1.5 Pneumatic Actuators
2.9.2 Solenoid-Operated Electric to Pneumatic Switch (EPS)
2.9.3 Electric to Pneumatic Transducers (EP)
2.9.4 Relays
2.10 USER INPUT DEVICES
2.11 MULTIFUNCTION DEVICES
2.11.1 Current Sensing Relay Command Switch
2.11.2 Space Sensor Module
2.12 COMPRESSED AIR STATIONS
2.12.1 Air Compressor Assembly
2.12.2 Compressed Air Station Specialties
2.12.2.1 Refrigerated Air Dryers
2.12.2.2 Compressed Air Discharge Filters
2.12.2.3 Air Pressure-Reducing Stations
2.12.2.4 Flexible Pipe Connections
2.12.2.5 Vibration Isolation Units
2.12.3 Compressed Air Tanks

PART 3 EXECUTION

3.1 INSTALLATION
3.1.1 General Installation Requirements
3.1.1.1 Device Mounting Criteria
3.1.1.2 Labels and Tags
3.1.2 Weathershield
3.1.3 Room Instrument Mounting
3.1.4 Indication Devices Installed in Piping and Liquid Systems
3.1.5 Occupancy Sensors
3.1.6 Switches

3.1.6.1 Temperature Limit Switch
3.1.6.2 Hand-Off Auto Switches
3.1.7 Temperature Sensors
3.1.7.1 Room Temperature Sensors
3.1.7.2 Duct Temperature Sensors
3.1.7.2.1 Probe Type
3.1.7.2.2 Averaging Type
3.1.7.3 Immersion Temperature Sensors
3.1.7.4 Outside Air Temperature Sensors
3.1.8 Air Flow Measurement Arrays (AFMA)
3.1.9 Duct Static Pressure Sensors
3.1.10 Relative Humidity Sensors
3.1.11 Meters
3.1.11.1 Flowmeters
3.1.11.2 Electric Meters
3.1.11.2.1 Meter Connections
3.1.11.2.2 Overall Meter Accuracy
3.1.11.2.3 Disconnecting Switches
3.1.11.2.4 Surge Protection
3.1.11.2.5 Meter Configuration Settings
3.1.11.2.6 Meter Testing and Inspection
3.1.11.2.6.1 Visual and Mechanical Inspection
3.1.11.2.6.2 Electrical Tests
3.1.11.3 Gas Meters
3.1.11.3.1 Piping
3.1.11.3.1.1 Cleanliness
3.1.11.3.1.2 Aboveground Steel Piping
3.1.11.3.1.2.1 Wrapping
3.1.11.3.1.3 Regulators and Valves
3.1.11.3.1.3.1 Pressure Regulator
3.1.11.3.1.3.2 Stop Valve and Shutoff Valve
3.1.11.3.1.4 Pipe Sleeves
3.1.11.3.1.5 Pipe Sleeves
3.1.11.4 Water Meters
3.1.11.4.1 Water Meter Warranty Requirements
3.1.12 Dampers
3.1.12.1 Damper Actuators
3.1.12.2 Damper Installation
3.1.13 Valves
3.1.13.1 Valve Actuators
3.1.14 Thermometers and Gauges
3.1.14.1 Local Gauges for Actuators
3.1.14.2 Thermometers
3.1.15 Wire and Cable
3.1.16 Copper Tubing
3.1.17 Plastic Tubing
3.1.18 Pneumatic Lines
3.1.18.1 Pneumatic Lines In Mechanical/Electrical Spaces
3.1.18.2 Pneumatic Lines External to Mechanical/Electrical Spaces
3.1.18.3 Terminal Single Lines
3.1.18.4 Connection to Liquid and Steam Lines
3.1.18.5 Connection to Ductwork
3.1.18.6 Tubing in Concrete
3.1.18.7 Tubing Connection to Actuators
3.1.19 Compressed Air Stations
3.1.20 Protective Covering for Aboveground Piping Systems

-- End of Section Table of Contents --

SECTION 23 09 13

INSTRUMENTATION AND CONTROL DEVICES FOR HVAC
11/15

PART 1 GENERAL

1.1 SUMMARY

This section provides for the instrumentation control system components excluding direct digital controllers, network controllers, gateways etc. that are necessary for a completely functional automatic control system. When combined with a Direct Digital Control (DDC) system, the Instrumentation and Control Devices covered under this section must be a complete system suitable for the control of the heating, ventilating and air conditioning (HVAC) and other building-level systems as specified and indicated.

a. Install hardware to perform the control sequences as specified and indicated and to provide control of the equipment as specified and indicated.

b. Install hardware such that individual control equipment can be replaced by similar control equipment from other equipment manufacturers with no loss of system functionality.

c. 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 installing Contractor.

1.1.1 Verification of Dimensions

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.

1.1.2 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.

1.2 RELATED SECTIONS

Related work specified elsewhere.

Section 01 30 00 ADMINISTRATIVE REQUIREMENTS

Section 23 00 00 AIR SUPPLY, DISTRIBUTION, VENTILATION, AND EXHAUST SYSTEMS

Section 23 05 15 COMMON PIPING FOR HVAC

Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC

Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER

BUILDING CONTROL SYSTEMS

Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM

1.3 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)

AGA ANSI B109.1	(2000) Diaphragm-Type Gas Displacement Meters (Under 500 cubic ft./hour Capacity)
AGA ANSI B109.2	(2000) Diaphragm-Type Gas Displacement Meters (500 cubic ft./hour Capacity and Over)
AGA ANSI B109.3	(2000) Rotary-Type Gas Displacement Meters

AIR MOVEMENT AND CONTROL ASSOCIATION INTERNATIONAL (AMCA)

AMCA 500-D	(2012) Laboratory Methods of Testing Dampers for Rating
AMCA 511	(2010) Certified Ratings Program for Air Control Devices

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-STD-101	(2014; Rev C) Color Code for Pipelines and for Compressed Gas Cylinders

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 9001	(2008; Corr 1 2009) Quality Management Systems- Requirements

MANUFACTURERS STANDARDIZATION SOCIETY OF THE VALVE AND FITTINGS INDUSTRY (MSS)

MSS SP-58	(1993; Reaffirmed 2010) Pipe Hangers and Supports - Materials, Design and Manufacture, Selection, Application, and Installation
MSS SP-69	(2003; Notice 2012) Pipe Hangers and Supports - Selection and Application (ANSI Approved American National Standard)

MASTER PAINTERS INSTITUTE (MPI)

MPI 9	(Oct 2009) Exterior Alkyd, Gloss, MPI Gloss Level 6

CONSUMER ELECTRONICS ASSOCIATION (CEA)

CEA-709.1-D	(2014) Control Network Protocol

Specification

ASME INTERNATIONAL (ASME)

ASME B1.1	(2003; R 2008) Unified Inch Screw Threads (UN and UNR Thread Form)
ASME B1.20.1	(2013) Pipe Threads, General Purpose (Inch)
ASME B16.11	(2011) Forged Fittings, Socket-Welding and Threaded
ASME B16.15	(2013) Cast Copper Alloy Threaded Fittings Classes 125 and 250
ASME B16.18	(2012) Cast Copper Alloy Solder Joint Pressure Fittings
ASME B16.22	(2013) Standard for Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
ASME B16.26	(2013) Standard for Cast Copper Alloy Fittings for Flared Copper Tubes
ASME B16.33	(2012) Manually Operated Metallic Gas Valves for Use in Gas Piping Systems Up to 125 psi, Sizes NPS 1/2 - NPS 2
ASME B16.34	(2013) Valves - Flanged, Threaded and Welding End
ASME B16.38	(2012) Large Metallic Valves for Gas Distribution (Manually Operated, NPS 2 1/2 to 12, 125 psig Maximum)
ASME B16.39	(2014) Standard for Malleable Iron Threaded Pipe Unions; Classes 150, 250, and 300
ASME B16.5	(2013) Pipe Flanges and Flanged Fittings: NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME B16.9	(2012) Standard for Factory-Made Wrought Steel Buttwelding Fittings
ASME B18.2.1	(2012; Errata 2013) Square and Hex Bolts and Screws (Inch Series)
ASME B18.2.2	(2010) Nuts for General Applications: Machine Screw Nuts, Hex, Square, Hex Flange, and Coupling Nuts (Inch Series)
ASME B31.8	(2014; Supplement 2014) Gas Transmission and Distribution Piping Systems
ASME B40.100	(2013) Pressure Gauges and Gauge Attachments
ASME BPVC SEC VIII D1	(2010) BPVC Section VIII-Rules for

Construction of Pressure Vessels Division 1

ASTM INTERNATIONAL (ASTM)

ASTM A193/A193M	(2015a) Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service and Other Special Purpose Applications
ASTM A194/A194M	(2015a) Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both
ASTM A269/A269M	(2015a) Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
ASTM A536	(1984; R 2014) Standard Specification for Ductile Iron Castings
ASTM B32	(2008; R 2014) Standard Specification for Solder Metal
ASTM A53/A53M	(2012) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM B75/B75M	(2011) Standard Specification for Seamless Copper Tube
ASTM B88	(2014) Standard Specification for Seamless Copper Water Tube
ASTM D1238	(2013) Melt Flow Rates of Thermoplastics by Extrusion Plastometer
ASTM D1693	(2015) Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics
ASTM D635	(2014) Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position
ASTM D638	(2014) Standard Test Method for Tensile Properties of Plastics
ASTM D792	(2013) Density and Specific Gravity (Relative Density) of Plastics by Displacement

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA C700	(2015) Standard for Cold Water Meters - Displacement Type, Bronze Main Case
AWWA C701	(2012) Standard for Cold-Water Meters -

	Turbine Type for Customer Service
AWWA C702	(2015)Cold-Water Meters - Compound Type

ASME INTERNATIONAL (ASME)

ASME B1.20.1	(2013) Pipe Threads, General Purpose (Inch)
ASME B16.1	(2010) Gray Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250

FLUID CONTROLS INSTITUTE (FCI)

FCI 70-2	(2013) Control Valve Seat Leakage

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE C2	(2012; Errata 1 2012; INT 1-4 2012; Errata 2 2013; INT 5-7 2013; INT 8-10 2014; INT 11 2015) National Electrical Safety Code
IEEE C37.90.1	(2012) Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
IEEE C57.13	(2008; INT 2009) Standard Requirements for Instrument Transformers
IEEE C62.41	(1991; R 1995) Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits
IEEE 142	(2007; Errata 2014) Recommended Practice for Grounding of Industrial and Commercial Power Systems - IEEE Green Book

INTERNATIONAL SOCIETY OF AUTOMATION (ISA)

ISA 7.0.01	(1996) Quality Standard for Instrument Air

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C12.1	(2014; Errata 2016) Electric Meters Code for Electricity Metering
ANSI C12.20	(2010) Electricity Meters - 0.2 and 0.5 Accuracy Classes
NEMA 250	(2014) Enclosures for Electrical Equipment (1000 Volts Maximum)

INTERNATIONAL ELECTRICAL TESTING ASSOCIATION (NETA)

NETA ATS	(2013) Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 54	(2015) National Fuel Gas Code
NFPA 70	(2017) National Electrical Code
NFPA 90A	(2015) Standard for the Installation of Air Conditioning and Ventilating Systems

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

SMACNA 1981	(2008) Seismic Restraint Manual Guidelines for Mechanical Systems, 3rd Edition

SOCIETY FOR PROTECTIVE COATINGS (SSPC)

SSPC 7/NACE No.4	(2007; E 2004) Brush-Off Blast Cleaning
SSPC Paint 25	(1997; E 2004) Zinc Oxide, Alkyd, Linseed Oil Primer for Use Over Hand Cleaned Steel, Type I and Type II
SSPC SP 1	(2015) Solvent Cleaning
SSPC SP 3	(1982; E 2004) Power Tool Cleaning

UNDERWRITERS LABORATORIES (UL)

UL 1820	(2004; Reprint May 2013) UL Standard for Safety Fire Test of Pneumatic Tubing for Flame and Smoke Characteristics
UL 508	(1999; Reprint Oct 2013) Industrial Control Equipment
UL 5085-3	(2006; Reprint Nov 20121) Low Voltage Transformers - Part 3: Class 2 and Class 3 Transformers
UL 555	(2006; Reprint Aug 2016) UL Standard for Safety Fire Dampers
UL 555S	(2014; Reprint Aug 2016) UL Standard for Safety Smoke Dampers
UL 94	(2013; Reprint Mar 2016) UL Standard for Safety Tests for Flammability of Plastic Materials for Parts in Devices and Appliances

1.4 SUBMITTALS

Submittal requirements are specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.

1.5 DELIVERY AND STORAGE

Store and protect products from the weather, humidity, and temperature

variations, dirt and dust, and other contaminants, within the storage condition limits published by the equipment manufacturer.

1.6 INPUT MEASUREMENT ACCURACY

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

1.7 SUBCONTRACTOR SPECIAL REQUIREMENTS

Perform all work in this section in accordance with the paragraph entitled CONTRACTOR SPECIAL REQUIREMENTS in Section 01 30 00 ADMINISTRATIVE REQUIREMENTS.

PART 2 PRODUCTS

2.1 EQUIPMENT

2.1.1 General Requirements

All products used to meet this specification must meet the indicated requirements, but not all products specified here will be required by every project. All products must meet the requirements both Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC and this Section.

2.1.2 Operation Environment Requirements

Unless otherwise specified, provide products rated for continuous operation under the following conditions:

2.1.2.1 Pressure

Pressure conditions normally encountered in the installed location.

2.1.2.2 Vibration

Vibration conditions normally encountered in the installed location.

2.1.2.3 Temperature

a. Products installed indoors: Ambient temperatures in the range of 32 to 112 degrees F and temperature conditions outside this range normally encountered at the installed location.

b. Products installed outdoors or in unconditioned indoor spaces: Ambient temperatures in the range of -35 to +151 degrees F and temperature conditions outside this range normally encountered at the installed location.

2.1.2.4 Humidity

10 to 95 percent relative humidity, noncondensing and also humidity conditions outside this range normally encountered at the installed location.

2.2 WEATHERSHIELDS

Provide weathershields constructed of galvanized steel painted white, unpainted aluminum, aluminum painted white, or white PVC.

2.3 TUBING

2.3.1 Copper

Provide ASTM B75/B75M or ASTM B88 rated tubing meeting the following requirements:

a. For tubing 0.375 inch outside diameter and larger provide tubing with minimum wall thickness equal to ASTM B88, Type M

b. For tubing less than 0.375 inch outside diameter provide tubing with minimum wall thickness of 0.025 inch

c. For exposed tubing and tubing for working pressures greater than 30 psig provide hard copper tubing.

d. Provide fittings which are ASME B16.18 or ASME B16.22 solder type using ASTM B32 95-5 tin-antimony solder, or which are ASME B16.26 compression type.

2.3.2 Stainless Steel

For stainless steel tubing provide tubing conforming to ASTM A269/A269M

2.3.3 Plastic

Provide plastic tubing with the burning characteristics of linear low-density polyethylene tubing which is self-extinguishing when tested in accordance with ASTM D635, has UL 94 V-2 flammability classification or better, and which withstands stress cracking when tested in accordance with ASTM D1693. Provide plastic-tubing bundles with Mylar barrier and flame-retardant polyethylene jacket.

2.3.4 Polyethylene Tubing

Provide flame-resistant, multiple polyethylene tubing in flame-resistant protective sheath with mylar barrier, or unsheathed polyethylene tubing in rigid metal, intermediate metal, or electrical metallic tubing conduit for areas where tubing is exposed. Single, unsheathed, flame-resistant polyethylene tubing may be used where concealed in walls or above ceilings and within control panels. Do not provide polyethylene tubing for [systems indicated as critical and] smoke removal systems, or for systems with working pressures over 30 psig. Provide compression or brass barbed push-on type fittings. Provide extruded seamless polyethylene tubing conforming to the following:

a. Minimum Burst Pressure Requirements: 100 psig at 75 degrees F to 25 psig at 150 degrees F.

b. Stress Crack Resistance: ASTM D1693, 200 hours minimum.

c. Tensile Strength (Minimum): ASTM D638, 1100 psi.

d. Flow Rate (Average): ASTM D1238, 0.30 decigram per minute.

e. Density (Average): ASTM D792, 57.5 pounds per cubic feet.

f. Burn rate: ASTM D635

g. Flame Propagation: UL 1820, less than 5 feet ASTM D635

h. Average Optical Density: UL 1820, less than 0.15 ASTM D635

2.4 WIRE AND CABLE

Provide wire and cable meeting the requirements of NFPA 70 and NFPA 90A in addition to the requirements of this specification and referenced specifications.

2.4.1 Terminal Blocks

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

2.4.2 Control Wiring for Binary Signals

For Control Wiring for Binary Signals, provide 18 AWG copper or thicker wire rated for 300-volt service.

2.4.3 Control Wiring for Analog Signals

For Control Wiring for Analog Signals, provide 18 AWG or thicker, copper, single- or multiple-twisted wire meeting the following requirements:

a. minimum 2 inch lay of twist

b. 100 percent shielded pairs

c. at least 300-volt insulation

d. each pair has a 20 AWG tinned-copper drain wire and individual overall pair insulation

e. cables have an overall aluminum-polyester or tinned-copper cable-shield tape, overall 20 AWG tinned-copper cable drain wire, and overall cable insulation.

2.4.4 Power Wiring for Control Devices

For 24-volt circuits, provide insulated copper 18 AWG or thicker wire rated for 300 VAC service. For 120-volt circuits, provide 14 AWG or thicker stranded copper wire rated for 600-volt service.

2.4.5 Transformers

Provide UL 5085-3 approved transformers. Select transformers sized so that the connected load is no greater than 80 percent of the transformer rated capacity.

2.5 AUTOMATIC CONTROL VALVES

Provide valves with stainless-steel stems and stuffing boxes with extended necks to clear the piping insulation. Provide valves with bodies meeting 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 indicated, provide valves meeting FCI 70-2 Class IV leakage rating . Provide valves rated for modulating or two-position service as indicated, which close against a differential pressure indicated as the Close-Off pressure and which are Normally-Open, Normally-Closed, or Fail-In-Last-Position as indicated.

2.5.1 Valve Type

2.5.1.1 Liquid Service 150 Degrees F or Less

Use either globe valves or ball valves except that butterfly valves may be used for sizes 4 inch and larger.

2.5.1.2 Liquid Service Above 150 Degrees F

a. Two-position valves: Use either globe valves or ball valves except that butterfly valves may be used for sizes 4 inch and larger.

b. Modulating valves: Use globe valves except that butterfly valves may be used for sizes 4 inch and larger.

2.5.1.3 Steam Service

Use globe valves except that butterfly valves may be used for sizes 4 inch and larger.

2.5.2 Valve Flow Coefficient and Flow Characteristic

2.5.2.1 Two-Way Modulating Valves

Provide the valve coefficient (Cv) indicated. Provide equal-percentage flow characteristic for liquid service except for butterfly valves. Provide linear flow characteristic for steam service except for butterfly valves.

2.5.2.2 Three-Way Modulating Valves

Provide the valve coefficient (Cv) indicated. Provide linear flow characteristic with constant total flow throughout full plug travel.

2.5.3 Two-Position Valves

Use full line size full port valves with maximum available (Cv).

2.5.4 Globe Valves

2.5.4.1 Liquid Service Not Exceeding 150 Degrees F

a. Valve body and body connections:

(1) valves 1-1/2 inches and smaller: brass or bronze body, with threaded or union ends

(2) valves from 2 inches to 3 inches inclusive: brass, bronze, or iron bodies. 2 inch valves with threaded connections; 2-1/2 to 3 inches valves with flanged connections

b. Internal valve trim: Brass or bronze.

c. Stems: Stainless steel.

d. Provide valves compatible with a solution of 50 percent ethylene or propylene glycol.

2.5.4.2 Liquid Service Not Exceeding 250 Degrees F

a. Valve body and body connections:

(a) valves 1-1/2 inches and smaller: brass or bronze body, with threaded or union ends

(b) valves from 2 inches to 3 inches inclusive: brass, bronze, or iron bodies. 2 inch valves with threaded connections; 2-1/2 to 3 inches valves with flanged connections

b. Internal trim: Type 316 stainless steel including seats, seat rings, modulation plugs, valve stems, and springs.

c. Provide valves with non-metallic parts suitable for a minimum continuous operating temperature of 250 degrees F or 50 degrees F above the system design temperature, whichever is higher.

d. Provide valves compatible with a solution of 50 percent ethylene or propylene glycol

2.5.4.3 Hot water service 250 Degrees F and above

a. Provide valve bodies conforming to ASME B16.34 Class 300. For valves 1 inch and larger provide valves with bodies which are carbon steel, globe type with welded ends. For valves smaller than 1 inch provide valves with socket-weld ends. Provide valves with virgin polytetrafluoroethylene (PTFE) packing. Provide valve and actuator combinations which are normally closed.

b. Internal trim: Type 316 stainless steel including seats, seat rings, modulation plugs, valve stems, and springs.

2.5.4.4 Steam Service

For steam service, provide valves meeting the following requirements:

a. Valve body and connections:

(a) valves 1-1/2 inches and smaller: complete body of brass or bronze, with threaded or union ends

(b) valves from 2 inches to 3 inches inclusive: body of brass, bronze, or carbon steel

(c) valves 4 inches and larger: body of carbon steel. 2 inch valves with threaded connections; valves2-1/2 inches and larger

with flanged connections.

b. Internal Trim: Type 316 stainless steel including seats, seat rings, modulation plugs, valve stems, and springs.

c. Valve sizing: sized for 15 psig inlet steam pressure with a maximum 12 psi differential through the valve at rated flow, except where indicated otherwise.

2.5.5 Ball Valves

2.5.5.1 Liquid Service Not Exceeding 150 Degrees F

a. Valve body and connections:

(a) valves 1-1/2 inches and smaller: bodies of brass or bronze, with threaded or union ends

(b) valves from 2 inches to 3 inches inclusive: bodies of brass, bronze, or iron. 2 inch valves with threaded connections; valves from 2-1/2 to 3 inches with flanged connections.

b. Ball: Stainless steel or nickel-plated brass or chrome-plated brass.

c. Seals: Reinforced Teflon seals and EPDM O-rings.

d. Stem: Stainless steel, blow-out proof.

e. Provide valves compatible with a solution of 50 percent ethylene or propylene glycol.

2.5.6 Butterfly Valves

Provide butterfly valves which are threaded lug type suitable for dead-end service and modulation to the fully-closed position, with carbon-steel bodies or with ductile iron bodies in accordance with ASTM A536. Provide butterfly valves with non-corrosive discs, stainless steel shafts supported by bearings, and EPDM seats suitable for temperatures from -20 to +250 degrees F. Provide valves with rated Cv of the Cv at 70 percent (60 degrees) open position. Provide valves meeting FCI 70-2 Class VI leakage rating.

2.5.7 Pressure Independent Control Valves (PICV)

Provide pressure independent control valves which include a regulator valve which maintains the differential pressure across a flow control valve. Pressure independent control valves must accurately control the flow from 0-100 percent full rated flow regardless of changes in the piping pressure and not vary the flow more than plus or minus 5 percent at any given flow control valve position when the PICV differential pressure lies between the manufacturer's stated minimum and maximum. The rated minimum differential pressure for steady flow must not exceed 5 psid across the PICV. Provide either globe or ball type valves meeting the indicated requirements for globe and ball valves. Provide valves with a flow tag listing full rated flow and minimum required pressure drop. Provide valves with factory installed Pressure/Temperature ports ("Pete's Plugs") to measure the pressure drop to determine the valve flow rate.

2.5.8 Duct-Coil and Terminal-Unit-Coil Valves

For duct or terminal-unit coils provide control valves with either [flare-type][screw type] or solder-type ends. Provide flare nuts for each flare-type end valve.

2.6 DAMPERS

2.6.1 Damper Assembly

Provide single damper sections with blades no longer than 48 inches and which are no higher than 72 inches and damper blade width of 8 inches or less. When larger sizes are required, combine damper sections. Provide dampers made of steel, or other materials where indicated and with assembly frames constructed of 0.07 inch minimum thickness stainless steel channels with mitered and welded corners. Steel channel frames constructed of 0.06 inch minimum thickness are acceptable provided the corners are reinforced.

a. Flat blades must be made rigid by folding the edges. Blade-operating linkages must be within the frame so that blade-connecting devices within the same damper section must not be located directly in the air stream.

b. Damper axles must be 1/2 inch minimum, plated steel rods supported in the damper frame by stainless steel or bronze bearings. Blades mounted vertically must be supported by thrust bearings.

c. Provide dampers which do not exceed a pressure drop through the damper of 0.04 inches water gauge at 1000 ft/min in the wide-open position. Provide dampers with frames not less than 2 inch in width. Provide dampers which have been tested in accordance with AMCA 500-D.

2.6.2 Operating Linkages

For operating links external to dampers, such as crank arms, connecting rods, and line shafting for transmitting motion from damper actuators to dampers, provide links able to withstand a load equal to at least 300 percent of the maximum required damper-operating force without deforming. Rod lengths must be adjustable. Links must be brass, bronze, zinc-coated steel, or stainless steel. Working parts of joints and clevises must be brass, bronze, or stainless steel. Adjustments of crank arms must control the open and closed positions of dampers.

2.6.3 Damper Types

2.6.3.1 Flow Control Dampers

Provide parallel-blade or opposed blade type dampers for outside air, return air, relief air, exhaust, face and bypass dampers as indicated on the Damper Schedule. Blades must have interlocking edges. The channel frames of the dampers must be provided with jamb seals to minimize air leakage. Unless otherwise indicated, dampers must meet AMCA 511 Class 1A requirements. Outside air damper seals must be suitable for an operating temperature range of -40 to +167 degrees F. Dampers must be rated at not less than 2000 ft/min air velocity.

2.6.3.2 Mechanical Rooms and Other Utility Space Ventilation Dampers

Provide utility space ventilation dampers as indicated. Unless otherwise

indicated provide AMCA 511 class 3 dampers. Provide dampers rated at not less than 1500 ft/min air velocity.

2.6.3.3 Smoke Dampers

Provide smoke-damper and actuator assemblies which meet the current requirements of NFPA 90A, UL 555, and UL 555S. For combination fire and smoke dampers provide dampers rated for 250 degrees F Class II leakage per UL 555S.

2.7 SENSORS AND INSTRUMENTATION

Unless otherwise specified, provide sensors and instrumentation which incorporate an integral transmitter. Sensors and instrumentation, including their transmitters, must meet the specified accuracy and drift requirements at the input of the connected DDC Hardware's analog-to-digital conversion.

2.7.1 Analog and Binary Transmitters

Provide transmitters which match the characteristics of the sensor. Transmitters providing analog values must produce a linear 4-20 mAdc, 0-10 Vdc signal corresponding to the required operating range and must have zero and span adjustment. Transmitters providing binary values must have dry contacts rated at 1A at 24 Volts AC.

2.7.2 Network Transmitters

Sensors and Instrumentation incorporating an integral network connection are considered DDC Hardware and must meet the DDC Hardware requirements of Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS when used in a Lonworks network, or the requirements of 23 09 23.02 BACNET DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS when used in a BACnet network.

2.7.3 Temperature Sensors

Provide the same sensor type throughout the project. Temperature sensors may be provided without transmitters. Where transmitters are used, the range must be the smallest available from the manufacturer and suitable for the application such that the range encompasses the expected range of temperatures to be measured. The end to end accuracy includes the combined effect of sensitivity, hysteresis, linearity and repeatability between the measured variable and the end user interface (graphic presentation) including transmitters if used.

2.7.3.1 Sensor Accuracy and Stability of Control

2.7.3.1.1 Conditioned Space Temperature

Plus or minus 0.5 degree F over the operating range.

2.7.3.1.2 Unconditioned Space Temperature

a. Plus or minus 1 degree F over the range of 30 to 131 degrees F AND

b. Plus or minus 4 degrees F over the rest of the operating range.

2.7.3.1.3 Duct Temperature

Plus or minus 0.5 degree F

2.7.3.1.4 Outside Air Temperature

a. Plus or minus 2 degrees F over the range of -30 to +130 degrees F AND

b. Plus or minus 1 degree F over the range of 30 to 130 degrees F.

2.7.3.1.5 High Temperature Hot Water

Plus or minus 3.6 degrees F.

2.7.3.1.6 Chilled Water

Plus or minus 0.8 degrees F over the range of 35 to 65 degrees F.

2.7.3.1.7 Dual Temperature Water

Plus or minus 2 degrees F.

2.7.3.1.8 Heating Hot Water

Plus or minus 2 degrees F.

2.7.3.1.9 Condenser Water

Plus or minus 2 degrees F.

2.7.3.2 Transmitter Drift

The maximum allowable transmitter drift: 0.25 degrees F per year.

2.7.3.3 Point Temperature Sensors

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

2.7.3.4 Temperature Sensor Details

2.7.3.4.1 Room Type

Provide the sensing element components within a decorative protective cover suitable for surrounding decor.

2.7.3.4.2 Duct Probe Type

Ensure the probe is long enough to properly sense the air stream temperature.

2.7.3.4.3 Duct Averaging Type

Continuous averaging sensors must be one foot in length for each 1 square foot of duct cross-sectional area, and a minimum length of 5 feet.

2.7.3.4.4 Pipe Immersion Type

Provide minimum 3 inch immersion. Provide each sensor with a corresponding

pipe-mounted sensor well, unless indicated otherwise. Sensor wells must be stainless steel when used in steel piping, and brass when used in copper piping.

2.7.3.4.5 Outside Air Type

Provide the sensing element rated for outdoor use

2.7.4 Relative Humidity Sensor

Relative humidity sensors must 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 must include removable protective membrane filters. Where required for exterior installation, sensors must be capable of surviving below freezing temperatures and direct contact with moisture without affecting sensor calibration. When used indoors, the sensor must be capable of being exposed to a condensing air stream (100 percent relative humidity) with no adverse effect to the sensor's calibration or other harm to the instrument. The sensor must be of the wall-mounted or duct-mounted type, as required by the application, and must be provided with any required accessories. Sensors used in duct high-limit applications must have a bulk polymer resistive sensing element. Duct-mounted sensors must be provided with a duct probe designed to protect the sensing element from dust accumulation and mechanical damage. Relative humidity (RH) sensors must measure relative humidity over a range of 0 percent to 100 percent with an accuracy of plus or minus 3 percent. RH sensors must function over a temperature range of 40 to 135 degrees F and must not drift more than 1 percent per year.

2.7.5 Carbon Dioxide (CO2) Sensors

Provide photometric type CO2 sensors with integral transducers and linear output. Carbon dioxide (CO2) sensors must measure CO2 concentrations between 0 to 2000 parts per million (ppm) using non-dispersive infrared (NDIR) technology with an accuracy of plus or minus 50 ppm and a maximum response time of 1 minute. The sensor must be rated for operation at ambient air temperatures within the range of 32 to 122 degrees F and relative humidity within the range of 20 to 95 percent (non-condensing). The sensor must have a maximum drift of 2 percent per year. The sensor chamber must be manufactured with a non-corrosive material that does not affect carbon dioxide sample concentration. Duct mounted sensors must be provided with a duct probe designed to protect the sensing element from dust accumulation and mechanical damage. The sensor must have a calibration interval no less than 5 years.

2.7.6 Differential Pressure Instrumentation

2.7.6.1 Differential Pressure Sensors

Provide Differential Pressure Sensors with ranges as indicated or as required for the application. Pressure sensor ranges must not exceed the high end range indicated on the Points Schedule by more than 50 percent. The over pressure rating must be a minimum of 150 percent of the highest design pressure of either input to the sensor. The accuracy must be plus or minus 1 percent of full scale. The sensor must have a maximum drift of 2 percent per year

2.7.6.2 Differential Pressure Switch

Provide differential pressure switches with a user-adjustable setpoint which are sized for the application such that the setpoint is between 25 percent and 75 percent of the full range. The over pressure rating must be a minimum of 150 percent of the highest design pressure of either input to the sensor. The switch must have two sets of contacts and each contact must have a rating greater than its connected load. Contacts must open or close upon rise of pressure above the setpoint or drop of pressure below the setpoint as indicated.

