

UFC 3-401-01
1 July 2013
Change 1, October 2015

UNIFIED FACILITIES CRITERIA (UFC)

MECHANICAL ENGINEERING



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MECHANICAL ENGINEERING

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U.S. ARMY CORPS OF ENGINEERS

NAVAL FACILITIES ENGINEERING COMMAND (Preparing Activity)

AIR FORCE CIVIL ENGINEER CENTER

Record of Changes (changes are indicated by \1\ ... /1/)

Change No.	Date	Location
<u>1</u>	<u>October 2015</u>	<u>Changes to Chapters 1, 2 and Appendix A in response to Criteria Change Requests (CCRs) and Tri-Service reviews.</u>

FOREWORD

The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with [USD \(AT&L\) Memorandum](#) dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

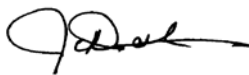
UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force \2\ Civil Engineer Center (AFCEC) /2/ are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: [Criteria Change Request](#). The form is also accessible from the Internet sites listed below.

UFC are effective upon issuance and are distributed only in electronic media from the following source:

- Whole Building Design Guide web site <http://dod.wbdg.org/>.

Hard copies of UFC printed from electronic media should be checked against the current electronic version prior to use to ensure that they are current.

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**UNIFIED FACILITIES CRITERIA (UFC)
NEW SUMMARY SHEET**

Document: UFC 3-401-01, *Mechanical Engineering*

Superseding: None

Description: This UFC is the core document for the mechanical discipline. It is intended as a reference for all mechanical work. It is organized to provide the top-level minimum mandatory mechanical design and analysis requirements and refers to other criteria as appropriate.

Reasons for Document:

- This new UFC provides a central point reference for all mechanical design criteria.
- Establishes minimum design analysis and drawing requirements in support of design activities
- Helps direct designers to the appropriate mechanical discipline criteria document.

Impact:

- There are negligible cost impacts. Creation of a single-source reference for mechanical design discipline helps clarify requirements for the design of DoD facilities.

Unification Issues:

- The Navy uses MO-230, *Petroleum Fuel Facilities* for maintenance of petroleum fuel systems while the Air Force and Army use UFC 3-460-03, *O&M: Maintenance of Petroleum Systems*. There is a project pending by the tri-service Fuel Facility Engineering Panel to unify these documents.
- The Navy uses UFC 3-430-08N, *Central Heating Plants* for design of central heating plants while the Army and Air Force use 3-430-02FA, *Central Steam Boiler Plants*. There is an ongoing Army project to update and unify these documents.

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION	1
1-1 PURPOSE AND SCOPE	1
1-2 APPLICABILITY	1
1-3 GENERAL BUILDING REQUIREMENTS	1
1-4 REFERENCES	1
1-5 GLOSSARY	1
CHAPTER 2 TECHNICAL REQUIREMENTS	3
2-1 BASIC PRINCIPLES	3
2-1.1 Life Cycle Considerations.....	3
2-1.2 Maintainability.....	3
2-1.3 Seismic Protection.....	3
2-1.4 Weather Data.....	3
2-1.5 Conflicts in Design.....	3
2-1.6 Conflicts in Criteria.....	4
2-1.7 Specifications.....	4
2-2 ASSOCIATED MECHANICAL SYSTEMS CRITERIA	4
2-2.1 Facility Plumbing Systems.....	4
2-2.2 Facility HVAC Systems and Controls.....	4
2-2.3 Utility Monitoring and Control Systems.....	4
2-2.4 Exterior Mechanical Distribution Systems.....	4
2-2.5 Petroleum Fuel Systems.....	4
2-2.6 Industrial Ventilation Systems.....	5
2-2.7 Compressed Air Systems.....	5
2-2.8 Refrigeration Systems for Cold Storage Facilities.....	5
2-2.9 Central Plants.....	5
2-2.10 Mechanical Systems for Health Care Facilities.....	5
CHAPTER 3 DOCUMENTATION REQUIREMENTS	7
3-1 DESIGN ANALYSIS	7
3-1.1 Basis of Design Narrative.....	7
3-1.2 Calculations and Analysis.....	8
3-2 FINAL DRAWING REQUIREMENTS	8

3-2.1	Drawing Units.	8
3-2.2	Legend.....	8
3-2.3	Seismic.	8
3-2.4	Demolition Plans.....	9
3-2.5	Floor Plans and Site Plans.	9
3-2.6	Sections and Elevations.	9
3-2.7	Access Space.....	9
3-2.8	Special Detailing.....	9
3-2.9	Equipment Schedules.....	9
3-2.10	Other Drawing Requirements.	9
APPENDIX A REFERENCES.....		11
APPENDIX B STANDARD CONVERSIONS AND TABLES.....		13
APPENDIX C GLOSSARY		15

TABLES

Table B-1 - Fuel Conversion Factors.....	13
Table B-2. Metric Pipe Size Equivalence	14
Table B-3. Metric Ductwork Dimensions	14

CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This Unified Facility Criteria (UFC) provides requirements and guidance for mechanical systems designed and constructed for the Department of Defense (DoD) together with criteria for selecting mechanical system materials and equipment. This information must be used by mechanical engineers to develop design calculations, specifications, plans, and design-build Requests for Proposal (RFPs) and must serve as the minimum mechanical design requirements.

This UFC is provided to ensure quality and consistency in design of mechanical systems with minimum life cycle costs which satisfy the functional and operational requirements of DoD facilities and which provide a healthy and safe environment for facility occupants. This UFC is intended as a reference for all mechanical work. Figure 1-1 shows the relationship of this UFC to other related mechanical UFCs.

1-2 APPLICABILITY.

This UFC is applicable to all service elements and contractors involved in the planning, design and construction of Department of Defense (DoD) facilities worldwide.

1-3 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, General Building Requirements. UFC 1-200-01 provides applicability of model building codes and government unique criteria for typical design disciplines and building systems, as well as for accessibility, antiterrorism, security, high performance, sustainability, and safety. Use this UFC in addition to UFC 1-200-01 and the government criteria referenced therein.

1-4 REFERENCES.

Appendix A contains a list of references used in this document.

1-5 GLOSSARY.

Appendix C contains acronyms, abbreviations, and terms.