2.7.7 Flow Sensors

2.7.7.1 Airflow Measurement Array (AFMA)

2.7.7.1.1 Airflow Straightener

Provide AFMAs which contain an airflow straightener if required by the AFMA manufacturer's published installation instructions. The straightener must be contained inside a flanged sheet metal casing, with the AFMA located as specified according to the published recommendation of the AFMA manufacturer. In the absence of published documentation, provide airflow straighteners if there is any duct obstruction within 5 duct diameters upstream of the AFMA. Air-flow straighteners, where required, must be constructed of 0.125 inch aluminum honeycomb and the depth of the straightener must not be less than 1.5 inches.

2.7.7.1.2 Resistance to Airflow

The resistance to air flow through the AFMA, including the airflow straightener must not exceed 0.085 inch water gauge at an airflow of 2,000 fpm. AFMA construction must be suitable for operation at airflows of up to 5000 fpm over a temperature range of 40 to 120 degrees F.

2.7.7.1.3 Outside Air Temperature

In outside air measurement or in low-temperature air delivery applications, provide an AFMA certified by the manufacturer to be accurate as specified over a temperature range of -20 to +120 degrees F .

2.7.7.1.4 Pitot Tube AFMA

Each Pitot Tube AFMA must contain an array of velocity sensing elements. The velocity sensing elements must be of the multiple pitot tube type with averaging manifolds. The sensing elements must be distributed across the duct cross section in the quantity and pattern specified or recommended by the published installation instructions of the AFMA manufacturer.

a. Pitot Tube AFMAs for use in airflows over 600 fpm must have an accuracy of plus or minus 5 percent over a range of 500 to 2500 fpm.

b. Pitot Tube AFMAs for use in airflows under 600 fpm must have an accuracy of plus or minus 5 percent over a range of 125 to 2500 fpm.

2.7.7.1.5 Electronic AFMA

Each electronic AFMA must consist of an array of velocity sensing elements of the resistance temperature detector (RTD) or thermistor type. The sensing elements must be distributed across the duct cross section in the

quantity and pattern specified or recommended by the published application data of the AFMA manufacturer. Electronic AFMAs must have an accuracy of plus or minus 5 percent over a range of 125 to 5,000 fpm and the output must be temperature compensated over a range of 32 to 212 degrees F.

2.7.7.1.6 Fan Inlet Measurement Devices

Fan inlet measurement devices cannot be used unless indicated on the drawings or schedules.

2.7.7.2 Insertion Magnetic Flow Meter

Provide insertion type magnetic flowmeters with all installation hardware necessary to enable insertion and removal of the meter without system shutdown. All parts must meet or exceed the pressure classification of the pipe system it is installed in. Flowmeter accuracy must be no greater than plus or minus 1 percent of rate from 2 to 20 feet/sec. Wetted material parts must be 300 series stainless steel. The flowmeter must include either dry contact pulse outputs, 4-20mA, 0-10Vdc or 0-5Vdc outputs.

2.7.7.3 Flow Switch

Flow switch must have a repetitive accuracy of plus or minus 10 percent of actual flow setting. Switch actuation must be adjustable over the operating flow range, and must be sized for the application such that the setpoint is between 25 percent and 75 percent of the full range.. The switch must have Form C snap-action contacts, rated for the application. The flow switch must 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 must be rated for use in corrosive environments encountered.

2.7.8 Electric Metering

2.7.8.1 Meter Connection Wiring

Meter connection wiring must be 12 AWG switchboard or panel wiring with XHHW insulation, or equivalent.

2.7.8.2 Potential Transformer (PT)

Provide potential voltage transformers sized for the application conforming to IEEE C57.13 and meeting the following requirements:

a. Type: Dry type, of two-winding construction.

b. Weather: Outdoor or Indoor rated for the application.

c. Frequency: Nominal 60Hz.

d. Accuracy: Plus or minus 0.3 percent at 60Hz, and as needed to meet the overall meter accuracy requirements as specified.

e. Insulation Class: Minimum 10kV Potential Basic Insulation Level (BIL). Potential Transformers located inside switchgear must have an insulation class and BIL rating that equals or exceeds the ratings of the associated switchgear.

2.7.8.3 Current Transformer

Provide current transformers (CTs) which are certified per IEEE C57.13 and which meet the following minimum requirements:

2.7.8.3.1 Current Transformer (CT) Insulation Class

Minimum 10 KV Basic Insulation Level (BIL). Current Transformers located inside switchgear must have an insulation class and BIL rating that equals or exceeds the ratings of the associated switchgear.

2.7.8.3.2 Current Transformer (CT) Accuracy

Current Transformer must have a IEEE C57.13 Accuracy Class of 1.2 or better, and as needed to meet the overall meter accuracy requirements as specified.

2.7.8.3.3 Current Transformer (CT) Secondary Side Output

Provide CTs which do not exceed 5 amps on the secondary side.

2.7.8.3.4 Current Transformer (CT) Size

Provide CTs sized for the amperage range to be measured. Size CTs such that the meter secondary side of the transformer outputs current to achieve a minimum of plus or minus 0.6 percent accuracy when measured between 10 percent and 90 percent of full amperage range, and accuracy as needed to meet the overall meter accuracy requirements as specified.

2.7.8.3.5 Current Transformer (CT) Core Type

Provide either busbar split core CTs or solid core bracket mount CTs for retrofit applications. For new construction, use only solid core bracket mount CTs

2.7.8.3.6 Multi-Ratio Current Transformer

Current Transformers must be multi-ratio current transformers where indicated and shown. Multi-ratio current transformers must have a top range equal to or greater than the actual load and must conform to IEEE C57.13.

2.7.8.4 Current Sensors

Provide current sensors which meet the requirements of Current Transformers except which provide a voltage output proportional to the sensed current instead of a current secondary side. Current Sensors must be sized properly for the application and provide voltage ranges compatible with the device reading the voltage. Select current sensors to provide a minimum accuracy of plus or minus 0.6 percent when measured between 10 percent and 90 percent of full amperage range or better as required to meet the overall meter accuracy requirements as specified.

2.7.8.5 Electric Meters

Electrical Meters communicating using CEA-709.1-D must meet the requirements for DDC Hardware in Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS. Provide microprocessor-based electric meters that do not have the ability to

disconnect the metered load unless explicitly specified and meeting the requirements of ANSI C12.1 and the following requirements:

2.7.8.5.1 General

Provide meters designed for multifunction electrical measurement on either single or 3 phase power systems and supporting the power configuration at the installed location: single phase (120 or 240 volt); 3 Phase, 3 Wire Delta; 3 Phase, 4 Wire Delta; 3 Phase, 4 Wire Wye.

2.7.8.5.2 Meter Accuracy

Provide meters with accuracy meeting the requirements of ANSI C12.20 Class 0.5 or better as required to meet the overall meter accuracy requirements as specified.

2.7.8.5.3 Certifications and Approvals

Provide meters that:

a. are UL 508 listed

b. are Canadian Standards Association (CSA) approved

c. have CE marking.

2.7.8.5.4 Voltage Requirements

a. Meter must accept independent voltage inputs from each phase. Meter must be auto-ranging over the full range of input voltages.

b. Voltage input must be optically isolated to 2500 volts DC from signal and communications outputs. Components must meet or exceed IEEE C37.90.1 (Surge Withstand Capability).

2.7.8.5.5 Current Requirements

a. Meter must accept independent current inputs from each phase, or independent voltage inputs from current sensors for each phase.

b. For meters used with external current transformers, the meter must accept current input from 5A secondary current transformers.

c. Current inputs must have a continuous rating in accordance with IEEE C57.13.

[2.7.8.5.6 Pulse Input

Provide meters with [2][____] additional configurable pulse inputs to be used for totalizing other utilities.

]2.7.8.5.7 Connections

Meters must have ring lugs for all meter connections.

2.7.8.5.8 Meter Output

Provide meter output by either LonWorks communication protocol or pulse output as specified.

2.7.8.5.8.1 Communication Protocol

Provide LonWorks meters communicating via CEA-709.1-D, meeting the requirements for DDC Hardware in Section 23 09 23.01 and provide the indicated values as network variables.

2.7.8.5.8.2 Pulse Output

Provide a pulse output with a maximum pulse rate of 20 pulses per second and duration of at least 30 ms.

[2.7.8.5.9 Meter Display and Interface

Provide meters designed for multifunction electrical measurement on either single or 3 phase power systems and supporting the power configuration at the installed location: single phase (120 or 240 volt); 3 Phase, 3 Wire Delta; 3 Phase, 4 Wire Delta; 3 Phase, 4 Wire Wye.

2.7.8.5.10 Trending

Provide meters with built-in trending capability for the trending of total energy used, and capacity for no less than 8,640 data entries (90 days at a 15 minute trend interval).

]2.7.8.5.11 Meter Configuration

Provide meters which are fully configurable for the application including but not limited to being configurable for units, demand interval, peak demand reset period, and trending rate.

2.7.8.5.12 Meter Configuration Software

All software required to configure the meter must run on a standard computer running the Windows operating system. License Meter Configuration Software to the project site and submit copies of the software as indicated.

2.7.9 Gas Metering

2.7.9.1 Gas Pipe, Fittings, Valves, and Regulators

Conform to NFPA 54 and with requirements specified herein.

2.7.9.2 Pipe and Fittings

2.7.9.2.1 Aboveground and Within Buildings and Vaults

2.7.9.2.1.1 Pipe

Black steel in accordance with ASTM A53/A53M, Schedule [40] [80], threaded ends for sizes 2 inches and smaller; otherwise, plain end beveled for butt welding.

2.7.9.2.1.2 Threaded Fittings

ASME B16.3, black malleable iron

2.7.9.2.1.3 Socket-Welding Fittings

ASME B16.11, forged steel

2.7.9.2.1.4 Butt-Welding Fittings

ASME B16.9, with backing rings of compatible material

2.7.9.2.1.5 Unions

ASME B16.39, black malleable iron. Provide dielectric unions where cathodic protection is provided on steel gas mains and/or service lines.

2.7.9.2.1.6 Flanges and Flanged Fittings

ASME B16.5 steel flanges or convoluted steel flanges conforming to ASME BPVC SEC VIII D1. Flange faces shall have integral grooves of rectangular cross-sections which afford containment for self-energizing gasket material.

2.7.9.2.2 Risers

Manufacturer's standard riser, transition from plastic to steel pipe with 7 to 12 mil thick epoxy coating. Use swaged gas-tight construction with O-ring seals, metal insert, and protective sleeve. Provide [remote bolt-on or bracket] [or] [wall-mounted] riser supports [as indicated].

2.7.9.2.3 Transition Fittings

[2.7.9.2.3.1 Steel to Plastic (PE)

As specified for "riser" except designed for steel-to-plastic with tapping tee or sleeve. Coat or wrap exposed steel pipe with heavy plastic coating.

2.7.9.2.3.2 Plastic to Plastic

[Manufacturer's standard bolt-on (PVC to PE) plastic tapping saddle tee, UL listed for gas service, rated for 100 psig, and O-ring seals.] [Manufacturer's standard slip-on PE mechanical coupling, molded, with stainless-steel ring support, O-ring seals, and rated for 150 psig gas service.] [Manufacturer's standard fused tapping (PE-to-PE) tee assembly with shut-off feature.]

]2.7.9.3 Valves, Aboveground

[Provide lockable valves where indicated.]

2.7.9.3.1 Shutoff Valves, Sizes Larger Than 2 Inches

[[Cast-iron] [or] [steel] body ball valve with flanged ends in accordance with ASME B16.38. Provide PTFE seats.] [Cast-iron body plug valve in accordance with ASME B16.38, nonlubricated, wedge-mechanism or tapered lift plug, and flanged ends.]

2.7.9.3.2 Shutoff Valves, Sizes 2 Inches and Smaller

[[Bronze] [Steel] body ball valve in accordance with ASME B16.33, full port pattern, reinforced PTFE seals, threaded ends, and PTFE seat.] [[Bronze] [Steel] body plug valve in accordance with ASME B16.33, straightway, taper

plug, regular pattern with a port opening at least equal to the internal pipe area or round port full bore pattern, non-lubricated, PTFE packing, flat or square head stem with lever operator, 125 psig rating, threaded ends.]

2.7.9.3.3 Pressure Regulator

Self-contained with spring-loaded diaphragm pressure regulator, psig to inches water reduction, pressure operating range as required for the pressure reduction indicated, volume capacity not less than indicated, and threaded ends for sizes 2 inches and smaller, otherwise flanged.

2.7.9.4 Hangers and Supports

MSS SP-58, as required by MSS SP-69.

2.7.9.5 Welding Filler Metal

ASME B31.8.

2.7.9.6 Pipe-Thread Tape

Antiseize and sealant tape of polytetrafluoroethylene (PTFE).

2.7.9.7 Bolting (Bolts and Nuts)

Stainless steel bolting; ASTM A193/A193M, Grade B8M or B8MA, Type 316, for bolts; and ASTM A194/A194M, Grade 8M, Type 316, for nuts. Dimensions of bolts, studs, and nuts shall conform with ASME B18.2.1 and ASME B18.2.2 with coarse threads conforming to ASME B1.1, with Class 2A fit for bolts and studs and Class 2B fit for nuts. Bolts or bolt-studs shall extend through the nuts and may have reduced shanks of a diameter not less than the diameter at root of threads. Bolts shall have American Standard regular square or heavy hexagon heads; nuts shall be American Standard heavy semifinished hexagonal.

2.7.9.8 Gaskets

Fluorinated elastomer, compatible with flange faces.

2.7.9.9 Identification for Aboveground Piping (Interior)

MIL-STD-101 for legends and type and size of characters. For pipes 3/4 inch OD and larger, provide printed legends to identify contents of pipes and arrows to show direction of flow. Color code label backgrounds to signify levels of hazard. Make labels of plastic sheet with pressure-sensitive adhesive suitable for the intended application. For pipes smaller than 3/4 inch OD, provide brass identification tags 1-1/2 inches in diameter with legends in depressed black-filled characters.

2.7.9.10 Gas Meters

Gas flow meter must be diaphragm or bellows type (gas positive displacement meters) for flows up to 2500 SCFH and axial flow turbine type for flows above 2500 SCFH, designed specifically for natural gas supply metering, and rated for the pressure, temperature, and flow rates of the installation. Meter must have a minimum turndown ratio of 10 to 1 with an accuracy of plus or minus 1 percent of actual flow rate. The meter index must include a direct reading mechanical totalizing register and electrical impulse dry

contact output for remote monitoring. The electrical impulse dry contact output must not require field adjustment or calibration. The electrical impulse dry contact output must have a minimum resolution of 100 cubic feet of gas per pulse and must not exceed 15 pulses per second at the design flow. Minimum service life shall be 30,000,000 cycles.

2.7.9.10.1 Utility Monitoring and Control (UMCS) Interface

Gas meters shall interface to the UMCS via the pulse output. Meters shall not require power to function and deliver data. Output signal shall be either a voltage or amperage signal with can be converted to a flow rate specification.

2.7.10 Water Metering

All water meters provided shall be manufactured by a registered ISO 9001 quality standard facility. All specifications shall meet or exceed the latest revision of AWWA C702.

2.7.10.1 Physical and Common Requirements

a. Metering system components shall be installed according to the Metering System Schedule shown [in this specification][on the drawings].

b. Meter shall be rated for use at temperatures from 33 degrees Fahrenheit to 80 [150] degrees Fahrenheit.

c. Surge withstand shall conform to IEEE C37.90.1.

d. All water meters provided shall be manufactured by a registered ISO 9001 quality standard facility. All specifications shall meet or exceed the latest revision of AWWA C702.

2.7.10.2 Cold -Water Meters - Displacement Type 5/8-inch x 3/4-inch, 1-inch, 1-1/2-inch, 2-inch Size

Small meters shall be as follows or shall be approved equivalents: Positive displacement meters provided hereunder shall be full-size nutating-disc, magnetic drive, sealed register, cold water meters and shall fully comply with the requirements of AWWA C700 unless otherwise specified hereunder. No oscillating-piston style meters will be accepted.

a. Materials

(1) Cases 5/8-Inch x 3/4-Inch, 1-Inch, 1-1/2-Inch: The main case of the meter shall be cast all-bronze, bottom caps shall be cast all-bronze, excepting register boxes and register box lids which shall be bronze or an approved plastic material as specified in AWWA C700. Meter cases constructed of plastic will not be accepted.

(2) Cases 2-Inch: The main case of the meter shall be cast all-bronze, including bottom caps, excepting register boxes and register box lids which shall be bronze or an approved plastic material. Meter cases constructed of plastic will not be accepted.

(3) Register Box Rings and Lids: Register box rings and lids shall be made of a copper alloy containing not less than 57 percent copper, or all bronze, or an approved suitable synthetic polymer.

(4) Measuring Chambers: Measuring chambers shall be made of a copper alloy containing not less than 85 percent copper and suitable amounts of tin, lead, and zinc or of a suitable synthetic polymer.

(5) Discs: Discs shall be made of vulcanized hard rubber or a suitable synthetic polymer with specific gravity approximately equal to that of water. They shall have sufficient dimensional stability to retain operating clearances at working temperatures of up to +80 degrees Fahrenheit and not warp or deform when exposed to operating temperatures of +98 degrees Fahrenheit.

(6) Measuring Chamber Diaphragms: Measuring chamber diaphragms shall be made of phosphor bronze, stainless steel, hard rubber, or a suitable synthetic polymer.

(7) Spindles, Thrust Rollers, and Thrust-Roller Bearing Plates: Spindles, thrust rollers and thrust-roller bearing plates shall be made of phosphor bronze, stainless steel, hard rubber, or a suitable synthetic polymer.

(8) Intermediate Gear Trains: Frames, gears, and pinions shall be made of a suitable copper alloy, other suitable non-corrosive metals, or other suitable materials.

(9) External Fasteners (Casing Bolts, Studs, Nuts, Screws, and Washers): External fasteners shall be made of a copper alloy containing not less than 57 percent copper, stainless steel, or steel treated to resist corrosion by a process approved by the Government. Fasteners for no-pressure assemblies may be made of a suitable synthetic polymer. All external case closures, such as rings, clamps, screws, bolts, cap bolts, nuts and washers, shall be designed for easy removal following lengthy service.

(10) Water Meter Coupling - 5/8-Inch x 3/4-Inch: A water coupling shall be composed of one meter coupling nut, one meter coupling tail piece (straight), and one rubber-type washer for meter coupling. The meter coupling tailpiece and nut shall be a copper alloy containing not less than 57 percent copper. The coupling nut shall have internal straight pipe threads conforming to ASME B1.20.1. Pitch diameter shall be that shown on AWWA C700. The coupling tailpiece shall have external taper pipe threads conforming to ASME B1.20.1 and an internal diameter approximately equal to the nominal thread size of the tailpiece. Lengths and thread sizes shall be those listed in AWWA C700. One water meter coupling and one additional rubber-type washer for meter coupling (total of two rubber-type washers) shall be provided with each meter.

(11) Spindles, Thrust Rollers, and Thrust-Roller Bearing Plates: Spindles, thrust rollers and thrust-roller bearing plates shall be made of phosphor bronze, stainless steel, hard rubber, or a suitable synthetic polymer.

b. General Design

(1) Pressure Requirements: Meters supplied under this specification shall operate without leakage or damage to any part at a working pressure of 150 psi.

(2) Accessibility: All 1-1/2-inch and 2-inch meters shall be designed for easy removal of all interior parts without disturbing the connections to the pipeline.

c. Detail Design

(1) Cases: All meters shall have an outer case with separate, removable measuring chambers. Cases shall not be repaired in any manner. The inlet and outlet shall have a common axis. A meter case shall include the top case and bottom case, or main case and bottom plate, whichever is applicable. Connection flanges shall be parallel.

(2) Connections: Meter case connections for 5/8-inch x 3/4-inch and 1-inch meters shall be meter casing spuds on both ends. Spuds shall have external straight threads conforming to ASME B1.20.1 as far as the specifications apply. Pitch diameters shall be those shown in AWWA C700. Main case connections for 1-1/2-inch and 2-inch meters shall be oval-flanged on both ends. Flanges shall be faced and drilled and shall be the oval type. The drilling shall be on a horizontal axis; the number of bolt holes and the diameters of the bolt holes and bolt circle shall be as listed in AWWA C700. Two oval companion flanges, gaskets, bolts and nuts shall be provided with each meter. Companion flanges shall be faced, drilled, and tapped in conformance with ASME B1.20.1. Dimensions shall be those listed in AWWA C700. Companion flanges shall be cast iron.

(3) Registers: Registers shall be straight-reading and shall read in 1000-gallon increments. The register shall be equipped with a center-sweep test hand with the test circle located on the periphery of the register and graduated in 100 equal parts, with each tenth graduation being numbered. Register construction shall conform to all applicable requirements of AWWA C700.

(4) Register Boxes: The lid shall be recessed and shall overlap the register box in order to protect the lens. The lens shall be held securely in place.

(5) Intermediate Gear Trains: Intermediate gear trains may be mounted on the measuring chamber, in the upper main casing, or when not exposed to water, combined with or adjacent to the register gearing.

(a) Oil-enclosed type - Gear trains exposed to water shall be of the oil-enclosed type, shall have a separate housing or form housing with the main casing or measuring chamber, and shall operate in a suitable lubricant.

(b) Magnetic coupled drives - When intermediate gear trains are located in the water compartment of the meter, the revolutions of the train output spindles shall be transmitted to the registers by means of magnetic couplings through the meter cases. When the intermediate gear trains are located in the register compartments, the disc nutations shall be transmitted by magnetic couplings.

(6) Measuring Chambers: The measuring chambers shall be self-contained units, smoothly finished, firmly seated, and easily

removed from the main cases, and shall not be cast as part of the main cases. The measuring chambers shall be so secured in the main cases that the accuracy of the meter will not be affected by any distortion of the cases that might occur when operating with a pressure less than 150 psi.

(7) Discs: Discs shall be smoothly finished, disc plated, whether flat or conical, shall be either reinforced or equipped with thrust rollers. Discs may be one piece or composed of a plate with two half balls. The disc spindles shall be fastened securely. The disc nutations shall not exceed the quantities listed in AWWA C700.

(8) Strainers: All meters shall be provided with strainer screens installed in the meter. Strainer screens shall be rigid, fit snugly, be easy to remove, and have an effective straining area at least double that of the main case inlet.

(9) Seal Wire Holes: Register box screws and inlet and outlet coupling nuts, if provided, shall be drilled for seal wires. Seal wire holes shall not be less than 3/32 inch in diameter.

(10) Registration Accuracy: Meters shall meet the following requirements for accuracy with water of a temperature of less than +80 degrees Fahrenheit.

(a) Normal Flow Limits - At any rate of flow within the normal test flow limits specified on AWWA C700, the meter shall not register less than 98.5 percent and not more than 101.5 percent of the water that actually passes through it.

(b) Minimum Test Flow - At the minimum test flow rate specified in AWWA C700, the meter shall not register less than 95 percent and not more than 101 percent of the water that actually passes through it.

(11) Markings: The size, model, and direction of flow through the meter shall be marked permanently on the outer case of all meters. All meters shall have the manufacturer's serial numbers stamped on the meter main case and top of the reading lid.

(12) Register Boxes: The name of the manufacturer shall be marked permanently on the lid of the register box. The serial number of the meter shall be imprinted on the lid and the main case.

2.7.10.3 Cold-Water Meters - Compound Type 2-Inch, 3-Inch, 4-Inch, and 6-Inch Size

Compound meters shall consist of a combination of a main-line meter of the turbine type for measuring high rates of flow and a meter of appropriate size for measuring low rates of flow. The compound meter shall have an automatic valve mechanism for diverting low rates of flow through the bypass meter. Both metering devices with registers shall be contained in the same case. The operating and physical characteristics shall conform to those specified within AWWA C702.

a. Materials

(1) Cases: The main case of the meter shall be made of a copper alloy

containing not less than 75 percent copper.

(2) Register Box Rings and Lids: Register box rings and lids shall be made of a cast copper alloy containing not less than 75 percent copper, forged or die-cast copper alloy containing not less than 57 percent copper or a suitable synthetic polymer.

(3) Measuring Cages or Chambers: Measuring cages or chambers shall be made of a copper alloy containing not less than 84 percent copper and suitable amounts of tin, lead, and zinc or of a suitable synthetic polymer.

(4) Measuring Turbines, Pistons and Discs: Turbines, pistons and discs shall be made of vulcanized hard rubber or a suitable synthetic polymer with specific gravity approximately equal to that of water. They shall have sufficient dimensional stability to retain operating clearances at working temperatures of up to +80 degrees Centigrade and not warp or deform when exposed to operating temperatures of +98 degrees Fahrenheit.

(5) Disc and Turbine Spindles: Measuring chamber spindles shall be made of phosphor bronze, stainless steel, ceramic, or suitable synthetic polymer.

(6) Intermediate Gear Trains: Frames, gears and pinions of intermediate gear trains exposed to water shall be made of copper alloy containing not less than 85 percent copper and suitable amounts of tin, lead, and zinc, or suitable synthetic polymer. When not exposed to water, intermediate gear trains may be made of a suitable synthetic polymer.

(7) External Fasteners (Casing Bolts, Studs, Nuts, Screws, and Washers): External fasteners shall be made of a copper alloy containing not less than 57 percent copper, stainless steel, or steel treated to resist corrosion by a process approved by the Government. Fasteners for no-pressure assemblies may be made of a suitable synthetic polymer. All external case closures, such as rings, clamps, screws, bolts, cap bolts, nuts and washers, shall be designed for easy removal following lengthy service.

(8) Companion Flanges: Companion flanges shall be made of cast iron

(9) Automatic Valves: The valve weights shall be lead, or a copper alloy containing not less than 75 percent copper, or a copper alloy shell loaded with lead. The valve and supplemental hinge pins or spindles shall be a copper alloy containing not less than 75 percent copper, or stainless steel, and all valve and supplemental weight hinge bearings shall be bushed with hard rubber or bronze or other suitable bushing material. If the valve contains a clapper, it shall be faced with a removable semi-hard seat. Valve seats shall be made of a copper alloy containing not less than 75 percent copper and suitable amounts of tin, lead, and zinc.

b. General Design

(1) Pressure Requirements: Meters supplied under this specification shall operate without leakage or damage to any part at a working pressure of 150 psi.

(2) Accessibility: All compound meters shall be designed for easy removal of all interior parts without disturbing the connections to the pipeline.

(3) Registration Accuracy: Meters shall meet the following requirements for accuracy with water of a temperature of less than +80 degrees Fahrenheit.

(a) Normal Flow Limits - The meter shall not register less than 97 percent and not more than 103 percent of the water actually passed through it at any rate of flow within the normal test flow limits specified in AWWA C702, except in the registration of flows within the changeover from bypass meter to main meter.

(b) Changeover Flow - The beginning of the changeover is when the accuracy of registration falls below 97 percent due to the operation of the automatic valve mechanism, and the end of changeover is when accuracy of registration again reaches 97 percent. The registration of these changeover rates of flow shall not be less than 90 percent and not more than 103 percent. The difference in the rate of flow at the beginning and at the end of the changeover shall not exceed the figures listed in AWWA C702.

(c) Minimum Test Flow - There shall not be less than 95 percent of actual flow recorded when a test is made at the minimum test flow shown in AWWA C702.

(4) Markings: The size, model, and direction of flow through the meter shall be cast or stamped in the outer case of all meters.

(a) Register Boxes - The name of the manufacturer shall be permanently impressed on the lid of the register box. The serial number of the meter shall be imprinted on the lid.

c. Detail Design

(1) Main Case: All meters shall have an outer case with separate, removable measuring chambers. Cases shall not be repaired in any manner. The inlet and outlet shall have a common axis. Connection flanges shall be parallel.

(2) External Case Screw, Bolts, Nuts and Washers: All external screws, bolts, cap bolts, nuts and washers shall be designed for easy removal after lengthy service.

(3) Main Case Connections: All main case connections shall be flanged. The bolt holes shall comply with AWWA C702.

(a) 2-Inch Meters - The flanges for 2-inch meters shall be oval. The drilling of oval flanges shall be on the horizontal axis.

(b) Meters Larger than 2-Inch - The flanges for 3-inch, 4-inch, and 6-inch meters shall be the round type, faced and drilled, and shall conform to ASME B16.1 for bronze pipe flange, Class 125.

(4) Companion Flanges: Companion flanges of the same size and type as the meter flanges shall be provided, and gaskets, nuts, and bolts shall be provided. Round companion flanges shall be faced,

drilled, and tapped in accordance with ASME B1.20.1 and shall conform to ASME B16.1 for cast-iron pipe flange, Class 125. All companion flanges shall comply with AWWA C702 for drilling, diameter, and thickness specifications.

(5) Tapped Bosses: All meters shall be provided with tapped bosses in the top of the case near the outlet for field testing purposes.

(6) Registers: Registers shall be straight reading and shall read in cubic feet (cu.ft.). Except for those instances when test conditions require the use of a different register, the register provided with the meter shall be the same register that was on the meter when it was tested for accuracy. The register lock and side gears shall be fastened securely to the number wheel discs and hubs. The tumbler pins shall mesh accurately at the turnover points with the lock and side gears of the adjacent number wheels. Both main and pinion shafts shall be so secured in the register frame and/or register plates that they cannot get out of position. The pinion shaft shall be so designed that there is no possibility of its bending and allowing the pinion to skip the turnover point. The numerals on the number wheels shall not be less than 3/16 inch in height and should be readable at a 45-degree angle from vertical. Registers that are hermetically sealed shall have gears and pinion which shall run free on fixed shafts or be fixed on shafts that run free in the register frame and/or register plates and shall be constructed so that they cannot be unmeshed. The registers shall have a center-sweep test hand with a test circle located on the periphery of the register and graduated in 100 equal parts, each tenth graduation numbered. The maximum quantity indicated by a single revolution of the test hand and the minimum capacity of the register shall be as listed in AWWA C702. The maximum indication on the test circle and the minimum register capacity of the bypass unit shall be in accordance with the approved AWWA Standard for the type of meter used as the bypass unit.

(a) Coordinator Registers - The meter may be equipped with a coordinator so that the readings of both sections can record on a single register. The register construction shall conform to previously mentioned requirements, and the maximum quantity indicated by a single revolution of the test hand and the minimum capacity of the register shall conform to AWWA C702.

(7) Register Boxes: The lid shall be recessed and shall overlap the register box to protect the lens.

(8) Intermediate Gear Trains: Intermediate gear trains may be mounted on the measuring chamber or cage or in the main casings. When not exposed to water, they may also be combined with or adjacent to the register gearing. Gear trains exposed to water shall be the oil-enclosed type, shall have separate housings or shall form housings with the main casings or measuring chambers, and shall operate in a suitable lubricant. Gear trains made of non-corrosive metals or synthetic polymers may be exposed to water.

(9) Measuring Chambers or Cages: The main-line section chambers or cages shall be self-contained units firmly seated and easily detached and removed from the main case. Chambers or cages with turbines that have revolving spindles shall have removable

bearings for such spindles. Chambers or cages with stationary spindles on which the turbines revolve shall provide rigid, centrally located fastenings for the spindles. The spindles shall be removable. The main-line section chambers or cages shall be interchangeable in all meters of the same size, make, and model.

(a) Bypass Chamber - The bypass chamber shall be a type covered by an approved AWWA Standard. The chamber shall be a self-contained unit, firmly seated and easily removed from the case, and shall not be cast as part of the outer case. The chamber shall be secured in position in the outer case so that any slight distortion of the case which might occur under 150 psi pressure will not affect the accuracy of the meter.

(10) Measuring Turbines and Discs: Measuring turbines that have revolving spindles shall rotate on spindles supported by bushings or replaceable bearings. Turbines that rotate on stationary spindles shall also have bushings or replaceable bearings. The plates of disc pistons, whether flat or conical, shall have metal reinforcements or shall be equipped with thrust rollers.