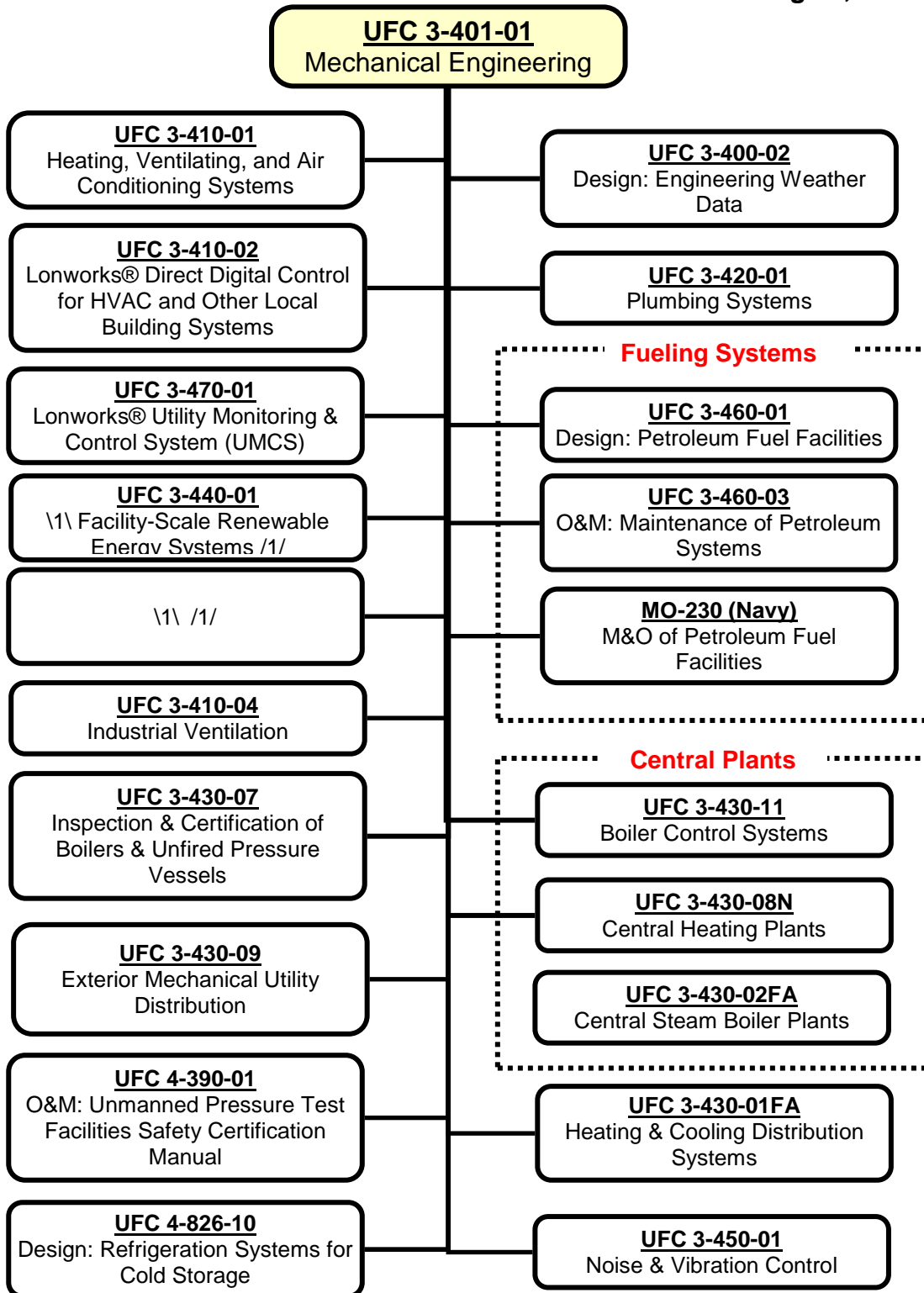


Figure 1-1 Mechanical UFC Delineation

CHAPTER 2 TECHNICAL REQUIREMENTS**2-1 BASIC PRINCIPLES.****2-1.1 Life Cycle Considerations.**

Energy and water-efficient and sustainable design attributes for military construction must be based on the cost-benefit analysis, return on investment, total ownership costs, and demonstrated payback. Provide mechanical systems based on achieving the lowest life cycle cost of the approved alternatives. Ensure that all operation and maintenance costs are included in any life cycle cost analysis. Follow procedures for Life Cycle Cost Analysis (LCCA) stated in UFC 1-200-02. HVAC system (including fuel source) preliminary design must be determined at the concept stage justified by a LCCA.

2-1.2 Maintainability.

Maintainability and reliability are paramount to the operation of DoD buildings. Mechanical equipment not required to be located outside must be located in an equipment room. All mechanical equipment must be based on a minimum of three manufacturers. Catalog cuts from those three manufacturers must be included in the mechanical design analysis. Size the mechanical room to accommodate the space required to house all equipment and piping. A three dimensional envelope must be shown on the mechanical drawings for each item of equipment showing the maximum dimensions of those three manufacturers including the space necessary for maintenance and replacement. Verify adequate door dimensions to permit passage of equipment into mechanical spaces. Provide system designs with the features necessary for easy access for maintenance and for successful testing, adjusting, balancing, and system commissioning. Provide protection for equipment materials located in corrosive environments.

2-1.3 Seismic Protection

Design mechanical systems with respect to seismic protection in accordance with UFC 3-310-04. Provide details to structural engineer for support verification and sizing.

2-1.4 Weather Data

Weather data needed for design calculations and analysis must be obtained from UFC 3-400-02.

2-1.5 Conflicts in Design

Avoid conflicts with other disciplines and building features.

2-1.6 Conflicts in Criteria.

Where, in any specific case, different sections of any mechanical UFC or referenced standards specify different materials, methods of construction or other requirements, the most restrictive requirement will govern.

2-1.7 Specifications

All projects including DBB and DB will use the applicable UFGS as part of the design and construction documentation. \1\ Construction specifications projects shall require all materials to be protected from moisture and conditions that have potential to result in deterioration of material properties or in mold growth during site storage and construction. Protective measures must be taken to ensure that the construction process adequately shelters the materials to prevent mold growth and material degradation during construction. /1/

2-2 ASSOCIATED MECHANICAL SYSTEMS CRITERIA.

2-2.1 Facility Plumbing Systems

Design and construct plumbing systems for facilities in accordance with this document and the current issue of UFC 3-420-01. \1\ When solar preheat and heating of domestic hot water is shown to be LCC effective, systems must be in accordance with UFC 3-440-01. /1/

2-2.2 Facility HVAC Systems and Controls.

Design and construct Heating, Ventilating, and Air Conditioning (HVAC) systems for facilities in accordance with this document and the current issues of UFC 3-410-01. \1\ Insulate piping with an operating temperature below dewpoint with jacketed insulation meeting the cold piping requirements. The insulation jacket must be sealed to provide an exterior vapor barrier. /1/

2-2.3 Utility Monitoring and Control Systems.

Utility Monitoring and Control System Front Ends must be designed and constructed in accordance with UFC 3-470-01 and UFGS 25 10 10.

2-2.4 Exterior Mechanical Distribution Systems.

Design and construct all exterior steam, chilled water, and hot water distribution systems in accordance with this document and UFC 3-430-01FA.

2-2.5 Petroleum Fuel Systems.

Design and construct petroleum fueling systems in accordance with this document and the current issue of UFC 3-460-01. Provisions for maintenance of fueling facilities must be provided in accordance with UFC 3-460-03 for the **Air Force** and **Army**. The maintenance aspects of Navy fuel facilities must follow MO-230.

2-2.6 Industrial Ventilation Systems.

Design industrial ventilation systems in accordance with UFC 3-410-04. Provide air flow and static pressure calculations with each design.

Mechanical requirements for stationary battery installations that do not perform battery maintenance must be designed in accordance with UFC 3-520-05.

2-2.7 Compressed Air Systems.

Design and construct exterior compressed air distribution systems in accordance with this document and the current issue of UFC 3-430-09. Interior distribution must be designed and constructed in accordance with the Compressed Air and Gas Institute's Compressed Air and Gas Handbook and the ASME BPVC (Boiler and Pressure Vessel Codes).

2-2.8 Refrigeration Systems for Cold Storage Facilities.

Design and construct refrigeration systems for cold storage facilities in accordance with this document, UFC 3-410-01 and the current issue of UFC 4-826-10.

2-2.9 Central Plants.

Design and construct central heating plants in accordance with this document and the current issue of UFC 3-430-08N for the **Navy** or 3-430-02FA for the **Army** and **Air Force**.

When a central plant is provided to serve multiple buildings, meter all utility services (gas, oil, steam, chilled, and hot water) at the central plant (both supply and return) and at each building served (supply only). Provide flow and temperature measurement for steam, chilled and hot water demand and measure BTU for energy consumption.

2-2.10 Mechanical Systems for Health Care Facilities.

Mechanical system designs for health care facilities will be in accordance with the current issue of UFC 4-510-01.

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CHAPTER 3 DOCUMENTATION REQUIREMENTS**3-1 DESIGN ANALYSIS.**

The Design Analysis must be submitted at a preliminary design stage equivalent to 35% design for concurrence of the results. The Design Analysis must consist of a Basis of Design Narrative and Calculations. The analysis must be updated as necessary as the design progresses. The results of this analysis are used for design decision-making in reducing total life cycle cost, while meeting mission objectives.

3-1.1 Basis of Design Narrative.

Provide a Basis of Design narrative as part of all design analysis.

3-1.1.1 User Requirements.

Document ventilation, temperature and humidity requirements, occupancies, functions, usage schedules, equipment loads, and exhaust requirements by space.

3-1.1.2 Criteria / Codes.

Identify the governing codes and criteria utilized for the design. Include the titles and the date of the applicable edition or publication.

3-1.1.3 Site Conditions.

Conduct detailed field investigation and interview the appropriate field personnel. Do not rely solely on the as-built drawings.

Determine energy sources available at the project site. Describe the source of thermal energy that will be used (i.e. Extension of central high pressure steam, hot water, natural gas, or stand alone heat source with the type of fuel utilized). Use fuel conversion factors provided in Appendix B for the analysis.

3-1.1.4 System Selection.

Provide a narrative description of all system alternatives considered. Describe in detail all systems and components selected at a preliminary design stage equivalent to 35% design to include the results of the LCCA and modeled energy use.

3-1.1.5 Special Mechanical Systems

Provide a description of special mechanical systems such as compressed air, hydraulic, nitrogen, lubrication oil, etc.

3-1.1.6 Other Basis of Design Narrative Requirements.

Provide any additional basis of design documentation as required by the specific mechanical UFCs.

3-1.2 Calculations and Analysis.

Show calculations and assumptions supporting equipment selections in a clear and organized manner. When charts or tables are used in the design analysis, cite the source and date of the publication.

3-1.2.1 Sizing Calculations.

Provide calculations for sizing equipment, piping, ductwork and all accessories. Provide the model number and manufacturer of each major piece of equipment used as the basis for the design.

3-1.2.2 LCCA.

Provide LCCA on optimized system level alternatives modeled in accordance with UFC 1-200-02. Provide energy model, including model inputs and outputs, on optimized system level alternatives by energy type in accordance with UFC 1-200-02.

3-1.2.3 Energy Compliance Analysis (ECA).