(11) Magnetic Coupled Drives: When intermediate gear trains are located in the water compartment of the main or bypass section of the meter, the revolutions of the train output spindles shall be transmitted to the registers by means of magnetic couplings through the meter case. When intermediate gear trains are located in the register compartments, the revolutions shall be transmitted by magnetic coupling.

(12) Automatic Valves: The automatic valve shall be of a type suitable for such purpose. It shall close by force. The weight of the valve and any supplemental force imposed on it shall offer sufficient resistance to the incoming water to divert all small rates of flow through the bypass meter until such time as the rate of flow through the meter is great enough to ensure efficient operation of the main measuring section. Valve hinge pins or spindles shall be bushed. Valve sets shall be bronze or other corrosion-resistant material, shall have a satisfactory width of face, and shall be held firmly in place. A clapper or swing-type valve shall be provided with a removable semi-hard seat.

(13) Bypass Meter: The physical and operating characteristics and dimensions of the bypass meter shall be in accordance with the approved AWWA Standard for the type of meter used as the bypass.

(14) Strainers: Strainers, if provided, shall be rigid, shall be easily removed and shall have an effective straining area at least double that of the water main-case inlet.

(15) Seal Wire Holes: Register box screws shall be drilled for seal wires. Seal wire holes shall be not less than 3/32 inch in diameter.

2.7.10.4 Cold-Water Meter - Turbine Type 2-Inch Size

Turbine meters provided hereunder shall be Class II, in-line, horizontal-axis, high-velocity type and shall fully conform to the requirements of AWWA C701, except as otherwise specified herein. The 2-inch turbine meter shall have oval flanged ends and shall be supplied

with one companion flange, gaskets, and with bolts and nuts as specified herein.

a. Materials

(1) Cases: All turbine main cases shall be bronze. No exceptions will be allowed.

(2) Register Box Rings and Lids: Register box rings and lids shall be made of a cast copper alloy containing not less than 75 percent copper, forged or die-cast copper alloy containing not less than 57 percent copper or a suitable synthetic polymer.

(3) Measuring Cages or Chambers: Measuring cages or chambers shall be made of a copper alloy containing not less than 84 percent copper and suitable amounts of tin, lead, and zinc or of a suitable synthetic polymer.

(4) Measuring Turbines, Pistons and Discs: Turbines, pistons and discs shall be made of vulcanized hard rubber or a suitable synthetic polymer with specific gravity approximately equal to that of water. They shall have sufficient dimensional stability to retain operating clearances at working temperatures of up to +80 degrees Fahrenheit and not warp or deform when exposed to operating temperatures of +98 degrees Fahrenheit

(5) Disc and Turbine Spindles: Measuring chamber spindles shall be made of phosphor bronze, stainless steel, ceramic, or suitable synthetic polymer.

(6) Intermediate Gear Trains: Frames, gears and pinions of intermediate gear trains exposed to water shall be made of copper alloy containing not less than 85 percent copper and suitable amounts of tin, lead, and zinc, or suitable synthetic polymer. When not exposed to water, intermediate gear trains may be made of a suitable synthetic polymer.

(7) External Fasteners: (casing bolts, studs, nuts, screws, and washers). External fasteners shall be made of a copper alloy containing not less than 57 percent copper, stainless steel, or steel treated to resist corrosion by a process to be approved by the Government. Fasteners for no-pressure assemblies may be made of a suitable synthetic polymer. All external case closures, such as rings, clamps, screws, bolts, cap bolts, nuts and washers, shall be designed for easy removal following lengthy service.

(8) Companion Flanges: Companion flanges shall be made of cast iron.

b. General Design

(1) Pressure Requirements: Meters supplied under this specification shall operate without leakage or damage to any part at a working pressure of 150 psi. Pressure drop through turbine meters and strainers, when operated within specified normal flow limits, shall not exceed the characteristics outlined in AWWA C701.

(2) Accessibility: All turbine meters shall be designed for easy removal of all interior parts without disturbing the connections to the pipeline. Turbine meters shall have readily accessible

change gears, adjustable vanes or other approved means to adjust meter registration. Such adjustment feature shall be an integral part of the removable rotor/register assembly and not of the main or bottom case of the meter.

(3) Registration Accuracy: Meters shall meet the following requirements for accuracy with water of a temperature of less than +80 degrees Centigrade.

(a) Normal Flow Limits - The meter shall not register less than 97 percent and not more than 103 percent of the water actually passed through it at any rate of flow within the normal test flow limits specified in AWWA C702, except in the registration of flows within the changeover from bypass meter to main meter. Turbine meters shall be designed to allow prolonged operation at or near the upper limit of the specified normal flow range without premature degradation of registration accuracy or other evidence of undue wear. Meters shall also be capable of accepting sudden increases in flow at high rates of flow without decoupling the register.

2.7.10.5 Cold-Water Meter Strainers 2-Inch, 3-Inch, 4-Inch and 6-Inch Size

All strainers provided shall have top access. Cases for 2-inch, 3-inch, 4-inch and 6-inch strainers shall be bronze or SeBiLOY. Strainer plates for all sizes shall be 18-8 stainless steel, or bronze, or SeBiLOY. All strainers shall conform to AWWA C702.

2.7.10.6 Utility Monitoring and Control (UMCS) Meter Reading Interfaces

All strainers provided shall have top access. Cases for 2-inch, 3-inch, 4-inch and 6-inch strainers shall be bronze or SeBiLOY. Strainer plates for all sizes shall be 18-8 stainless steel, or bronze, or SeBiLOY. All strainers shall conform to AWWA C702.

a. Water meters shall provide a pulse output for each [____] gallons of water used for interfacing to the UMCS. Pulse shall have a minimum pulse width of 30 milliseconds.

b. Meters shall not require power to function and deliver data. Output signal shall be either a voltage or amperage signal which can be converted to a flow rate specification.

c. Meter shall be equipped with one pulse output channel ("Pulse" in Metering Systems Schedule) that can be configured for operation.

2.7.10.7 Spare Parts List

Provide spare parts as follows:

a. Water meters - one for every 20 installed.

b. Communications modules - one for every 20 used.

c. Protocol modules - one for every 20 used.

d. Other electronic and power components - one for each type used.

2.7.11 Steam Meters

Steam meters must be the vortex type, with pressure compensation, a minimum turndown ratio of 10 to 1, and an output signal compatible with the DDC system.

2.7.12 Hydronic BTU Meters

The BTU meter is to be supplied with wall mount hardware and be capable of being installed remote from the flow meter. The BTU meter must include an LCD display for local indication of energy rate and for display of parameters and settings during configuration. Each BTU meter must be factory configured for its specific application and be completely field configurable by the user via a front panel keypad (no special interface device or computer required). The unit must output Energy Rate, Energy Total, Flow Rate, Supply Temperature, and Return Temperature. An integral transmitter is to provide a linear analog or configurable pulse output signal representing the energy rate; and the signal must be compatible with building automation system DDC Hardware to which the output is connected.

2.7.13 pH Sensor

The sensor must be suitable for applications and chemicals encountered in water treatment systems of boilers, chillers and condenser water systems. Construction, wiring, fittings and accessories must be corrosion and chemical resistant with fittings for tank or suspension installation. Housing must be polyvinylidene fluoride with O-rings made of chemical resistant materials which do not corrode or deteriorate with extended exposure to chemicals. The sensor must be encapsulated. Periodic replacement must not be required for continued sensor operation. Sensors must use a ceramic junction and pH sensitive glass membrane capable of withstanding a pressure of 100 psig at 150 degrees F. The reference cell must be double junction configuration. Sensor range must be 0 to 12 pH, stability 0.05, sensitivity 0.02, and repeatability of plus or minus 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 76 degrees F.

2.7.14 Oxygen Analyzer

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

2.7.15 Carbon Monoxide Analyzer

Carbon monoxide analyzer must 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 must be provided. Both assemblies must include internal blower systems to keep optical windows free of dust and ash at all times. The third component of the analyzer must be the electronics cabinet. Automatic flue gas temperature compensation and manual/automatic zeroing devices must be provided. Unit must read parts per million (ppm) of carbon monoxide in the range of 0 to 500 ppm and the response time must be less than 3 seconds to 90 percent value. Unit measurement range must not exceed specified range by more that 50 percent. Repeatability must be plus or minus 1

percent of full scale with an accuracy of plus or minus 1 percent of full scale.

2.7.16 Occupancy Sensors

Occupancy sensors must have occupancy-sensing sensitivity adjustment and an adjustable off-delay timer with a setpoint of 15 minutes. Adjustments accessible from the face of the unit are preferred. Occupancy sensors must be rated for operation in ambient air temperatures ranging from 40 to 95 degrees F or temperatures normally encountered in the installed location. Sensors integral to wall mount on-off light switches must have an auto-off switch. Wall switch sensors must be decorator style and must fit behind a standard decorator type wall plate. All occupancy sensors, power packs, and slave packs must be UL listed. In addition to any outputs required for lighting control, the occupancy sensor must provide an output for the HVAC control system.

2.7.16.1 Passive Infrared (PIR) Occupancy Sensors

PIR occupancy sensors must 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 20 feet unless otherwise indicated or specified. PIR Sensors must 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 must be immune to false triggering from RFI and EMI.

2.7.16.2 Ultrasonic Occupancy Sensors

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

2.7.16.3 Dual-Technology Occupancy Sensor (PIR and Ultrasonic)

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

2.7.17 Vibration Switch

Vibration switch must be solid state, enclosed in a NEMA 250 Type 4 or Type 4X housing with sealed wire entry. Unit must 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 must be a true rms reading, suitable for the application. The unit must include either displacement response for low speed or velocity response for high speed application. The frequency range must be at least 3 Hz to 500 Hz. Contact time delay must be 3 seconds. The unit must have independent start-up and running delay on each switch contact. Alarm limits must be adjustable and setpoint accuracy must be plus or minus 10 percent of setting with repeatability of plus or minus 2 percent.

2.7.18 Conductivity Sensor

Sensor must include local indicating meter and must be suitable for measurement of conductivity of water in boilers, chilled water systems, condenser water systems, distillation systems, or potable water systems as indicated. Sensor must sense from 0 to 10 microSeimens per centimeter (µS/cm) for distillation systems, 0 to 100 µS/cm for boiler, chilled water,

and potable water systems and 0 to 1000 µS/cm for condenser water systems. Contractor must field verify the ranges for particular applications and adjust the range as required. The output must be temperature compensated over a range of 32 to 212 degrees F. The accuracy must be plus or minus 2 percent of the full scale reading. Sensor must have automatic zeroing and must require no periodic maintenance or recalibration.

2.7.19 Compressed Air Dew Point Sensor

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

2.7.20 NOx Monitor

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

2.7.21 Turbidity Sensor

Sensor must include a local indicating meter and must be suitable for measurement of turbidity of water. Sensor must sense from 0 to 1000 Nephelometric Turbidity Units (NTU). Range must be field-verified for the particular application and adjusted as required. The output must be temperature compensated over a range of 32 to 212 degrees F. The accuracy must be plus or minus 5 percent of full scale reading. Sensor must have automatic zeroing and must not require periodic maintenance or recalibration.

2.7.22 Chlorine Detector

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

2.7.23 Floor Mounted Leak Detector

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

2.7.24 Temperature Switch

2.7.24.1 Duct Mount Temperature Low Limit Safety Switch (Freezestat)

Duct mount temperature low limit switches (Freezestats) must be manual reset, low temperature safety switches at least 1 foot long per square foot of coverage which must respond to the coldest 18 inch segment with an accuracy of plus or minus 3.6 degrees F. The switch must have a field-adjustable setpoint with a range of at least 30 to 50 degrees F. The switch must have two sets of contacts, and each contact must have a rating greater than its connected load. Contacts must open or close upon drop of temperature below setpoint as indicated and must remain in this state until reset.

2.7.24.2 Pipe Mount Temperature Limit Switch (Aquastat)

Pipe mount temperature limit switches (aquastats) must have a field adjustable setpoint between 60 and 90 degrees F, an accuracy of plus or minus 3.6 degrees F and a 10 degrees F fixed deadband. The switch must have two sets of contacts, and each contact must have a rating greater than its connected load. Contacts must open or close upon change of temperature above or below setpoint as indicated.

2.7.25 Damper End Switches

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

End switches integral to an electric damper actuator are allowed as long as at least one is adjustable over the travel of the actuator.

2.7.26 Air Quality Sensors

Provide full spectrum air quality sensors using a hot wire element based on the Taguchi principle. The sensor must monitor a wide range of gaseous volatile organic components common in indoor air contaminants like paint fumes, solvents, cigarette smoke, and vehicle exhaust. The sensor must automatically compensate for temperature and humidity, have span and calibration potentiometers, operate on 24 VDC power with output of 0-10 VDC, and have a service rating of 32 to 140 degrees F and 5 to 95 percent relative humidity.

2.8 INDICATING DEVICES

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

2.8.1 Thermometers

Provide bi-metal type thermometers at locations indicated. Thermometers must have either 9 inch long scales or 3.5 inch diameter dials, with insertion, immersion, or averaging elements. Provide matching thermowells for pipe-mounted installations. Select scale ranges suitable for the intended service, with the normal operating temperature near the scale's midpoint. The thermometer's accuracy must be plus or minus 2 percent of the scale range.

2.8.1.1 Piping System Thermometers

Piping system thermometers must 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 9 inch scale. Piping system thermometers must have an accuracy of plus or minus 1 percent of scale range. Thermometers for piping systems must have rigid stems with straight, angular, or inclined pattern. Thermometer stems must have expansion heads as required to prevent breakage at extreme temperatures. On rigid-stem thermometers, the space between bulb and stem must be filled with a heat-transfer medium.

2.8.1.2 Air-Duct Thermometers

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

2.8.2 Pressure Gauges

Provide pipe-mounted pressure gauges at the locations indicated. Gauges must conform to ASME B40.100 and have a 4 inch diameter dial and shutoff cock. Select scale ranges suitable for the intended service, with the normal operating pressure near the scale's midpoint. The gauge's accuracy must be plus or minus 2 percent of the scale range.

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

2.8.3 Low Differential Pressure Gauges

Gauges for low differential pressure measurements must be a minimum of 3.5 inch (nominal) size with two sets of pressure taps, and must have a diaphragm-actuated pointer, white dial with black figures, and pointer zero adjustment. Gauge range must be suitable for the application with an upper end of the range not to exceed 150 percent of the design upper limit. Accuracy must be plus or minus two percent of scale range.

2.8.4 Pressure Gauges for Pneumatic Controls

Gauges must sufficient scale to display the full range of expected pressures with 1 psi graduations.

2.9 OUTPUT DEVICES

2.9.1 Actuators

Actuators must be electric (electronic) or pneumatic as indicated. All actuators must be normally open (NO), normally closed (NC) or fail-in-last-position (FILP) as indicated. Normally open and normally closed actuators must be of mechanical spring return type. Electric actuators must have an electronic cut off or other means to provide burnout protection if stalled. Actuators must have a visible position indicator. Electric actuators must provide position feedback to the controller as indicated. Actuators must smoothly and fully open or close the devices to

which they are applied. Electric actuators must have a full stroke response time in both directions of 90 seconds or less at rated load. Electric actuators must 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 must provide an output signal identical to its input signal to the additional devices. Pneumatic actuators must be rated for 25 psi operating pressure except for high-pressure cylinder-type actuators. All actuators must be rated for their operating environment. Actuators used outdoors must be designed and rated for outdoor use. Actuators under continuous exposure to water, such as those used in sumps, must be submersible.

Actuators incorporating an integral network connection are considered DDC Hardware and must meet the DDC Hardware requirements of Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS .

2.9.1.1 Valve Actuators

Valve actuators must provide shutoff pressures and torques as indicated on the Valve Schedule.

2.9.1.2 Damper Actuators

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

2.9.1.3 Positive Positioners

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

2.9.1.4 Electric Actuators

Each actuator must have distinct markings indicating the full-open and full-closed position. Each actuator must deliver the torque required for continuous uniform motion and must have internal end switches to limit the travel, or be capable of withstanding continuous stalling without damage. Actuators must function properly within 85 to 110 percent of rated line voltage. Provide actuators with hardened steel running shafts and gears of steel or copper alloy. Fiber or reinforced nylon gears may be used for torques less than 16 inch-pounds.

a. Two-position actuators must be single direction, spring return, or reversing type. Two position actuator signals may either be the control power voltage or line voltage as needed for torque or appropriate interlock circuits.

b. Modulating actuators must be capable of stopping at any point in the cycle, and starting in either direction from any point. Actuators must be equipped with a switch for reversing direction, and a button to disengage the clutch to allow manual adjustments. Provide the actuator with a hand crank for manual adjustments, as applicable. Modulating actuator input signals can either be a 4 to 20 mAdc or a 0-10 VDC signal.

c. Floating or pulse width modulation actuators are acceptable for non-fail safe applications unless indicated otherwise provided that the floating point control (timed actuation) must have a scheduled re-calibration of span and position no more than once a day and no less than once a week. The schedule for the re-calibration should not affect occupied conditions and be staggered between equipment to prevent falsely loading or unloading central plant equipment.

2.9.1.5 Pneumatic Actuators

Provide piston or diaphragm type actuators with replaceable diaphragm/piston.

2.9.2 Solenoid-Operated Electric to Pneumatic Switch (EPS)

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

2.9.3 Electric to Pneumatic Transducers (EP)

Electric to Pneumatic Transducers (EPs) must convert either a 4-20 mAdc input signal, a 0-10 Vdc input signal to a proportional 0 to 20 psig pneumatic output. The EP must withstand pressures at least 150 percent of the system supply air pressure (main air). EPs must include independent offset and span adjustment. Steady state air consumption must not be greater than 0.05 scfm. EPs must have a manual adjustable override for the EP pneumatic output. EPs must have sufficient output capacity to provide full range stroke of the actuated device in both directions within 90 seconds.

2.9.4 Relays

Relays must have contacts rated for the intended application, indicator light, and dust proof enclosure. The indicator light must be lit when the coil is energized and off when coil is not energized.

Control relay contacts must have utilization category and ratings selected for the application. Each set of contacts must incorporate a normally open (NO), normally closed (NC) and common contact. Relays must be rated for a minimum life of one million operations.

2.10 USER INPUT DEVICES

User Input Devices, including potentiometers, switches and momentary contact push-buttons. Potentiometers must be of the thumb wheel or sliding bar type. Momentary Contact Push-Buttons may include an adjustable timer for their output. User input devices must be labeled for their function.

Provide emergency ventilation shutdown buttons with maintained pushbutton and label (EMERGENCY VENTILATION STOP). Provide a red solid lid that is lockable with detached lock and label (Raise Lid-Push Button).

2.11 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 must meet all requirements of each component device. Where the requirements for the component devices conflict, the multifunction device must meet the most stringent of the requirements.

2.11.1 Current Sensing Relay Command Switch

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

Current Sensing Relays used for Variable Frequency Drives must be rated for Variable Frequency applications unless installed on the source side of the drive. If used in this situation, the threshold for showing status must be set to allow for the VFD's control power when the drive is not enabled and provide indication of operation when the drive is enabled at minimum speed.

2.11.2 Space Sensor Module

Space Sensor Modules must be multifunction devices incorporating a temperature sensor and one or more of the following as specified and indicated on the Space Sensor Module Schedule:

a. A temperature indicating device.

b. A User Input Device which must adjust a temperature setpoint output.

c. A User Input Momentary Contact Button and an output to the control system indicating zone occupancy.

d. A three position User Input Switch labeled to indicate heating, cooling and off positions ('HEAT-COOL-OFF' switch) and providing corresponding outputs to the control system.

e. A two position User Input Switch labeled with 'AUTO' and 'ON' positions and providing corresponding output to the control system..

f. A multi-position User Input Switch with 'OFF' and at least two fan speed positions and providing corresponding outputs to the control system.

Space Sensor Modules cannot contain mercury (Hg).

2.12 COMPRESSED AIR STATIONS

2.12.1 Air Compressor Assembly

Air compressors for pneumatic control systems must be the tank-mounted, electric motor driven, air cooled, reciprocating type with integral duplex motors and compressors, tank, controller, alternator switch, pressure switch, belt guards, pressure relief valve, automatic moisture drain valve and must be supported by a steel base mounted on an air storage tank. Compressor piston speeds must not exceed 450 fpm. Provide compressors with a dry-type combination intake air filter and silencer with baked enamel steel housing. The filter must be 99 percent efficient at 10 microns. The pressure switch must start the compressors at 70 psig and stop the compressors at 90 psig. The relief valve must be set for 10 to 25 psig

above the control switch cut-off pressure. Provide compressor capacity suitable for not more than a 50 percent run time, at full system control load. Compressors must have a combination type magnetic starter with undervoltage protection and thermal-overload protection for each phase and must automatically restart after a power outage. Motors 0.5 hp and larger must be three-phase

2.12.2 Compressed Air Station Specialties

2.12.2.1 Refrigerated Air Dryers

Provide each air compressor tank with a refrigerant air dryer sized for continuous operation at full delivery capacity of the compressor. The air must be dried at a pressure of not less than 70 psi to a temperature not greater than 35 degrees F and an ambient air temperature between 55 and 95 degrees F. The dryer must be provided with an automatic condensate drain trap with manual override feature with an adjustable cycle and drain time. Locate each dryer in the air piping between the tank and the pressure-reducing station. The refrigerant used in the dryer must 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 must be provided in the dryer discharge.

2.12.2.2 Compressed Air Discharge Filters

Provide a disposable type in-line filter in the incoming pneumatic main at each pneumatic control panel. The filter must be capable of eliminating 99.99 percent of all liquid or solid contaminants 0.1 micron or larger. Provide the filter with fittings that allow easy removal/replacement. Each filter bowl must be rated for 150 psi maximum working pressure. A pressure regulator, with high side and low side pressure gauges, and a safety valve must be provided downstream of the filter.

2.12.2.3 Air Pressure-Reducing Stations

Provide air compressors with a pressure-reducing valve (PRV) with a field adjustable range of 0 to 50 psig discharge pressure, at an inlet pressure of 70 to 90 psig. Provide a factory-set pressure relief valve downstream of the PRV to relieve over-pressure. Provide a pressure gage upstream of the PRV with range of 0 to 100 psig and downstream of the PRV with range of. For two-pressure control systems, provide an additional PRV and downstream pressure gage. Pressure regulators of the relieving type must not be used.

2.12.2.4 Flexible Pipe Connections

The flexible pipe connections must be designed for 150 psi and 250 degrees F service, and must 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 must be suitable for the service intended and must have threaded or soldered ends. The length of the connectors must be as recommended by the manufacturer for the service intended.

2.12.2.5 Vibration Isolation Units

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

2.12.3 Compressed Air Tanks

The air storage tank must be fabricated for a working pressure of not less than 200 psi and constructed and certified in accordance with ASME BPVC SEC VIII D1. The tank must be of sufficient volume so that no more than six compressor starts per hour are required with the starting pressure switch differential set at 20 psi. The tank must be provided with an automatic condensate drain trap with manual override feature. Provide drain valve and piping routing the drainage to a floor sink or other safe and visible drainage location.

PART 3 EXECUTION

3.1 INSTALLATION

3.1.1 General Installation Requirements

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

3.1.1.1 Device Mounting Criteria

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

3.1.1.2 Labels and Tags

Match labels and tags to the unique identifiers indicated on the As-Built drawings. Label all enclosures and instrumentation. Tag all sensors and actuators in mechanical rooms. Tag airflow measurement arrays to show flow rate range for signal output range, duct size, and pitot tube AFMA flow coefficient. Tag duct static pressure taps at the location of the pressure tap. Provide plastic or metal tags, mechanically attached directly to each device or attached by a metal chain or wire. Labels exterior to protective enclosures must be engraved plastic and mechanically attached to the enclosure or instrumentation. Labels inside protective enclosures may attached using adhesive, but must not be hand written.

3.1.2 Weathershield

Provide weathershields for sensors located outdoors. Install weathershieldssuch that they prevent the sun from directly striking the sensor and prevent rain from directly striking or dripping onto the sensor. Install weather shields with adequate ventilation so that the sensing element responds to the ambient conditions of the surroundings. When installing weathershields near outside air intake ducts, install them such that normal outside air flow does not cause rainwater to strike the sensor.

3.1.3 Room Instrument Mounting

Mount room instruments, including but not limited to wall mounted

non-adjustable space sensor modules and sensors located in occupied spaces, 60 inches above the floor unless otherwise indicated. Install adjustable devices to be ADA compliant unless otherwise indicated on the Room Sensor Schedule:

a. Space Sensor Modules for Fan Coil Units may be either unit or wall mounted but not mounted on an exterior wall.

b. Wall mount all other Space Sensor Modules.

3.1.4 Indication Devices Installed in Piping and Liquid Systems

Provide snubbers for gauges in piping systems subject to pulsation. For gauges for steam service use pigtail fittings with cock. Install thermometers and temperature sensing elements in liquid systems in thermowells. Provide spare Pressure/Temperature Ports (Pete's Plug) for all temperature and pressure sensing elements installed in liquid systems for calibration/testing.

3.1.5 Occupancy Sensors

Provide a sufficient quantity of occupancy sensors to provide complete coverage of the area (room or space). Occupancy sensors are to be ceiling mounted. Install occupancy sensors in accordance with NFPA 70 requirements and the manufacturer's instructions. Do not locate occupancy sensors within 6 feet of HVAC outlets or heating ducts, or where they can "see" beyond any doorway. Installation above doorway(s) is preferred. Do not use ultrasonic sensors in spaces containing ceiling fans. Install sensors to detect motion to within 2 feet of all room entrances and to not trigger due to motion outside the room. Set the off-delay timer to 15 minutes unless otherwise indicated. Adjust sensors prior to beneficial occupancy, but after installation of furniture systems, shelving, partitions, etc. For each controlled area, provide 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.

3.1.6 Switches

3.1.6.1 Temperature Limit Switch

Provide a temperature limit switch (freezestat) to sense the temperature at the location indicated. Provide a sufficient number of temperature limit switches (freezestats) to provide complete coverage of the duct section but no less than 1 foot in length per square foot of cross sectional area. Install manual reset limit switches in approved, accessible locations where they can be reset easily. Install temperature limit switch (freezestat) sensing elements in a side-to-side (not top-to-bottom) serpentine pattern with the relay section at the highest point and in accordance with the manufacturer's installation instructions.

3.1.6.2 Hand-Off Auto Switches

Wire safety controls such as smoke detectors and freeze protection thermostats to protect the equipment during both hand and auto operation.

3.1.7 Temperature Sensors

Install temperature sensors in locations that are accessible and provide a good representation of sensed media. Installations in dead spaces are not

acceptable. Calibrate and install sensors according to manufacturer's instructions. Select sensors only for intended application as designated or recommended by manufacturer. Mount outdoor air sensors and transmitters on a north facing wall eight feet above grade.

3.1.7.1 Room Temperature Sensors

Mount the sensors on interior walls to sense the average room temperature at the locations indicated. Avoid locations near heat sources such as copy machines or locations by supply air outlet drafts. Mount the center of all user-adjustable sensors [5 feet above the finished floor][54 inches above the floor to meet ADA requirements]at the heights indicated. Non user-adjustable sensors can be mounted as indicated in paragraph ROOM INSTRUMENT MOUNTING.

3.1.7.2 Duct Temperature Sensors

3.1.7.2.1 Probe Type

Place tip of the sensor in the middle of the airstream or in accordance with manufacturer's recommendations or instructions.Provide a gasket between the sensor housing and the duct wall. Seal the duct penetration air tight. When installed in insulated duct, provide enclosure or stand off fitting to accommodate the thickness of duct insulation to allow for maintenance or replacement of the sensor and wiring terminations. Seal the duct insulation penetration vapor tight.

3.1.7.2.2 Averaging Type

Weave the sensing element in a serpentine fashion from side to side perpendicular to the flow, across the duct or air handler cross-section, using durable non-metal supports in accordance with manufacturer's installation instructions. Avoid tight radius bends or kinking of the sensing element. Prevent contact between the sensing element and the duct or air handler internals. Provide a duct access door at the sensor location. The access door must be hinged on the side, factory insulated, have cam type locks, and be as large as the duct will permit, maximum 18 by 18 inches. For sensors inside air handlers, the sensors must be fully accessible through the air handler's access doors without removing any of the air handler's internals.

3.1.7.3 Immersion Temperature Sensors

Provide thermowells for sensors measuring piping, tank, or pressure vessel temperatures. Locate wells to sense continuous flow conditions. Do not install wells using extension couplings. When installed on insulated piping, provide stand enclosure or stand off fitting to accommodate the thickness of the pipe insulation and allow for maintenance or replacement of the sensor or wiring terminations. Where piping diameters are smaller than the length of the wells, provide wells in piping at elbows to sense flow across entire area of well. Wells must not restrict flow area to less than 70 percent of pipe area. Increase piping size as required to avoid restriction. Provide the sensor well with a heat-sensitive transfer agent between the sensor and the well interior ensuring contact between the sensor and the well.

3.1.7.4 Outside Air Temperature Sensors

Provide outside air temperature sensors on the building's north side with a

protective weather shade that does not inhibit free air flow across the sensing element, and protects the sensor from snow, ice, and rain. Location must not be near exhaust hoods and other areas such that it is not influenced by radiation or convection sources which may affect the reading. Provide a shield to shade the sensor from direct sunlight.

3.1.8 Air Flow Measurement Arrays (AFMA)

Locate Outside Air AFMAs downstream from the Outside Air filters

Install AFMAs with the manufacturer's recommended minimum distances between upstream and downstream disturbances. Airflow straighteners may be used to reduce minimum distances as recommended by the AFMA manufacturer.

3.1.9 Duct Static Pressure Sensors

Locate the duct static pressure sensing tap at 75 percent of the distance between the first and last air terminal units [as indicated on the design documents]. If the transmitter output is a 0-10Vdc signal, locate the transmitter in the same enclosure as the air handling unit (AHU) controller for the AHU serving the terminal units. If a remote duct static pressure sensor is to be used, run the signal wire back to the controller for the air handling unit.

3.1.10 Relative Humidity Sensors

Install relative humidity sensors in supply air ducts at least 10 feet downstream of humidity injection elements.

3.1.11 Meters

3.1.11.1 Flowmeters

Install flowmeters to ensure minimum straight unobstructed piping for at least 10 pipe diameters upstream and at least 5 pipe diameters downstream of the flowmeter, and in accordance with the manufacturer's installation instructions.

3.1.11.2 Electric Meters

Locate meters as indicated. Install meters inside or immediately adjacent to the building located to facilitate connection to the building control system. Connect each meter output to the DDC system, to measure both instantaneous demand/energy and other variables as indicated.

3.1.11.2.1 Meter Connections

Use meter ring lugs for all connections. Color code and mark the conductors as follows:

a. Red - Phase A CT - C1

b. Orange - Phase B CT - C2

c. Brown - Phase C CT - C3

d. Gray with white stripe - neutral current return - C0

e. Black - Phase A voltage - V1.

f. Yellow - Phase B voltage - V2

g. Blue - Phase C voltage - V3

h. White - Neutral voltage

3.1.11.2.2 Overall Meter Accuracy

Provide Electric Meters with internal or external current and potential transformers such that the combines Root Sum Square (RSS) accuracy of the meter and all connected transformers is 2.35 percent or better, where Root Sum Square accuracy is calculated as the square root of the sum of the squares of the accuracy of each component. Note that this requirement is in addition to the accuracy requirements specified for the individual products.

3.1.11.2.3 Disconnecting Switches

a. Disconnecting wiring blocks must be provided between the current transformer and the meter. A shorting mechanism must be built into the wiring block to allow the current transformer wiring to be changed without removing power to the transformer. The wiring blocks must be located where they are accessible without the necessity of disconnecting power to the transformer. For multi-ratio current transformers, provide a shorting block from each tap to the common lead

b. Voltage-monitoring circuits must be equipped with disconnect switches to isolate the meter base or socket from the voltage source.

3.1.11.2.4 Surge Protection

Meters shall comply with IEEE/ANSI C37.90.1. Protect equipment connected to AC circuits to withstand power-line surges in accordance with IEEE C62.41. Do not use fuses for surge protection.

3.1.11.2.5 Meter Configuration Settings

For each meter and as part of Operation and Maintenance data submittals required in section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC, provide copies of the installed configuration settings as source code compatible with the configuration tool software for that meter.

3.1.11.2.6 Meter Testing and Inspection

As part of PVT procedures described in section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC and applicable testing from NETA ATS, include the following tests at a minimum:

3.1.11.2.6.1 Visual and Mechanical Inspection

a. Compare equipment nameplate data with drawings and specifications.

b. Inspect physical and mechanical condition.

c. Inspect bolted electrical connections for high resistance.

3.1.11.2.6.2 Electrical Tests

a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable.

b. Verify accuracy of meters at all cardinal points.

c. Verify all instrument multipliers.

d. Verify that current transformer and voltage transformer secondary circuits are intact.

3.1.11.3 Gas Meters

Install gas piping, appliances, and equipment in accordance with NFPA 54. [Install distribution piping in accordance with ASME B31.8.] Meters shall be installed in accordance with [AGA ANSI B109.1] [AGA ANSI B109.2] [AGA ANSI B109.3]

3.1.11.3.1 Piping

Cut pipe to actual dimensions and assemble to prevent residual stress. [Provide supply connections entering the buildings as indicated.] Within buildings, run piping parallel to structure lines and conceal in finished spaces. Terminate each vertical supply pipe to burner or appliance with tee, nipple and cap to form a sediment trap. To supply multiple items of gas-burning equipment, provide manifold with inlet connections at both ends.

3.1.11.3.1.1 Cleanliness

Clean inside of pipe and fittings before installation. Blow lines clear using 80 to 100 psig clean, dry compressed air. Rap steel lines sharply along entire pipe length before blowing clear. Cap or plug pipe ends to maintain cleanliness throughout installation.

3.1.11.3.1.2 Aboveground Steel Piping

Determine and establish measurements for piping at the job site and accurately cut pipe lengths accordingly. For 2 inch diameter and smaller, use threaded or socket-welded joints. For 2-1/2 inch diameter and larger, use flanged or butt-welded joints.

a. Threaded Joints: Where possible, use pipe with factory-cut threads; otherwise cut pipe ends square, remove fins and burrs, and cut taper pipe threads in accordance with ASME B1.20.1. Provide threads smooth, clean, and full-cut. Apply anti-seize paste or tape to male threads portion. Work piping into place without springing or forcing. Backing off to permit alignment of threaded joints will not be permitted. Engage threads so that not more than three threads remain exposed. Use unions for connections to [valves] [meters] for which a means of disconnection is not otherwise provided.

b. Welded Joints: Weld by the shielded metal-arc process, using covered electrodes and in accordance with procedures established and qualified in accordance with ASME B31.8.

c. Flanged Joints: Use flanged joints for connecting welded joint pipe and fittings to valves to provide for disconnection. Install joints so that flange faces bear uniformly on gaskets. Engage bolts so that

there is complete threading through the nuts and tighten so that bolts are uniformly stressed and equally torqued.

d. Pipe Size Changes: Use reducing fittings for changes in pipe size. Size changes made with bushings will not be accepted.

e. Painting: Paint new ferrous metal piping, including supports, in accordance with Section 09 90 00 PAINTS AND COATINGS. Do not apply paint until piping tests have been completed.

f. Identification of Interior Piping: Identify interior piping aboveground in accordance with MIL-STD-101, using adhesive-backed or snap-on plastic labels and arrows. In lieu of labels, identification tags may be used. Apply labels or tags to finished paint at intervals of not more than 50 feet). Provide two copies of the piping identification code framed under glass and install where directed.

3.1.11.3.1.2.1 Wrapping

Where connection to existing steel line is made underground, tape wrap new steel transition fittings and exposed existing pipe having damaged coating. Clean pipe to bare metal. Initially stretch first layer of tape to conform to the surface while spirally half-lapping. Apply a second layer,
half-lapped and spiraled as the first layer, but with spirals perpendicular to first wrapping. Use 10 mil minimum thick polyethylene tape. In lieu of tape wrap, heat shrinkable 10 mil minimum thick polyethylene sleeve may be used.

3.1.11.3.1.3 Regulators and Valves

3.1.11.3.1.3.1 Pressure Regulator

Provide [plug cock] [or] [ball valve] ahead of regulator. [Install regulator outside of building and 18 inches aboveground on riser.] [Install regulator inside building and extend a full-size vent line from relief outlet on regulator to a point outside of building.] [Install gas meter in conjunction with pressure regulator]. On outlet side of [regulator] [meter], provide a union and a 3/8 inch gage tap with plug.

3.1.11.3.1.3.2 Stop Valve and Shutoff Valve

Provide stop valve on service branch at connection to main and shut-off valve on riser outside of building.

3.1.11.3.1.4 Pipe Sleeves

[Comply with Section 07 84 00 FIRESTOPPING.] Where piping penetrates concrete or masonry wall, floor, or firewall, provide pipe sleeve poured or grouted in place. Make sleeve of steel or cast-iron pipe of such size to provide 1/4 inch or more annular clearance around pipe. Extend sleeve through wall or slab and terminate flush with both surfaces. Pack annular space with oakum, and caulk at ends with silicone construction sealant.

3.1.11.3.1.5 Pipe Sleeves

Selection, fabrication, and installation of piping hangers and supports shall conform with MSS SP-69 and MSS SP-58, unless otherwise indicated. [Provide seismic restraints in accordance with SMACNA 1981.]

3.1.11.4 Water Meters

Water meter installations shall conform to AWWA C700, AWWA C701 and AWWA C702. Electrical installations shall conform to IEEE C2, NFPA 70 (National Electrical Code), and to the requirements specified herein. Provide new equipment and materials unless otherwise indicated or specified.

3.1.11.4.1 Water Meter Warranty Requirements

The equipment items shall be supported by service organizations which are reasonably convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract. All water meters shall carry the following published warranties:

a. Meters shall be guaranteed to be free from defective materials and workmanship and meet AWWA New Meter Accuracy Standards for a period of five years from the date of installation. At the expiration of this period, meters shall be guaranteed to meet AWWA Repaired Meter Accuracy Standards for the following time periods:

   (1) 5/8 inch to 1 inch: 5 to 15 years from the date of shipment.

   (2) 1-1/2 inch and larger: 5 to 10 years from the date of shipment.

b. All registers are guaranteed for a ten-year period from the date of purchase. Any defective register will be replaced at no cost to the Government.

c. All brass maincases are guaranteed for life by the manufacturer. Any defective maincase will be replaced at no cost to the Government.

3.1.12 Dampers

3.1.12.1 Damper Actuators

Provide spring return actuators which fail to a position that protects the served equipment and space on all control dampers related to freeze protection or force protection. For all outside, makeup and relief dampers provide dampers which fail closed. Terminal fan coil units, terminal VAV units, convectors, and unit heaters nay be non-spring return unless indicated otherwise. Do not mount actuators in the air stream. Do not connect multiple actuators to a common drive shaft. Install actuators so that their action seal the damper to the extent required to maintain leakage at or below the specified rate and so that they move the blades smoothly throughout the full range of motion.

3.1.12.2 Damper Installation

Install dampers straight and true, level in all planes, and square in all dimensions. Dampers must move freely without undue stress due to twisting, racking (parallelogramming), bowing, or other installation error. External linkages must operate smoothly over the entire range of motion, without deformation or slipping of any connecting rods, joints or brackets that will prevent a return to its normal position. Blades must close completely and leakage must not exceed that specified at the rated static pressure. Provide structural support for multi-section dampers. Acceptable methods o structural support 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 must not sag due to lack of support. Do not use jackshafts to link more than three damper sections. Do not use blade to blade linkages. Install outside and return air dampers such that their blades direct their respective air streams towards each other to provide for maximum mixing of air streams.

3.1.13 Valves

Install the valves in accordance with the manufacturer's instructions.

3.1.13.1 Valve Actuators

Provide spring return actuators on all control valves where freeze protection is required. Spring return actuators for terminal fan coil units, terminal VAV units, convectors, and unit heaters are not required unless indicated otherwise.

3.1.14 Thermometers and Gauges

3.1.14.1 Local Gauges for Actuators

Provide a pressure gauge at each pneumatic control input and output. Pneumatic actuators must have an accessible and visible pressure gauge installed in the tubing lines at the actuator as indicated.

3.1.14.2 Thermometers

Mount devices to allow reading while standing on the floor or ground, as applicable.

3.1.15 Wire and Cable

Provide complete electrical wiring for the Control System, including wiring to transformer primaries. Wire and Cable must be installed without splices between control devices and in accordance with NFPA 70 and NFPA 90A. Instrumentation grounding must be installed per the device manufacturer's instructions and as necessary to prevent ground loops, noise, and surges from adversely affecting operation of the system. Test installed ground rods as specified in IEEE 142. Cables and conductor wires must be tagged at both ends, with the identifier indicated on the shop drawings. Electrical work must be as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM and as indicated. Wiring external to enclosures must be run in raceways[, except low-voltage control and low-voltage network wiring may be installed as follows:

a. plenum rated cable in suspended ceilings over occupied spaces may be run without raceways

b. nonmetallic-sheathed cables or metallic-armored cables may be installed as permitted by NFPA 70.]

Install control circuit wiring not in raceways in a neat and safe manner. Wiring must not use the suspended ceiling system (including tiles, frames or hangers) for support. Where conduit or raceways are required, control circuit wiring must not run in the same conduit/raceway as power wiring over 50 volts. Run all circuits over 50 volts in conduit, metallic tubing, covered metal raceways, or armored cable.

3.1.16 Copper Tubing

Provide hard-drawn copper tubing in exposed areas and either hard-drawn or annealed copper tubing in concealed areas. Use only tool-made bends. Use only brass or copper solder joint type fittings, except for connections to apparatus. For connections to apparatus use brass compression type fittings.

3.1.17 Plastic Tubing

Install plastic tubing within covered raceways or conduit except when otherwise specified. Do not use plastic tubing for applications where the tubing could be subjected to a temperature exceeding 130 degrees F. For fittings, use brass or acetal resin of the compression or barbed push-on type for instrument service. 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.

3.1.18 Pneumatic Lines

Run tubing concealed in finished areas, run tubing exposed in unfinished areas like mechanical rooms. For tubing enclosed in concrete, provide rigid metal conduit. Run tubing parallel and perpendicular to building walls. Use 5 foot maximum spacing between tubing supports. With the compressor turned off, test each tubing system pneumatically at 1.5 times the working pressure and prove it air tight, locating and correcting leaks as applicable. Caulking joints is not permitted. Do not run tubing and electrical power conductors in the same conduit.

a. Install pneumatic lines must such that they are not exposed to outside air temperatures. Conceal pneumatic lines except in mechanical rooms and other areas where other tubing and piping is exposed.

b. Install all tubes and tube bundles exposed to view in lines parallel to the lines of the building. Route tubing in mechanical/electrical so that the lines are easily traceable.

c. Purge air lines of dirt, impurities and moisture before connecting to the control equipment. Number-code or color-code air lines and key the coding in the As-Built Drawings for future identification and servicing the control system.

3.1.18.1 Pneumatic Lines In Mechanical/Electrical Spaces

In mechanical/electrical spaces, use plastic or copper tubing for pneumatic lines. Install horizontal and vertical runs of plastic tubing or soft copper tubing min raceways or rigid conduit dedicated to tubing. Support dedicated raceways, conduit, and hard copper tubing not installed in raceways every 6 feet for horizontal runs and every 8 feet for vertical runs.

3.1.18.2 Pneumatic Lines External to Mechanical/Electrical Spaces

External to mechanical/electrical spaces, use plastic tubing in raceways not containing power wiring or copper tubing with sweat fittings. Support raceways and tubing not in raceways every 8 feet. For pneumatic lines

concealed in walls use 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.

3.1.18.3 Terminal Single Lines

For terminal single lines use hard-drawn copper tubing, except when the run is less than 12 inches in length, flexible polyethylene may be used.

3.1.18.4 Connection to Liquid and Steam Lines

Use Series 300 stainless steel with stainless-steel compression fittings for connection of sensing elements and transmitters to liquid and steam lines.

3.1.18.5 Connection to Ductwork

Use plastic tubing for connections to sensing elements in ductwork.

3.1.18.6 Tubing in Concrete

Install tubing in concrete in rigid conduit. Install tubing in walls containing insulation, fill, or other packing materials in raceways dedicated to tubing.

3.1.18.7 Tubing Connection to Actuators

For final connections to actuators use plastic tubing no more than 12 inches long and unsupported at the actuator.

3.1.19 Compressed Air Stations

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. Provide compressed air station specialties with required tubing, including condensate tubing to a floor drain. Compressed air stations must 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.

3.1.20 Protective Covering for Aboveground Piping Systems

Inspect for compliance with [NFPA 54] [and] [ASME B31.8]. Replace, repair, and then re-inspect defective welds.][Apply finish painting conforming to the applicable paragraphs of Section 09 90 00 PAINTS AND COATINGS and as follows: for Ferrous Surfaces, touch up shop-primed surfaces with ferrous metal primer of the same type paint as the shop primer. Solvent-clean surfaces that have not been shop primed in accordance with SSPC SP 1. Mechanically clean surfaces that contain loose rust, loose mill scale, and other foreign substances by power wire brushing in accordance with SSPC SP 3 or brush-off blast clean in accordance with SSPC 7/NACE No.4 and primed with ferrous metal primer in accordance with SSPC Paint 25. Finish primed surfaces with two coats of exterior alkyd paint conforming to MPI 9.

-- End of Section --

THIS PAGE INTENTIONALLY LEFT BLANK

Appendix M: Insert: UFGS - 23 09 23.01 (Tailored to Fort Leonard Wood): LonWorks DDC for HVAC and Other Building Control Systems

SECTION TABLE OF CONTENTS

DIVISION 23 - HEATING, VENTILATING, AND AIR CONDITIONING (HVAC)

SECTION 23 09 23.01

LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS

11/15

PART 1 GENERAL

1.1 SUMMARY
1.1.1 System Requirements
1.1.2 Verification of Specification Requirements
1.2 REFERENCES
1.3 DEFINITIONS
1.4 SUBMITTALS

PART 2 PRODUCTS

2.1 NETWORK HARDWARE
2.1.1 CEA-709.1-D Routers
2.1.2 CEA-709.1-D Repeaters
2.1.3 CEA-709.1-D Gateways
2.1.4 CEA-852-C Router
2.2 CONTROL NETWORK WIRING
2.3 DIRECT DIGITAL CONTROL (DDC) HARDWARE
2.3.1 Hardware Input-Output (I/O) Functions
2.3.1.1 Analog Inputs
2.3.1.2 Analog Outputs
2.3.1.3 Binary Inputs
2.3.1.4 Binary Outputs
2.3.1.4.1 Relay Contact Closures
2.3.1.4.2 Triac Outputs
2.3.1.5 Pulse Accumulator
2.3.1.6 Integrated H-O-A Switches
2.3.2 Local Display Panel (LDP)
2.3.3 Application Specific Controller (ASC)
2.3.4 General Purpose Programmable Controller (GPPC)
2.3.5 Application Generic Controller (AGC)
2.4 Electric Metering

PART 3 EXECUTION

3.1 CONTROL SYSTEM INSTALLATION
3.1.1 Building Control Network (BCN)
3.1.1.1 Building Control Network (BCN) Installation
3.1.1.2 Non-IP Building Control Network (BCN) Channel
3.1.1.3 Building Control Network (BCN) IP Network
3.1.2 DDC Hardware
3.1.2.1 Hand-Off-Auto (H-O-A) Switches
3.1.2.2 Local Display Panels
3.1.2.3 Overrides for GPPCs and AGCs
3.1.2.4 Overrides for ASCs
3.1.3 Scheduling, Alarming, Trending and Overrides

3.1.3.1 Scheduling
3.1.3.1.1 Schedule Groupings
3.1.3.1.2 Occupancy Mode Mapping to SNVT Values
3.1.3.2 Alarming
3.1.3.3 Trending
3.1.3.4 Overrides
3.1.4 Gateways
3.1.5 Network Interface Jack

-- End of Section Table of Contents --

SECTION 23 09 23.01

LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS
11/15

PART 1 GENERAL

1.1 SUMMARY

Provide a complete Direct Digital Control (DDC) system, except for the Front End which is specified in Section 25 10 10 UTILITY MONITORING AND CONTROL (UMCS) FRONT END AND INTEGRATION, suitable for the control of the heating, ventilating and air conditioning (HVAC) and other building-level systems as specified and shown and in accordance with Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.

1.1.1 System Requirements

Provide a system meeting the requirements of both Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC and this Section and with the following characteristics:

a. The control system must be an open implementation of LonWorks technology using CEA-709.1-D as the communications protocol. The system must use LonMark Standard Network Variable Types as defined in LonMark SNVT List exclusively for communication over the network.

b. Use LonWorks Network Services (LNS) for all network management including addressing and binding of network variables. As specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC, submit copies of the complete, fully-commissioned, valid, as-built Final LNS database, including all LNS credits, for the complete control system provided under this specification. All devices must be on-line and commissioned into the LNS database.

c. Install and configure control hardware to provide all input and output Standard Network Variables (SNVTs) as indicated and as needed to meet the requirements of this specification.

d. All DDC hardware installed under this specification must communicate via CEA-709.1-D. Install the control system such that a SNVT output from any node on the network can be bound to any other node in the same domain.

1.1.2 Verification of Specification Requirements

Review all specifications related to the control system installation and advise the Contracting Officer of any discrepancies before performing any work. If Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC or any other Section referenced in this specification is not included in the project specifications advise the Contracting Officer and either obtain the missing Section or obtain Contracting Officer approval before performing any work.

1.2 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.

CONSUMER ELECTRONICS ASSOCIATION (CEA)

CEA-709.1-D	(2014) Control Network Protocol Specification
CEA-709.3	(1999; R 2004) Free-Topology Twisted-Pair Channel Specification
CEA-852-C	(2014) Tunneling Component Network Protocols Over Internet Protocol Channels

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 802.3	(2015; BW 2015) Standard Information Technology--Telecommunications and Information Exchange Between Systems--Specific Requirements Part 3: CSMA/CD Access Method and Physical Layer Specifications

INTERNET ENGINEERING TASK FORCE (IETF)

IETF RFC 4361	(2006) Node-specific Client Identifiers for Dynamic Host Configuration Protocol Version Four (DHCPv4)

LONMARK INTERNATIONAL (LonMark)

LonMark Interoperability Guide	(2005) LonMark Application-Layer Interoperability Guide and LonMark Layer 1-6 Interoperability Guide; Version 3.4
LonMark SCPT List	(2003) LonMark SCPT Master List; Version 12
LonMark SNVT List	(2003) LonMark SNVT Master List; Version 113
LonMark XIF Guide	(2001) LonMark External Interface File Reference Guide; Revision 4.402

U.S. FEDERAL COMMUNICATIONS COMMISSION (FCC)

FCC Part 15	Radio Frequency Devices (47 CFR 15)

UNDERWRITERS LABORATORIES (UL)

UL 916	(2007; Reprint Aug 2014) Standard for Energy Management Equipment

1.3 DEFINITIONS

For definitions related to this section, see Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.

1.4 SUBMITTALS

Submittals related to this Section are specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.

PART 2 PRODUCTS

All products used to meet this specification must meet the specified requirements, but not all products specified here will be required by every project. Provide products which meet the requirements of both Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC and this Section.

2.1 NETWORK HARDWARE

2.1.1 CEA-709.1-D Routers

CEA-709.1-D Routers must meet the requirements of CEA-709.1-D and must provide connection between two or more CEA-709.3 TP/FT-10 channels, or between one or more CEA-709.3 TP/FT-10 channels and a LonMark Interoperability Guide TP/XF-1250 channel.

2.1.2 CEA-709.1-D Repeaters

CEA-709.1-D Repeaters must be CEA-709.1-D Routers configured as repeaters. Physical layer repeaters are prohibited.

2.1.3 CEA-709.1-D Gateways

In addition to the requirements for DDC Hardware, CEA-709.1-D gateways must

a. Allow bi-directional mapping of data between the non-CEA-709.1-D protocol and SNVTs

b. Incorporate a network connection to a TP/FT-10 network in accordance with CEA-709.3 and a separate connection appropriate for the a non-CEA-709.1-D network

Although Gateways must meet DDC Hardware requirements they are not DDC Hardware and must not be used when DDC Hardware is required.

2.1.4 CEA-852-C Router

CEA-852-C Routers must perform layer 3 routing of CEA-709.1-D packets over an IP network in accordance with CEA-852-C. The router must provide the appropriate connection to the IP network and connections to the CEA-709.3 TP/FT-10 or LonMark Interoperability Guide TP/XF-1250 network. CEA-852-C Routers must support the Dynamic Host Configuration Protocol (DHCP; IETF RFC 4361 for IP configuration and the use of an CEA-852-C Configuration Server (for CEA-852-C configuration), but must not rely on these services for configuration. CEA-852-C Routers must be capable of manual configuration via a console RS-232 or USB port.

Additionally, provide CEA-852-C Routers with the following capabilities:

a. two impulse meter inputs and screw terminal connections to support impulse meter inputs that are DIN 43 864 (open terminal voltage at 12VDC maximum and maximum current of 27mA) with a minimum pulse width of 30 ms

b. two single pole single throw output relays rated at 240 VAC at 10 amps

c. two optically isolated dry contact inputs rated for 30 VAC and 30 VDC

d. web services using SOAP/XML with built-in scheduling, alarming, data logging, and meter reading applications.

e. configuration features matching those in existing Fort Leonard Wood Security Configuration Guide (SCG) documentation with equivalent capabilities for hardening. Contact DPW for most recent SCG documentation.

2.2 CONTROL NETWORK WIRING

a. Provide TP/FT-10 control wiring in accordance with CEA-709.3 and with purple thermoplastic covering.

b. Provide TP/XF-1250 control wiring in accordance with the LonMark Interoperability Guide and with purple thermoplastic covering.

c. For the Building Control Network IP Network provide media that is CAT-5e Ethernet media at a minimum and meets all requirements of IEEE 802.3 .

d. Provide horizontal copper cables with four each individually twisted pair, minimum size 24 AWG conductors, Category 6, with a blue thermoplastic jacket. Provide cable with imprinted with manufactures name flammability rating, gauge of conductor, transmission performance rating and length marking at regular intervals.

2.3 DIRECT DIGITAL CONTROL (DDC) HARDWARE

All DDC Hardware must meet the following general requirements:

a. It must 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 must be distinguishable and accessible.

b. It must incorporate a light to indicate the device is receiving power.

c. It must incorporate a TP/FT-10 transceiver in accordance with CEA-709.3 and connections for TP/FT-10 control network wiring.

d. It must communicate on the network using only the CEA-709.1-D protocol.

e. It must be capable of having network communications configured via LNS.

f. It must be locally powered; link powered devices are not acceptable.

g. LonMark external interface files (XIF files), as defined in the LonMark XIF Guide, must be submitted for each type of DDC Hardware.

h. Application programs and configuration settings must be stored in a manner such that a loss of power does not result in a loss of the application program or configuration settings:

(1) Loss of power must never result in the loss of application programs, regardless of the length of time power is lost.

(2) Loss of power for less than 2,500 hours must not result in the loss of configured settings.

i. Where DDC hardware is used for connection to pulse input instrumentation, provide DDC hardware with two impulse meter inputs and screw terminal connections to support impulse meter inputs with open terminal voltage at 12VDC maximum and maximum current of 27mA) and a minimum pulse width of 30 ms.

j. It must 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 must provide input and output SNVTs as specified, as indicated on the Points Schedule, and as otherwise required to support the sequence and application in which it is used. All SNVTs must have meaningful names identifying the value represented by the SNVT. Unless a standard network variable type of an appropriate engineering type is not available, all network variables must be of a standard network variable type with engineering units appropriate to the value the variable represents.

(2) All settings and parameters used by the application in which the DDC hardware is used must be configurable via one of the following: standard configuration properties (SCPTs) as defined in the LonMark SCPT List, user-defined configuration properties (UCPTs), network configuration inputs (*ncis*) of a SNVT type as defined in the LonMark SNVT List, network configuration inputs (*ncis*) of a user defined network variable type, or hardware settings on the controller itself.

k. It must meet FCC Part 15 requirements and have UL 916 or equivalent safety listing.

l. In addition to these general requirements and the DDC Hardware Input-Output (I/O) Function requirements, all DDC Hardware must also meet the requirements of a Local Display Panel (LDP), Application Specific Controller (ASC), General Purpose Programmable Controller (GPPC), or an Application Generic Controller (AGC). All pieces of DDC Hardware must have their DDC Hardware Type identified as part of the Manufacturer's Product Data submittal as specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC. Except for Local Display Panels provided as part of another controller, where a single device meets the requirements of multiple types, select a single type for that specific device based on it's use. Where a Local Display Panel is provided as part of another device, indicate both the controller type and local display panel. One model of DDC hardware may be submitted as different DDC Hardware types when used in multiple applications.

m. The user interface on all DDC Hardware with a user interface which allows for modification of a value must be password protected.

n. Clocks in DDC Hardware incorporating a Clock must continue to function for 120 hours upon loss of power to the DDC Hardware.

2.3.1 Hardware Input-Output (I/O) Functions

DDC Hardware incorporating hardware input-output (I/O) functions must meet

the following requirements:

2.3.1.1 Analog Inputs

DDC Hardware analog inputs (AIs) must 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 Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC. Signal conditioning including transient rejection must be provided for each analog input. Analog inputs must be capable of being individually calibrated for zero and span. Calibration via software scaling performed as part of point configuration is acceptable. The AI must 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.

2.3.1.2 Analog Outputs

DDC Hardware analog outputs (AOs) must 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 must be capable of being individually calibrated for zero and span. Calibration via software scaling performed as part of point configuration is acceptable. DDC Hardware with Hand-Off-Auto (H-O-A) switches for analog outputs must provide for overriding the output through the range of 0 percent to 100 percent

2.3.1.3 Binary Inputs

DDC Hardware binary inputs (BIs) must accept contact closures and must ignore transients of less than 5 milli-second duration. Protection against a transient of 50 Vac must be provided.

2.3.1.4 Binary Outputs

DDC Hardware binary outputs (BOs) must provide relay contact closures or triac outputs for momentary and maintained operation of output devices. DDC Hardware with H-O-A switches for binary outputs must provide for overriding the output open or closed.

2.3.1.4.1 Relay Contact Closures

Closures must have a minimum duration of 0.1 second. Relays must provide at least 180V of isolation. Electromagnetic interference suppression must be provided on all output lines to limit transients to 50 Vac. Minimum contact rating must be 0.5 amperes at 24 Vac.

2.3.1.4.2 Triac Outputs

Triac outputs must provide at least 180 V of isolation. Minimum contact rating must be 0.5 amperes at 24 Vac.

2.3.1.5 Pulse Accumulator

DDC Hardware pulse accumulators must have the same characteristics as the BI. In addition, a buffer must be provided to totalize pulses. The pulse accumulator must accept rates of at least 20 pulses per second. The totalized value must be resettable via a configurable parameter.

2.3.1.6 Integrated H-O-A Switches

Where integrated H-O-A switches are provided on hardware outputs, controller must provide means of monitoring position or status of H-O-A switch. This feedback may be provided via network variable.

2.3.2 Local Display Panel (LDP)

The Local Display Panels (LDPs) must be DDC Hardware with a display and navigation buttons or a touch screen display, and must provide display and adjustment of network variables as indicated on the Points Schedule and as specified. LDPs must be provided as stand-alone DDC Hardware or as an integral part of another piece of DDC Hardware. LDPs must come factory installed with all applications necessary for the device to function as an LDP.

The adjustment of values using display and navigation buttons must be password protected.

2.3.3 Application Specific Controller (ASC)

Application Specific Controllers (ASCs) have a fixed factory-installed application program (i.e. ProgramID) with configurable settings and do not have the ability to be programmed for custom applications. ASCs must meet the following requirements in addition to the General DDC Hardware and DDC Hardware Input-Output (I/O) Function requirements:

a. ASCs must be LonMark Certified.

b. Unless otherwise approved, all necessary Configuration Properties and network configuration inputs (*ncis*) for the sequence and application in which the ASC is used must be fully configurable through an LNS plug-in. LNS Plug-ins must be submitted for each type (manufacturer and model) of Application Specific Controller. LNS Plug-ins distributed under a license must be licensed to the project site. (Note: configuration accomplished via hardware settings does not require configuration via LNS plug-in.)

c. ASCs may include an integral or tethered Local Display Panel

2.3.4 General Purpose Programmable Controller (GPPC)

A General Purpose Programmable Controller (GPPC) must be programmed for the application. GPPCs must meet the following requirements in addition to the general DDC Hardware requirements and Hardware Input-Output (I/O) Functions:

a. The programmed GPPC must conform to the LonMark Interoperability Guide.

b. All programming software required to program the GPPC must be delivered to and licensed to the project site in accordance with Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC. Submit the most recent version of the Programming software for each type (manufacturer and model) of General Purpose Programmable Controller (GPPC).

c. Submit copies of the installed GPPC application programs (all software that is not common to every controller of the same manufacturer and model) as source code compatible with the supplied programming software in accordance with Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC. The submitted GPPC application program must 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.

d. GPPCs may be include an integral or tethered Local Display Panel

e. Provide and install the general purpose programmable control software as a plug-in under the network configuration tool on three government maintenance workstations and the government provided development workstation(s).

f. Program all sequences of operation in programmable controllers such that IP disconnection at the CEA-852-C router does not affect any sequences of operation.

2.3.5 Application Generic Controller (AGC)

An Application Generic Controller (AGC) has a fixed application program which includes the ability to be programmed for custom applications. AGCs must meet the following requirements in addition to the general DDC Hardware requirements and Hardware Input-Output (I/O) Functions:

a. The programmed AGC must conform to the LonMark Interoperability Guide.

b. The AGC must have a fixed ProgramID and fixed XIF file.

c. Unless otherwise approved, the ACG must be fully configurable and programmable for the application using one or more LNS plug-ins, all of which must be submitted as specified for each type of AGC (manufacturer and model).

d. Submit copies of the installed AGC application programs as source code compatible with the supplied LNS plug-in used for programming the device in accordance with Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC. The submitted AGC application program must be the complete application program necessary for the AGC to function as installed and be sufficient to allow replacement of the installed controller with an AGC of the same type.

e. AGCs may be include an integral or tethered Local Display Panel

f. Program all sequences of operation in programmable controllers such that IP disconnection at the FPOC does not limit any sequences of operation required in SECTION 23 09 93.

2.4 Electric Metering

An electric meter controller and related components must meet the requirements from Section 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC.

PART 3 EXECUTION

3.1 CONTROL SYSTEM INSTALLATION

3.1.1 Building Control Network (BCN)

Provide a Building Control Network (BCN) connecting all DDC hardware as specified. The Building Control Network (BCN) must consist of an IP

Network, one or more CEA-852-C Routers, and one or more Non-IP Building Control Network Channels:

3.1.1.1 Building Control Network (BCN) Installation

Provide building control networks meeting the following requirements:

a. Provide a Building Control Network IP Network, Non-IP Building Control Network Channels and CEA-852-C Routers to a create a single building control network connecting all DDC Hardware.

b. In addition to the connection to theCEA-852-C Router, each Non-IP Building Control Network (BCN) Channel directly connected to a CEA-852-C Router must be directly connected to either DDC Hardware or to CEA-709.1-D Routers, but not to both. A channel containing only CEA-709.1-D Routers is a backbone channel and a channel containing DDC Hardware is a non-backbone channel.

c. When only a single CEA-852-C Router is required, the IP network consists of only the CEA-852-C Router. When multiple CEA-852-C Routers are required, provide an IP Network connecting all CEA-852-C Routers.

d. Connect all DDC Hardware to a non-backbone BCN Channel.

e. Install components such that there is no more than than one CEA-709.1-D Router between any DDC Hardware and a CEA-852-C Router

f. Install the network such that the peak expected bandwidth usage for each and every channel is less than 70 percent, including device-to-device traffic and traffic to the Utility Monitoring and Control System (UMCS) as indicated on the Points Schedule.

g. Where multiple pieces of DDC Hardware are used in the execution of a single sequence of operation, directly connect all DDC Hardware used to execute the sequence to the same channel and do not install other DDC Hardware to that channel.

h. Use the real property facility number as LNS database name. Coordinate with DPW for building numbers.

i. Setup web page graphics at the CEA 852 router using the Points Schedules and Fort Leonard Wood standard for graphics display and functionality. Contact DPW for most recent graphics display and functionality standard (example screenshots of existing Echelon Smart Server web pages). When the building control system includes solar photo voltaic or solar water heating equipment, monitor and measure energy consumption and equipment performance to compare solar ouput with solar irradiance and show the amount of power being generated daily, monthly and annually.

j. Match the CEA-709.3 Router configuration settings in the Fort Leonard Wood SCG documentation.

3.1.1.2 Non-IP Building Control Network (BCN) Channel

Provide Non-IP Building Control Network (BCN) Channels meeting the following requirements:

a. For each non-backbone channel, provide a TP/FT-10 channel in doubly

terminated bus topology in accordance with CEA-709.3. For each backbone channel, provide either a TP/FT-10 channel in doubly terminated bus topology in accordance with CEA-709.3 or a TP/XF-1250 channel in accordance with the LonMark Interoperability Guide.

b. Connect no more than 2/3 the maximum number of devices permitted by CEA-709.3 to each TP/FT-10 channel. Connect no more than 2/3 the maximum number of devices permitted by LonMark Interoperability Guide to TP/XF-1250 channel.

c. Connect no more than 2/3 the maximum number of devices permitted by the manufacturer of the device transceivers to each channel. When more than one type of transceiver is used on the same channel, use the transceiver with the lowest maximum number of devices to calculate the 2/3 limit.

3.1.1.3 Building Control Network (BCN) IP Network

Install IP Network Cabling in conduit. Install Ethernet Switches in lockable enclosures. Install the Building Control Network (BCN) IP Network so that it is available at the Facility Point of Connection (FPOC) location as specified. When the FPOC location is a room number, provide sufficient additional media to ensure that the Building Control Network (BCN) IP Network can be extended to any location in the room.

3.1.2 DDC Hardware

Install CEA-852-C Routers in lockable enclosures. Install other DDC Hardware which is not is suspended ceilings in [lockable]enclosures.

Configure and commission all DDC Hardware on the Building Control Network via LNS using an LNS-based Network Configuration Tool. Use Application Specific Controllers whenever an Application Specific Controller suitable for the application exists. When an Application Specific Controller suitable for the application does not exist use Application Generic Controllers, General Purpose Programmable Controllers or multiple Application Specific Controllers

3.1.2.1 Hand-Off-Auto (H-O-A) Switches

Provide Hand-Off-Auto (H-O-A) switches as specified and as indicated on the Points Schedule. H-O-A switches must be integral to the controller hardware, an external device co-located with (in the same enclosure as) the controller, integral to the controlled equipment, or an external device co-located with (in the same enclosure as) the controlled equipment.

a. For H-O-A switches integral to DDC Hardware, meet the requirements specified in paragraph DIRECT DIGITAL CONTROL (DDC) HARDWARE.

b. For external H-O-A switches for binary outputs, provide switches capable of overriding the output open or closed.

c. For external H-O-A switches for analog outputs, provide switches capable of overriding through the range of 0 percent to 100 percent.

3.1.2.2 Local Display Panels

Provide LDPs to display and override values of Network Variables as indicated on the Points Schedule. Install LDPs displaying points for

anything other than a terminal unit in the same room as the equipment. Install LDPs displaying points for only terminal units in a mechanical room central to the group of terminal units it serves.

3.1.2.3 Overrides for GPPCs and AGCs

Provide the capability to override points for all General Purpose Programmable Controllers and Application Generic Controllers as specified and as indicated on the Points Schedule using one of the following methods:

a. Override SNVT of Same SNVT Type method:

(1) Use this method for all setpoint overrides and for overrides of inputs and outputs whenever practical.

(2) Provide a SNVT input to the DDC hardware containing the point to be overridden of the same SNVT type as the point to be overridden.

(3) Program and configure the DDC hardware such that:

(a) If the value of the SNVT on the override input is the *Invalid Value* defined for that SNVT by the LonMark SNVT List, then the point is not overridden (its value is determined from the sequence).

(b) If the value of the SNVT on the override input is not the *Invalid Value* defined for that SNVT by the LonMark SNVT List then set the value of the point to be overridden to the value of the SNVT on the override input.

b. HVAC Override SNVT method:

(1) Use this method for override of inputs and outputs when the "Override SNVT Shares SNVT Type" method is impractical.

(2) Provide a SNVT input to the DDC hardware containing the point to be overridden of SNVT type *SNVT_hvac_overid*. Show on the Points Schedule how to perform the specified override using this SNVT.

3.1.2.4 Overrides for ASCs

Whenever possible use the methods specified for General Purpose Programmable Controllers and Application Generic Controllers to perform overrides for all Application Specific Controllers. If neither the "Override SNVT of Same SNVT Type" method or "HVAC Override SNVT" method are supported by the Application Specific Controller show this on the Points Schedule and perform overrides as follows:

a. Provide one or more SNVT input(s) to the DDC hardware containing the point to be overridden. Document the number and type of each SNVT provided on the Points Schedule.

b. Configure the Application Specific Controller such that:

(1) For some specific combination or combinations of values at the SNVT override input(s) the point is not overridden, and its value is determined from the sequence as usual. Show on the Points Schedule the values required at the SNVT override input(s) to not override the point.

(2) For other specific combinations of SNVT override input(s), the value of the point to be overridden is determined from the value of the override input(s). Show on the Points Schedule the correlation between the SNVT override input(s) and the resulting value of the overridden point.

3.1.3 Scheduling, Alarming, Trending and Overrides

3.1.3.1 Scheduling

Provide DDC Hardware with LonMark Objects meeting the Simple Scheduler Functional Profile and configure schedules as specified on the Points Schedule and as specified.

3.1.3.1.1 Schedule Groupings

Provide a separate schedule for each AHU including it's associated Terminal Units and for each stand-alone Terminal Unit (those not dependent upon AHU service) or group of stand-alone Terminal Units acting according to a common schedule.

3.1.3.1.2 Occupancy Mode Mapping to SNVT Values

Use the following mapping between SNVT_Occupancy enumerations and occupancy modes:

a. OCCUPIED mode: Enumeration value of OC_OCCUPIED

b. UNOCCUPIED mode: Enumeration value of OC_UNOCCUPIED

c. WARM-UP/COOL-DOWN (PRE-OCCUPANCY) mode: Enumeration value of OC_STANDBY

3.1.3.2 Alarming

For each point which is shown on the Points Schedule with an alarm condition, provide a SNVT output for the point to be used by the UMCS Front End for alarm generation.

3.1.3.3 Trending

For each point which is shown on the Points Schedule as requiring a trend, provide a SNVT output for the point to be used by the UMCS Front End for trending.

3.1.3.4 Overrides

For each point shown on the Points Schedule as requiring an override, provide an override as specified in paragraphs "Overrides for GPPCs and AGCs" and "Overrides for ASCs".

3.1.4 Gateways

The requirements in this paragraph do not permit the installation of hardware not meeting the other requirements of this section. All control hardware installed under this project must meet the requirements of this specification, including control hardware provided as part of a package unit or as part of equipment specified under another section. Only use gateways to connect to pre-existing control devices.

Provide Gateways to non-CEA-709.1-D control hardware as required to connect existing non-CEA-709.1-D packaged units and in accordance with the following:

a. Each gateway must communicate with and perform protocol translation for non-CEA-709.1-D control hardware controlling one and only one package unit.

b. Connect one network port on the gateway to the Building Control Network and the other port to the single piece of controlled equipment.

c. Configure gateway to map writeable data points in the controlled equipment to Network Variable Inputs of Standard Network Variable Types as defined by the LonMark SNVT List as indicated in the Points Schedule and as specified.

d. Configure gateway to map readable data points in the controlled equipment to Network Variable Outputs of Standard Network Variable Types as defined by the LonMark SNVT Listas indicated in the Points Schedule and as specified.

e. Do not use non-CEA-709.1-D control hardware for controlling built-up units or any other equipment that was not furnished with factory-installed controls.

f. Do not use non-CEA-709.1-D control hardware for system scheduling functions.

g. Non-CEA-709.1-D network wiring connecting the gateway to the package unit must not exceed 10 feet in length and must connect to exactly two devices: the controlled equipment (packaged unit) and the gateway.

3.1.5 Network Interface Jack

Provide standard network interface jacks such that each node on the control network is within 10 ft of an interface jack. For terminal unit controllers with hardwired thermostats this network interface jack may instead be located at the thermostat. Locating the interface jack near the controller is preferred. If the network interface jack is other than a 1/8 inch phone jack, provide an interface cable with a standard 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 must be required to access all network interface jacks. Furnish one interface cable(s).

-- End of Section --

Appendix N: Insert: UFGS - 23 09 93 (Tailored to Fort Leonard Wood): Sequences of Operation for HVAC Control

SECTION TABLE OF CONTENTS

DIVISION 23 - HEATING, VENTILATING, AND AIR CONDITIONING (HVAC)

SECTION 23 09 93

SEQUENCES OF OPERATION FOR HVAC CONTROL

11/15

PART 1 GENERAL

1.1 REFERENCES
1.2 DEFINITIONS
1.3 SUBMITTALS

PART 2 PRODUCTS

PART 3 EXECUTION

3.1 SEQUENCES OF OPERATION FOR OCCUPANCY SCHEDULING
3.1.1 System Mode
3.1.2 System Scheduler Requirements
3.1.2.1 Scheduled Occupancy Input
3.1.2.2 Occupancy Override Input
3.1.2.3 Space Occupancy Inputs
3.1.2.4 Air Handler Occupancy Output
3.1.2.5 Terminal Unit Occupancy Output
3.1.2.6 Default Schedule
3.1.2.7 Communication Determination
3.1.3 System Scheduler Output Determination
3.1.3.1 Air Handler Occupancy Output
3.1.3.2 Terminal Unit Occupancy Output
3.1.4 Air Handler System Scheduling
3.1.5 Stand-Alone Terminal Unit Scheduling
3.2 SEQUENCES OF OPERATION FOR AIR HANDLING UNITS
3.2.1 All-Air Small Package Unitary System
3.2.1.1 Fan ON-AUTO Switch
3.2.1.1.1 ON
3.2.1.1.2 AUTO
3.2.1.2 HEAT-OFF-COOL Switch
3.2.1.2.1 HEAT-COOL
3.2.1.2.2 OFF
3.2.1.3 Occupancy Modes
3.2.1.3.1 Occupied
3.2.1.3.2 Unoccupied
3.2.1.4 Safeties
3.2.1.5 Zone Temperature Control
3.2.2 Heating and Ventilating Unit (or Unit Ventilator)
3.2.2.1 HAND-OFF-AUTO Switches
3.2.2.1.1 HAND
3.2.2.1.2 OFF
3.2.2.1.3 AUTO
3.2.2.2 Occupancy Modes
3.2.2.2.1 Occupied

```
      3.2.2.2.2   Unoccupied
    3.2.2.3   System Enable and Loop Enable
      3.2.2.3.1   Occupied Mode
      3.2.2.3.2   Unoccupied Mode
    3.2.2.4   Proofs and Safeties
      3.2.2.4.1   Proofs
      3.2.2.4.2   Safeties
      3.2.2.4.3   DDC Hardware
    3.2.2.5   Zone Temperature Control
      3.2.2.5.1   Enabled Loop
      3.2.2.5.2   Disabled Loop
    3.2.2.6   Mixed Air Damper Control
  3.2.3   Single Zone with Heating and DXCooling Coils
    3.2.3.1   HAND-OFF-AUTO Switch
      3.2.3.1.1   HAND
      3.2.3.1.2   OFF
      3.2.3.1.3   AUTO
    3.2.3.2   Occupancy Modes
    3.2.3.3   System Enable and Loop Enable
      3.2.3.3.1   Occupied Mode
      3.2.3.3.2   Unoccupied Mode
      3.2.3.3.3   Warm Up / Cool Down Mode
    3.2.3.4   Proofs and Safeties
      3.2.3.4.1   Proofs
      3.2.3.4.2   Safeties
      3.2.3.4.3   DDC Hardware
    3.2.3.5   Fan Control
    3.2.3.6   Supply Air Temperature Control
    3.2.3.7   Minimum Outside Air Flow Control
      3.2.3.7.1   Enable Loop
      3.2.3.7.2   CO2-Based Minimum Outside Air Damper Control
    3.2.3.8   Economizer Damper Control
      3.2.3.8.1   Enabled Loop
      3.2.3.8.2   Disabled Loop
      3.2.3.8.3   Economizer Enable Logic
      3.2.3.8.4   CO2-Based Economizer Damper Control
    3.2.3.9   Heating Coil Control
    3.2.3.10   Cooling Coil Control
  3.2.4   Single Zone with Dual-Temperature Coil
    3.2.4.1   HAND-OFF-AUTO Switch
      3.2.4.1.1   HAND
      3.2.4.1.2   OFF
      3.2.4.1.3   AUTO
    3.2.4.2   Occupancy Modes
    3.2.4.3   System Enable and Loop Enable
      3.2.4.3.1   Occupied Mode
      3.2.4.3.2   Unoccupied Mode
      3.2.4.3.3   Warm Up / Cool Down Mode
    3.2.4.4   Proofs and Safeties
      3.2.4.4.1   Proofs
      3.2.4.4.2   Safeties
      3.2.4.4.3   DDC Hardware
    3.2.4.5   Fan Control
    3.2.4.6   Supply Air Temperature Control
    3.2.4.7   Minimum Outside Air Flow Control
      3.2.4.7.1   Enable Loop
      3.2.4.7.2   CO2-Based Minimum Outside Air Damper Control
    3.2.4.8   Economizer Damper Control
      3.2.4.8.1   Enabled Loop
```

```
    3.2.4.8.2   Disabled Loop
    3.2.4.8.3   Economizer Enable Logic
    3.2.4.8.4   CO2-Based Economizer Damper Control
  3.2.4.9   Dual Temperature Coil Control
    3.2.4.9.1   Enabled Loop
    3.2.4.9.2   DDC Hardware
    3.2.4.9.3   Disabled Loop
3.2.5   Single Zone with Heating and Cooling Coils and Return Air Bypass
  3.2.5.1   HAND-OFF-AUTO Switch
    3.2.5.1.1   HAND
    3.2.5.1.2   OFF
    3.2.5.1.3   AUTO
  3.2.5.2   Occupancy Modes
  3.2.5.3   System Enable and Loop Enable
    3.2.5.3.1   Occupied Mode
    3.2.5.3.2   Unoccupied Mode
    3.2.5.3.3   Warm Up / Cool Down Mode
  3.2.5.4   Proofs and Safeties
    3.2.5.4.1   Proofs
    3.2.5.4.2   Safeties
    3.2.5.4.3   DDC Hardware
  3.2.5.5   Fan Control
  3.2.5.6   Supply Air Temperature Control
  3.2.5.7   Minimum Outside Air Flow Control
    3.2.5.7.1   Enable Loop
    3.2.5.7.2   CO2-Based Minimum Outside Air Damper Control
  3.2.5.8   Economizer Damper Control
    3.2.5.8.1   Enabled Loop
    3.2.5.8.2   Disabled Loop
    3.2.5.8.3   Economizer Enable Logic
    3.2.5.8.4   CO2-Based Economizer Damper Control
  3.2.5.9   Temperature Control Loop Heating Coil Control
3.2.6   Single Zone with Humidity Control
  3.2.6.1   HAND-OFF-AUTO Switch
    3.2.6.1.1   HAND
    3.2.6.1.2   OFF
    3.2.6.1.3   AUTO
  3.2.6.2   Occupancy Modes
  3.2.6.3   System Enable and Loop Enable
    3.2.6.3.1   Occupied Mode
    3.2.6.3.2   Unoccupied Mode
    3.2.6.3.3   Warm Up / Cool Down Mode
  3.2.6.4   Proofs and Safeties
    3.2.6.4.1   Proofs
    3.2.6.4.2   Safeties
    3.2.6.4.3   DDC Hardware
  3.2.6.5   Fan Control
  3.2.6.6   Supply Air Temperature Control
  3.2.6.7   Minimum Outside Air Flow Control
    3.2.6.7.1   Enable Loop
    3.2.6.7.2   CO2-Based Minimum Outside Air Damper Control
  3.2.6.8   Preheat Coil Control Loop
  3.2.6.9   Cooling-and-Dehumidification Coil Control
  3.2.6.10   Reheat Coil Control
  3.2.6.11   Humidification Control
3.2.7   Multizone or Dual-Duct
  3.2.7.1   HAND-OFF-AUTO switches and Fire Alarm Panel (FAP) Signal
    3.2.7.1.1   HAND
    3.2.7.1.2   OFF

                    SECTION 23 09 93  Page 3
```

```
      3.2.7.1.3   AUTO
    3.2.7.2   Supply Fan VFD
    3.2.7.3   Return Fan VFD
    3.2.7.4   Occupancy Modes
    3.2.7.5   System Enable and Loop Enable
      3.2.7.5.1   Occupied Mode
      3.2.7.5.2   Unoccupied Mode
      3.2.7.5.3   Warm Up / Cool Down Mode
    3.2.7.6   Proofs and Safeties
      3.2.7.6.1   Proofs
      3.2.7.6.2   Safeties
      3.2.7.6.3   DDC Hardware Reset
    3.2.7.7   Minimum Outside Air Flow Control
      3.2.7.7.1   Enable Loop
      3.2.7.7.2   CO2-Based Minimum Outside Air Damper Control
    3.2.7.8   Mixed Air Temperature Control With Economizer
      3.2.7.8.1   Enabled Loop
      3.2.7.8.2   Disabled Loop
      3.2.7.8.3   Economizer Enable Logic
      3.2.7.8.4   CO2-Based Economizer Damper Control
    3.2.7.9   Hot Deck Coil Control
      3.2.7.9.1   Enabled Loop
      3.2.7.9.2   DDC Hardware Reset
    3.2.7.10   Cold Deck Coil Control
    3.2.7.11   Zone Temperature Control
      3.2.7.11.1   Zone Temperature Setpoint
      3.2.7.11.2   DDC Hardware Modulation
  3.2.8   Multizone with Hot Deck Bypass
    3.2.8.1   HAND-OFF-AUTO Switches
      3.2.8.1.1   HAND
      3.2.8.1.2   OFF
      3.2.8.1.3   AUTO
    3.2.8.2   Return Fan Motor Starter
      3.2.8.2.1   HAND
      3.2.8.2.2   OFF
      3.2.8.2.3   AUTO
    3.2.8.3   Occupancy Modes
    3.2.8.4   System Enable and Loop Enable
      3.2.8.4.1   Occupied Mode
      3.2.8.4.2   Unoccupied Mode
      3.2.8.4.3   Warm Up / Cool Down Mode
    3.2.8.5   Proofs and Safeties
      3.2.8.5.1   Proofs
      3.2.8.5.2   Safeties
      3.2.8.5.3   DDC Hardware Reset
    3.2.8.6   Supply Fan Control
    3.2.8.7   Minimum Outside Air Flow Control
      3.2.8.7.1   Enable Loop
      3.2.8.7.2   CO2-Based Minimum Outside Air Damper Control
    3.2.8.8   Mixed Air Temperature Control With Economizer
      3.2.8.8.1   Enabled Loop
      3.2.8.8.2   Disabled Loop
      3.2.8.8.3   Economizer Enable Logic
      3.2.8.8.4   CO2-Based Economizer Damper Control
    3.2.8.9   Cold Deck Coil Control
    3.2.8.10   Zone Temperature Control
  3.2.9   Variable Air Volume System
    3.2.9.1   HAND-OFF-AUTO Switches
      3.2.9.1.1   HAND
```

```
        3.2.9.1.2   OFF
        3.2.9.1.3   AUTO
      3.2.9.2   Return Fan Variable Frequency Drive
        3.2.9.2.1   HAND
        3.2.9.2.2   OFF
        3.2.9.2.3   AUTO
      3.2.9.3   Occupancy Modes
      3.2.9.4   Proofs and Safeties
        3.2.9.4.1   Proofs
        3.2.9.4.2   Safeties
        3.2.9.4.3   DDC Hardware Reset
      3.2.9.5   System Enable and Loop Enable
        3.2.9.5.1   Occupied Mode
        3.2.9.5.2   Unoccupied Mode
        3.2.9.5.3   Warm Up/Cool Down
      3.2.9.6   Fan Capacity Control
        3.2.9.6.1   Supply Duct Static Pressure Control
        3.2.9.6.2   Supply Duct Static Pressure Control Reset Loop
        3.2.9.6.3   Return Fan Volume Control
      3.2.9.7   Minimum Outside Air Flow Control
        3.2.9.7.1   Enable Loop
        3.2.9.7.2   CO2-Based Minimum Outside Air Damper Control
      3.2.9.8   Mixed Air Temperature Control With Economizer
        3.2.9.8.1   Enabled Loop
        3.2.9.8.2   Disabled Loop
        3.2.9.8.3   Economizer Enable Logic
      3.2.9.9   Cooling Coil Control
      3.2.9.10   Preheat Coil Control
  3.3   SEQUENCES OF OPERATION FOR TERMINAL UNITS
    3.3.1   Zone Temperature Control - Cooling-Only VAV Box
      3.3.1.1   Occupancy Modes
        3.3.1.1.1   Occupied
        3.3.1.1.2   Unoccupied
      3.3.1.2   Safeties
      3.3.1.3   Zone Temperature Control
        3.3.1.3.1   Occupied Mode
        3.3.1.3.2   Unoccupied Mode
    3.3.2   Zone Temperature Control - VAV Box with Reheat
      3.3.2.1   Occupancy Modes
        3.3.2.1.1   Occupied
        3.3.2.1.2   Unoccupied
      3.3.2.2   Safeties
      3.3.2.3   Flow Control
      3.3.2.4   Zone Temperature Control
    3.3.3   Zone Temperature Control - Fan Powered VAV Box
      3.3.3.1   Occupancy Modes
        3.3.3.1.1   Occupied
        3.3.3.1.2   Unoccupied
      3.3.3.2   Safeties
      3.3.3.3   Fan Control
      3.3.3.4   Flow Control
      3.3.3.5   Zone Temperature Control
        3.3.3.5.1   Occupied Mode
        3.3.3.5.2   Unoccupied Mode
        3.3.3.5.3   Sequencing
          3.3.3.5.3.1   Cooling Mode
          3.3.3.5.3.2   Heating Mode
    3.3.4   Perimeter Radiation Control Sequence
      3.3.4.1   Occupancy Modes

                    SECTION 23 09 93  Page 5
```

```
        3.3.4.1.1   Occupied
        3.3.4.1.2   Unoccupied
      3.3.4.2   Safeties
      3.3.4.3   Space Temperature Control
        3.3.4.3.1   Occupied Mode
        3.3.4.3.2   Unoccupied Mode
    3.3.5   Unit Heater and Cabinet Unit Heater
      3.3.5.1   Off-Auto Switch
        3.3.5.1.1   OFF
        3.3.5.1.2   AUTO
      3.3.5.2   Occupancy Modes
        3.3.5.2.1   Occupied
        3.3.5.2.2   Unoccupied
      3.3.5.3   Safeties
      3.3.5.4   Space Temperature Control
        3.3.5.4.1   Occupied Mode
        3.3.5.4.2   Unoccupied Mode
    3.3.6   Gas-Fired Infrared Heater
      3.3.6.1   On-Off-Auto Switch
        3.3.6.1.1   ON
        3.3.6.1.2   OFF
        3.3.6.1.3   AUTO
      3.3.6.2   Occupancy Modes
        3.3.6.2.1   Occupied
        3.3.6.2.2   Unoccupied
      3.3.6.3   Safeties
      3.3.6.4   Space Temperature Control
        3.3.6.4.1   Occupied Mode
        3.3.6.4.2   Unoccupied Mode
    3.3.7   Dual Temperature Fan-Coil Unit
      3.3.7.1   Off-Auto Switch
        3.3.7.1.1   OFF
        3.3.7.1.2   AUTO
      3.3.7.2   Occupancy Modes
        3.3.7.2.1   Occupied
        3.3.7.2.2   Unoccupied
      3.3.7.3   Heat/Cool Modes
      3.3.7.4   Safeties
      3.3.7.5   Space Temperature Control
        3.3.7.5.1   Occupied Mode
        3.3.7.5.2   Unoccupied Mode
  3.4   SEQUENCES OF OPERATION FOR HYDRONIC SYSTEMS
    3.4.1   Hydronic Heating Hot Water from Distributed HTHW Converter
      3.4.1.1   System Enable and Loop Enable
      3.4.1.2   HAND-OFF-AUTO Switch
        3.4.1.2.1   HAND
        3.4.1.2.2   OFF
        3.4.1.2.3   AUTO
      3.4.1.3   Proofs and Safeties
        3.4.1.3.1   Proofs
        3.4.1.3.2   Safeties
        3.4.1.3.3   DDC Hardware Reset
      3.4.1.4   Heat Exchanger Valve Control
    3.4.2   Hydronic Heating Hot Water From Single-Building Boiler
      3.4.2.1   System Enable and Loop Enable
      3.4.2.2   HAND-OFF-AUTO Switch
        3.4.2.2.1   HAND
        3.4.2.2.2   OFF
        3.4.2.2.3   AUTO
```

3.4.2.3 Proofs and Safeties
3.4.2.3.1 Proofs
3.4.2.3.2 Safeties
3.4.2.3.3 DDC Hardware Reset
3.4.2.4 Boiler Control
3.4.2.5 Hot Water Temperature Control
3.4.3 Hydronic Dual-Temperature System with High Temperature Hot Water Heat Exchanger and Chilled Water
3.4.3.1 System Enable and Loop Enable
3.4.3.2 Switchover Valve Operation
3.4.3.2.1 HEATING/COOLING Switch in the HEATING Position
3.4.3.2.2 HEATING/COOLING Switch in the COOLING Position
3.4.3.3 HAND-OFF-AUTO Switch
3.4.3.3.1 HAND
3.4.3.3.2 OFF
3.4.3.3.3 AUTO
3.4.3.4 Proofs and Safeties
3.4.3.4.1 Proofs
3.4.3.4.2 Safeties
3.4.3.4.3 DDC Hardware Reset
3.4.3.5 Heat Exchanger Valve Control
3.4.4 Hydronic Secondary with Variable Speed Pump
3.4.4.1 System Enable and Loop Enable
3.4.4.2 HAND-OFF-AUTO Switch
3.4.4.2.1 HAND
3.4.4.2.2 OFF
3.4.4.2.3 AUTO
3.4.4.3 Proofs and Safeties
3.4.4.3.1 Proofs
3.4.4.3.2 Safeties
3.4.4.3.3 DDC Hardware Reset
3.4.4.4 Pressure Control

-- End of Section Table of Contents --

SECTION 23 09 93

SEQUENCES OF OPERATION FOR HVAC CONTROL
11/15

PART 1 GENERAL

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.

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

ASHRAE 62.1	(2016) Ventilation for Acceptable Indoor Air Quality

1.2 DEFINITIONS

For definitions related to this Section, see Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.

1.3 SUBMITTALS

Submittals related to this Section are specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC.

PART 2 PRODUCTS

Products related to this Section are specified in Section 23 09 00 INSTRUMENTATION AND CONTROL FOR HVAC and related Sections 23 09 13 INSTRUMENTATION AND CONTROL DEVICES FOR HVAC and 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC

PART 3 EXECUTION

3.1 SEQUENCES OF OPERATION FOR OCCUPANCY SCHEDULING

3.1.1 System Mode

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

3.1.2 System Scheduler Requirements

The System Scheduler functionality must reside in the CEA 852-C router and the default scheduler 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 dedicated to scheduling (performing no other control functionality) may contain multiple System

Schedulers. Provide a unique System Scheduler 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 must provide the following functionality:

3.1.2.1 Scheduled Occupancy Input

Accept network variable of type SNVT_occupancy. Support the following possible values: OC_STANDBY, OC_OCCUPIED and OC_UNOCCUPIED.

3.1.2.2 Occupancy Override Input

Accept network variable of type SNVT_occupancy. Support the following possible values: OC_STANDBY, OC_OCCUPIED, OC_UNOCCUPIED, and OC_NUL.

3.1.2.3 Space Occupancy Inputs

For systems with multiple occupancy sensors, accept multiple inputs of network variable type SNVT_Occupancy. 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.

3.1.2.4 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.

3.1.2.5 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.

3.1.2.6 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.

3.1.2.7 Communication Determination

Determine the time elapsed between receipts of the scheduled occupancy input SNVT, and use this elapsed time to activate and deactivate the Default Schedule as specified. (This provides the capability for the system scheduler to use its Default Schedule if it loses communication with the UMCS).

3.1.3 System Scheduler Output Determination

For controlling an Air Handler, interpret a SNVT input of OC_STANDBY as Warm-Up-Cool-Down if the sequence of operation supports that mode, otherwise interpret OC_STANDBY as Occupied. For Terminal Units, interpret OC_STANDBY as Occupied.

3.1.3.1 Air Handler Occupancy Output

If more than 95 minutes have passed since the last receipt of the Scheduled Occupancy input, determine the Air Handler Occupancy Output by the default schedule and the Space Occupancy Inputs. Otherwise, determine the output as follows:

a. If the Override Occupancy Input is not OC_NUL, determine the Air Handler Occupancy Output from the Override Occupancy Input.

b. Otherwise, if 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 must be OC_OCCUPIED.

c. Otherwise, determine the Air Handler Occupancy Output from the Scheduled Occupancy Input SNVT.

3.1.3.2 Terminal Unit Occupancy Output

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

a. If the Override Occupancy Input is not OC_NUL, determine the Terminal Unit Occupancy Output from the Override Occupancy Input SNVT:

b. Otherwise, determine the Terminal Unit Occupancy Output from the Scheduled Occupancy SNVT.

3.1.4 Air Handler System Scheduling

a. Bind the AHU Occupancy Output SNVT 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, bind the output SNVT (of type SNVT_Occupancy) of each occupancy sensor to a Space Occupancy Input of the System Scheduler.

c. Bind the Terminal Unit Occupancy Output SNVT from the System Scheduler to each AHU-Dependent Terminal Unit.

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

3.1.5 Stand-Alone Terminal Unit Scheduling

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

3.2 SEQUENCES OF OPERATION FOR AIR HANDLING UNITS

3.2.1 All-Air Small Package Unitary System

Install DDC hardware to perform this Sequence of Operation and to provide

SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control must be proportional-integral (PI) control.

3.2.1.1 Fan ON-AUTO Switch

3.2.1.1.1 ON

With the thermostat fan ON-AUTO switch in the ON position, the DDC Hardware must start and continuously run the fan.

3.2.1.1.2 AUTO

With the thermostat fan ON-AUTO switch in the AUTO position, the DDC Hardware operates the fan according to HEAT-OFF-COOL switch.

3.2.1.2 HEAT-OFF-COOL Switch

3.2.1.2.1 HEAT-COOL

With the thermostat switch in the HEAT or COOL positions, use the DDC Hardware to operate the package unit according to the Occupancy Mode.

3.2.1.2.2 OFF

With the thermostat switch in the OFF position, de-energize the heating unit and cooling unit with the DDC Hardware.

3.2.1.3 Occupancy Modes

3.2.1.3.1 Occupied

The unit DDC Hardware must 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.

3.2.1.3.2 Unoccupied

The unit DDC Hardware must 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.

3.2.1.4 Safeties

Run the unit subject to the unit manufacturer's safeties.

3.2.1.5 Zone Temperature Control

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

b. In the Unoccupied Mode the zone temperature setpoint (ZN-T-SP-UNOCC) must be at the configured setpoint (ZN-T-SP-UNOCC) as indicated.

c. Cycle the fan, cooling unit, heating unit with the DDC Hardware, in accordance with the HEAT-COOL switch setting, to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP).

3.2.2 Heating and Ventilating Unit (or Unit Ventilator)

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

3.2.2.1 HAND-OFF-AUTO Switches

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

3.2.2.1.1 HAND

With the H-O-A switch in HAND position, the supply fan starts and runs continuously, subject to Safeties.

3.2.2.1.2 OFF

With the H-O-A switch in OFF position, the supply fan stops.

3.2.2.1.3 AUTO

With the H-O-A switch in AUTO position, the supply fan runs subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.

3.2.2.2 Occupancy Modes

Obtain the system's Occupancy Mode input from the System Scheduler as specified and indicated. Operate the system in one of the following modes:

3.2.2.2.1 Occupied

The Unit's DDC Hardware must 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.

3.2.2.2.2 Unoccupied

The Unit's DDC Hardware must 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.

3.2.2.3 System Enable and Loop Enable

3.2.2.3.1 Occupied Mode

Enable the supply fan (SYS-ENA) and command to run (SF-SS). Enable the Zone Temperature Control loop and Mixed Air Damper Control.

3.2.2.3.2 Unoccupied Mode

Disable all control loops. When BLDG-T drops below BLDG-T-LL-SP (with a 5 degrees F deadband) enable the supply fan (SYS-ENA) and command to run (SF-SS) and enable the Zone Temperature Control loop.

3.2.2.4 Proofs and Safeties

Subject the supply fan and all DDC Hardware control loops to Proofs and Safeties. Direct-hardwire interlock safeties to the fan starter circuit as indicated. DDC Hardware must monitor all proofs and safeties and failure of any proof or activation of any safety must result in all control loops being disabled and the AHU fan being commanded off until reset.

3.2.2.4.1 Proofs

Supply fan status (proof) (SF-S)

3.2.2.4.2 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)

3.2.2.4.3 DDC Hardware

DDC Hardware reset all proofs and safeties 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 indicated on the Points Schedule drawing.

3.2.2.5 Zone Temperature Control

3.2.2.5.1 Enabled Loop

When this loop is enabled, the DDC Hardware must 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). Provide sequencing as indicated: Upon a rise in zone temperature above zone temperature setpoint (ZN-T-SP), subject to the zone temperature setpoint deadband as indicated, modulate the outside air, relief, and return air dampers to maintain zone temperature at setpoint. During occupied mode, outside air damper minimum position (OA-D-MIN) shall be as indicated. Upon a fall in zone temperature below zone temperature setpoint, subject to the deadband as indicated, modulate the heating valve towards open to maintain zone temperature setpoint.

3.2.2.5.2 Disabled Loop

When this loop is disabled, close the heating valve and close the outside air damper and relief damper and open the return damper.

3.2.2.6 Mixed Air Damper Control

When this is enabled, open the outside air and relief air dampers and close the return air damper. When this is disabled, close the outside air and relief air dampers and open the return air damper.

3.2.3 Single Zone with Heating and DXCooling Coils

Install DDC hardware to perform this Sequence of Operation and to provide

SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control must be proportional-integral (PI) control.

3.2.3.1 HAND-OFF-AUTO Switch

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

3.2.3.1.1 HAND

With the H-O-A switch in HAND position, the supply fan starts and runs continuously, subject to Safeties.

3.2.3.1.2 OFF

With the H-O-A switch in OFF position, the supply fan stops.

3.2.3.1.3 AUTO

With the H-O-A switch in AUTO position, the supply fan runs subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.

3.2.3.2 Occupancy Modes

Obtain the system's Occupancy Mode input from the System Scheduler as specified and indicated. Operate the system in one of the following modes: Occupied, Unoccupied, or WarmUp/CoolDown.

3.2.3.3 System Enable and Loop Enable

3.2.3.3.1 Occupied Mode

Enable the supply fan (SYS-ENA) and command to run (SF-SS) and enable all control loops.

3.2.3.3.2 Unoccupied Mode

While the building temperature (BLDG-T) is above the low limit setpoint (BLDG-T-LL) disable all control loops and the supply fan does not run. When BLDG-T drops below BLDG-T-LL (with a 5 degrees F deadband) enable the supply fan (SYS-ENA) and command to run (SF-SS) and enable the Heating Coil Temperature Control loop. Disable the Outside Air Flow Control, Economizer Damper Control, and Cooling Coil Control loops.

3.2.3.3.3 Warm Up / Cool Down Mode

Enable the supply fan (SYS-ENA) and command to run (SF-SS) and disable the Minimum Outside Air Flow Control loop. Enable all other control loops.

3.2.3.4 Proofs and Safeties

The supply fan and all DDC Hardware control loops are subject to Proofs and Safeties. Safeties must be direct-hardwire interlocked to the fan starter circuit as indicated. DDC Hardware must monitor all proofs and safeties and failure of any proof or activation of any safety result in all control

loops being disabled and the AHU fan being commanded off until reset.

3.2.3.4.1 Proofs

Supply fan status (proof) (SF-S)

3.2.3.4.2 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)

3.2.3.4.3 DDC Hardware

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.

3.2.3.5 Fan Control

When this loop is enabled the DDC Hardware shall vary supply fan speed between 100% (SF-C-MAX) and a lower limit determined by the TAB contractor that corresponds to minimum outside air flow (SF-C-MIN) to maintain zone temperature set point (ZN-T-SP) within a deadband of 1 degree F.

3.2.3.6 Supply Air Temperature Control

When this loop is enabled the DDC Hardware shall vary supply air temperature setpoint (SA-T-SP) between design heating and cooling supply air temperatures to maintain zone temperature set point (ZN-T-SP) within a deadband of 1 degree F.

3.2.3.7 Minimum Outside Air Flow Control

3.2.3.7.1 Enable Loop

When this loop is enabled the DDC Hardware shall open the 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.

3.2.3.7.2 CO2-Based Minimum Outside Air Damper Control

When this loop is enabled the DDC Hardware shall vary the minimum outside air damper position between 100% (MINOA-C-MAX) and a lower limit (MINOA-C-MIN) corresponding to the zone's square footage-based ventilation requirement as determined by ASHRAE 62.1 (Ventilation Rate Procedure). This minimum outside air damper command reset shall be based on the comparison of the zone CO2 measurement (ZN-CO2) to a configurable zone CO2 reset range (ZN-CO2-MIN AND ZN-CO2-MAX) that is determined by the TAB contractor from a recorded measurement of local ambient CO2 for minimum and initially set at 1100 ppm for maximum.

3.2.3.8 Economizer Damper Control

3.2.3.8.1 Enabled Loop

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 damper setpoint (MA-D-C) in sequence with the DX cooling coil control and heating coil control valve as shown to maintain zone temperature setpoint (ZN-T-SP) and as shown.

3.2.3.8.2 Disabled Loop

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

3.2.3.8.3 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 2 degrees F deadband.

3.2.3.8.4 CO2-Based Economizer Damper Control

When this loop is enabled and when the zone temperature control loop is not calling for a greater ECONO-C-SP, the DDC Hardware shall vary the economizer dampers between 100% (ECONO-C-MAX) and a lower limit (MINOA-C-MIN) corresponding to the zone's square footage-based ventilation requirement as determined by ASHRAE 62.1 (Ventilation Rate Procedure). This economizer damper command reset shall be based on the comparison of the zone CO2 measurement (ZN-CO2) to a configurable zone CO2 reset range (ZN-CO2-MIN AND ZN-CO2-MAX) that is determined by the TAB contractor from a recorded measurement of local ambient CO2 for minimum and initially set at 1100 ppm for maximum.

3.2.3.9 Heating Coil Control

When this loop is enabled the DDC Hardware shall modulate the heating coil control valve in sequence with the DX staging control or cooling coil valve and economizer dampers as shown to maintain supply air temperature (SA-T) at setpoint (SA-T-SP) as shown. When this loop is disabled, the heating coil control valve shall be closed.

3.2.3.10 Cooling Coil Control

When this loop is enabled the DDC Hardware shall stage the DX Unit or modulate the cooling coil control valve in sequence with the heating coil valve and economizer dampers as shown to maintain supply air temperature (SA-T) at setpoint (SA-T-SP) as shown. When this loop is disabled, the DX unit shall be off or cooling coil control valve shall be closed.

3.2.4 Single Zone with Dual-Temperature Coil

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

3.2.4.1 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:

3.2.4.1.1 HAND

With the H-O-A switch in HAND position, the supply fan starts and runs continuously, subject to Safeties.

3.2.4.1.2 OFF

With the H-O-A switch in OFF position, the supply fan stops.

3.2.4.1.3 AUTO

With the H-O-A switch in AUTO position, the supply fan runs subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.

3.2.4.2 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.

3.2.4.3 System Enable and Loop Enable

3.2.4.3.1 Occupied Mode

The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS) and all control loops shall be enabled.

3.2.4.3.2 Unoccupied Mode

While the building temperature (BLDG-T) is above the building low limit setpoint (BLDG-T-LL) all control loops shall be disabled and the supply fan shall not run. When BLDG-T drops below BLDG-T-LL (with a 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.

3.2.4.3.3 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.

3.2.4.4 Proofs and Safeties

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.

3.2.4.4.1 Proofs

Supply fan status (proof) (SF-S)

3.2.4.4.2 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)

3.2.4.4.3 DDC Hardware

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.

3.2.4.5 Fan Control

When this loop is enabled the DDC Hardware shall vary supply fan speed between 100% (SF-C-MAX) and a lower limit determined by the TAB contractor that corresponds to minimum outside air flow (SF-C-MIN) to maintain zone temperature set point (ZN-T-SP) within a deadband of 1 degree F.

3.2.4.6 Supply Air Temperature Control

When this loop is enabled the DDC Hardware shall vary supply air temperature setpoint (SA-T-SP) between design heating and cooling supply air temperatures to maintain zone temperature set point (ZN-T-SP) within a deadband of 1 degree F.

3.2.4.7 Minimum Outside Air Flow Control

3.2.4.7.1 Enable Loop

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.

3.2.4.7.2 CO2-Based Minimum Outside Air Damper Control

When this loop is enabled the DDC Hardware shall vary the minimum outside air damper position between 100% (MINOA-D-MAX) and a lower limit (MINOA-D-MIN) corresponding to the zone's square footage-based ventilation requirement as determined by ASHRAE 62.1 (Ventilation Rate Procedure) and the TAB contractor. This minimum outside air damper command reset shall be based on the comparison of the zone CO2 measurement (ZN-CO2) to a configurable zone CO2 reset range (ZN-CO2-MIN AND ZN-CO2-MAX) that is determined by the TAB contractor from a recorded measurement of local ambient CO2 for minimum and initially set at 1100 ppm for maximum.

3.2.4.8 Economizer Damper Control

3.2.4.8.1 Enabled Loop

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 dual temperature coil to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP) as shown.

3.2.4.8.2 Disabled Loop

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.

3.2.4.8.3 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 2 degrees F deadband.

3.2.4.8.4 CO2-Based Economizer Damper Control

When this loop is enabled and when the zone temperature control loop is not calling for a greater MA-D-C, the DDC Hardware shall vary the mixed air dampers between design minimum outside air position (MA-D-C-MIN1) and a lower limit (MA-D-C-MIN2) corresponding to the zone's square footage-based ventilation requirement as determined by ASHRAE 62.1 (Ventilation Rate Procedure) and the TAB contractor. This mixed air damper command reset shall be based on the comparison of the zone CO2 measurement (ZN-CO2) to a configurable zone CO2 reset range (ZN-CO2-MIN AND ZN-CO2-MAX) that is determined by the TAB contractor from a recorded measurement of local ambient CO2 for minimum and initially set at 1100 ppm for maximum.

3.2.4.9 Dual Temperature Coil Control

3.2.4.9.1 Enabled Loop

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.

3.2.4.9.2 DDC Hardware

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.

3.2.4.9.3 Disabled Loop

When this loop is disabled, the control valve shall be closed.

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

Install DDC hardware to perform this Sequence of Operation and to provide SNVT inputs and outputs as specified and shown on the Points Schedule. Unless otherwise specified, all modulating control shall be

proportional-integral (PI) control.

3.2.5.1 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:

3.2.5.1.1 HAND

With the H-O-A switch in HAND position, the supply fan shall start and run continuously, subject to Safeties.

3.2.5.1.2 OFF

With the H-O-A switch in OFF position, the supply fan shall stop.

3.2.5.1.3 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.

3.2.5.2 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.

3.2.5.3 System Enable and Loop Enable

3.2.5.3.1 Occupied Mode

The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS) and all control loops shall be enabled.

3.2.5.3.2 Unoccupied Mode

While the building temperature (BLDG-T) is above the low limit setpoint (BLDG-T-LL) all control loops shall be disabled and the supply fan shall not run. When BLDG-T drops below BLDG-T-LL (with a 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.

3.2.5.3.3 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.

3.2.5.4 Proofs and Safeties

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.

3.2.5.4.1 Proofs

Supply fan status (proof) (SF-S)

3.2.5.4.2 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)

3.2.5.4.3 DDC Hardware

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.

3.2.5.5 Fan Control

When this loop is enabled the DDC Hardware shall vary supply fan speed between 100% (SF-C-MAX) and a lower limit determined by the TAB contractor that corresponds to minimum outside air flow (SF-C-MIN) to maintain zone temperature set point (ZN-T-SP) within a deadband of 1 degree F.

3.2.5.6 Supply Air Temperature Control

When this loop is enabled the DDC Hardware shall vary supply air temperature setpoint (SA-T-SP) between design heating and cooling supply air temperatures to maintain zone temperature set point (ZN-T-SP) within a deadband of 1 degree F.

3.2.5.7 Minimum Outside Air Flow Control

3.2.5.7.1 Enable Loop

When this loop is enabled the DDC Hardware shall open the 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.

3.2.5.7.2 CO2-Based Minimum Outside Air Damper Control

When this loop is enabled the DDC Hardware shall vary the minimum outside air damper position between 100% (MINOA-D-MAX) and a lower limit (MINOA-D-MIN) corresponding to the zone's square footage-based ventilation requirement as determined by ASHRAE 62.1 (Ventilation Rate Procedure) and the TAB contractor. This minimum outside air damper command reset shall be based on the comparison of the zone CO2 measurement (ZN-CO2) to a configurable zone CO2 reset range (ZN-CO2-MIN AND ZN-CO2-MAX) that is determined by the TAB contractor from a recorded measurement of local ambient CO2 for minimum and initially set at 1100 ppm for maximum.

3.2.5.8 Economizer Damper Control

3.2.5.8.1 Enabled Loop

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.

3.2.5.8.2 Disabled Loop

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.

3.2.5.8.3 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 2 degrees F deadband.

3.2.5.8.4 CO2-Based Economizer Damper Control

When this loop is enabled and when the zone temperature control loop is not calling for a greater MA-D-C, the DDC Hardware shall vary the mixed air dampers between design minimum outside air position (MA-D-C-MIN1) and a lower limit (MA-D-C-MIN2) corresponding to the zone's square footage-based ventilation requirement as determined by ASHRAE 62.1 (Ventilation Rate Procedure) and the TAB contractor. This mixed air damper command reset shall be based on the comparison of the zone CO2 measurement (ZN-CO2) to a configurable zone CO2 reset range (ZN-CO2-MIN AND ZN-CO2-MAX) that is determined by the TAB contractor from a recorded measurement of local ambient CO2 for minimum and initially set at 1100 ppm for maximum.

3.2.5.9 Temperature Control Loop Heating Coil Control

When this loop is enabled the DDC Hardware shall modulate the heating coil control valve, modulate the economizer dampers if enabled, open and close the 2-position cooling coil valve and modulate the bypass and supply air dampers in sequence to maintain supply air temperature) (SA-T) at setpoint (SA-T-SP) as shown. When this loop is disabled both valves shall be closed and the bypass and supply air dampers shall be positioned to bypass air.

3.2.6 Single Zone with Humidity Control

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

3.2.6.1 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 indicated. The supply fan motor starter shall

have an H-O-A switch:

3.2.6.1.1 HAND

With the H-O-A switch in HAND position, the supply fan shall start and run continuously, subject to Safeties.

3.2.6.1.2 OFF

With the H-O-A switch in OFF position, the supply fan shall stop.

3.2.6.1.3 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.

3.2.6.2 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.

3.2.6.3 System Enable and Loop Enable

3.2.6.3.1 Occupied Mode

Enable the supply fan (SYS-ENA) and command to run (SF-SS) and enable all control loops.

3.2.6.3.2 Unoccupied Mode

While the building temperature (BLDG-T) is above the low limit setpoint (BLDG-T-LL) all control loops shall be disabled and the supply fan shall not run. When BLDG-T drops below BLDG-T-LL (with a 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.

3.2.6.3.3 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.

3.2.6.4 Proofs and Safeties

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.

3.2.6.4.1 Proofs

Supply fan status (proof) (SF-S)

3.2.6.4.2 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)

3.2.6.4.3 DDC Hardware

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 both reset functions are provided and the operator can use either one to perform the reset), as shown on the Points Schedule drawing.

3.2.6.5 Fan Control

When this loop is enabled the DDC Hardware shall vary supply fan speed between 100% (SF-C-MAX) and a lower limit determined by the TAB contractor that corresponds to minimum outside air flow (SF-C-MIN) to maintain zone temperature set point (ZN-T-SP) within a deadband of 1 degree F.

3.2.6.6 Supply Air Temperature Control

When this loop is enabled the DDC Hardware shall vary supply air temperature setpoint (SA-T-SP) between design heating and cooling supply air temperatures to maintain zone temperature set point (ZN-T-SP) within a deadband of 1 degree F.

3.2.6.7 Minimum Outside Air Flow Control

3.2.6.7.1 Enable Loop

When this loop is enabled the DDC Hardware shall open the 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.

3.2.6.7.2 CO2-Based Minimum Outside Air Damper Control

When this loop is enabled the DDC Hardware shall vary the minimum outside air damper position between 100% (MINOA-D-MAX) and a lower limit (MINOA-D-MIN) corresponding to the zone's square footage-based ventilation requirement as determined by ASHRAE 62.1 (Ventilation Rate Procedure) and the TAB contractor. This minimum outside air damper command reset shall be based on the comparison of the zone CO2 measurement (ZN-CO2) to a configurable zone CO2 reset range (ZN-CO2-MIN AND ZN-CO2-MAX) that is determined by the TAB contractor from a recorded measurement of local ambient CO2 for minimum and initially set at 1100 ppm for maximum.

3.2.6.8 Preheat Coil Control Loop

When this loop is enabled the DDC Hardware shall disable the cooling-and-dehumidification coil control and 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.

3.2.6.9 Cooling-and-Dehumidification Coil Control

When this loop is enabled the DDC Hardware shall modulate the cooling and dehumidification valve to maintain supply air temperature (SA-T) at setpoint (SA-T-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.

3.2.6.10 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.

3.2.6.11 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 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.

3.2.7 Multizone or Dual-Duct

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

3.2.7.1 HAND-OFF-AUTO switches and Fire Alarm Panel (FAP) Signal

Supply Fan VFD. 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:

3.2.7.1.1 HAND

With the H-O-A switch in HAND position, the supply fan starts and runs continuously, subject to Safeties.

3.2.7.1.2 OFF

With the H-O-A switch in OFF position, the supply fan stops.

3.2.7.1.3 AUTO

With the H-O-A switch in AUTO position, the supply fan runs subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.

3.2.7.2 Supply Fan VFD

When this loop is enabled the DDC Hardware shall vary supply fan speed between 100% (SF-C-MAX) and a lower limit determined by the TAB contractor that corresponds to minimum outside air flow (SF-C-MIN) to maintain the most open hot or cold deck zone damper command (Z-D-C-EFF) at a configurable setpoint (ZN-D-SP) initially set at 95%.

3.2.7.3 Return Fan VFD

The return fan shall incorporate an integral H-O-A switch, manual speed adjustment and also accept a Fire Alarm Panel (FAP) signal. The return fan shall run according to the following inputs (in order of decreasing priority):

a. FAP signal shall cause the RF to run at 100 percent

b. SF-S (proof) shall be connected to the RF VFD safety circuit such that if SF is not running, RF shall be off.

c. RF H-O-A switch shall select RF mode as follows:

(1) When switch is in Hand, fan shall run. Fan speed shall be under manual control.

(2) When switch is in Off, fan shall be off.

(3) When switch is in Auto, fan shall run. Fan speed shall be under control of the DDC Hardware and when enabled 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..

3.2.7.4 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.

3.2.7.5 System Enable and Loop Enable

3.2.7.5.1 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.

3.2.7.5.2 Unoccupied Mode

While the building temperature (BLDG-T) is above the low limit setpoint (BLDG-T-LL) all control loops shall be disabled and the supply fan shall not run. When BLDG-T drops below BLDG-T-LL (with a 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.

3.2.7.5.3 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.

3.2.7.6 Proofs and Safeties

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.

3.2.7.6.1 Proofs

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

b. Return fan status (proof) (RF-S)

3.2.7.6.2 Safeties

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

b. Supply air smoke (SA-SMK)

c. Return air smoke (RA-SMK)

3.2.7.6.3 DDC Hardware Reset

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.

3.2.7.7 Minimum Outside Air Flow Control

3.2.7.7.1 Enable Loop

When this loop is enabled the DDC Hardware shall open the 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.

3.2.7.7.2 CO2-Based Minimum Outside Air Damper Control

When this loop is enabled the DDC Hardware shall vary the minimum outside air damper position between 100% (MINOA-D-MAX) and a lower limit (MINOA-D-MIN) corresponding to the zone's square footage-based ventilation requirement as determined by ASHRAE 62.1 (Ventilation Rate Procedure) and the TAB contractor This minimum outside air damper command setpoint reset shall be based on the comparison of the largest zone CO2 measurement (ZN-CO2-EFF) to a configurable zone CO2 reset range (ZN-CO2-MIN AND ZN-CO2-MAX) that is determined by the TAB contractor from a recorded measurement of local ambient CO2 for minimum and initially set at 1100 ppm for maximum.

3.2.7.8 Mixed Air Temperature Control With Economizer

3.2.7.8.1 Enabled Loop

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.

3.2.7.8.2 Disabled Loop

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.

3.2.7.8.3 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 2 degrees F deadband.

3.2.7.8.4 CO2-Based Economizer Damper Control

When this loop is enabled and when the zone temperature control loop is not calling for a greater MA-D-C, the DDC Hardware shall vary the mixed air dampers between design minimum outside air position (MA-D-C-MIN1) and a lower limit (MA-D-C-MIN2) corresponding to the zone's square footage-based ventilation requirement as determined by ASHRAE 62.1 (Ventilation Rate Procedure) and the TAB contractor. This mixed air damper command setpoint reset shall be based on the comparison of the largest zone CO2 measurement (ZN-CO2-EFF) to a configurable zone CO2 reset range (ZN-CO2-MIN AND ZN-CO2-MAX) that is determined by the TAB contractor from a recorded measurement of local ambient CO2 for minimum and initially set at 1100 ppm for maximum.

3.2.7.9 Hot Deck Coil Control

3.2.7.9.1 Enabled Loop

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.

3.2.7.9.2 DDC Hardware Reset

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 Coldest Zone Temperature.

3.2.7.10 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.

3.2.7.11 Zone Temperature Control

When this loop is enabled:

3.2.7.11.1 Zone Temperature Setpoint

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.

3.2.7.11.2 DDC Hardware Modulation

The DDC Hardware shall modulate the hot deck and cold deck dampers to maintain zone temperature (ZN-T) at setpoint (ZN-T-SP).

3.2.8 Multizone with Hot Deck Bypass

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

3.2.8.1 HAND-OFF-AUTO Switches

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

3.2.8.1.1 HAND

With the H-O-A switch in HAND position, start and continuously run the supply fan, subject to Safeties.

3.2.8.1.2 OFF

With the H-O-A switch in OFF position, stop the supply fan.

3.2.8.1.3 AUTO

With the H-O-A switch in AUTO position, run the supply fan subject to the Supply Fan Start/Stop (SF-SS) command and Safeties.

3.2.8.2 Return Fan Motor Starter

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

3.2.8.2.1 HAND

With the H-O-A switch in HAND position, run the return fan subject to Safeties.

3.2.8.2.2 OFF

With the H-O-A switch in OFF position, the return fan must be off.

3.2.8.2.3 AUTO

With the H-O-A switch in AUTO position, run the return fan subject to the supply fan running.

3.2.8.3 Occupancy Modes

Obtain the system's Occupancy Mode input from the System Scheduler as specified and indicated. Operate the system in one of the following modes: Occupied, Unoccupied, or WarmUp/CoolDown.

3.2.8.4 System Enable and Loop Enable

3.2.8.4.1 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.

3.2.8.4.2 Unoccupied Mode

While the building temperature (BLDG-T) is above the low limit setpoint (BLDG-T-LL) all control loops shall be disabled and the supply fan shall not run. When BLDG-T drops below BLDG-T-LL (with a 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.

3.2.8.4.3 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.

3.2.8.5 Proofs and Safeties

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.

3.2.8.5.1 Proofs

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

b. Return fan status (proof) (RF-S)

3.2.8.5.2 Safeties

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

b. Supply air smoke (SA-SMK)

c. Return air smoke (RA-SMK)

3.2.8.5.3 DDC Hardware Reset

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.

3.2.8.6 Supply Fan Control

When this loop is enabled the DDC Hardware shall vary supply fan speed between 100% (SF-C-MAX) and a lower limit determined by the TAB contractor that corresponds to minimum outside air flow (SF-C-MIN) to maintain the most open hot or cold deck zone damper command (Z-D-C-EFF) at a configurable setpoint (ZN-D-SP) initially set at 95%.

3.2.8.7 Minimum Outside Air Flow Control

3.2.8.7.1 Enable Loop

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.

3.2.8.7.2 CO2-Based Minimum Outside Air Damper Control

When this loop is enabled the DDC Hardware shall vary the minimum outside air damper position between 100% (MINOA-D-MAX) and a lower limit (MINOA-D-MIN) corresponding to the zone's square footage-based ventilation requirement as determined by ASHRAE 62.1 (Ventilation Rate Procedure) and the TAB contractor This minimum outside air damper command setpoint reset shall be based on the comparison of the largest zone CO2 measurement (ZN-CO2-EFF) to a configurable zone CO2 reset range (ZN-CO2-MIN AND ZN-CO2-MAX) that is determined by the TAB contractor from a recorded measurement of local ambient CO2 for minimum and initially set at 1100 ppm for maximum.

3.2.8.8 Mixed Air Temperature Control With Economizer

3.2.8.8.1 Enabled Loop

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.

3.2.8.8.2 Disabled Loop

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.

3.2.8.8.3 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 2 degrees F deadband.

3.2.8.8.4 CO2-Based Economizer Damper Control

When this loop is enabled and when the zone temperature control loop is not calling for a greater MA-D-C, the DDC Hardware shall vary the mixed air dampers between design minimum outside air position (MA-D-C-MIN1) and a lower limit (MA-D-C-MIN2) corresponding to the zone's square footage-based ventilation requirement as determined by ASHRAE 62.1 (Ventilation Rate Procedure) and the TAB contractor. This mixed air damper command setpoint reset shall be based on the comparison of the largest zone CO2 measurement (ZN-CO2-EFF) to a configurable zone CO2 reset range (ZN-CO2-MIN AND ZN-CO2-MAX) that is determined by the TAB contractor from a recorded measurement of local ambient CO2 for minimum and initially set at 1100 ppm for maximum.

3.2.8.9 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.

3.2.8.10 Zone Temperature Control

a. 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.

b. The DDC Hardware shall modulate the zone bypass and cold deck dampers, and the zone heating 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.

c. Systems with electric resistance heating elements shall require proof of air flow before activating the heating elements.

3.2.9 Variable Air Volume System

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

3.2.9.1 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:

3.2.9.1.1 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.

3.2.9.1.2 OFF

With the H-O-A switch in OFF position, the supply fan shall stop.

3.2.9.1.3 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.

3.2.9.2 Return Fan Variable Frequency Drive

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:

3.2.9.2.1 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.

3.2.9.2.2 OFF

With the H-O-A switch in OFF position, the return fan shall be off.

3.2.9.2.3 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.

3.2.9.3 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.

3.2.9.4 Proofs and Safeties

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.

3.2.9.4.1 Proofs

a. Supply fan status (SF-S)

b. Return fan status (RF-S)

3.2.9.4.2 Safeties

a. Preheat coil discharge air temperature low limit (freezestat) (PH-DA-T-LL) for systems with a preheat coil. Cooling coil discharge air temperature low limit (freezestat) (CLG-DA-T-LL) for all other systems

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

c. Supply air smoke (SA-SMK)

d. Return air smoke (RA-SMK)

3.2.9.4.3 DDC Hardware Reset

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.

3.2.9.5 System Enable and Loop Enable

3.2.9.5.1 Occupied Mode

The supply fan shall be enabled (SYS-ENA) and commanded to run (SF-SS). All control loops shall be enabled.

3.2.9.5.2 Unoccupied Mode

While the building temperature (BLDG-T) is above the low limit setpoint (BLDG-T-LL) all control loops shall be disabled and the supply fan shall not run. When BLDG-T drops below BLDG-T-LL (with a 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.

3.2.9.5.3 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.

3.2.9.6 Fan Capacity Control

3.2.9.6.1 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.

3.2.9.6.2 Supply Duct Static Pressure Control Reset Loop

When this loop is enabled the DDC Hardware shall vary the supply duct static pressure setpoint (SA-P-SP) between the design cooling static

pressure setpoint (SA-P-SP-MAX) and a lower limit (SA-P-SP-MIN) determined by the TAB contractor but no more than half the design setpoint based on comparison of the critical zone damper command (ZN-D-C-EFF) to configurable maximum and minimum values (ZN-D-C-MAX and ZN-D-C-MIN) initially set at 90% and 50%. The critical zone damper command shall be determined as the real-time maximum of all individual zone damper commands (ZN-D-C) included in the supply duct static pressure control reset sequence as shown (include all zones if none shown). The supply duct static pressure setpoint rate of change shall be limited by a configurable ramp rate (SA-P-SP-RT) initially set at 0.01 inches w.c. per minute.

3.2.9.6.3 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.

3.2.9.7 Minimum Outside Air Flow Control

3.2.9.7.1 Enable Loop

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.

3.2.9.7.2 CO2-Based Minimum Outside Air Damper Control

When this loop is enabled and when the mixed air temperature control loop is not calling for a greater outside air flow setpoint (OA-F-SP), DDC Hardware shall vary the OA-F-SP between the design minimum outside air flow (MINOA-F-MAX) and a lower limit (MINOA-F-MIN) corresponding to the building's square footage-based ventilation requirement as determined by ASHRAE 62.1 (Ventilation Rate Procedure). This minimum outside air damper command reset shall be based on supply air or minimum outside air flow setpoints being reset off zone CO2 at each VAV box (VAV-S-F or VAV-MINOA-F-SP).

3.2.9.8 Mixed Air Temperature Control With Economizer

3.2.9.8.1 Enabled Loop

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.

3.2.9.8.2 Disabled Loop

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.

3.2.9.8.3 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 2 degrees F deadband.

3.2.9.9 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.

3.2.9.10 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.

3.3 SEQUENCES OF OPERATION FOR TERMINAL UNITS

3.3.1 Zone Temperature Control - Cooling-Only VAV Box

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

3.3.1.1 Occupancy Modes

3.3.1.1.1 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.

3.3.1.1.2 Unoccupied

The VAV box DDC Hardware must 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.

3.3.1.2 Safeties

This system has no safeties.

3.3.1.3 Zone Temperature Control

3.3.1.3.1 Occupied Mode

In the Occupied Mode the zone temperature setpoint (ZN-T-SP) must be at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as shown. The DDC Hardware must 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. Sequences indicated: Upon a rise in zone temperature (ZN-T) above zone setpoint (ZN-T-SP), subject to the zone temperature setpoint deadband as indicated, adjust the airflow setpoint between minimum and maximum flow based on the difference between zone temperature and zone temperature setpoint as indicated.

3.3.1.3.2 Unoccupied Mode

In the Unoccupied Mode the VAV box damper shall be at its minimum position.

3.3.2 Zone Temperature Control - VAV Box with Reheat

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

3.3.2.1 Occupancy Modes

3.3.2.1.1 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.

3.3.2.1.2 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.

3.3.2.2 Safeties

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

3.3.2.3 Flow Control

When this loop is enabled and when the zone temperature control loop is not calling for a greater VAV box flow setpoint (VAV-SA-F-SP), the DDC Hardware shall vary the VAV-S-F-SP between the design minimum outside air flow (VAV-SA-F-MIN1) and a lower limit (VAV-SA-F-MIN2) corresponding to the zone's square footage-based ventilation requirement as determined by ASHRAE 62.1 (Ventilation Rate Procedure). This reset shall be based on the comparison of the zone CO2 measurement (ZN-CO2) to a configurable zone CO2 reset range (ZN-CO2-MIN AND ZN-CO2-MAX) that is determined by the TAB contractor from a recorded measurement of local ambient CO2 for minimum and initially set at 1100 ppm for maximum.

3.3.2.4 Zone Temperature Control

a. 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.

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

c. 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.

3.3.3 Zone Temperature Control - Fan Powered VAV Box

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

3.3.3.1 Occupancy Modes

3.3.3.1.1 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.

3.3.3.1.2 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.

3.3.3.2 Safeties

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

3.3.3.3 Fan Control

Series fans shall run whenever the box is occupied or the Zone Temperature Control loop determines that the box is in heating mode. Prior to starting the fan, the supply damper shall close. The controller shall pause after closing the damper before starting the fan to ensure that the fan is not spinning due to supply air delivered by the AHU. After the fan starts, the supply damper shall be controlled by the Zone Temperature Control loop. Parallel fans shall run whenever the Zone Temperature Control loop determines that the box is in heating mode.

3.3.3.4 Flow Control

When this loop is enabled and when the zone temperature control loop is not calling for a greater VAV box flow setpoint (VAV-SA-F-SP), the DDC Hardware shall vary the VAV-S-F-SP between the design minimum outside air flow (VAV-SA-F-MIN1) and a lower limit (VAV-SA-F-MIN2) corresponding to the zone's square footage-based ventilation requirement as determined by ASHRAE 62.1 (Ventilation Rate Procedure). This reset shall be based on the comparison of the zone CO2 measurement (ZN-CO2) to a configurable zone CO2 reset range (ZN-CO2-MIN AND ZN-CO2-MAX) that is determined by the TAB contractor from a recorded measurement of local ambient CO2 for minimum and initially set at 1100 ppm for maximum.

3.3.3.5 Zone Temperature Control

3.3.3.5.1 Occupied Mode

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.

3.3.3.5.2 Unoccupied Mode

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

3.3.3.5.3 Sequencing

3.3.3.5.3.1 Cooling Mode

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.

3.3.3.5.3.2 Heating Mode

Upon a fall in zone temperature below zone temperature setpoint, subject to the deadband as shown, the DDC Hardware shall first turn on the parallel fan and then 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.

3.3.4 Perimeter Radiation Control Sequence

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

3.3.4.1 Occupancy Modes

3.3.4.1.1 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.

3.3.4.1.2 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.

3.3.4.2 Safeties

This system has no safeties.

3.3.4.3 Space Temperature Control

3.3.4.3.1 Occupied Mode

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.

3.3.4.3.2 Unoccupied Mode

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

3.3.5 Unit Heater and Cabinet Unit Heater

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

3.3.5.1 Off-Auto Switch

3.3.5.1.1 OFF

With the thermostat OFF-AUTO switch in the OFF position, the DDC Hardware shall stop the fan and close the heating control valve.

3.3.5.1.2 AUTO

With the thermostat OFF-AUTO switch in the AUTO position, the DDC Hardware shall control the unit in accordance with its Occupancy Mode.

3.3.5.2 Occupancy Modes

3.3.5.2.1 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.

3.3.5.2.2 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.

3.3.5.3 Safeties

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

3.3.5.4 Space Temperature Control

3.3.5.4.1 Occupied Mode

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.

3.3.5.4.2 Unoccupied Mode

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.

3.3.6 Gas-Fired Infrared Heater

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

3.3.6.1 On-Off-Auto Switch

3.3.6.1.1 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.

3.3.6.1.2 OFF

With the thermostat ON-OFF-AUTO switch in the OFF position, the DDC Hardware shall de-energize the heater.

3.3.6.1.3 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.

3.3.6.2 Occupancy Modes

3.3.6.2.1 Occupied

The unit DDC Hardware shall be in the Occupied Mode when the local space occupancy input(s) indicate that the space is occupied.

3.3.6.2.2 Unoccupied

The unit DDC Hardware shall be in the Unoccupied Mode when the local space occupancy input(s) indicate that the space is unoccupied.

3.3.6.3 Safeties

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

3.3.6.4 Space Temperature Control

3.3.6.4.1 Occupied Mode

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 indicated.

3.3.6.4.2 Unoccupied Mode

In the Unoccupied Mode the DDC Hardware shall operate the heater to maintain space setpoint at the configured unoccupied setpoint as indicated.

3.3.7 Dual Temperature Fan-Coil Unit

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

3.3.7.1 Off-Auto Switch

3.3.7.1.1 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.

3.3.7.1.2 AUTO

With the thermostat OFF-AUTO switch in the AUTO position, the DDC Hardware shall control the unit in accordance with its Occupancy Mode.

3.3.7.2 Occupancy Modes

3.3.7.2.1 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.

3.3.7.2.2 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.

3.3.7.3 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.

3.3.7.4 Safeties

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

3.3.7.5 Space Temperature Control

3.3.7.5.1 Occupied Mode

In the Occupied Mode the DDC Hardware shall modulate the dual-temperature control valve and modulate the multi-speed fan to maintain space temperature at the configured setpoint or at the occupant-adjustable setpoint via the wall-mounted thermostat, as indicated.

3.3.7.5.2 Unoccupied Mode

In the Unoccupied Mode the DDC Hardware shall modulate the dual-temperature control valve and modulate the multi-speed fan to maintain space temperature at the configured setpoint as indicated.

3.4 SEQUENCES OF OPERATION FOR HYDRONIC SYSTEMS

3.4.1 Hydronic Heating Hot Water from Distributed HTHW Converter

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

3.4.1.1 System Enable and Loop Enable

a. This system shall monitor the enabled status of all systems served by this system. If two or more systems served by this system are enabled, this system shall be enabled (SYS-ENA), otherwise this system shall be disabled.

b. When this system is enabled (SYS-ENA) command the hot water pump on via the Hot Water Pump Start/Stop (HW-PMP-SS) command.

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

3.4.1.2 HAND-OFF-AUTO Switch

The hot water pump motor starter shall have an H-O-A switch:

3.4.1.2.1 HAND

With the H-O-A switch in HAND position, the pump starts and runs continuously.

3.4.1.2.2 OFF

With the H-O-A switch in OFF position, the pump stops.

3.4.1.2.3 AUTO

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

3.4.1.3 Proofs and Safeties

DDC Hardware shall monitor all proofs and safeties.

3.4.1.3.1 Proofs

Hot water pump status (HW-PMP-S)

3.4.1.3.2 Safeties

None

3.4.1.3.3 DDC Hardware Reset

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 indicated on the Points Schedule drawing.

3.4.1.4 Heat Exchanger Valve Control

When this loop is enabled DDC Hardware shall modulate the 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.

3.4.2 Hydronic Heating Hot Water From Single-Building Boiler

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

3.4.2.1 System Enable and Loop Enable

a. 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 no systems served by this system are enabled, this system shall be disabled.

b. 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.

3.4.2.2 HAND-OFF-AUTO Switch

The hot water pump motor starter shall have an H-O-A switch:

3.4.2.2.1 HAND

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

3.4.2.2.2 OFF

With the H-O-A switch in OFF position, the pump shall stop.

3.4.2.2.3 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.

3.4.2.3 Proofs and Safeties

DDC Hardware shall monitor all proofs and safeties.

3.4.2.3.1 Proofs

Hot water pump

3.4.2.3.2 Safeties

None

3.4.2.3.3 DDC Hardware Reset

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.

3.4.2.4 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.

3.4.2.5 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.

3.4.3 Hydronic Dual-Temperature System with High Temperature Hot Water Heat Exchanger and Chilled Water

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

3.4.3.1 System Enable and Loop Enable

a. 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.

b. When the system is enabled (SYS-ENA) the pump shall run.

c. When this system is enabled (SYS-ENA), and the HEATING/COOLING switch is in HEATING the Heat Exchanger Control loop shall be enabled.

d. 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 85 degrees F, the chiller shall be enabled.

3.4.3.2 Switchover Valve Operation

The DDC Hardware shall monitor the status of the DTWR-T-LL and DTWR-T-HL switches.

3.4.3.2.1 HEATING/COOLING Switch in the HEATING Position

With the HEATING/COOLING switch in the HEATING position, the switchover valve shall open the heat-cool system piping to the heat exchanger and close the heat-cool system piping to the chiller.

3.4.3.2.2 HEATING/COOLING Switch in the COOLING Position

With the HEATING/COOLING switch in the COOLING position, the switchover valve shall open the heat-cool system piping to the chiller and close the heat-cool system piping to the heat exchanger whenever the dual-temperature return water temperature (DTWR-T) is below the dual-temperature return water high-limit temperature (DTWR-T-HL).

3.4.3.3 HAND-OFF-AUTO Switch

The Dual-Temperature water pump motor starter shall have an H-O-A switch:

3.4.3.3.1 HAND

With the H-O-A switch in HAND position, the pump starts and runs continuously.

3.4.3.3.2 OFF

With the H-O-A switch in OFF position, the pump stops.

3.4.3.3.3 AUTO

With the H-O-A switch in AUTO position, the pump runs subject to the Dual-Temperature Water Pump Start/Stop (DTW-PMP-SS) System Enable (SYS-ENA) command.

3.4.3.4 Proofs and Safeties

DDC Hardware shall monitor all proofs and safeties.

3.4.3.4.1 Proofs

None

3.4.3.4.2 Safeties

Heat exchanger differential pressure switch (HX-P-LL) shall be direct-hardwire interlocked to the high temperature hot water valve.

3.4.3.4.3 DDC Hardware Reset

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.

3.4.3.5 Heat Exchanger Valve Control

When this loop is enabled the DDC Hardware shall modulate the 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 (HWS-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 Hydronic Secondary with Variable Speed Pump

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

3.4.4.1 System Enable and Loop Enable

a. 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.

b. When this system is enabled (SYS-ENA) the Pressure Control loop shall be enabled.

3.4.4.2 HAND-OFF-AUTO Switch

The hot water pump variable frequency drive (VFD) unit shall have an integral H-O-A switch:

3.4.4.2.1 HAND

With the H-O-A switch in HAND position, the pump starts and runs continuously. Pump speed shall be under manual-operator control.

3.4.4.2.2 OFF

With the H-O-A switch in OFF position, the pump stops.

3.4.4.2.3 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.

3.4.4.3 Proofs and Safeties

DDC Hardware shall monitor all proofs and safeties.

3.4.4.3.1 Proofs

None

3.4.4.3.2 Safeties

None

3.4.4.3.3 DDC Hardware Reset

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.

3.4.4.4 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.

-- End of Section --

Appendix O: Insert: UFGS - 25 10 10 (Tailored to Fort Leonard Wood): Utility Monitoring and Control System (UMCS) Front-End and Integration

SECTION TABLE OF CONTENTS

DIVISION 25 - INTEGRATED AUTOMATION

SECTION 25 10 10

UTILITY MONITORING AND CONTROL SYSTEM (UMCS) FRONT END AND INTEGRATION

11/15

PART 1 GENERAL

1.1 SUMMARY
1.1.1 System Requirements
1.1.2 General Cybersecurity Requirements
1.2 REFERENCES
1.3 DEFINITIONS
1.3.1 Alarm Generation
1.3.2 Alarm Handling
1.3.3 Alarm Routing
1.3.4 Application Generic Controller (AGC)(LonWorks)
1.3.5 Application Specific Controller (ASC)(LonWorks)
1.3.6 BACnet (BACnet)
1.3.7 BACnet Advanced Application Controller (B-AAC)(BACnet)
1.3.8 BACnet Advanced Operator Workstation (B-AWS)(BACnet)
1.3.9 BACnet Application Specific Controller (B-ASC)(BACnet)
1.3.10 BACnet Building Controller (B-BC)(BACnet)
1.3.11 BACnet Internetwork (BACnet)
1.3.12 BACnet Interoperability Building Blocks (BIBBs) (BACnet)
1.3.13 BACnet Operator Display (B-OD)(BACnet)
1.3.14 BACnet Operator Workstation (B-OWS)(BACnet)
1.3.15 BACnet Smart Actuator (B-SA)(BACnet)
1.3.16 BACnet Smart Sensor (B-SS)(BACnet)
1.3.17 BACnet Testing Laboratories (BTL)(BACnet)
1.3.18 BACnet Testing Laboratories (BTL) Listed (BACnet)
1.3.19 Binary
1.3.20 Binding (LonWorks)
1.3.21 Broadcast
1.3.22 Building Control Network (BCN)
1.3.23 Building Control System (BCS)
1.3.24 Building Point of Connection (BPOC)
1.3.25 Channel (LonWorks)
1.3.26 Commandable (BACnet)
1.3.27 Configuration Property (LonWorks)
1.3.28 Control Logic Diagram
1.3.29 Device Object (BACnet)
1.3.30 Explicit Messaging (LonWorks)
1.3.31 External Interface File (XIF) (LonWorks)
1.3.32 Field Point Of Connection (FPOC)
1.3.33 Field Control Network
1.3.34 Field Control System (FCS)
1.3.35 Fox Protocol (Niagara Framework)
1.3.36 Functional Profile (LonWorks)
1.3.37 Gateway
1.3.38 General Purpose Programmable Controller (GPPC) (LonWorks)
1.3.39 Internetwork (BACnet)

1.3.40 JACE (Niagara Framework)
1.3.41 LonMark Object (LonWorks)
1.3.42 LNS Plug-in (LonWorks)
1.3.43 LonMark (LonWorks)
1.3.44 LonMark International (LonWorks)
1.3.45 LonWorks (LonWorks)
1.3.46 LonWorks Network Services (LNS) (LonWorks)
1.3.47 LonWorks Network Services (LNS) Database (LonWorks)
1.3.48 Modbus
1.3.49 Master-Slave/Token Passing (MS/TP) (BACnet)
1.3.50 Monitoring and Control (M&C) Software
1.3.51 Network (BACnet)
1.3.52 Network Variable (LonWorks)
1.3.53 Network Configuration Tool (LonWorks)
1.3.54 Niagara Framework
1.3.55 Niagara Framework Supervisory Gateway (Niagara Framework)
1.3.56 Node (LonWorks)
1.3.57 Node Address (LonWorks)
1.3.58 Node ID (LonWorks)
1.3.59 Object (BACnet)
1.3.60 Override
1.3.61 Point, Calculated
1.3.62 Point, Network
1.3.63 Polling
1.3.64 Program ID (LonWorks)
1.3.65 Property (BACnet)
1.3.66 Protocol Implementation Conformance Statement (PICS) (BACnet)
1.3.67 Repeater
1.3.68 Router (LonWorks)
1.3.69 Router (BACnet)
1.3.70 Segment
1.3.71 Service (BACnet)
1.3.72 Service Pin (LonWorks)
1.3.73 Standard BACnet Object/Property/Service (BACnet)
1.3.74 Standard Configuration Property Type (SCPT) (LonWorks)
1.3.75 Standard Network Variable Type (SNVT) (LonWorks)
1.3.76 Subnet (LonWorks)
1.3.77 Supervisory Controller
1.3.78 Supervisory Gateway
1.3.79 TP/FT-10 (LonWorks)
1.3.80 TP/XF-1250 (LonWorks)
1.3.81 UMCS Network
1.3.82 User-defined Configuration Property Type (UCPT) (LonWorks)
1.3.83 User-defined Network Variable Type (UNVT) (LonWorks)
1.3.84 Utility Control System (UCS)
1.4 SUBMITTALS
1.5 PROJECT SEQUENCING
1.5.1 Sequencing for Submittals
1.5.2 Sequencing for Activities
1.5.3 Abbreviations
1.6 QUALITY CONTROL (QC) CHECKLISTS
1.7 OPERATION AND MAINTENANCE (O&M) INSTRUCTIONS

PART 2 PRODUCTS

2.1 CONTROL HARDWARE
2.1.1 Control Protocol Gateways
2.1.1.1 Gateway for CEA-709.1

PART 3 EXECUTION

3.1 EXISTING CONDITIONS SURVEY
3.2 DRAWINGS AND CALCULATIONS
3.2.1 UMCS Contractor Design Drawings
3.2.2 As-Built Drawings
3.3 INSTALLATION OF EQUIPMENT
3.3.1 IP Addresses
3.4 INTEGRATION OF FIELD CONTROL SYSTEMS
3.4.1 Integration Step 1: Install Control Hardware
3.4.1.1 Installation of Control Protocol Gateway
3.4.1.2 Installation of Control Protocol Router
3.4.2 Integration Step 2: Add Field Control System to M&C Software
3.4.2.1 Integration of Field Control Systems Via ANSI-709.1-C
3.4.2.2
3.4.3 Integration Step 3: Configure M&C Software
3.4.3.1 Configure M&C Software Communication
3.4.3.2 Configure M&C Software Functionality
3.5 START-UP AND START-UP TESTING
3.6 PERFORMANCE VERIFICATION TEST (PVT)
3.6.1 PVT Phase I Procedures
3.6.2 PVT Phase I
3.6.3 PVT Phase II
3.7 TRAINING
3.7.1 Training Documentation
3.7.1.1 Course Attendance List
3.7.1.2 Training Manuals
3.7.2 Training Tasks

ATTACHMENTS:

QC Checklist

-- End of Section Table of Contents --

SECTION 25 10 10

UTILITY MONITORING AND CONTROL SYSTEM (UMCS) FRONT END AND INTEGRATION
11/15

PART 1 GENERAL

1.1 SUMMARY

Integrate local CEA-709.1-D building control systems installed per Section 23 09 23.01 LONWORKS DIRECT DIGITAL CONTROL FOR HVAC AND OTHER BUILDING CONTROL SYSTEMS into the existing Utility Monitoring and Control System (UMCS) UMCS as specified and maintain the LNS database(s) for the entire network

1.1.1 System Requirements

Provide a UMCS as specified and indicated, and in accordance with the following characteristics:

1.1.2 General Cybersecurity Requirements

Address cybersecurity in accordance with existing accreditation requirements.

1.2 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.

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

ASHRAE 135	(2016; INT 1 2016) BACnet—A Data Communication Protocol for Building Automation and Control Networks

CONSUMER ELECTRONICS ASSOCIATION (CEA)

CEA-709.1-D	(2014) Control Network Protocol Specification
CEA-709.3	(1999; R 2004) Free-Topology Twisted-Pair Channel Specification
CEA-852-C	(2014) Tunneling Component Network Protocols Over Internet Protocol Channels

LONMARK INTERNATIONAL (LonMark)

LonMark Interoperability Guide	(2005) LonMark Application-Layer Interoperability Guide and LonMark Layer 1-6 Interoperability Guide; Version 3.4
LonMark SNVT List	(2003) LonMark SNVT Master List; Version 113

LonMark XIF Guide	(2001) LonMark External Interface File Reference Guide; Revision 4.402

MODBUS ORGANIZATION, INC (MODBUS)

Modbus	(2006) Modbus Application Protocol Specification; Version 1.1b and Modbus Messaging on TCP/IP Implementation Guide; Version V1.0b

OPC FOUNDATION (OPC)

OPC DA	(2002) OPC Data Access (DA) Specification; Version 2.05a

1.3 DEFINITIONS

The following list of definitions may contain terms not found elsewhere in this Section but are included here for completeness. Some terms are followed with a protocol reference in parenthesis indicating to which protocol the term and definition applies. Inclusion of protocol-specific definitions does not create a requirement to support that protocol, nor does it relax any requirements to support specific protocols as indicated elsewhere in this section."

1.3.1 Alarm Generation

The process of comparing a point value (the point being alarmed) with a pre-defined alarm condition (e.g. a High Limit) and performing some action based on the result of the comparison.

1.3.2 Alarm Handling

see Alarm Routing

1.3.3 Alarm Routing

Alarm routing is M&C software functionality that starts with a notification that an alarm exists (typically as the output of an Alarm Generation process) and sends a specific message to a specific alarm recipient or device.

1.3.4 Application Generic Controller (AGC)(LonWorks)

A device that is furnished with a (limited) pre-established application that also has the capability of being programmed. Further, the ProgramID and XIF file of the device are fixed. The programming capability of an AGC may be less flexible than that of a General Purpose Programmable Controller (GPPC).

1.3.5 Application Specific Controller (ASC)(LonWorks)

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.

1.3.6 BACnet (BACnet)

The term BACnet is used in two ways. First meaning the BACnet Protocol Standard - the communication requirements as defined by ASHRAE 135 including all annexes and addenda. The second to refer to the overall technology related to the ASHRAE 135 protocol.

1.3.7 BACnet Advanced Application Controller (B-AAC) (BACnet)

A hardware device BTL Listed as a B-AAC. A control device which contains BIBBs in support of scheduling and alarming but otherwise has limited resources relative to a B-BC. It may be intended for specific applications and supports some degree of programmability.

1.3.8 BACnet Advanced Operator Workstation (B-AWS) (BACnet)

Monitoring and Control (M&C) Software BTL Listed as an Advanced Operator Workstation and includes the ability to manage scheduling, alarming and trending in an open manner. The B-AWS is the advanced operator's window into a BACnet system. It is primarily used to monitor the performance of a system and to modify parameters that affect the operation of a system.

1.3.9 BACnet Application Specific Controller (B-ASC) (BACnet)

A hardware device BTL Listed as a B-ASC. A controller with limited resources relative to a B-AAC. It is intended for use in a specific application and supports limited programmability.

1.3.10 BACnet Building Controller (B-BC) (BACnet)

A hardware device BTL Listed as a B-BC. A general-purpose, field-programmable device capable of carrying out a variety of building automation and control tasks including control and monitoring via direct digital control (DDC) of specific systems and data storage for trend information, time schedules, and alarm data. Like the other BTL Listed controller types (B-AAC, B-ASC etc.) a B-BC device is required to support the server ("B") side of the ReadProperty and WriteProperty services, but unlike the other controller types it is also required to support the client ("A") side of these services. Communication between controllers requires that one of them support the client side and the other support the server side, so a B-BC is often used when communication between controllers is needed.

1.3.11 BACnet Internetwork (BACnet)

Two or more BACnet networks connected with BACnet routers. In a BACnet Internetwork, there exists only one message path between devices.

1.3.12 BACnet Interoperability Building Blocks (BIBBs) (BACnet)

A BIBB is a collection of one or more BACnet services intended to define a higher level of interoperability. BIBBs are combined to build the BACnet functional requirements for a device in a specification. Some BIBBs define additional requirements (beyond requiring support for specific services) in order to achieve a level of interoperability. For example, the BIBB DS-V-A (Data Sharing-View-A), which would typically be used by an M&C client, not only requires the client to support the ReadProperty Service, but also provides a list of data types (Object / Properties) which the client must be able to interpret and display for the user.

1.3.13 BACnet Operator Display (B-OD)(BACnet)

A hardware device BTL Listed as a B-OD. A basic operator interface with limited capabilities relative to a B-OWS. It is not intended to perform direct digital control. The B-OD profile could be used for wall-mounted LCD devices, displays affixed to BACnet devices; hand-held terminals or other very simple user interfaces.

1.3.14 BACnet Operator Workstation (B-OWS)(BACnet)

Monitoring and Control (M&C) Software BTL Listed as a B-OWS. An operator interface with limited capabilities relative to a B-AWS. The B-OWS is used for monitoring and basic control of a system, but differs from a B-AWS in that it does not support configuration activities, nor does it provide advanced troubleshooting capabilities.

1.3.15 BACnet Smart Actuator (B-SA)(BACnet)

A hardware device BTL Listed as a B-SA. A simple control output device with limited resources; it is intended for specific applications.

1.3.16 BACnet Smart Sensor (B-SS)(BACnet)

A hardware device BTL Listed as a B-SS. A simple sensing device with very limited resources.

1.3.17 BACnet Testing Laboratories (BTL)(BACnet)

Established by BACnet International to support compliance testing and interoperability testing activities and consists of BTL Manager and the BTL Working Group (BTL-WG). BTL also publishes Implementation Guidelines.

1.3.18 BACnet Testing Laboratories (BTL) Listed (BACnet)

A device that has been certified by BACnet® Testing Laboratory. Devices may be certified to a specific device profile, in which case the certification indicates that the device supports the required capabilities for that profile, or may be certified as "other".

1.3.19 Binary

A two-state system or signal; for example one 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'.

1.3.20 Binding (LonWorks)

The act of establishing communications between CEA-709.1-D devices by associating the output of a device to the input of another so that information is automatically (and regularly) sent without being requested by the recipient.

1.3.21 Broadcast

Unlike most messages, which are intended for a specific recipient device, a broadcast message is intended for all devices on the network.

1.3.22 Building Control Network (BCN)

The network used by the Building Control System. Typically the BCN is a BACnet ASHRAE 135 or LonWorks CEA-709.1-D network installed by the building control system contractor.

1.3.23 Building Control System (BCS)

One type of Field Control System. A control system for building electrical and mechanical systems, typically HVAC (including central plants) and lighting. A BCS generally uses Direct Digital Control (DDC) Hardware and generally does NOT include its own local front end.

1.3.24 Building Point of Connection (BPOC)

A FPOC for a Building Control System. (This term is being phased out of use in preference for FPOC but is still used in some specifications and criteria. When it was used, it typically referred to a piece of control hardware. The current FPOC definition typically refers instead to IT hardware)

1.3.25 Channel (LonWorks)

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.

1.3.26 Commandable (BACnet)

A point (Object) is commandable if its Present_Value Property is writable and it supports the optional Priority_Array Property. This functionality is useful for Overrides.

1.3.27 Configuration Property (LonWorks)

Controller parameter used by the application which is usually set during installation/testing and seldom changed. For example, the P and I settings of a P-I control loop. Also see 'Standard Configuration Property Type (SCPT)'

1.3.28 Control Logic Diagram

A graphical representation of control logic for multiple processes that make up a system.

1.3.29 Device Object (BACnet)

Every BACnet device requires one Device Object, whose properties represent the network visible properties of that device. Every Device Object requires a unique Object_Identifier number on the BACnet internetwork. This number is often referred to as the device instance or device ID.

1.3.30 Explicit Messaging (LonWorks)

A non-standard and often vendor (application) specific method of communication between devices.

1.3.31 External Interface File (XIF) (LonWorks)

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.

1.3.32 Field Point Of Connection (FPOC)

The FPOC is part of the UMCS IP network and acts as the point of connection between the UMCS IP Network and the field control IP network. The FPOC is an IT device such as a switch, IP router, or firewall, typically managed by the site IT staff. (Note that the field control IP network may consist of a single IP device, or that integration may require installation of a field control network IP device.)

1.3.33 Field Control Network

The network used by a field control system.

1.3.34 Field Control System (FCS)

A building control system or utility control system.

1.3.35 Fox Protocol (Niagara Framework)

The protocol used for communication between components in the Niagara Framework. By default, Fox uses TCP port 1911

1.3.36 Functional Profile (LonWorks)

A standard description, defined by LonMark International, of a LonMark Object used to classify and certify devices.

1.3.37 Gateway

A device that translates from one protocol to another. Devices that change only the transport mechanism of the protocol - "translating" from LonWorks over TP/FT-10 to LonWorks over IP for example - are not gateways as the underlying protocol (data format) does not change. Gateways are also called Communications Bridges or Protocol Translators.

1.3.38 General Purpose Programmable Controller (GPPC) (LonWorks)

Unlike an ASC or AGC, a GPPC is not furnished with a fixed application program and does not have a fixed ProgramID or XIF file. A GPPC can be (re-) programmed, usually using vendor-supplied software. When a change to the program affects the external interface (and the XIF file) the ProgramID will change.

1.3.39 Internetwork (BACnet)

See BACnet Internetwork.

1.3.40 JACE (Niagara Framework)

Java Application Control Engine. See Niagara Framework Supervisory Gateway

1.3.41 LonMark Object (LonWorks)

A collection of network variables, configuration properties, and associated behavior defined by LonMark International and described by a Functional Profile. It defines how information is exchanged between devices on a network (inputs from and outputs to the network).

1.3.42 LNS Plug-in (LonWorks)

Software which runs in an LNS compatible software tool, typically a network configuration tool. Device configuration plug-ins provide a 'user friendly' method to edit a device's configuration properties.

1.3.43 LonMark (LonWorks)

See LonMark International. Also, a certification issued by LonMark International to CEA-709.1-D devices.

1.3.44 LonMark International (LonWorks)

Standards committee consisting of independent product developers, system integrators and end users dedicated to determining and maintaining the interoperability guidelines for LonWorks. Maintains guidelines for the interoperability of CEA-709.1-D devices and issues the LonMark Certification for CEA-709.1-D devices.

1.3.45 LonWorks (LonWorks)

The term used to refer to the overall technology related to the CEA-709.1-D protocol (sometimes called "LonTalk"), including the protocol itself, network management, interoperability guidelines and products.

1.3.46 LonWorks Network Services (LNS) (LonWorks)

A network management and database standard for CEA-709.1-D devices.

1.3.47 LonWorks Network Services (LNS) Database (LonWorks)

The standard database created and used by LonWorks Network Services (LNS) compatible tools, such as LNS Network Configuration tools.

1.3.48 Modbus

A basic protocol for control network communications generally used in utility control systems. The Modbus protocol standard is maintained by The Modbus Organization.

1.3.49 Master-Slave/Token Passing (MS/TP)(BACnet)

Data link protocol as defined by the BACnet standard. Multiple speeds (data rates) are permitted by the BACnet MS/TP standard.

1.3.50 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.

1.3.51 Network (BACnet)

In BACnet, a portion of the control internetwork consisting of one or more segments of the same media connected by repeaters. Networks are separated by routers.

1.3.52 Network Variable (LonWorks)

See 'Standard Network Variable Type (SNVT)'.

1.3.53 Network Configuration Tool (LonWorks)

The software used to configure the control network and set device configuration properties. This software creates and modifies the control network database (LNS Database).

1.3.54 Niagara Framework

A set of hardware and software specifications for building and utility control owned by Tridium Inc. and licensed to multiple vendors. The Framework consists of front end (M&C) software, web based clients, field level control hardware, and engineering tools. While the Niagara Framework is not adopted by a recognized standards body and does not use an open licensing model, it is sufficiently well-supported by multiple HVAC vendors to be considered a de-facto Open Standard.

1.3.55 Niagara Framework Supervisory Gateway (Niagara Framework)

DDC Hardware component of the Niagara Framework. A typical Niagara architecture has Niagara specific supervisory gateways at the IP level and other (non-Niagara specific) controllers on field networks (TP/FT-10, MS/TP, etc.) beneath the Niagara supervisory gateways. The Niagara specific controllers function as a gateway between the Niagara framework protocol (Fox) and the field network beneath. These supervisory gateways may also be used as general purpose controllers and also have the capability to provide a web-browser based user interface.

Note that different vendors refer to this component by different names. The most common name is "JACE"; other names include "EC-BOS", "FX-40", and "UNC".

1.3.56 Node (LonWorks)

A device that communicates using the CEA-709.1-D protocol and is connected to a CEA-709.1-D network.

1.3.57 Node Address (LonWorks)

The logical address of a node on the network, consisting of a Domain number, Subnet number and Node number. Note that the "Node number" portion of the address is the number assigned to the device during installation and is unique within a subnet. This is not the factory-set unique Node ID (see Node ID).

1.3.58 Node ID (LonWorks)

A unique 48-bit identifier assigned (at the factory) to each CEA-709.1-D device. Sometimes called the Neuron ID.

1.3.59 Object (BACnet)

A BACnet Object. The concept of organizing BACnet information into standard components with various associated Properties. Examples include Analog Input objects and Binary Output objects.

1.3.60 Override

To change the value of a point outside of the normal sequence of operation where this change has priority over the sequence. An override can be accomplished in one of two ways: the point itself may be Commandable and written to with a priority or there may be a separate point on the controller for the express purpose of implementing the override.

Typically this override is from the Utility Monitoring and Control System (UMCS) Monitoring and Control (M&C) Software. Note that this definition is not standard throughout industry.

1.3.61 Point, Calculated

A value within the M&C Software that is not a network point but has been calculated by logic within the software based on the value of network points or other calculated points. Calculated points are sometimes called virtual points or internal points.

1.3.62 Point, Network

A value that the M&C Software reads from or writes to a field control network.

1.3.63 Polling

A requested transmission of data between devices, rather than an unrequested transmission such as Change-Of-Value (COV) or Binding where data is automatically transmitted under certain conditions.

1.3.64 Program ID (LonWorks)

An identifier (number) stored in the device (usually EEPROM) that identifies the node manufacturer, functionality of device (application & sequence), transceiver used, and intended device usage.

1.3.65 Property (BACnet)

A BACnet Property - a data element associated with an Object. Different Objects have different Properties, for example an Analog Input Object has a Present_Value Property (which provides the value of the underlying hardware analog input), a High_Limit Property (which contains a high limit for alarming), as well as other properties.

1.3.66 Protocol Implementation Conformance Statement (PICS)(BACnet)

A document, created by the manufacturer of a device, which describes which potions of the BACnet standard are implemented by a given device.

1.3.67 Repeater

A device that connects two control network segments and retransmits all information received on one side onto the other.

1.3.68 Router (LonWorks)

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.

1.3.69 Router (BACnet)

A device that connects two or more BACnet networks and controls traffic between the networks by retransmitting signals received from one network onto another based on the signal destination. Routers are used to subdivide an internetwork and to control bandwidth usage.

1.3.70 Segment

A 'single' section of a control network that contains no repeaters or routers. There is generally a limit on the number of devices on a segment, and this limit is dependent on the topology/media and device type. For example, a TP/FT-10 segment with locally powered devices is limited to 64 devices, and a BACnet MS/TP segment is limited to 32 devices.

1.3.71 Service (BACnet)

A BACnet Service. A defined method for sending a specific type of data between devices. Services are always defined in a Client-Server manner, with a Client initiating a Service request and a Server Executing the Service. Some examples are ReadProperty (a client requests a data value from a server), WriteProperty (a client writes a data value to a server), and CreateObject (a client requests that a server create a new object within the server device).

1.3.72 Service Pin (LonWorks)

A hardware push-button on a device which causes the device to broadcast a message containing its Node ID and Program ID. This broadcast can also be initiated via software.

1.3.73 Standard BACnet Object/Property/Service (BACnet)

BACnet Objects, Properties, or Services that are standard Objects, Properties, or Services enumerated and defined in ASHRAE 135. Clause 23 of ASHRAE 135 defines methods to extend ASHRAE 135 to non-standard or proprietary information. Standard BACnet Objects/Properties/Services specifically exclude any vendor specific extensions.

1.3.74 Standard Configuration Property Type (SCPT) (LonWorks)

Pronounced 'skip-it'. A standard format type (maintained by LonMark International) for Configuration Properties.

1.3.75 Standard Network Variable Type (SNVT) (LonWorks)

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.

1.3.76 Subnet (LonWorks)

Consists of a logical grouping of up to 127 nodes, where the logical grouping is defined by node addressing. Each subnet is assigned a number which is unique within the Domain. See also Node Address.

1.3.77 Supervisory Controller

A controller implementing a combination of supervisory logic (global control strategies or optimization strategies), scheduling, alarming, event management, trending, web services or network management. Note this is defined by use; many supervisory controllers have the capability to also directly control equipment.

1.3.78 Supervisory Gateway

A device that is both a supervisory controller and a gateway.

1.3.79 TP/FT-10 (LonWorks)

A Free Topology Twisted Pair network (at 78 kbps) defined by CEA-709.3. This is the most common media type for a CEA-709.1-D control network.

1.3.80 TP/XF-1250 (LonWorks)

A high speed (1.25 Mbps) twisted pair, doubly-terminated bus network defined by the LonMark Interoperability Guidelines. This media is typically used only as a backbone media to connect multiple TP/FT-10 networks.

1.3.81 UMCS Network

An IP network connecting multiple field control systems to the Monitoring and Control Software using one or more of: LonWorks (CEA-709.1-D and CEA-852-C), BACnet (ASHRAE 135 Annex J), Modbus or OPC DA.

1.3.82 User-defined Configuration Property Type (UCPT) (LonWorks)

Pronounced 'u-keep-it'. A Configuration Property format type that is defined by the device manufacturer.

1.3.83 User-defined Network Variable Type (UNVT) (LonWorks)

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.

1.3.84 Utility Control System (UCS)

One type of field control system. Used for control of utility systems such as an electrical substation, sanitary sewer lift station, water pump station, etc. Building controls are excluded from a UCS, however it is possible to have a Utility Control System and a Building Control System in the same facility, and for those systems to share components such as the

FPOC. A UCS may include its own local front-end.

1.4 SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government. [Submit items designated with a "G,DO" concurrently in a "system submittal" to permit simultaneous review of functionally interrelated items. Omission of a required item from the package may result in disapproval of the submittal. Unless noted in the submittal review comments, disapproval of any element within the package will require a re-submittal of the entire system package.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES and TABLE 1: PROJECT SEQUENCING:

SD-02 Shop Drawings

UMCS Contractor Design Drawings; G, DO

UMCS Contractor Design Drawings as a single complete package: 2 hard copies and 2 copies on CDROM. Submit hardcopy drawings on A3 17 by 11 inches sheets, and electronic drawings in both PDF and Microstation format.

Draft As-Built Drawings; G, DO

Draft As-Built Drawings as a single complete package: 2 hard copies and 2 copies on CDROM. Submit hardcopy drawings must on A3 17 by 11 inches sheets, and electronic drawings in both PDF and Microstation format.

Final As-Built Drawings; G, DO

Final As-Built Drawings as a single complete package: 2 hard copies and 2 copies on CDROM. Submit hardcopy drawings on A3 17 by 11 inches sheets, and electronic drawings in both PDF and Microstation format.

SD-06 Test Reports

Pre-Construction QC Checklist; G, RO

Four copies of the Pre-Construction QC Checklist.

Post-Construction QC Checklist; G, RO

Four copies of the Post-Construction QC Checklist.

Existing Conditions Report; G, RO

2 copies of the Existing Conditions Report.

Start-Up and Start-Up Testing Report; G, RO

2 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 Phase I Procedures; G, RO

2 copies of the PVT Phase I Procedures. The PVT Procedures may be submitted as a Technical Data Package.

PVT Phase I Report; G, RO

2 copies of the PVT Phase I Report. The PVT Phase I Report may be submitted as a Technical Data Package.

PVT Phase II Report; G, RO

2 copies of the PVT Phase II Report. The PVT Phase II Report may be submitted as a Technical Data Package.

SD-10 Operation and Maintenance Data

Operation and Maintenance (O&M) Instructions; G, RO

2 bound O&M Instructions and 2 copies of the Instructions in PDF format on optical disc. Index and tab bound instructions. Submit instructions in PDF form as a single PDF file, or as multiple PDF files with a PDF file table of contents containing links to the other files. O&M Instructions may be submitted as a Technical Data Package.

SD-11 Closeout Submittals

Closeout QC Checklist; G, RO

Four copies of the Closeout QC Checklist.

1.5 PROJECT SEQUENCING

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

1.5.1 Sequencing for Submittals

The sequencing specified for submittals is the deadline by which the submittal must 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 re-submittal there will be an additional Government review period. If the submittal is not accepted the process repeats until the submittal is accepted by the Government.

1.5.2 Sequencing for Activities

The sequencing specified for activities indicates the earliest the activity may begin.

1.5.3 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		~~[Acceptance of Factory Test Report]~~ [Notice to proceed]~~[_____]~~	
2	S	Existing Conditions Report	[_____] days after #1
3	S	Design Drawings	[_____] days after #1
5	S	UMCS IP Network Bandwidth Usage Estimate	[_____] days after #1
6	S	Pre-construction QC Checklist	[_____] days after #1
9	S	Post-Construction QC Checklist	[_____] days ACO #8
12	S	Draft As-Built Drawings	[_____] days ACO #8
13	S	PVT Phase I Procedures	[_____] days before scheduled start of #14 and AAO #11
14	E	PVT Phase I	AAO #13 and #12
15	S	PVT Phase I Report	[_____] days ACO #14
16	S	Preventive Maintenance Work Plan	AAO #11
17	S	O&M Instructions	AAO #11
18	S	Basic Training Documentation	AAO #11 and [_____] days before scheduled start of #19
19	E	Basic Training (PVT Phase II)	AAO #16, #17 and #18
20	S	PVT Phase II Report	[_____] days ACO #19
21	S	Final As-Built Drawings	[_____] days AAO #20
22	S	Advanced Training Documentation	[_____] days before schedule start of #23 and AAO #18

TABLE I. PROJECT SEQUENCING

ITEM	TYPE	DESCRIPTION	SEQUENCING (START OF ACTIVITY or DEADLINE FOR SUBMITTAL)
23	E	Advanced Training	ACO #19, [_____] days AAO #22, and no later than [60] days ACO #19
24	S	Refresher Training Documentation	[_____] days before #25 and AAO #18 and #22
25	E	Refresher Training	between [_____] and [_____] days ACO #19 and AAO #24
26	S	Closeout QC Checklist	ACO #23

1.6 QUALITY CONTROL (QC) CHECKLISTS

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

The APPENDIX A QC Checklist is available as an editable file at http://www.wbdg.org/ccb/NAVGRAPH/graphtoc.pdf.

1.7 OPERATION AND MAINTENANCE (O&M) INSTRUCTIONS

Provide UMCS Operation and Maintenance Instructions which include:

a. Procedures for the UMCS system start-up, operation and shut-down.

b. Final As-Built drawings.

c. Routine maintenance checklist, arranged in a columnar format: The first column listing all installed devices, the second column stating the maintenance activity or stating that no maintenance required, the third column stating the frequency of the maintenance activity, and the fourth column providing any additional comments or reference.

d. Qualified service organization list including points of contact with phone numbers.

e. Start-Up and Start-Up Testing Report.

f. Performance Verification Test (PVT) Procedures and Reports.

PART 2 PRODUCTS

2.1 CONTROL HARDWARE

2.1.1 Control Protocol Gateways

Provide Control Protocol Gateways which perform bi-directional protocol translation between two of the following protocols, or between one of the following protocols and another protocol: CEA-709.1-D, ASHRAE 135, Modbus, and OPC DA. Provide Control Protocol Gateways which also meet the following requirements.

a. Gateways must have two or more separate network connections, each appropriate for the protocol and media used. A single network connection must not be used for both protocols.

b. Gateways must be capable of being installed, configured and programmed through the use of instructions in the manual supplied by the Contractor.

c. Provide and license to the Government all software required for gateway configuration.

d. Gateways must retain their configuration after a power loss of an indefinite time, and must automatically return to their pre-power loss state once power is restored.

e. Gateways must provide capacity for mapping all required points as indicated[plus an additional [10 percent][_____]] between the two protocols it uses.

f. Gateways must, in addition, meet all requirements specified (in the following subparagraphs) for each of the two protocols it translates.

2.1.1.1 Gateway for CEA-709.1

For a gateways using CEA-709.1-D provide gateways which meet the following requirements in addition to the requirements for all gateways:

a. It must allow bi-directional mapping of data in the Gateway to Standard Network Variable Types (SNVTs) according to the LonMark SNVT List.

b. Gateways communicating CEA-709.1-D over an IP network must communicate in accordance with CEA-852-C.

c. It must allow of its standard network variables (SNVTs) and support transmitting data using the "min, max, and delta" (throttling and heartbeat) methodology.

d. It must provide the ability to label SNVTs.

e. It must supply a LonMark external interface file (XIF) as defined in the LonMark XIF Guide for use with LNS tools and utilities.

f. It must have a "service pin" which, when pressed, will cause the Gateway to broadcast its 48-bit NodeID and ProgramID over the network.

g. It must provide a configurable self-documenting string.

PART 3 EXECUTION

3.1 EXISTING CONDITIONS SURVEY

Perform a field survey, including but not limited to testing and inspection of equipment to be part of the UMCS, and submit an Existing Conditions Report documenting the current status and its impact on the Contractor's ability to meet this specification. For field control systems to be integrated to the UMCS which are not already connected to the UMCS IP network, verify the availability of the building network backbone at the FPOC location, and verify that FPOCs shown as existing are installed at the FPOC location.

3.2 DRAWINGS AND CALCULATIONS

3.2.1 UMCS Contractor Design Drawings

Revise and update the Contract Drawings to include details of the system design and all hardware components, including contractor provided and Government furnished components. Details to be shown on the Design Drawing include:

a. The logical structure of the network, including but not limited to the location of all Control Hardware (including but not limited to each Control Protocol Gateway, Control Protocol Router, and Monitoring and Control (M&C) Controller).

b. Manufacturer and model number for each piece of Computer Hardware and Control Hardware.

c. Physical location for each piece of Computer Hardware and Control Hardware.

d. Version and service pack number for all software and for all Control Hardware firmware.

3.2.2 As-Built Drawings

Prepare draft as-built drawings consisting of Points Schedule drawings for the entire UMCS, including Points Schedules for each Gateway, and an updated Design Drawing including details of the actual installed system as it is at the conclusion of Start-Up and Start-Up Testing. Provide As-Built Drawings which include details of all hardware components, including contractor provided and Government furnished components. In addition to the details shown in the design drawings, the as-built drawing must include:

a. IP address(es) and Ethernet MAC address(es) as applicable for each piece of Control Hardware (including but not limited to each Control Protocol Gateway, Control Protocol Router, and Monitoring and Control (M&C) Controller).

b. IP address and Ethernet MAC address for each computer server, workstation, and networked printer.

c. Network identifier (name) for each printer, computer server and computer workstation.

d. List of ports, protocols and network services for each device connected to an IP network.

e. Network Addresses: CEA-709.1-D address (domain, subnet, node address) for all Control Hardware using CEA-709.1-D.

Prepare Draft As-Built Drawings upon the completion of Start-Up and Start-Up Testing and Final As-Built Drawings upon completion of PVT Phase II.

3.3 INSTALLATION OF EQUIPMENT

3.3.1 IP Addresses

For all Control Hardware requiring an IP address on the UMCS IP Network, coordinate with the NEC to obtain IP addresses .

3.4 INTEGRATION OF FIELD CONTROL SYSTEMS

Fully integrate the field control systems in accordance with the following three step sequence and as specified and shown.

STEP 1: Install and configure Control Hardware as necessary to connect the field control system to the FPOC, which is part of the UMCS IP network, and to provide control protocol translation and supervisory functionality.

STEP 2: Add Field Control System to M&C Software: Perform system discovery, system database merges, or any other actions necessary to allow M&C Software access to the field control system.

STEP 3: Configure M&C Software to provide monitoring and control of the field control system, including but not limited to the creation of system displays and the configuration of scheduling, alarming, and trending.

3.4.1 Integration Step 1: Install Control Hardware

Install Control Hardware as specified at the FPOC location [as shown] [___] to connect the field control system to the UMCS IP network via the FPOC and, if necessary, to provide control protocol translation and supervisory functionality. Coordinate all connections and other activities related to an FPOC with [___]. Depending on the field control system media and protocol this must be accomplished through one of the following:

a. Connect the existing field control network hardware at the FPOC location to the FPOC. =

b. Install a Control Protocol Gateway connected to both the field control network and the FPOC.c. Install a Control Protocol Router connected to both the field control network and the FPOC.

d. Install a Control Protocol Gateway connected to the field control network. Then install a Control Protocol Router connected to both the Control Protocol Gateway and the FPOC.

3.4.1.1 Installation of Control Protocol Gateway

If the field control system uses a protocol which is not supported by the M&C Software, install a gateway to convert the field control system protocol to CEA-709.1-D. Install additional field control system network

media and hardware as needed to connect the Gateway to the field control system. Connect the Gateway according to one of the two following methods:

a. Connect the Gateway to the field control network and to the FPOC..

b. Connect the Gateway to the field control network and to a LonWorks/IP Router installed as specified.

Create and configure points and establish network communication between the Control Protocol Gateway and the field control system to provide points from the field control system to the M&C software.

3.4.1.2 Installation of Control Protocol Router

If there is not an existing connection between the FPOC and the field control network, install a LonWorks/IP Router to connect the field control network to the FPOC. Install additional field control system network media as needed to connect the Router to the field control system.

3.4.2 Integration Step 2: Add Field Control System to M&C Software

Perform system discovery, system database merges, or any other actions necessary to allow M&C Software access to points and data in the field control system.

3.4.2.1 Integration of Field Control Systems Via ANSI-709.1-C

a. When a LNS Database of the field control system is not available, use the Network Configuration Tool software to discover the field control system and create an LNS Database for the field control system.

b. When the UMCS does not already contain an LNS Server, provide an LNS Server to support the UMCS LNS Database.

c. When there is no existing UMCS LNS Database, use the field control system database as the UMCS Database.

d. When there is an existing UMCS LNS Database, merge the field control system with the UMCS LNS database.

e. After integration of field control systems, disable web pages in the CEA-852-C devices.

3.4.2.2 Integration of Field Control Systems Via Other (non-CEA-709.1-D) Protocols

Perform all actions necessary to make all points as shown on the Points Schedule from the field control system available in the M&C Software.

3.4.3 Integration Step 3: Configure M&C Software

Configure M&C Software to provide monitoring and control of the field control system, including but not limited to the creation of system displays and the configuration of scheduling, alarming, and trending.

3.4.3.1 Configure M&C Software Communication

Create and configure points and establish network communication between M&C Software and Field Control Systems as specified to support M&C Software

functionality:

a. Update points on currently active displays via polling as necessary to meet M&C Software display refresh requirements.

b. Send points used for overrides to the device receiving the override as shown on the Points Schedule. For LonWorks systems, for points used for overrides use the network variable and SNVT type indicated on the Points Schedule. For SNVTs for overriding schedules (via the Simple Scheduler) use SNVT type SNVT_occupancy and support the following values: OC_OCCUPIED, OC_UNOCCUPIED, OC_STANDBY and OC_NUL. For SNVTs used to override schedules or setpoints for Demand Limiting functions use the acknowledged service.

c. points from CEA-709.1-D field control systems used using acknowledged service or poll the point at 5 minute intervals.

d. Update points used for currently active trends via polling as necessary to meet trend interval requirements.

e. Send points used for scheduling to the field control system with a maximum time between subsequent transmissions of the point of 30 minutes. For LonWorks field control systems, send points used for scheduling to the appropriate System Scheduler using SNVTs of type SNVT_occupancy which support the following values: OC_OCCUPIED, OC_UNOCCUPIED and OC_STANDBY.

f. Maintain control sequence logic in DDC hardware in the building such that the building control network is not dependent upon connection to the IP network or the FPOC for performance of control sequences in this specification.

Edit the Description field of each point to include the Real Property Unique IDs (RPUID) associated with that point as shown on the Points Schedule

3.4.3.2 Configure M&C Software Functionality

Fully configure M&C Software functionality using the M&C Software capabilities specified in PART 2 of this Section.

a. Create System Displays using the Fort Leonard Wood sample displays, including overrides, as shown on the Points Schedule and as specified. Label all points on displays with the point name as shown on the Points Schedule. Configure user permissions for access to and executions of action using graphic pages. Coordinate user permissions with the HVAC shop supervisor

b. Configure alarm generation and alarm handling as shown on the Points Schedule, as shown on the Alarm Routing Schedule, and as specified. For alarms requiring notification via text message or email, configure the alarm notification to use the specified Government furnished SMTP server to send the alarm notification.

c. Configure scheduling as indicated and as shown on the points schedule. Configure M&C Software scheduling functionality for LonWorks field control systems which do not use the Simple Scheduler Object. For LonWorks field control systems which do use the Simple Scheduler Object, configure the Simple Scheduler Objects in the field control

system. Create and configure displays for configuration of M&C Software schedules and Simple Scheduler Objects in the field control system. Label schedules and scheduled points with full English-language descriptors. Provide a separate configuration capability for each schedule. A single configuration display may be used to configured multiple schedules, provided that each schedule is separately configurable from the display.

d. Create M&C Software trends for required points as shown on the Points Schedule and as specified. Where specified, Trend points at 15 minute intervals.Create and configure displays for creation and configuration of trends and for display of all trended points.

e. Configure Demand Limiting as shown on the Demand Limit Schedule and Points Schedule and as specified.

f. Configure M&C Software standard reports.

3.5 START-UP AND START-UP TESTING

Test all equipment and perform all other tests necessary to ensure the system is installed and functioning as specified. Prepare a Start-Up and Start-Up Testing Report documenting all tests performed and their results and certifying that the system meets the requirements specified in the contract documents.

3.6 PERFORMANCE VERIFICATION TEST (PVT)

3.6.1 PVT Phase I Procedures

Provide PVT Procedures which include:.

a. Network bandwidth usage and available bandwidth (throughput) measurements. Network bandwidth usage must reference the normal usage network Bandwidth Calculations.

b. Test System Reaction during PVT: The total system response time from initiation of a control action command from the workstation, to display of the resulting status change on the workstation must not exceed 20 seconds under system normal heavy load conditions assuming a zero response time for operation of the node's control device.

c. Verification of IP Connectivity.

d. Verification of configuration of M&C Software functionality.

3.6.2 PVT Phase I

Demonstrate compliance of the control system with the contract documents. Using test plans and procedures previously approved by the Government, demonstrate all physical and functional requirements of the project. Upon completion of PVT Phase I and as specified, prepare and submit the PVT Phase I Report documenting all tests performed during the PVT and their results. In the PVT report, include all tests in the PVT Procedures and any other testing performed during the PVT. Document failures and repairs with test results.

3.6.3 PVT Phase II

Include Basic Training as part of PVT Phase II. Failures or deficiencies of the UMCS during Basic Training are considered PVT failures. Upon completion of PVT Phase II, and as specified, prepare and submit the PVT Phase II Report documenting any failures which occurred and repairs performed during PVT Phase II.

3.7 TRAINING

Conduct training courses for designated personnel in the maintenance, service, and operation of the system as specified, including specified hardware and software. The training must be oriented to the specific system provided under this contract. Provide audiovisual equipment and other training material and supplies required for the training. When training is conducted at Government facilities, the Government reserves the right to record the training sessions for later use. A training day is defined as 8 hours of classroom instruction, excluding lunchtime, Monday through Friday, during the daytime shift in effect at the training facility. For guidance in planning the required instruction, the Contractor should assume that attendees will be tradesmen such as electricians or boiler operators. Obtain approval of the training schedule from the Government at least 14 days prior to the first day of training.

3.7.1 Training Documentation

Prepare and submit one set of Training manuals that consists of:

3.7.1.1 Course Attendance List

Course Attendance List developed in coordination with and signed by the HVAC shop supervisor.

3.7.1.2 Training Manuals

Include an agenda, defined objectives for each lesson, and a detailed description of the subject matter for each lesson in the training manuals. Where portions of the course material are presented by audiovisuals, incldue copies of those audiovisuals as a part of the printed training manuals.

3.7.2 Training Tasks

Conduct a Basic Training course at the project site on the installed system for a period of no less than 1 training days during Phase 2 of the PVT. A maximum of ten personnel will attend this course. Design training targeted towards training personnel in the day-to-day operation and basic maintenance of the system. Upon completion of this course, each student, using appropriate documentation, should be able to start the system, operate the system, recover the system after a failure, perform routine maintenance and describe the specific hardware architecture and operation of the system. Include the following topics at a minimum:

a. General system architecture.

b. Functional operation of the system, including workstations and system navigation.

c. System start-up procedures.

d. Failure recovery procedures.

e. Schedule configuration.

f. Trend configuration.

g. Perform point overrides and override release.

h. Reports generation.

i. Alarm reporting and acknowledgements.

j. Diagnostics.

k. Historical files.

l. Maintenance procedures:

(1) Physical layout of each piece of hardware.

(2) Troubleshooting and diagnostic procedures.

(3) Preventive maintenance procedures and schedules.

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 1-2)	( )
	Post-Construction QC Checklist Submittal (Items 1-6)	( )
	Close-out QC Checklist Submittal (Items 1-14)	( )
Instructions: Initial each item in the space provided (|____|) verifying that the requirement has been met.		
Verify the following items for Pre-Construction, Post-Construction and Closeout QC Checklist Submittals:		
1	Contractor Design Drawing Riser Diagram includes location and types of all Control Hardware and Computer Hardware.	|____|
2	M&C Software supports , and . M&C Software is LonWorks Network Services (LNS) based.	|____|
Verify the following items for Post-Construction and Closeout QC Checklist Submittal:		
3	Communication between the M&C Software and CEA-709.1-D field control systems uses only CEA-709.1-D.	|____|

QC CHECKLIST		
4	Connections to non-CEA-709.1-Dfield control systems are via a Gateway from the field control system to CEA-709.1-D or via a UMCS supported protocol without the use of a hardware Gateway.	|____|
5	Computer workstations and servers are installed as shown on the UMCS Riser Diagram.	|____|
6	Training schedule and course attendee lists have been developed and coordinated with shops and submitted.	|____|
Verify the following items for Closeout QC Checklists Submittal:		
7	LNS Database is up-to-date and accurately represents the final installed system. All points in field control systems are available at the M&C Software.	|____|
8	All software has been licensed to the Government.	|____|
9	M&C software monitoring displays have been created for all building systems, including all override and display points indicated on Points Schedule drawings.	|____|
10	Final As-built Drawings accurately represent the final installed system.	|____|
11	Default trends have been set up (per Points Schedule drawings).	|____|
12	Scheduling has been configured at the M&C Software (per Occupancy Schedule drawing).	|____|
13	O&M Instructions have been completed and submitted.	|____|

QC CHECKLIST		
14	Basic Operator and Advanced Training courses have been completed.	|____|
	_____ _____	
	(QC Representative Signature) (Date)	

-- End of Section --

Acronyms and Abbreviations

Term	Definition
AHU	Air Handling Unit
AMI	Advanced Metering Infrastructure
AMP	Army Metering Program
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ATFP	Anti-Terrorism/Force Protection
ATO	Authority To Operate
AWS	American Welding Society
BAS	Building Automation System
B-AWS	BACnet Advanced Workstation
BCN	Building Control Network
BCS	Building Control System
BTL	BACnet Testing Laboratories
CEA	Consumer Electronics Association
CEERD	U.S. Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
CSI	Construction Specifications Institute
DA	Discharge Air
DCV	Demand-Controlled Ventilation
DDC	Direct Digital Control
DHCP	Dynamic Host Configuration Protocol
DIN	Deutsches Institut für Normung [the German national standards organization]
DIP	Dual in-Line Package
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DPW	Directorate of Public Works
DSPR	Duct Static Pressure Reset
DX	Direct Expansion
EBI	Enterprise Buildings Integrator
ECM	Energy Conservation Measure
EEDRS	Enterprise Energy Data Reporting System
ERDC	US Army Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
ESPC	Energy Savings Performance Contract
FPT	Functional Performance Test
FTE	Full-Time Equivalent
FY	Fiscal Year
GSM/GPRS	Global System for Mobile Communications/General Packet Radio Service

Term	Definition
GUI	Graphical User Interface
HEM	Honeywell Energy Manager
HNC	Huntsville Center, Alabama
HVAC	Heating, Ventilating, and Air-Conditioning
I/O	Input/Output
IA	Information Assurance
IAW	In Accordance With
ICAN	Installation Campus Area Network
ID	Identification
ID/IQ	indefinite delivery indefinite quantity
IDIQ	Indefinite Delivery/Indefinite Quantity
IIS	Internet Information Services
IMCOM	U.S. Army Installation Management Command
IP	Internet Protocol
ISEC	Information Systems Engineering Command
ISSP	Integrated Strategic and Sustainability Plan
IT	Information Technology
LAN	Local Area Network
LNS	LonWorks Network Services
M&C	monitoring and control
M&V	Measurement and Verification
MAC	Media Access Control (MAC)
MCA	Military Construction, Army
MCWB	Mean Coincident Wet Bulb
MCX	Huntsville Mandatory Center of Expertise
MDMS	Maintenance Data Management System
MILCON	Military Construction
MIPR	Military Interdepartmental Purchase Request
MZ	Multizone
N/A	Not Applicable
NA	Not Applicable
NDAA	National Defense Authorization Act
NEC	Network Enterprise Center
NWK	Kansas City District
O&M	Operations and Maintenance
OTS	Off the Shelf
OMB	Office of Management and Budget
OSA	Outside Air
PAIO	Plans, Analysis, and Integration Office
PM	Project Manager
PNNL	Pacific Northwest National Laboratory

Term	Definition
POA&M	Plan of Action and Milestones
POC	Point of Contact
PPS	Ports, Protocols and Services
PROSPECT	Proponent Sponsored Engineer Corps Training
PV	PhotoVoltaic
PVT	Performance Verification Test
RA	Return Air
RFP	Request for Proposal
RH	Relative Humidity
RMS	Root Mean Square
RPM	Revolutions per Minute
RTU	Remote Terminal Unit
SLA	Service Level Agreement
SI	System Integration
TAB	Testing, Adjusting and Balancing
TFW	Tsay/Ferguson-Williams
TP/FT	Twisted-Pair/Free Topology
TR	Technical Report
TRM	Technical Resource Manager
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification
UMCS	Utility Monitoring and Control System
URL	Universal Resource Locator
USACE	U.S. Army Corps of Engineers
USAG	U.S. Army Garrison
USC	U.S. Code
VAC	Volt AC
VAV	Variable Air Volume
VLAN	Virtual Local Area Network
VPN	Virtual Private Network
XML	Extensible Markup Language

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
06/22/2017	Final	

4. TITLE AND SUBTITLE
Utility Monitoring and Control System (UMCS) and Utility Metering Plan and Specifications for Fort Leonard Wood, MO

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT

6. AUTHOR(S)
David M. Schwenk, Dave M. Underwood, Joseph Bush, Brian Clark, Tapan Patel, Annette L. Stumpf, and Susan J. Bevelheimer

5d. PROJECT NUMBER
MIPR No. 10768675

5e. TASK NUMBER
A1070

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Research and Development Center (ERDC)
Construction Engineering Research Laboratory (CERL)
PO Box 9005,
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/CERL TR-17-15

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Garrison Fort Leonard Wood
Plans, Analysis, and Integration Office (PAIO)
Fort Leonard Wood, MO 65473

10. SPONSOR/MONITOR'S ACRONYM(S)
PAIO

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Fort Leonard Wood, MO has two separate Utility Monitoring and Control Systems (UMCSs) that remotely monitor and supervise hundreds of building control systems. The garrison is currently considering whether it would best to merge the two existing systems into a single, integrated UMCS. However, coordinating the operation of these separate systems is a significant issue that will affect the garrison's decision on how to move forward. This work reviewed and analyzed the installation's building automation technology, related industry standards, utility metering requirements, and market trends, and made specific recommendations to outline a path forward to configure a single installation-wide UMCS with a front-end that provides DPW access to perform supervisory monitoring and control functions including access to utility metering data.

15. SUBJECT TERMS
Military bases, Fort Leonard Wood (Mo.), Public utilities—Management, Utility meters

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER (include area code)
Unclassified	Unclassified	Unclassified	SAR	359	