If required by UFC 1-200-02, provide a computerized Energy Compliance Analysis. The ECA is a building level analysis which takes into account the interaction between architectural, electrical and mechanical components of the facility design and confirms compliance with the energy reduction goals.

3-1.2.4 Other Calculation Requirements.

Provide any additional calculation documentation as required by the specific mechanical UFCs.

3-2 FINAL DRAWING REQUIREMENTS.

Drawings must be accurate and to scale. Drawings must show equipment, ductwork, and piping sufficiently to indicate all aspects of installation. Where practical, group all notes, legends, and schedules at the right of the drawings above the title block.

3-2.1 Drawing Units.

Unless otherwise authorized, the IP System of measurement must be used on CONUS projects and the SI system of measurement must be utilized on OCONUS projects. Metric and English pipe sizes are listed in Appendix C.

3-2.2 Legend.

Provide legends to clarify all symbols and abbreviations used on the drawings.

3-2.3 Seismic.

Show all pertinent seismic detailing for the mechanical systems on the contract drawings.

3-2.4 Demolition Plans.

“Demolition” plans should be separate and distinct from “new work” plans.

3-2.5 Floor Plans and Site Plans.

Exercise judgment to avoid overly congested drawings. Provide north arrows on all building and site plans. The orientation of drawings must be arranged with the north arrow toward the top of the plotted sheets, unless overriding circumstances dictate otherwise. The orientation of all partial building or site plans must be identical to that of the larger plan from which it is derived or referenced. Consistency in drawing orientation must be maintained with all disciplines. Enlarged plans must be drawn at no less than 1:50 ($\frac{1}{4}'' = 1'-0''$).

3-2.6 Sections and Elevations.

Provide as required to supplement plan views.

3-2.7 Access Space.

Identify space necessary to access and replace items that require maintenance, such as filters, coils, heat exchangers, tube bundles, strainers, and chillers on the drawings in three-dimensions.

3-2.8 Special Detailing

Provide details on the drawings necessary to ensure drainage for “winterizing” equipment where appropriate.

3-2.9 Equipment Schedules.

The equipment actually installed on a project may be different from that used as your basis of design. Therefore, mechanical equipment schedules must reflect actual required equipment capacities as calculated, not capacities provided by manufacturers' catalog data. This helps ensure that the installed equipment is optimally sized for the application.

3-2.10 Other Drawing Requirements.

Provide any additional drawing requirements indicated in the specific mechanical UFCs.

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APPENDIX A REFERENCES

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

www.asme.org

ASME BPVC, Boiler and Pressure Vessel Codes

COMPRESSED AIR AND GAS INSTITUTE (CAGI)

www.cagi.org

The Compressed Air and Gas Handbook

UNITED STATES NAVY

MO-230, Maintenance and Operation of Petroleum Fuel Facilities,

<http://www.wbdg.org/ccb/NAVFAC/OPER/mo230.pdf>

UNITED STATES DEPARTMENT OF DEFENSE

MIL-STD 3007, Standard Practice for Unified Facilities Criteria and Unified Facilities Guide Specifications, <http://www.wbdg.org/ccb/FEDMIL/std3007f.pdf>

UNITED STATES DEPARTMENT OF DEFENSE, UNIFIED FACILITIES CRITERIA

<http://dod.wbdg.org/>

UFC 1-200-01, General Building Requirements

UFC 1-200-02, High Performance and Sustainable Building Requirements

UFC 3-310-04, Seismic Design for Buildings

UFC 3-400-02, Design: Engineering Weather Data

UFC 3-410-01, Heating, Ventilating, and Air Conditioning Systems

UFC 3-410-02, Lonworks (R) Direct Digital Control for HVAC and Other Local Building Systems

UFC 3-410-04, Industrial Ventilation

UFC 3-420-01, Plumbing Systems

UFC 3-430-01FA, Heating and Cooling Distribution Systems

UFC 3-430-02FA, Central Steam Boiler Plants

UFC 3-430-07, Inspection and Certification of Boilers and Unfired Pressure Vessels

UFC 3-430-08N, Central Heating Plants

UFC 3-430-09, Exterior Mechanical Utility Distribution

UFC 3-430-11 Boiler Control Systems

UFC 3-440-01, \1\ Facility-Scale Renewable Energy Systems /1/

\1\ /1/

UFC 3-450-01, Noise and Vibration Control

UFC 3-460-01, Design: Petroleum Fuel Facilities

UFC 3-460-03, O&M: Maintenance of Petroleum Systems

UFC 3-470-01, Lonworks (R) Utility Monitoring and Control System (UMCS)

UFC 3-520-05, Stationary Battery Areas

UFC 4-390-01, O&M: Unmanned Pressure Test Facilities Safety Certification Manual

UFC 4-510-01, Design: Medical Military Facilities

UFC 4-826-10, Design: Refrigeration Systems for Cold Storage

**UNITED STATES DEPARTMENT OF DEFENSE, UNIFIED FACILITIES GUIDE
SPECIFICATIONS (UFGS)**

<http://dod.wbdg.org/>

UFGS 25 10 10, Utility Monitoring and Control System (UMCS) Front End Integration

APPENDIX B STANDARD CONVERSIONS AND TABLES

Table B-1 - Fuel Conversion Factors

Type of Fuel	Conversion Factors (See note (a))	Notes
Anthracite Coal	28.4 Million Btu/Short Ton	
	29.9 kJ/kg	
Bituminous Coal	24.6 Million Btu/Short Ton	
	25.9 kJ/kg	
Electricity	3413 Btu/KWH	
	12.3 MJ	
No. 2 Distillate Fuel Oil	138,700 Btu/Gallon	
	38.7 MJ/L	
Residual Fuel Oil	149,700 Btu/Gallon	
	41.8 MJ/L	
Kerosene	135,000 Btu/Gallon	
	37.7 MJ/L	
LP Gas	95,500 Btu/Gallon	
	26.6 MJ/L	
Natural Gas	1,031 Btu/Cubic Foot	
	38.5 MJ/L	
Purchased or Steam from Central Plant	1,000 Btu/Pound	See note (b)
	2.3 MJ/kg	

Notes:

(a) At specific installations where the energy source Btu content is known to vary consistently by 10% or more from the values given below, the local value may be used provided there is adequate data on file for two years or more to justify the revision and that this value is expected to hold true for at least five years following building occupancy.

(b) High temperature, medium temperature, or chilled water from a central plant must use the heat value of fluid based on the actual temperature and pressure delivered to the 1.5 m (5 ft) line.

Table B-2. Metric Pipe Size Equivalence

NPS (Inches)	DN (mm)	NPS (Inches)	DN (mm)
1/8	6	2-1/2	65
3/16	7	3	80
1/4	8	3-1/2	90
3/8	10	4	100
1/2	15	4-1/2	115
5/8	18	5	125
3/4	20	6	150
1	25	8	200
1-1/4	32	10	250
1-1/2	40	12	300
2	50		

Notes:

1. NPS is the inch-pound designation for “nominal pipe size”.
2. DN is the metric designation for “diameter nominal”.
3. For pipe sizes over 12 inches, use the conversion factor of 25 mm per inch.

Table B-3. Metric Ductwork Dimensions

Inches	mm
3	80
4	100
5	130
6	150
7	180
8	200
10	250
12	300

Notes:

1. For dimensions over 12 inches, increase mm size in increments of 50

APPENDIX C GLOSSARY

ACRONYMS

AFCEE	Air Force Center for Engineering and the Environment
AHJ	Authority Having Jurisdiction
ASME	American Society of Mechanical Engineers
BIA	Bilateral Infrastructure Agreement
BPVC	Boiler and Pressure Vessel Codes
BTU	British Thermal Unit
CAGI	Compressed Air and Gas Institute
CONUS	Continental United States
DB	Design Build
DBB	Design Bid Build
DN	Diameter Nominal
DoD	Department of Defense
ECA	Energy Compliance Analysis
Ft	Foot
HQUSACE	Headquarters United States Army Corp of Engineers
HNFA	Host Nation Funded Construction Agreements
HVAC	Heating, Ventilating and Air Conditioning
IP	Inch-Pound
Kg	Kilogram
Kj	Kilojoule
Kwh	Kilowatt-Hours
L	Liter
LCC	Life Cycle Cost

LCCA	Life Cycle Cost Analysis
LP	Liquid Petroleum
Mil-Std	Military Standard
MJ	Million joules
m	meter
mm	Millimeters
MO	Maintenance & Operation
NAVFAC	Naval Facilities Engineering Command
NPS	Nominal Pipe Size
O&M	Operation and Maintenance
OCONUS	Outside the Continental United States
RFP	Request for Proposal
SOFA	Status of Forces Agreement
UFC	Unified Facility Criteria
UFGS	Unified Facilities Guide Specification
UMCS	Utility Monitoring & Control System
USD (AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics