

FACILITIES CRITERIA (FC)

AIR FORCE CRITERIA FOR PRECISION MEASUREMENT EQUIPMENT LABORATORY DESIGN AND CONSTRUCTION



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PRECISION MEASUREMENT EQUIPMENT
LABORATORY DESIGN AND CONSTRUCTION**

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AIR FORCE CIVIL ENGINEER CENTER (Preparing Activity)

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

Change No.	Date	Location
1	Jun-2020	Table 1-1b. Variance is defined in integer values of degrees C rather than in degrees F.

This FC supersedes FC 4-218-01F, *Air Force Criteria for Precision Measurement Equipment Laboratory Design and Construction*, dated 28 October 2015.

FOREWORD

Facilities Criteria (FC) provide functional requirements (i.e., defined by users and operational needs of a particular facility type) for specific DoD Component(s), and are intended for use with unified technical requirements published in DoD Unified Facilities Criteria (UFC). FC are applicable only to the DoD Component(s) indicated in the title, and do not represent unified DoD requirements. Differences in functional requirements between DoD Components may exist due to differences in policies and operational needs.

All construction outside of the United States is also governed by Status of Forces Agreements (SOFA), Host Nation Funded Construction (HNFC) agreements, and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the most stringent of the FC, the SOFA, the HNFC agreement, and the BIA, as applicable.

Because FC are coordinated with unified DoD technical requirements, they form an element of the DoD UFC system applicable to specific facility types. The UFC system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applicable to the Military Departments, Defense Agencies, and the DoD Field Activities. The UFC System also includes technical requirements and functional requirements for specific facility types, both published as UFC documents and FC documents.

FC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQ USACE), Naval Facilities Engineering Command (NAVFAC), and the Air Force Civil Engineer Center (AFCEC) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content 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](#).

FC 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/>.

Refer to UFC 1-200-01, *General Building Requirements*, for implementation of new issuances on projects.

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**FACILITIES CRITERIA (FC)
REVISION SUMMARY SHEET**

Document: FC 4-218-01F, *Air Force Criteria for Precision Measurement Equipment Laboratory Design and Construction.*

Superseding: Facilities Criteria (FC) 4-218-01F, *Air Force Criteria for Precision Measurement Equipment Laboratory Design and Construction..*

Description: This FC prescribes Air Force criteria for design and construction of new Precision Measurement Equipment Laboratories (PMELs) and updates to existing facilities on Air Force installations. It incorporates the provisions of Unified Facilities Criteria (UFC) 3-410-01, *Heating, Ventilating, and Air Conditioning Systems*, and UFC 3-401-01, *Mechanical Engineering*.

Reasons for Document:

- Incorporates Criteria Change Request (CCR) 7691.
- Provides a design guide for Architect and Engineering firms, design agencies, planners, and Air Force organizations for the design of PMEL facilities.
- Updates existing criteria to reflect new and revised industry standards.

Impact:

- Improves energy efficiency.
- Ensures that PMEL environmental systems provide temperature and humidity conditions that will enable performance of traceable measurements for Test, Measurement, and Diagnostic Equipment (TMDE).

Unification Issues:

- Design criteria for Air Force PMEL facilities are specific to accommodate Air Force-unique organizational and operational considerations.

Disclaimer:

- Use of the name or mark of any specific manufacturer, commercial product, commodity, or service in this publication does not imply endorsement by the Air Force.

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CHAPTER 1 INTRODUCTION

1-1 PURPOSE AND SCOPE.

This FC provides guidelines for evaluating, planning, programming, and designing PMEL Facilities. Alteration and renovation projects should update existing facilities to meet the guidance and criteria within budgetary constraints. This FC is not intended as a substitution for thorough review by individual Program Managers and Operations Staff in the appropriate agency. This FC is a guide for site selection and design of a new metrology laboratory or for modification of an existing facility. This FC outlines standards for design and construction of Type II and Type III PMELs.

1-2 REQUIREMENTS.

Requirements which directly affect the accuracy and integrity of the measurements made and are unique to a calibration laboratory are addressed. Criteria in this FC must not be used as sole justification for a new facility or to improve an existing facility if the facility's condition does not adversely affect the environmental requirements enabling performance of traceable measurements.

1-3 APPLICABILITY.

The information in this FC applies to the design of all new construction projects, to include additions, alterations, and renovation projects in the continental United States (CONUS) and outside the continental United States (OCONUS).

1-4 USERS OF THIS DOCUMENT.

This FC is intended to be a source of basic architectural and engineering information for all individuals involved in the planning, design, and evaluation of PMEL facilities.

1-4.1 Architects and Engineers.

Architects and engineers (A/Es) who provide design services for PMEL facility construction or renovation will be under the direction of the AFCEC Facility Engineering Directorate.

1-4.2 Planning Personnel.

Planning personnel will use this FC along with other documents for programming new or replacement facilities, pre-design planning, or assessing the extent of improvements required in an existing or new PMEL in order to achieve the standard established herein.

1-4.3 Additional Users.

Additional users include:

- Headquarters staff, Air Force Installation and Mission Support Center (AFIMSC) detachments, and Primary Subordinate Units (PSUs).
- Major command staff/regions.
- Installation commanders.
- Installation facilities management.
- Installation technical proponents.
- Program directors.
- Facility/program operations staff.

1-5 RESPONSIBILITIES.

1-5.1 Air Force Civil Engineer Center (AFCEC).

AFCEC establishes standards and criteria for Air Force PMEL design and construction and provides technical assistance to the design agents and base PMEL managers.

1-5.2 Air Force Metrology and Calibration (AFMETCAL).

AFMETCAL manages the Air Force Metrology and Calibration program.

1-5.3 Base Civil Engineer (BCE).

Ensures this FC is referenced in all PMEL project design documents, and reviews A/E Design Documents to ensure compliance. Hosts preplanning workshops prior to the development of programming documentation for new construction or upgrades.

1-6 SCOPE OF FACILITY.

The PMEL Facility is composed of the Administrative Area, the Calibration and Repair (C/R) Area and the Support Areas. The scope may vary depending on the location and mission requirements. All of the program areas are described in greater detail in Chapters 2 and 4. These criteria apply to Type II and Type III PMELs.

1-7 REFERENCES.

Appendix A contains a list of references used in this document. If the publication date of the code or standard is not included, use the latest available issuance of the reference.

1-8 GLOSSARY.

Refer to Appendixes B and C for definitions of acronyms, abbreviations, and terms.

1-9 PROGRAM AREAS.

1-9.1 Administrative Support, Calibration and Repair, and Support Area.

Tables 1-1a through 1-1d list the core and optional functional program areas for PMEL facilities. These functional program areas are administrative support, calibration and repair, support and special requirements. These are traditional for a typical PMEL, and core areas may be adjusted to accommodate mission requirements. The administrative support area includes equipment check-in, a service entrance, technical library, conference room, break room, and offices. The C/R area includes force and pressure measurement, equipment storage, azimuth reference, a temperature/humidity-sensitive area, a night vision area, and shield room, if survey indicates a need. The support area includes an equipment cleaning room, shipping and receiving, a liquid flow calibration area, and covered equipment area. A 68 degree room, if required, is a separate modular control module.

Table 1-1a. Functional Program Areas

Program Area	Description
Administrative Support Area	
Equipment check-in and check-out, vestibule, and lobby	Minimal entry space in front of control and/or vestibule. Usually combined with the waiting and equipment check-in and pickup. Include a customer service counter to separate the customer from the equipment storage and processing areas. Provide a waiting area with seating and computerized check-in as required for customers.
Service entrance	Service entrance (with canopy) for oversized equipment entry with sealed double doors between the calibration and repair area and the building exterior. Fully enclose the canopy to create an insulated entryway in extreme climates.
Conference room, classroom & training room	Conference room for meetings, planning, and classroom for training personnel.
Break room, copier, and work layout	Break area, copier, and layout space. Food and beverages. May have refrigerator and self-serve (vending). Include copy machine with electrical outlets and work table for drawings and paperwork and small storage area.
Restrooms/janitor supply room	Restrooms for PMEL staff/visitors and janitor supply room with supplies.
Technical library	Library containing technical orders (TOs), equipment descriptions, maintenance manuals, and Air Force manuals and instructions.
Offices	
Flight Chief/Site Manager's office	Private office.
Laboratory Chief's office	Private office
Administrative offices	Offices for administrative staff.
Quality Assurance Supervisor office	Private office

Table 1-1b. Functional Program Areas

Program Area	Description
Calibration and Repair (C/R)	
C/R area	This area is maintained under a positive pressure at specified temperature and humidity levels. Various functions occur within this area; some require specific areas or rooms. The C/R area includes: the shield room, technical library, force and pressure measurement, equipment storage, azimuth reference, and a 68 degree room, if required. A positive static pressure as compared to surrounding areas is required to prevent infiltration of dust-laden air. Excess ventilation air for pressurization and a continuous air barrier system to control infiltration and exfiltration in buildings to maintain air tightness is required. Air locks are required for entry into the C/R area. Locate the C/R area adjacent to other conditioned areas.
Temperature/humidity sensitive area	This is a special temperature/humidity sensitive controlled area for PMELs that do not have a requirement for a 68 degree room. The temperature and humidity requirements for this area are $73 \pm 1.8^{\circ}\text{F}$ ($22.8 \pm 1^{\circ}\text{C}$) and a relative humidity of 35, +10/-15%. The temperature may not vary more than 1°F (0.5°C) in any one-hour period during normal system operation. Maximum temperature gradient across the room is 1.8°F (1°C). /1/
Force and pressure measurement area	Safety screens or shields may be required in the immediate vicinity of force and pressure calibration equipment to protect operators and other laboratory personnel from flying projectiles, high pressure gas, or fluids.
Night vision area	Night vision calibration area for testing under controlled conditions of lighting, temperature, and humidity. Calibration of the night vision ANV-126 test set should be done in a room with ambient lighting levels of less than 0.1 foot candle (1.08 lux) in the general area of the test set. The ANV-20/20 low light level calibration requires total darkness during the adjustment procedures for night vision test set calibration.
Shield room	Usually constructed of copper screening to minimize effects of excessive electromagnetic interference (EMI) or radio frequency interference (RFI), a shield room typically is not required unless EMI/RFI survey results indicate a need.

Table 1-1b. Functional Program Areas (Continued)

Program Area	Description
Calibration and Repair (continued)	
Azimuth reference	If an external azimuth reference line is required, the line can range in length up to one mile terminating at a target mount, depending on location. However, only a few selected PMELs are designated as azimuth verification facilities. The primary azimuth references are established within the facility by an optical target collimator located on an isolated pier. The directions of the external line and the normals to the collimator are determined by observing Polaris (the North Star) from outside the facility. Transfer of direction from Polaris and/or the line to the optical reference is accomplished using a precision theodolite. The PMEL verification facility is an environmentally-controlled facility. Facilities must be located to permit laying out unobstructed lines of sight to the target monument, ranging 45 degrees either side of astronomic north, and in an area relatively free from vibrational disturbances such as heavy local traffic. The test area in the PMEL must provide a steady state internal environment with regard to temperature and air movement. Since total darkness is necessary to conduct azimuth reference surveys, ensure appropriate lighting design is provided. Stable piers are provided for the optical reference collimator and temperature is maintained at 73 ± 6 °F (22.8 ± 3.3 °C) throughout the year.
Liquid flow calibration area	A specially-equipped, isolated area required in PMELs to perform liquid flow meter calibration using propylene glycol as primary test fluid. The enclosure housing a liquid flow calibration area must be constructed of non-combustible or fire resistive materials as defined by the National Fire Protection Association (NFPA). This generally refers to masonry, reinforced concrete, or protected steel construction. The facility also must be equipped with a minimum of two exits, separated to preclude both being cut off in the event of a localized fire. Ensure that doors swing out in the direction of egress per NFPA 101, <i>Life Safety Code</i> and NFPA 45, <i>Standard on Fire Protection for Laboratories Using Chemicals</i>. Outward-swing exit doors are required where chemicals are used for testing. Floor space is determined by considering the type and number of flow calibrators needed for the mission. Double doors are required to facilitate installation of flow calibrator units. The liquid flow room is located outside the calibration and repair area.

Table 1-1c. Functional Program Areas

Program Area	Description
Special Requirements	
68 degree room (modular control module)	This is a special temperature controlled area in some PMELs where a 68 degree room is required to maintain a closely-controlled environmental area for calibration and use of higher-accuracy dimensional TMDE. These conditions can be maintained using an off-the-shelf, self-contained, environmental control module, as an option. The environmental control system must maintain 68 ± 1 °F (20 ± 0.5 °C) and an optimum relative humidity of 35, +10/-15%. The temperature may not change more than 1 °F (0.5 °C) in any one hour period during normal system operation.

Table 1-1d. Functional Program Areas

Program Area	Description
Support Area	
Equipment cleaning room	A specially-equipped and isolated area is required for cleaning and washing mechanical, electrical, and electronic equipment. The TMDE cleaning room is separate from the C/R area, and supplied with utilities for cleaning parts. Requirements for the area are determined by the types of equipment to be serviced. Each cleaning unit requires a minimum 15 ft ² (1.4 m ²) additional floor space. A stainless steel sink and drain board with hot and cold water and exhaust hood is required. Provide an equipment canopy-type exhaust hood with a wall-mounted manual timer, with capability of variable operation up to 2 hours (i.e., twist type or similar occupant-controlled timer). Where a canopy-type hood would pull fumes into the breathing zone, consider installing a bench-style slot-type hood to pull fumes away from the breathing zone. The drying oven for standard cleaning rooms requires 212 cfm (6 m ³ /min) for the purge blower intake and exhaust. Provide a vacuum port in the equipment cleaning room.
Shipping and receiving	A shipping and receiving area is required to facilitate loading and unloading of customer equipment for shipment and for short term storage. Install gasket-type stops, astragals, and automatic door bottoms on air lock doors located closest to the C/R area. Seal joints between doors and frames with gaskets.
Covered equipment area	Provide a protected entrance for unloading equipment: either a double-entry door with a drive-through canopy; or a service entry with a roll-up door large enough to allow a small truck or van to back into the unloading area. Quantity and size of equipment handled and weather conditions should determine which entry is appropriate. Consider a covered entry for extreme or cold weather.

CHAPTER 2 FUNCTIONAL REQUIREMENTS

2-1 DESIGN APPROACH.

The design criterion in this section simplifies construction or renovation to a wide variety of PMELs, including the basic requirements which apply to any PMEL. All Air Force construction projects, regardless of scope, shall comply with A7C Policy Memorandum, *"Air Force Sustainable Design and Development (SDD) Implementing Guidance."*

2-1.1 Structural, Mechanical, Electrical, and Plumbing Requirements.

Using the internal and site layouts, locate interfaces between the facility structure and equipment items. Verify the design contains openings, conduit, and raceways to install cables, equipment, and piping with minimum disruption to finished work. During the pre-design stages of the project, the PMEL supervisor must provide the design agent with technical data for any equipment which requires special connections.

2-1.2 The Commissioning Process and Verification of Operation.

The commissioning process ensures that a facility and its components will perform as designed and intended. Optimally, the commissioning process starts during planning and programming prior to design. It continues during design with review of design information, performance data in specifications, and evaluation of submissions. During construction, the commissioning process includes checklists, scheduling of tests, testing and verification, and documentation. Commissioning includes witnessing field tests, adherence to specified performance criteria. Commissioning of building systems is critical to ensuring their expected operation. Commissioning of heating, ventilation, and air conditioning (HVAC) systems must be provided by certified commissioning agents as required by UFC 1-200-02, *High Performance and Sustainable Building Requirements*, and construction documents must follow Unified Facilities Guide Specification (UFGS) 01 91 00.00 40, *Commissioning*, and UFGS 23 08 00.00 10, *Commissioning of HVAC Systems*. Performance testing must be conducted during both peak seasons to ensure compliance with functional and performance requirements as described for each space. Certified commissioning agents will have in-depth knowledge of commissioning processes and technical expertise on projects of similar scope, size, and complexity.

2-1.3 Environmentally Safe Materials and Indoor Air Quality.

Ensure that mission and user requirements, as well as occupant health and safety are considered during design, construction and operations for material selection and environmental systems. Hazardous materials used in the laboratory must be considered in the design. The user will provide the design agent a list of hazardous materials, including quantity, use, and location in the laboratory. Refer to UFC 1-200-02.

2-2 SPACE REQUIREMENTS.

The space requirements for PMEL office spaces and functional area rooms are found in Air Force Manual (AFMAN) 32-1084, *Facility Requirements*. The space requirements

are based on the typical PMEL. The size of the PMEL varies depending on the inventory and type of facility (Type II or Type III).

2-3 FUNCTIONAL LAYOUT.

2-3.1 Functional Layouts for Overall Building.

Figures 2-1 through 2-4 show the functional layouts for the overall building, and the C/R, support, and administrative areas.

Figure 2-1 Overall Building Functional Layout

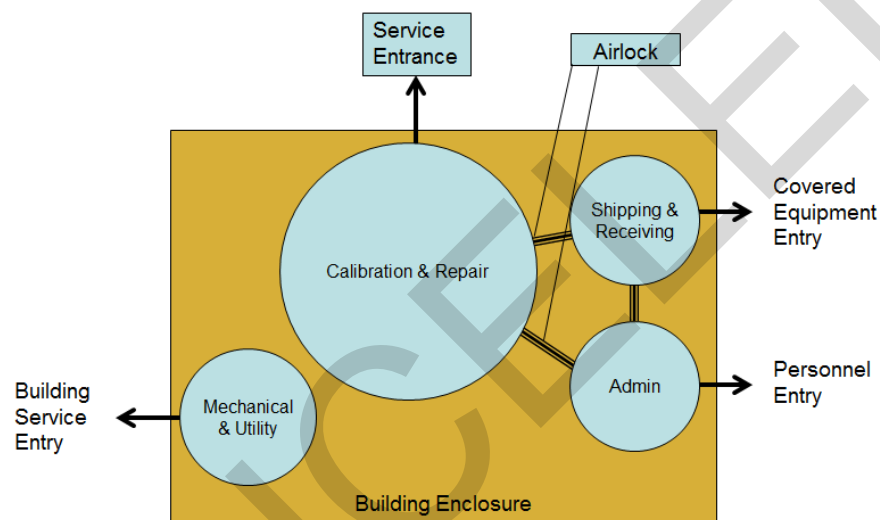


Figure 2-2 Calibration and Repair Area Functional Layout

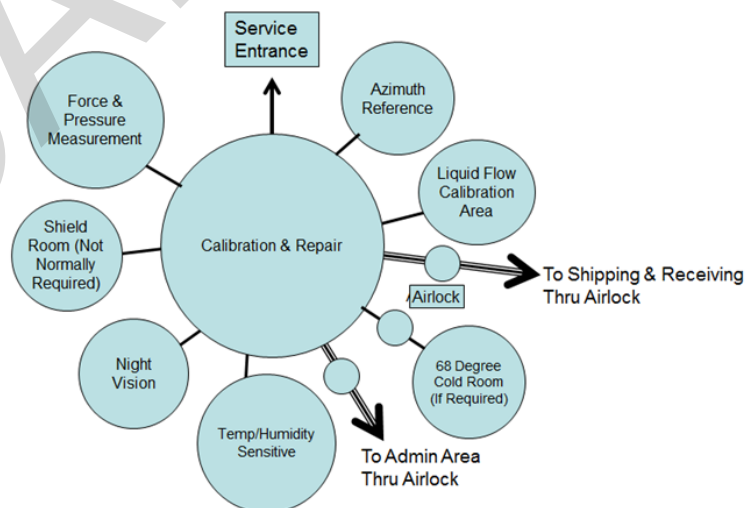


Figure 2-3 Support Area Functional Layout

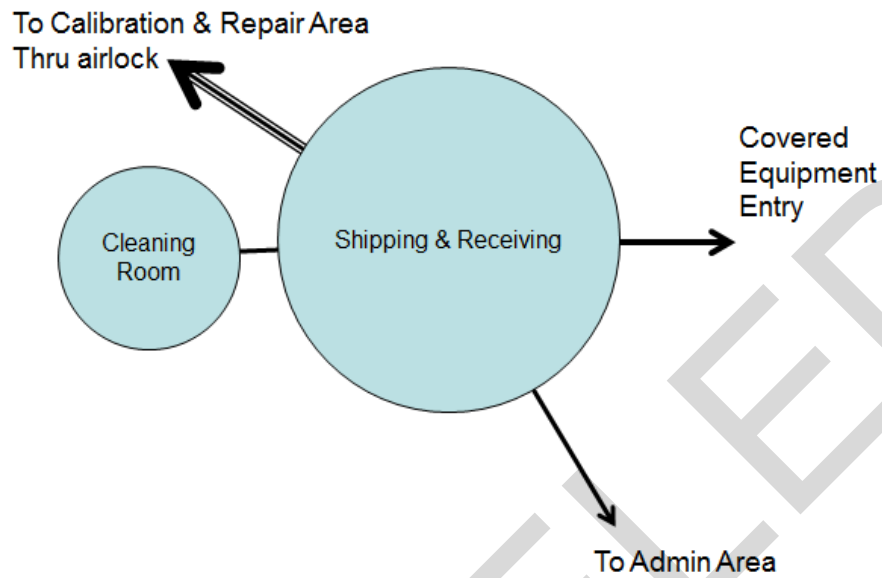
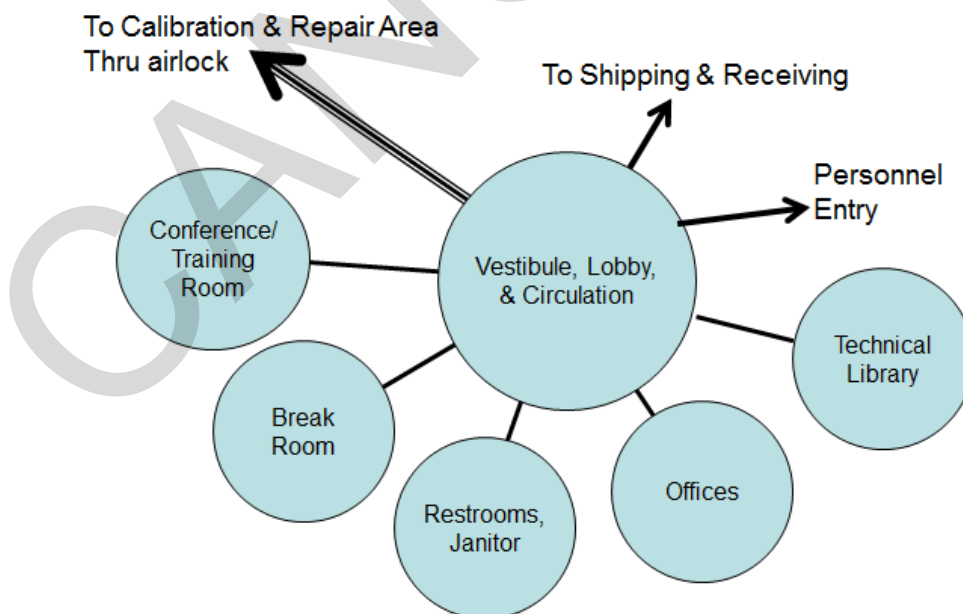


Figure 2-4 Administrative Area Functional Layout



2-3.2 Alterations to Existing Facilities.

Figures 2-1 through 2-4 illustrate acceptable layouts for the overall building. These layouts may have to be modified to accommodate alterations to existing structures. However, proposed modifications must be sent to AFMETCAL for approval. Existing buildings being considered for modification should be assessed as to whether they can support all the core and optional spaces and dimensional requirements.

2-3.3 Other Considerations.

Consider the site of the existing facility and its limitations with regard to the PMEL requirements. Only permanent facilities should be considered for conversion to a PMEL facility. Ensure that existing buildings can accommodate the environmental temperature requirements of a PMEL facility.

Quantities of workload, physical size of workload, proposed workload, or expansion of workload are the primary factors in determining the design of PMEL support areas. From quantities of equipment that will be received, processed, and stored daily, initial floor space requirements can be estimated. Human engineering and the integration of other PMEL operations must be considered to determine location and layout of the support areas. Equipment storage areas must be isolated from visitors for security and to prevent unauthorized movement of equipment.

2-3.4 Location of Rooms, Spaces, and Equipment

Locate rooms, spaces, and equipment to ensure orderly workflow, and provide security and property management. Incompatible areas should not be in close proximity; e.g., equipment that vibrates should not be near the C/R area when vibration may affect measurements. Moisture-generating areas such as restrooms and break rooms should not be near the C/R area. Limit outside walls in the C/R area as much as possible. North and east exposures are preferred. Ensure traffic from movement of equipment, technicians, and customers are isolated from the C/R area. Where possible, design doors and air locks to allow movement of large PMEL equipment and appropriate material handling equipment within the facility. Whenever practical, locate the C/R area adjacent to other environmentally-conditioned areas.

CHAPTER 3 GENERAL DESIGN CRITERIA

3-1 GENERAL BUILDING REQUIREMENTS.

Comply with UFC 1-200-01, *General Building Requirements*. UFC 1-200-01 provides guidance on applicability of model building codes, government-unique criteria for typical design disciplines and building systems, and guidance regarding accessibility, antiterrorism, security, high performance sustainability requirements, and safety. Use this FC in addition to UFC 1-200-01 and the UFCs and government criteria referenced therein. This chapter provides general criteria only and consists mainly of references to the technical design criteria documents and general considerations. Chapter 4 provides the specific design requirements for PMEL facilities.

3-2 STRUCTURE.

3-2.1 Foundation.

The foundation is site specific and must be designed upon known geotechnical considerations, by an engineer knowledgeable of the local conditions. Facilities must be located to permit laying out unobstructed lines of sight to the target monument, ranging from 45 degrees either side of astronomic north, which is specific to PMELs with Azimuth Reference only. Refer to UFC 3-101-01, *Architecture*, for additional guidance.

3-2.2 Vibration.

The PMEL facility site must be isolated from sources of vibration such as railroads, local heavy vehicle or aircraft traffic, crane or machine operations, foot traffic, or similar disturbances. An infrequently used option is constructing the facility below ground level. An acceptable vibration level for a PMEL is anything less than 10 μin (0.25 μm) displacement peak for frequencies from 0.1 to 30 Hz. The maximum acceleration peak is 0.001 g for frequencies from 30 to 200 Hz. To minimize vibration, apply the guidance in paragraphs 3-2.2.1 through 3-2.2.8.

3-2.2.1 Expansion and Isolating Joints.

Use expansion/isolation joints in the concrete floor on the outside toe of the walls defining the conditioned area to isolate the thermal mass of the floor and reduce vibration transmission. Use vibration isolating joints in the utility room where walls and floor adjoin the main structure.

3-2.2.2 Vibration Equipment Location.

Locate vibration-generating equipment such as blowers, compressors, heating and air conditioning units, vacuum pumps, and transformers on separate, isolated utility pads. Equipment that vibrates should not be located near the C/R area.

3-2.2.3 Specialized Shock Mounts.

Use specialized shock mounts, air bag supports, or isolated massive blocks.

3-2.2.4 Steel Spring Type Isolators.

Mount air conditioning equipment (condenser/compressor or fan coil units) to the structure using steel spring type isolators which limit vibration transmission to 0.001 g or less.

3-2.2.5 Flexible Boots.

Use flexible boots or connectors to reduce vibration transmission through ductwork, piping, and rigid tubing.

3-2.2.6 Rigid Conduit Contact.

Do not allow rigid conduit such as feeders, subfeeders, and their supports to contact other non-supporting objects.

3-2.2.7 Flexible Neoprene-Jacketed Conduits.

Use flexible neoprene-jacketed conduits for connections to vibration producing equipment. Install flexible bonding ground straps to ensure continuity of the ground.

3-2.2.8 Air Bearings and Isolators.

Use vibration isolators or air bearings mounted on workbenches and surface plates where extensive isolation techniques cannot be used. This will reduce vibration transmitted to sensitive instrumentation in contact with these surfaces.

3-2.3 Structural Elements in the Superstructure.

Use masonry walls, metal studs, steel joists, steel columns, and steel beams in the superstructure. Where possible, locate specially conditioned areas within the structure so the walls are interior partitions. The building must be single-story, ground floor, and concrete slab construction; exterior doors must not face prevailing winds. Ensure proper floor load bearing design to account for ancillary equipment. Interior partitions must extend above the vapor barrier of the ceiling.

3-3 EXTERIOR DESIGN.

In general, the building's image, theme, and fixtures must be consistent with the functions offered. The building design should reflect the local geographical and cultural environment and comply with the appropriate Service and Installation architectural standards.

3-3.1 Exterior Finishes.

The exterior color, texture, and design should be consistent with the programs offered and the local environment in accordance with Installation standards. They should also be appropriate for the building type.

3-3.2 Entrances/Exits.

The main facility entrance to the lobby should serve as a welcome and transition point; elements such as a covered entry are very desirable. In cold climates, provide a canopy (or a recess) at required egress doors to ensure that doors can open completely without obstruction from snow and ice. The number and location of exits must comply with UFC 3-600-01, *Fire Protection Engineering for Facilities*, to preclude being cut off in the event of a localized fire.

3-3.2.1 Covered Equipment Entry.

Provide a protected entrance for unloading equipment: either a double-entry door with a drive through canopy; or a service entry with a roll-up door large enough to allow a small truck or van to back into the unloading area. Quantity and size of equipment handled and weather conditions should determine which entry is appropriate.

3-3.2.2 Service Entrance (Oversized Equipment Entry).

Where oversized equipment cannot be moved through the air lock, provide a set of tightly-sealed double doors between the C/R area and the building exterior. Equip doors with low leakage seals to prevent exfiltration from pressurized C/R areas. Provide a canopy to shield equipment and the laboratory from precipitation when moving oversized equipment in and out. Fully enclose the canopy to create an insulated entryway in extreme climates.

3-3.3 Exterior Walls and Mold.

Comply with current industry standards, UFC 3-101-01, and UFC 3-410-01, *Heating, Ventilating, and Air Conditioning Systems*, during design to help prevent the development of mold in exterior walls.

3-3.4 Doors and Windows.

Provide windows to allow natural light into the facility, considering antiterrorism and energy conservation/sustainable design issues (reference paragraphs 2-1 and 3-6). All windows and unused doors or other openings shall be sealed to prevent non-conditioned air infiltration and dust contamination from outside. Design and arrange doors opening into the PMEL to maintain effective dust and temperature controls. Minimize the number of doors for personnel passage consistent with fire and safety regulations.

3-3.5 Exterior Signage.

The main entrance should be equipped with a clearly visible sign that provides the program hours of operation. Ensure that signage complies with Installation requirements and UFC 3-120-01, *Design: Sign Standards*. Sign placement and type are site-specific, but signs must be strategically located, adequately lit, and of sufficient size to permit proper viewing by individuals approaching the facility.

3-3.6 Utility Rooms.

Mechanical equipment is usually housed separately from major electrical equipment, which should be located in a dedicated electrical utility room. It is critical that equipment fits the space without crowding and allows adequate space for maintenance. Designers should plan on equipment utilizing a minimum of 15 percent of the total structure area. Utility rooms must be structurally (seismically) separate from the rest of the PMEL building. Mechanical and electrical utility rooms must comply with UFC 3-401-01, *Mechanical Engineering*, UFC 3-501-01, *Electrical Engineering*, and UFC 3-520-01, *Interior Electrical Systems*.

3-4 INTERIOR DESIGN AND CONSTRUCTION.

Interior walls should be Type I or Type II construction as outlined in the International Building Code® using noncombustible materials. Interior walls and ceiling should be insulated and have as much thermal mass on the controlled area side of the wall as possible. If the wall is stud construction, use two layers of 5/8-inch (16-millimeter) gypsum board on the C/R side, with batt insulation, air barrier, and 1/2-inch (13-millimeter) gypsum board on the outside. Tape and seal all gypsum board and seal the sill plate. Good workmanship is essential in finishing each joint and seam of the walls to minimize air infiltration and exfiltration. Refer to UFC 3-101-01 for additional guidance. Interior construction should be extremely durable. Use no hollow core wood doors. All interior glass must be tempered safety glass and mirrors must be made of break-resistant materials. Do not place exterior windows (except for optical windows, as required) in the C/R area; however, sealed glass viewing ports may be installed in calibration areas to permit viewing without entering. Pass-through windows are not permitted.

3-4.1 Interior Wall and Ceiling Construction.

3-4.1.1 Vapor Barriers for Walls and Ceilings.

Vapor barriers usually are placed on the warm side of a wall and ceiling. If the primary method of environmental control is cooling, or if heating and cooling are used about equally, place the vapor barrier away from (outside) the conditioned area. This will reduce the probability of moisture buildup, and result in fewer penetrations of the vapor barrier, since most power outlets will be facing into the conditioned area. Where heating is the primary method of environmental control, place the barrier toward the inside of the wall and the ceiling. On concrete masonry units, use foil-face rigid insulation on the outside of the wall. Fur out and finish the wall. Install a vapor barrier underneath new floor slabs. Seal all penetrations in walls, ceilings, and floors.

3-4.1.2 Air Barrier Systems for Walls and Ceilings.

Provide a continuous air barrier system to control air infiltration and exfiltration in environmentally-controlled areas. The purpose of the air barrier is to make the walls and ceiling airtight with materials having a low air permeance or resistance to air flow, to seal the joints and penetrations, and to control air pressure relationships within the building. An air barrier must be provided between spaces that have either significantly

different temperature or humidity requirements. Provide excess ventilation air for pressurization and a continuous air barrier system to control infiltration and exfiltration to maintain air tightness. Avoid selecting materials that are too air-permeable, such as fiberboard, perlite board, and uncoated concrete block in air barrier systems.

3-4.2 Clean Construction Protocol.

Cleanliness within a PMEL facility is necessary to: (1) protect precise measurement surfaces from abrasive damage caused by dust particles; (2) prevent contamination of fluids, chemicals, and metals used during the calibration process; although cleanliness and particle filtration requirements for most PMELS are not as stringent as for clean rooms, incorporating clean construction protocol (CCP) in design and construction contracts is recommended.

3-4.3 Interior Finishes.

Finishes should take into account the intended uses, be appropriately durable, and be low maintenance. Finishes should have good acoustical, noise reducing characteristics. All interior finishes must comply with UFC 3-600-01. Facility interior design must comply with Air Force corporate facilities standards, UFC 3-120-10, *Interior Design*, and Air Force interior design standards, as well as applicable installation or agency design standards and policies. Prepare surfaces to prevent, or at least reduce, dust accumulation. Clean concrete masonry thoroughly to remove dirt, fungus, grease, oil, glaze, loose particles, and scale. Fill voids to give a smooth surface without pits or holes. Repair joints, cracks, holes, and other surface defects in gypsum wallboard so the surface is flush and smooth. Where there are painted surfaces, use a smooth, non-chalking, mildew-resistant semi-gloss finish which will stand up to frequent cleaning. Use light neutral tints, such as light blue or beige, to prevent eye fatigue, increase light reflectivity, and improve lighting efficiency.

3-4.4 Counters and Cabinets.

Counters, casework, and workbenches should be of high-quality and durable construction. Specify Architectural Woodwork Institute (AWI) Premium or Custom for finishes per *AWI Architectural Woodwork Standards*. Workbenches and surface plates mounted on vibration isolators or air bearings should be used in PMELs where extensive isolation techniques cannot be used. This will reduce vibration transmitted to sensitive instrumentation in contact with these surfaces.

3-4.5 Non-conductive Floor Covering.

Non-conductive floor covering has a minimum resistance of 1×10^9 ohms (1 giga-ohm). Non-conductive flooring is required to protect personnel servicing equipment where voltages up to 3,000 volts may be present. [Note: Vinyl flooring is inherently non-conductive, provided conductive materials (such as carbon, graphite, etc.) have not been added to reduce the resistance to modify it as either conductive (2.5×10^4 to 1×10^6 ohms) or static-dissipative (1×10^6 to 1×10^9 ohms)]. Sheet vinyl is recommended because its smooth, continuous surface simplifies daily cleanup,

including chemical and mercury spills. Epoxy resin flooring is a suitable alternative, provided it is non-conductive.

3-5 SITE DESIGN AND ORGANIZATION.

The site design and all exterior features must comply with the antiterrorism standards in paragraph 3-6.

3-5.1 Landscaping.

Refer to UFC 3-201-02, *Landscape Architecture*, for landscaping requirements and any base or agency design standards.

3-5.2 Parking and Access Drives.

Provide adequate parking for both staff and patrons with the appropriate access drives. Comply with UFC 3-201-02. Also refer to AFMAN 32-1084.

3-5.3 General Site Lighting.

Ensure that parking areas and the facility have adequate lighting for safety, evacuation, and security measures. Comply with UFC 3-530-01, *Interior and Exterior Lighting Systems and Controls*. Include parking and lighting requirements in final site plan.

3-5.4 Service Drive.

The size of required service vehicles should be verified by the designer prior to planning the service access areas. Provide a service vehicle apron and consolidate service access when possible.

3-6 ANTITERRORISM.

Refer to UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*, for antiterrorism requirements. Provide controlled access, including protection from unauthorized entry, and security for maintaining classified equipment and documents.

3-7 SERVICES.

3-7.1 Plumbing.

Design domestic hot and cold water, sanitary and storm drainage, propane, fuel oil, and natural gas systems to meet the requirements of UFC 3-420-01, *Plumbing Systems*, and local Installation standards.

3-7.2 Fire Protection.

Refer to UFC 3-600-01 for fire protection requirements. The PMEL facility must have a complete automatic sprinkler system and a fire alarm evacuation system conforming to UFC 3-600-01.

3-7.3 Lighting.

Provide lighting and control systems throughout the facility in accordance with UFC 3-530-01. Refer to Chapter 4 for specific lighting design criteria for each functional area.

3-7.3.1 Illuminance.

Facilities require a minimum uniform illumination, depending on the task requirement, calculated at the midlife of the tubes, as measured at bench level in the various areas. Light shall be evenly distributed to minimize glare, spectral reflection, and radiant heat to the extent that measurements are nominally unaffected by any of these parameters. Refer to TO 00-20-14, *Technical Manual: Air Force Metrology and Calibration Program*, for specific absolute minimum illumination levels in various PMEL rooms. The following areas should have a minimum 50 foot-candles (538 lux) design level: equipment storage, restrooms/toilets, janitor's closet, bench stock, stairways, corridors, halls, airlocks, elevators, shipping docks, and utility/storage rooms. Other areas in the PMEL not listed above will have a minimum 100 foot-candles (1076 lux) design lighting level. Additional general lighting shall be used for tasks that are difficult to perform within the ambient light level. Other areas must conform to UFC 3-530-01. Provide zone lighting by work area when required, and locate switches near the air lock entrances. Motion sensor lighting is prohibited in the C/R areas. Provide lighting controls per ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, in areas not involved with the calibration process.

3-7.3.2 Emergency Lighting.

Provide emergency lighting in accordance with NFPA 101, Section 7.9. Evaluate the standard carefully, as its requirements may not include considerations for the unique layout and equipment configurations in a metrology facility. Installed emergency lights are recommended. Ensure emergency lights have a battery backup installed. If portable lights are mounted on the wall, locate an electrical receptacle near the light.

3-7.3.3 Hazardous (Classified) Area Lighting.

Class 1 Division 2 hazardous area light fixtures should be used in hazardous (classified) areas housing pressurized flammable liquids. Protect luminaries located above hazardous classified areas as required in NFPA 70, Article 501, Section 130, (B)(1) through (B)(3).

3-7.4 Electrical.

Provide electric service, distribution equipment, wiring receptacles, grounding, interior and exterior lighting, control, emergency lighting, telephone, communication systems, fire alarm, other health and safety alarms, and intrusion systems in accordance with NFPA 70, UFC 3-520-01, and the latest Installation design requirements. Service grounding system and all wiring methods must meet the current NFPA 70 requirements. All service equipment must be Underwriters Laboratories (UL) listed. Alternately, published proof from an approved independent testing laboratory may be provided.

3-7.4.1 Voltage Regulation.

Voltage drop of the building wiring system will not exceed 3% to any outlet. Provide outlets for technical testing with regulating equipment to maintain voltage within ± 2 percent of the basic voltage, except 28 Vdc, which will be regulated to $\pm 3\%$. Time constant (response time) of the voltage regulators should not exceed 0.3 seconds, and total harmonic distortion must not exceed 5%. Power conditioning and continuation interface equipment (PCCIE) must be supplied by the using agency.

3-7.4.2 Types of Electrical Power.

Normally, electric service will be provided at 480 Vac, 3-phase, 60 Hz. Table 3-1 lists possible PMEL power requirements for testing. This list does not include lighting and air conditioning requirements. Power demand varies depending on the workload of the individual PMEL. The PMEL superintendent will assist the Base Civil Engineer in determining power requirements and equipment heat loads, and identifying any special mission requirements. Design 400 Hz distribution systems to the requirements of UFC 3-555-01N, *400 Hertz Medium Voltage Conversion/Distribution and Low Voltage Utilization Systems* (note: motor generator is not real property installed equipment [RPIE]).

Table 3-1. Power Requirements for PMEL Facilities Testing

Nominal System Voltage	Phase	Frequency
277/480	1 & 3	50/60 $\pm$ 1 Hz
120/240	1 & 3	50/60 $\pm$ 1 Hz
120/208	1 & 3	50/60 $\pm$ 1 Hz
208 or 240	1	50/60 $\pm$ 1 Hz
120/240	1 & 3	400 $\pm$ 10 Hz
120/208	1 & 3	400 $\pm$ 10 Hz
28	DC	N/A
220/240	1 & 3	50/60 $\pm$ 1 Hz

3-7.4.3 Tagging and Labeling.

Tag or label electrical power outlets, connectors, or receptacles with a technical description of the type or amplitude of a voltage source, the power rating, and phase or connection scheme, and indicate the breaker servicing them.

3-7.4.4 Wiring Installation.

Install electrical wiring in metal raceways, concealed but accessible, in attics, plenums, or utility housings. Install wiring for frequencies greater than 60 Hz in nonferrous raceways and label with the correct frequency. Extend utilities into the C/R area within utility chases concealed in walls and partitions. Do not use under-the-ceiling utility services. Direct overhead utility connections to workbenches and stations are permitted if the most feasible and economical and if the design minimizes dust collection. Use

gaskets and seals to maintain room pressure and prevent dust infiltration where ducts, pipes, and conduit penetrate walls.

3-7.4.5 Grounding.

Install grounding in accordance with the National Electrical Code, and Air Force Instruction (AFI) 32-1065, *Grounding Systems*. The resistance to ground of the service ground must be 10 ohms or less. Where 10 ohms cannot be obtained with basic electrode configuration due to high soil resistivity, rock formations, or other terrain features, consider alternate methods for reducing the resistance to earth. Power the C/R area from (an) isolation transformer(s) with an electrostatic shield between the primary and secondary windings installed as a separately derived system as close as practical to the loads. A table, bonded at each end to a static bus bar, may be used in place of the equipotential plane, as appropriate.

3-7.4.6 Electromagnetic Interference/Radio Frequency Interference (EMI/RFI).

The amount of EMI/RFI generated by nearby overhead high voltage lines, radio and TV transmitters, and microwave antennas determines the suitability of a site, and the extent of internal facility shielding required. Most building sites not close to sources of EMI/RFI will meet the electromagnetic requirements for PMELs, since average magnetic field in the vicinity of overhead electrical distribution lines drops off rapidly with distance. However, EMI from overhead high voltage power lines, radio/TV transmitters and aircraft operations may introduce calibration errors. With maximum currents of up to 243 amperes, average maximum field exposure is approximately 13.53 milligauses at zero feet (zero meters) and 2.48 milligauses at 100 feet (30.5 meters). These levels of exposure would be acceptable for most laboratories. EMI/RFI levels should be reevaluated whenever generators are installed after a PMEL is operational. If excessive EMI/RFI is suspected, contact AFMETCAL.

3-7.4.7 Internal Electromagnetic Interference (EMI/RFI) Control.

Within the laboratory itself, interference suppression should include RF-shielded lenses, ballast RF suppressors, and power line filters for fluorescent lighting. EMI/RFI is best controlled by following the guidance in Military Standard (MIL STD) 188-124B, *Grounding, Bonding, and Shielding for Common Long Haul Tactical Communication Systems Including Ground Based Communications - Electronics Facilities and Equipments*; MIL STD 188-125-1, *Department of Defense Interface Standard: High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C4I Facilities Performing Critical, Time-Urgent Missions, Part 1, Fixed Facilities*; Military Handbook (MIL HDBK) 419, *Grounding, Bonding, and Shielding for Electronic Equipment and Facilities*; and MIL HDBK 423, *High-Altitude Electromagnetic Pulse (HEMP) Protection for Fixed and Transportable Ground-Based C4I Facilities*.

3-7.4.8 Electrical Outlets and Cabling.

Computer network, intercom, and telephone conduits and outlets should be installed during construction at enough locations to meet current layout and future expansion

needs. Cabling should be installed in conduit in the walls, and in metal raceways above suspended ceilings. A doorbell should be installed on the customer entry door. Electrical power loads should not be on the same circuits providing electricity to the calibration areas.

3-7.4.9 Emergency Electrical Power Disconnects.

Emergency electrical power switches or disconnects are recommended at a central location in every room of the calibration area. They should be well-marked, unobstructed, and have a lockout feature. Electrical power switches should not turn off the overhead lights.

3-7.4.10 Electrical Receptacles.

Location and type of electrical receptacles must match the purpose of the equipment served and comply with the National Electrical Code (NEC). It is recommended to locate electrical receptacle high on the wall for portable emergency lights and at mid-wall level for connecting to work benches located along the walls. Do not use the common 60 Hz, 120 Vac receptacles for 28 Vdc, 50 Hz, or 400 Hz services. Install receptacles in accordance with NEC Articles 406, 501, 502, 503, and 647 as shown below:

- Install sufficient number of receptacles and circuits to allow for future changes in layout due to relocation or addition of new measurement systems.
- Install general-use receptacles so that they are accessible every four feet. Do not install a general purpose receptacle in the center of a wall where large equipment or furniture is typically located. Do not install more than six duplex receptacles on a single circuit and situate circuits so that each room has access to at least two circuits.
- Install and mark receptacles in hazardous locations in accordance with NEC Articles 501, 502, and 503.
- Determine placement of special-use receptacles by the location of equipment to be supported. Provide one additional circuit above work benches to allow for future expansion of work bench or services. Mark special-use receptacles in accordance with NEC Article 647.7.

3-7.4.11 Main Power Panels or Services.

If possible, especially in locations having frequent inclement weather, no two adjacent receptacles should be on a single circuit.

3-7.4.12 Backup Power.

Provide a means for connecting a portable backup power unit to serve critical circuits within the PMEL. Use a double-throw switch; and, if feasible, provide a matching plug and receptacle approved by the Base Civil Engineer. Locate the switch for easy access

by a power unit. Comply with isolated neutral requirements in NEC 250-5(d), *Alternating-Current Circuits and Systems to be Grounded, Separately Derived Systems*.

3-7.4.13 Electrical Utility Room.

Install electrical facility equipment such as transformers, power distribution systems, frequency converters, rectifiers, and voltage regulators in the utility room. The 28 Vdc power supply and the 400 Hz motor-generator or frequency converter will be provided by the using agency and installed by the contractor. Follow applicable portions of the NEC and Occupational Safety and Health Administration (OSHA) standards. Provide PCCIE for testing and powering sensitive electronic equipment. The using agency (PMEL) must obtain PCCIE through the PCCIE program office, AFLCMC/HBZBD, 6039 Wardleigh Road, Building 1206, Hill AFB UT 84056, (801)-777-5752. PCCIE maintenance is the responsibility of the using agency.

3-7.4.14 Antenna Ports.

An antenna port must be installed in a PMEL facility during construction. Port location is dependent on the location of certain instruments (e.g., precise time (GPS) receivers). Antenna port penetrations through the walls in the C/R area should be properly finished and sealed to prevent loss of positive pressure.

3-7.5 Communications and Data.

A phone and intercom system is required to allow two-way conversation between rooms in the PMEL facility. Provide conduit runs and terminal boxes to support the intercom, telephone, and computer systems as part of facility design. Include data outlets in walls, recessed floor boxes, and offices to provide internet connection for work areas. Confirm the technical design requirements for the phone and intercom system with the Laboratory Manager. Provide local area network (LAN) internet connections to work benches for access to technical manuals and maintenance procedures as required.

3-7.6 Alarm System.

Provide an alarm system for intrusion detection to protect equipment and assets. The calibration area environment shall have an alarm system which will relay an alarm when the temperature or humidity is out of tolerance. Provisions for an alarm system must be identified during the planning/programming process.

3-7.7 Heating, Ventilating, and Air Conditioning (HVAC).

Design the HVAC system to meet the requirements of UFC 3-401-01, UFC 3-410-01, and UFC 3-410-02, *Lonworks® Direct Digital Control for HVAC and Other Local Building Systems*.

3-7.7.1 HVAC Design Criteria.

Climatic design criteria will be obtained from UFC 3-400-02, *Design: Engineering Weather Data*. Systems will be designed and sized to maintain space temperature and humidity requirements at the following ambient load conditions:

- The 0.4% dry bulb temperature and the corresponding mean coincident wet bulb temperature.
- The 1% humidity ratio and the corresponding mean coincident dry bulb temperature.
- The 99% dry bulb temperature and the corresponding mean coincident wet bulb temperature.

3-7.7.2 HVAC Systems Required.

Provide separate HVAC zone controls to meet the environmental requirements of the following areas: C/R, administration, support, and shipping and receiving. Provide HVAC system(s) specific to the building (i.e., NOT connected to a central system servicing other buildings). Where a 68 degree room is required, a modular environmental enclosure system can be considered as an option.

3-7.8 HVAC Design Considerations.

3-7.8.1 Equipment Heat Gain.

The using agency must provide the test and measurement equipment specifications, approximate equipment location, and use patterns so that heat gains can be accurately estimated during the predesign stages of the project.

3-7.8.2 Design Analysis.

The HVAC design analysis for new facilities or renovation of existing facilities must include a psychometric analysis documenting that the system meets the PMEL design criteria. The analysis must provide calculations of system cooling load, energy/mass transfer through conditioning equipment and fans, and a system schematic indicating the dry bulb and wet bulb temperatures (or humidity ratios) of outside air, mixed air, supply air, and return air flow streams. The cooling load for this analysis must be based on the load conditions as previously identified. Refer to UFC 3-401-01 and UFC 3-410-01 for details on HVAC design analysis. Provide capability to tie into the base-wide Energy Management Control System (EMCS), if available.

3-7.8.3 Ventilation Air.

Supply ventilation air to satisfy UFC 3-410-01 given the number of occupants and to provide for air exhausted from hoods, etc., to meet the positive pressure requirements for the rooms and the building as a whole. Integrate static pressure monitoring of individual rooms to ensure proper control of ventilation air. See paragraph 3-7.9.5

regarding use of a dedicated outdoor air system. Refer to UFC 3-410-04N, *Industrial Ventilation*, and UFC 3-410-01, for further details on ventilation air systems.

3-7.8.4 Ventilation Filtering.

Filter ventilation air before it enters an air handler, heat recovery equipment, or preconditioning equipment. Use extended media filters with a Minimum Efficiency Reporting Value (MERV) of 8 or greater, in accordance with ASHRAE 52.2-2012, *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*.

3-7.8.5 HVAC Zone Design.

Provide single zone controls to isolate environmental requirements for each major PMEL area. Size the cooling coils for each space to maintain the required temperature and relative humidity under the location design conditions listed in UFC 3-400-02. Determine the minimum acceptable room air change rate from UFC 3-410-01. The design requirement is to provide an even temperature, consistent with required temperature gradients, throughout the controlled spaces.

3-7.8.6 Air Distribution.

Design the air distribution system to circulate air throughout the facility to prevent stratification. Use non-unidirectional air flow pattern control. Specifications apply within the space 3 feet to 4.9 feet (0.9 meter to 1.5 meters) above the floor (working area); air velocity in the working area must be 25 ± 9.8 fpm (7.6 ± 3 meters per minute). Keep noise level below 45 dB as measured by a meter meeting ANSI/ASA S1.4, *American National Standard Electroacoustics – Sound Level Meters*. Locate heat-generating equipment (such as temperature baths) to prevent heat buildup; also isolate high-heat-generating equipment to maintain temperature within required limits. Localized exhaust may be used for this purpose, provided makeup air requirements do not adversely affect system operation. Locate and select supply air diffusers to ensure even-conditioning of the space. Locate return air grills above heat producing equipment to quickly remove excess heat and minimize temperature fluctuations.

3-7.8.7 HVAC System Response.

The system must heat, cool, humidify, and dehumidify as required at all anticipated flow rates. Design and construction documents must specify: the maximum difference in temperature and humidity between supply air and room air (to establish the rate of change of the room environment); and the number, type, and location of room thermostats and humidistats and how the environmental system should respond to their signals. Duct design should not rely on adjusting dampers on diffusers or grills for control because of the effect on air distribution patterns. Where required, provide dampers inside ducts and install access panels.

3-7.8.8 Air Locks for Calibration and Repair (C/R) Area.

Access into the C/R area is only through air locks. Provide a shoe cleaner at the entrance to the air lock, including a grounded touch pad to dissipate electricity. Use a minimum 6-foot (1.8-meter) -wide air lock at the entrance to the C/R area, with a door opening at least 5 feet (1.5 meters) wide to accommodate large equipment. The air lock must be at least 9 feet (2.7 meters) long to ensure both sets of doors are not open at the same time. Door interlocking systems are not necessary. Double doors are preferred (exception: a sliding door may be used). If double doors are used, install a pair of 3-foot (0.9-meter) -wide double doors to allow movement of large pieces of equipment when necessary. Do not position air lock doors in-line with building entry doors. Air lock doors must have 24- by 30-inch (610- by 760-millimeter) shatterproof glass vision panels (or the closest standard size that fits) and bumpers to prevent equipment and cart damage. Air will flow from the C/R area through the air lock toward the administrative or shipping and receiving areas. Install gasket-type stops, astragals, automatic door bottoms on air lock doors located closest to the C/R areas, and a properly sized grille above the inside air lock doors to permit air flow through the air lock. Seal joints between doors and frames with gaskets.

3-7.8.9 Modular Environmental Enclosure Considerations.

Provide an off-the-shelf, self-contained, environmentally-controlled module where a 68 degree room is required, as an option. Typically, they are more cost effective and provide better environmental control for the stringent environmental requirements. Their self-contained environmental system provides temperature and relative humidity control, and dust particle filtration. The modular structure is normally installed inside the PMEL, but separate from the C/R area. Before contracting construction of a modular environmental enclosure, consider: (1) size (fits the space); (2) possible vibration and electromagnetic interference; and (3) volume and type of work to be processed. The environmental enclosure system should include the following line items as shown in Table 3.2.

Table 3-2. Modular Environmental Enclosure Design Considerations

Design Features
External duct work, plumbing, wiring, painting, and testing as part of the installation
An electrical supply system providing protection from voltage surges, spikes, or transient noise.
Control equipment with good earth ground.
A suitable drain for condensate disposal in the fan-coil area.
A smooth concrete floor for the enclosure installation, with maximum deviation in the horizontal plane of 3/8 in (9.5 mm).
Non-conductive vinyl floor covering.
If required for the humidification system, a year-round supply of potable water operating at a flow rate and pressure required by the system.

3-7.9 HVAC Equipment Selection.

3-7.9.1 Maintainability.

To ensure maintainability, select and locate equipment to provide adequate access for servicing, filter replacements, and coil removal.

3-7.9.2 Moisture Carryover.

To preclude moisture carryover, coil face velocities must not exceed 550 fpm (167.6 m/min).

3-7.9.3 Cooling Coil Characteristics and Performance Requirements.

Specify cooling coil characteristics and performance requirements in the construction bid documents. These requirements include total cooling capacity, sensible capacity, coil design entering and leaving air conditions (wet and dry bulb temperatures), design airflow rate, face velocities, coil sensible heat ratio, and entering chill water temperature.

3-7.9.4 Dehumidification and Energy Consumption.

Select equipment that will meet the design requirements for dehumidification and provide the lowest life cycle cost and energy consumption.

3-7.9.5 Dedicated Outdoor Air System (DOAS).

DOAS systems should be considered, with other options, for humidity control and supplying ventilation air, especially in high-humidity areas. The DOAS supplies a volume of preconditioned makeup/outside ventilation air to the calibration areas of the PMEL. The system must be equipped with heating and cooling (chilled water/glycol) coils and controls to temper outside air to a neutral dry bulb temperature and regulate humidity levels. In some climates, an air-to-air heat exchanger may be beneficial to precondition makeup air. Humidity in non-administrative areas will be controlled by regulating the humidity in the outside/makeup air system. Coils must meet 99% design conditions. Ensure that DOAS systems are designed to handle both the ventilation and zone-generated latent loads. In humid areas, the amount of conditioned outside air required to dehumidify the calibration areas (see Figure 2-2) may exceed the amount required for ventilation and makeup. In these cases, a portion of the return air can be drawn through this system and dehumidified with the outside air stream. To facilitate inspection and cleaning of coils, install access doors between coils, and ensure coils are no more than eight rows deep. Also consider using desiccants in areas of high humidity. Refer to UFC 3-410-01 for further design details.

3-7.9.6 Ducted Return Air System.

Provide a fully-ducted return air system. Use of the space above the ceiling as a plenum is not allowed.

3-7.9.7 Piping Insulation.

Insulate piping with an operating temperature below dew point with jacketed insulation meeting the cold piping requirements of UFGS 23 07 00, *Thermal Insulation for Mechanical Systems*. The insulation jacket must be sealed to provide an exterior vapor barrier.

3-7.9.8 Maintenance Access.

Sufficiently safe access space must be provided for the maintenance of valves, variable air volume (VAV) boxes, dampers, controls, and other HVAC components.

3-7.9.9 Equipment Compliance with Design.

Construction specifications must provide documentation that HVAC equipment submittals for proposed equipment are in compliance with the design specifications. Design calculations should recognize the effect of brief deviations in outside temperature and humidity beyond those listed. Careful application of the weather data found in UFC 3-400-02 is essential to develop designs that meet critical environmental control requirements. The designer should optimize the selection of cooling equipment to take into account all aspects of performance, reliability, maintainability, and capital and maintenance costs. Calculate equipment sizing as described in UFC 3-410-01.

3-7.9.10 Chilled Water Equipment Selection.

A chilled water system with reheat is the recommended option to maintain required temperature tolerances in PMELs. A central building chilled water system with modulating control is most satisfactory for the required 40 to 42 °F (4.4 to 5.5 °C) water. The optimum supply and return water temperature differential must be determined by life cycle cost analysis. Select compressors that are the most efficient over the range of anticipated loads.

3-7.9.11 Recording Devices, Monitoring and Alarms.

Temperature and humidity must be monitored and recorded continuously, and pressure must be monitored. The recording system must be continuous, and use self-contained sensors/recorders, or remote sensors with centrally-located recorders. Sensors are required in each separate room in the calibration area, and a minimum of one set of sensors for every 2000 ft² (186 m²) of calibration area. When selecting recording devices, consider accuracy and response time; critical environments require immediate response and high accuracy. Mount sensors in the center of the room away from walls, vibration, sunlight, and supply air diffusers, as near as possible to the most critical area of measurement. If the PMEL facility is monitored by a base-wide EMCS system, the system will transmit an alarm when any space goes out of tolerance for temperature, humidity, or pressure. Notice of the alarm will be communicated by automatic notification back to PMEL staff. Both the recording device and the alarm system will indicate real time. All sensors, including wall-mounted assemblies, will be removable for calibration. Refer to TO 00-20-14.

3-7.9.12 Accuracy of Recording Devices.

The following requirements apply to temperature and humidity recorders:

- Recording devices monitoring 68 °F (20 °C) C/R areas must be accurate to a minimum of ± 0.5 °F (± 0.28 °C), $\pm 5\%$ RH.
- Recording devices monitoring 73 °F (22.8 °C) C/R areas must be accurate to a minimum of ± 2.0 °F (± 1.11 °C), $\pm 5\%$ RH.
- Recording devices must be calibrated across the full range for the area being monitored.
- If a computerized system is used to record environmental data, the time between data samples shall not exceed 15 minutes.
- Daily or weekly charts must be used when not using computerized or roll type recording devices.

3-7.9.13 Room Filtration.

The 68 degree room must have a filtration system which satisfies a particle count not exceeding 700 particles per ft³ (24,700 particles per m³) of atmosphere, 5 microns and larger; and 100,000 particles per ft³ (3,530,000 particles per m³) of atmosphere, 0.5 microns and larger. Accurately describe filter installation to ensure easy access and quick changing of filters, minimizing air system shutdown. Install diaphragm-activated draft gages with remote audible alarms across all filter banks to signal when filter replacement is required. (Reference UFC 3-410-01 for details on filter requirements.)

For all other spaces, air filters will have a MERV of 8 when tested by an acceptable atmospheric dust spot test. (Reference ANSI/ASHRAE 52.2-2012.)

Add filter specification and installation requirements to the maintenance manual for the building.

3-7.10 Compressed Air and Nitrogen Systems.

3-7.10.1 Compressed Air and Nitrogen Supply.

Compressed air and nitrogen must be supplied considering the requirements for the type and number of flow calibrators necessary to accommodate the workload. Compressed air delivered to flow calibrators must be of instrument quality conforming to the requirements of ANSI/ISA-S7.0.01, *Quality Standard for Instrument Air*.

Compressed nitrogen must conform to the requirements of Defense Logistics Agency (DLA) A-A-59503A (Commercial Item Description) *Nitrogen, Technical*, Type I, Class I Grade B. Service must be adequate to support the simultaneous operation of all major systems in the facility. Refer to NFPA 55, *Compressed Gases and Cryogenic Fluids Code*, for safety considerations for compressed air and nitrogen gas.

3-7.10.2 Compressed Air Quality.

Use oil-free, dry, compressed air for technical use in the C/R area. Compressed air for the equipment cleaning room must be supplied from an oil-free compressor. The compressed air supplied to the cleaning stations must have an adjustable regulator with a 0-35 psig range at the stations. Compressed air must conform to ANSI/ISA S7.0.01, with minimum pressure of 120 psig (827 kPa). The pressure of compressed air used at work benches should be reduced with a precision valve and a 0-827 kPa gauge. Compressed air quality for technical use in the C/R area or for operating TMDE must satisfy operating manuals for the TMDE to be serviced. In no case will the oil content of compressed air be greater than 24 ppm (wt) and the compressed air no greater than -40 °F (-40 °C) atmospheric dew point. (For more information on atmospheric dew point, refer to the latest version of ASHRAE's *Fundamentals Handbook*, chapter on psychrometrics). Reduce the line pressure at the work stations, generally to 15 psig (103 kPa), depending on mission requirements. This quality may be achieved using dryers fitted with appropriate pre-filters or coalescent air filters that remove oil and particulates. Provide an in-line oil monitor to check quality. Supply a refrigerated dryer for high flow requirements. Minimum filter requirement for equipment cleaning areas for the incoming airline is 75 microns. All air lines into the laboratory must have an automatic blow-down valve ahead of each filter. Each top connection and line tie must lead off the top of the line. The number of outlets and total capacity may vary by individual laboratory; but normally, a minimum 20 scfm (9.4 L/s) is needed. Each PMEL organization will determine specific requirements and incorporate them into the design criteria. Install the air compressor in the utility room as real property and size it to satisfy total facility requirements. Mark compressed air lines to show pressure and appropriate piping color code for the service.

3-7.10.3 Dry Nitrogen.

Water-pumped dry nitrogen (oil free) is required for technical use. It must conform to DLA A-A-59503A. Install dry nitrogen cylinders in the utility room. Piping run to the C/R area must be rated at 1600 psig (11032 kPa). Mark nitrogen lines to show pressure. Review design requirements to determine the number of lines required.

3-8 SUSTAINABLE DESIGN.

Use an integrated approach to the planning and design of PMEL Facilities that minimizes energy consumption and optimizes life cycle cost renewable energy possibilities. Comply with the guidance in UFC 1-200-02, which addresses Air Force sustainable policy.

CHAPTER 4 SPECIFIC DESIGN CRITERIA

4-1 PMEL FUNCTIONAL AREA DESIGN CRITERIA.

This chapter identifies the specific design requirements for each functional area. Tables 4-1 through 4-13 provide this data in a standard Functional Data Sheet format.

Table 4-1. Administrative Offices

Description/ Usage	The administrative offices consist of a mix of private and open office space. Locate the site manager's office and the administrative staff near the main laboratory entrance to control building access and to receive visitors. Generally speaking, the following office spaces are provided: Flight Chief or Site Manager, Laboratory Chief, Administrative and support staff, and Quality Assurance Supervisor. The main laboratory entrance is usually combined with a waiting and equipment check-in and pickup area. Refer to AFMAN 32-1084 for office space sizes and requirements.
Min. Ceiling Ht.	9 ft (2.74 m) finished ceilings to provide a finished surface and to conceal conduits
Finishes	Walls. Painted gypsum wall board with flush and smooth surface to reduce dust. Floor. Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. Static dissipative carpet may be added for offices. Ceiling. Acoustical Ceiling Panels (ACP). Provide air-tight, dust-tight ceiling access panels for environmental system balancing and required maintenance. Windows. Where possible, locate offices on exterior wall and provide windows for natural light admission.
Plumbing	Drinking fountain.
HVAC	Reference the most recent Air Force or installation policy on temperature set points for HVAC systems.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Ensure an adequate number of circuits to power all equipment. Provide standard duplex outlets in closed offices as required. Install additional outlets for data, telephones and to operate shared equipment such as printers, fax, etc.
Lighting	100 foot-candles (1076 lux) ambient lighting.
Communication	CCTV. None required. CATV/Internal Video: None required. PA/Audio. One speaker, with controls in the Flight Chief's/Site Manager's office. Telephone. One line per staff plus one additional line for fax and copier. Data. One outlet per staff plus one outlet for each printer, copier, scanner, etc. Security. None required.
Casework/Built-in Equipment	A custom-built customer service counter to separate customer incoming equipment storage from the completed equipment storage and calibration areas.
Furnishings Fixtures & Equipment (FF&E)	Private Offices —Furniture for 120 ft ² (11 m ²) or 100 ft ² (9.3 m ²) office: desk, credenza, filing cabinet, desk chair, and two side chairs. Workstations —Furniture for 64 ft ² (6 m ²) workstation: desk chair and side chair for open offices. Workstation systems furniture must provide adequate space for filing and overhead storage.
Special Requirements	Side lights next to the office doors for supervision and security.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers
Min. net ft² (m²)	

Table 4-2. Conference Room/Training Room

Description/ Usage	This space is used as a conference and training room for related PMEL business. In sizing the room, consider number of personnel that will use the room; and training aids and furnishings required. Locate near the Flight Chief's/Site Manager's office and provide space for special PMEL projects.
Min. Ceiling Ht.	9 ft (2.74 m)
Finishes	Walls. Painted gypsum wall board with flush and smooth surface to reduce dust. Floor. Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. Static dissipative carpet may be added. Ceiling. ACP; air-tight, dust-tight ceiling access panels for environmental system balancing and required maintenance.
Plumbing	None required.
HVAC	Reference the most recent Air Force or installation policy on temperature set points for HVAC systems.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Ensure an adequate number of circuits to power all equipment. Provide standard duplex outlets in closed offices as required. Install additional outlets for data, telephones and to operate equipment such as printers, fax.
Lighting	100 foot-candles (1076 lux) ambient lighting. Provide dimmable recessed lighting for training purposes.
Communication	CCTV. Outlets as required for coverage. CATV/Internal Video. One outlet as required. PA/Audio. One speaker. Telephone. One line with conference room capability. Data. Minimum of one outlet. Consider providing additional outlets for training purposes for internet data connection. Security. None required.
Casework/Built-in Equipment	Storage closet for training materials and audio-visual cart. Provide an electrically operated retractable screen, a built-in computer projector, and conference call capability.
Furnishings Fixtures & Equipment (FF&E)	CCTV cameras per the outlet count. Tables, chairs, bulletin board with tack surface and dry-erase board. Consider providing overhead projector, printer, and TV, VCR, and DVD player.
Special Requirements	Consider the acoustics of the space and features to eliminate potential distractions. Provide a minimum sound transmission coefficient (STC) rating of 50 to 55. Provide a vision panel in the door.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers
Min. net ft² (m²)	

Table 4-3. Shipping, Receiving, and Equipment Storage

Description/ Usage	Shipping and receiving area dedicated to customer support for test items. Includes control counter to receive and pickup test items. Install equipment storage area in conjunction with shipping and receiving.
Min. Ceiling Ht.	10 ft (3.05 m)
Finishes	Walls. Painted gypsum wall board with flush and smooth surface to reduce dust. Floor. Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. Ceiling. ACP; air-tight, dust-tight ceiling access panels for environmental system balancing and required maintenance.
Plumbing	Work sink with hot and cold water connections and a floor drain.
HVAC	Reference the most recent Air Force or installation policy on temperature set points for HVAC systems
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code and additional outlets as necessary to operate any dedicated equipment.
Lighting	100 foot-candles (1076 lux) ambient lighting.
Communication	CCTV. None required. CATV/Internal Video. None required. PA/Audio. One speaker. Telephone. One line with internal two-way communication. Data. One outlet per staff member, plus one outlet for each printer, copier, scanner, etc. Security. None required.
Casework/Built-in Equipment	Work bench(s) within the storage area for equipment inspection and review. Secure storage area for equipment, tools, supplies, and test items. Include adequate shelving, bins, and open end cubicles to store equipment. Install additional areas as required for storage, depending on volume of workflow.
Furnishings Fixtures & Equipment (FF&E)	None required.
Special Requirements (Covered Equipment Area)	A protected entrance for unloading equipment: either a double-entry door with a drive-thru canopy; or a service entry with a roll-up door large enough to allow a small truck or van to back into the unloading area. The quantity and size of equipment handled and weather conditions should determine which entry is appropriate.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers
Min. net ft² (m²)	

Table 4-4. 68 Degree Room

Description/ Usage	Where a 68 degree room is required, provide an area in the PMEL, with utilities, to install an off the shelf modular environmental control module. The 68 degree room is used to maintain a closely-controlled environmental area for calibration and use of higher accuracy dimensional TMDE.
Min. Ceiling Ht.	10 ft (3.05 m)
Finishes	Walls. Painted gypsum wall board with flush and smooth surface to reduce dust. Floor. Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. Ceiling. ACP; air-tight, dust-tight ceiling panels for environmental system balancing and required maintenance.
Plumbing	None required.
HVAC	68 ± 1 °F (20 ± 0.6 °C) and an optimum RH of 35, +10/-15%. The temperature may not vary more than 1 °F (0.6 °C) in any one hour period during normal system operation. Maximum temperature gradient across the room is 2 °F (1.1 °C). A minimum positive static pressure of 0.05 inch of water (12.5 pascals) compared to ambient pressure is required to prevent infiltration of dust-laden air.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code and additional outlets as necessary to operate any dedicated equipment.
Lighting	100 foot-candles (1076 lux) ambient lighting using permanent overhead-recessed vapor-proof/dust-resistant fixtures sealed with gaskets to prevent air or moisture leakage and dust accumulation/intrusion from the interstitial area.
Communication	CCTV. None required. CATV/Internal Video. None required. PA/Audio. One speaker. Telephone. One line with internal two-way communication. Data. One LAN Internet connection per work bench, and a WLAN signal, if required. Security. None required.
Casework/Built-in Equipment	Work bench(s) within the storage area for equipment inspection and repair.
Furnishings Fixtures & Equipment (FF&E)	Modular environmental enclosure system will be provided, per user requirements, to meet environmental requirements. The modular structure is normally erected inside the building, along with the environmental control system, electrical system, laboratory equipment, and furniture. Typically, the modular system is more cost effective based on life cycle cost.
Special Requirements	The 68 degree room must have a filtration system which satisfies a particle count not exceeding 700 particles per ft ³ (24,700 particles per m ³) of atmosphere, 5 microns and larger; and 100,000 particles per ft ³ (3,530,000 particles per m ³) of atmosphere, 0.5 microns and larger. Design the filter installation to ensure easy access and quick changing of filters, minimizing air system shutdown. Install diaphragm-activated draft gages with remote audible alarms across all filter banks to signal when filter replacement is required.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers
Min. net ft² (m²)	

Table 4-5. Calibration and Repair (C/R) Area

Description/ Usage	This area is maintained under a positive pressure at specified temperature and humidity levels. Air locks are required for entry into the C/R area. Locate the C/R area adjacent to other conditioned areas. Use only oil-free, dry, compressed air.
Min. Ceiling Ht.	10 ft (3.05 m)
Finishes	Walls. Painted gypsum wall board with flush and smooth surface to reduce dust. Floor. Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. Ceiling. ACP; air-tight, dust-tight ceiling panels for environmental system balancing and required maintenance.
Plumbing	None required.
HVAC	73 ± 6°F (22.8 ± 3.3 °C) for Type II and Type III PMELs. Size cooling coils to maintain an optimum operational RH level of 35, +10/-15%. Refer to UFC 3-400-02. A minimum positive static pressure of 0.05 inch of water (12.5 pascals) compared to ambient pressure is required to prevent infiltration of dust-laden air. Exhaust ventilation systems must accommodate the fume hoods over the temperature calibration baths.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code and additional outlets as necessary to operate any dedicated equipment, such as printers, fax, etc.
Lighting	100 foot-candles (1076 lux) ambient lighting using permanent overhead-recessed vapor-proof/dust-resistant fixtures sealed with gaskets to prevent air or moisture leakage and dust accumulation/intrusion from the interstitial area.
Communication	CCTV. None required. CATV/Internal Video. None required. PA/Audio. One speaker. Telephone. One line with internal two-way communication. Data. One LAN internet connection per work bench plus an outlet for printer/copier/scanner. Ensure WLAN signal is available, if required. Security. None required.
Casework/Built-in Equipment	Work bench(s) within the storage area for equipment inspection and repair.
Furnishings Fixtures & Equipment (FF&E)	A monolithic surface of gypsum or plaster construction with finished joints between the walls and ceiling. If the wall is stud construction, use two layers of 5/8-in (16-mm) gypsum board. Install compressive base sill plate seals under all walls enclosing this area. Tape and seal all wall and ceiling penetrations (conduit, pipe, duct and light fixtures, etc.) to ensure positive pressure in the area.
Special Requirements	Air locks: Use a minimum 6 ft- (1.8 m-) wide air lock at the entrance to the C/R area, with a door opening at least 5 ft (1.5 m) wide to accommodate large equipment. Install gasket-type stops, astragals, and automatic door bottoms on airlock doors located closest to the C/R Area. Seal joints between doors and frames with gaskets.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers.
Min. net ft² (m²)	

Table 4-6. Temperature/Humidity Sensitive Area

Description/ Usage	This is a special temperature/humidity sensitive (T/H S) controlled area for PMELs that do not have a requirement for a 68 degree room.
Min. Ceiling Ht.	10 ft (3.05 m)
Finishes	Walls. Painted gypsum wall board with flush and smooth surface to reduce dust. Floor. Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. Ceiling. ACP; air-tight, dust-tight ceiling panels for environmental system balancing and required maintenance.
Plumbing	None required.
HVAC	The temperature and humidity requirements for this area are $73 \pm 2^{\circ}\text{F}$ ($22.8 \pm 1.1^{\circ}\text{C}$) and an RH of 35, +10/-15%. Though room temperature may vary by 4°F (2.2°C), the temperature may not vary more than 1°F (0.5°C) in any one hour period during normal system operation. Maximum temperature gradient across the room is 2°F (1.1°C). A minimum positive static pressure of 0.05 inch of water (12.5 pascals) compared to ambient pressure is required to prevent infiltration of dust-laden air.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code and additional outlets as necessary to operate any dedicated equipment.
Lighting	100 foot-candles (1076 lux) ambient lighting using permanent overhead-recessed vapor-proof/dust-resistant fixtures sealed with gaskets to prevent air or moisture leakage and dust accumulation/intrusion from the interstitial area.
Communication	CCTV. None required. CATV/Internal Video. None required. PA/Audio. One speaker. Telephone. One line with internal two-way communication. Data. One LAN internet connection per work bench plus an outlet for a printer, copier, and scanner. Ensure WLAN signal is available, if required. Security. None required.
Casework/Built-in Equipment	Work bench(s) within the storage area for equipment inspection and repair.
Furnishings Fixtures & Equipment (FF&E)	A modular clean room may be provided to meet these requirements. Modular environmental enclosure systems are available as controlled laboratories for high precision metrology. The self-contained environmental system provides temperature and relative humidity control, and dust particle filtration. The modular structure is normally erected inside a building, along with the environmental control system, the electrical system, laboratory equipment, and furniture.
Special Requirements	None required.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers.
Min. net ft² (m²)	

Table 4-7. Liquid Flow Calibration Area

Description/ Usage	A specially-equipped, isolated area required in PMELs to perform liquid flow meter calibration using propylene glycol. Ensure that doors swing out in the direction of egress per the NFPA 101. Determine floor space by considering the type and number of flow calibrators necessary for the mission. Include space for work benches, tool storage, and systems furniture as required.
Min. Ceiling Ht.	10 ft (3.05 m), or high enough to reasonably clean mission equipment.
Finishes	Walls. Painted gypsum wall board with flush and smooth surface to reduce dust. Floor. Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. Ceiling. ACP; air-tight, dust-tight ceiling panels for environmental system balancing and required maintenance.
Plumbing	Supply chilled water considering the requirements of flow calibrator heat exchangers. Minimum service consists of 20 gpm (75.7 L/min) of 40 ± 5 °F (4.4 ± 2.7 °C) water for a low flow liquid flow calibrator and 25 gpm (94.6 L/min) of chilled water for a high flow liquid flow calibrator supplied using 1.5 inch tubing.
HVAC	Ventilate the area according to the requirements of 29 CFR 1910, <i>Occupational Safety and Health Standards</i> . Provide a ventilation rate of not less than 1 cfm per square foot of solid floor area. Temperature requirement is 73 ± 6 °F (22.8 ± 3.3 °C) and an RH of 35, +10/-15%. A minimum positive static pressure of 0.05 inch of water (12.5 pascals) as compared to ambient pressure is required to prevent infiltration of dust-laden air.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code and additional outlets as necessary to operate any dedicated equipment. Each liquid flow calibrator requires a 3-phase, 208V, 20 amp outlet.
Lighting	100 foot-candles (1076 lux) recessed vapor-proof/dust-resistant fixtures.
Communication	CCTV. None required. CATV/Internal Video. None required. PA/Audio. One speaker. Provide an emergency call/alarm in the liquid flow calibration area. Telephone. One line per staff. Data. LAN internet connections and ensure WLAN signal is available, if required. Security. None required.
Casework/Built-in Equipment	Install double doors to facilitate installation of large liquid flow calibration units and test equipment. Two sizes of liquid flow calibrators may be installed: low flow liquid flow calibrator footprint: 1.9 ft x 6.3 ft (0.6 m x 1.9 m); high flow liquid flow calibrator footprint: 2.17 ft x 13.9 ft (0.67 m x 4.24 m). The number of calibrators may vary from one to four, depending on mission.
Furnishings Fixtures & Equip. (FF&E)	Furniture for 64 ft ² (6 m ²) workstation: desk chair and side chair for open offices. Workstation systems furniture must provide adequate space for filing and overhead storage.
Special Req.	Supply utilities, services, furnishings, tools, and equipment, including the following: Compressed air, cleaning system, exhaust system, work bench with lipped stainless steel top that drains into the sink, and a vacuum port. Supply oil-free dry compressed air at 80 psig (552 kPa) and 75 gpm (284 L/min) for a low flow liquid flow calibrator and 80 psig (552 kPa) and 150 gpm (568 L/min) for a high flow liquid flow calibrator.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers.
Min. net ft² (m²)	

Table 4-8. Equipment Cleaning Room

Description/ Usage	A specially-equipped and isolated area required for cleaning and washing of mechanical, electrical, and electronic equipment. Install a drying oven meeting the requirements of the standard PMEL cleaning room. Install a bench type slot hood or canopy hood to remove fumes from calibration baths and gas monitors
Min. Ceiling Ht.	10 ft (3.05 m), or high enough to reasonably clean mission equipment.
Finishes	Walls. Ceramic wall tile or other hard surfaces approved for the cleaning room. Floor. Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. Ceiling. ACP; air-tight, dust-tight ceiling panels for environmental system balancing and required maintenance.
Plumbing	Hot and cold water supply piping and floor drain with mercury trap to be connected to the government supplied cleaning system and utility sink..
HVAC	Reference most recent Air Force or installation policy on temperature set points for HVAC systems. Exhaust ventilation systems must accommodate the fume hoods over temperature calibration baths. Install a bench style slot hood to pull fumes away from the breathing zone where a canopy type hood would allow fumes into the breathing zone. The drying oven requires 212 cfm (6 m ³ /min) of room air for the purge blower intake and exhaust.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Dedicated 120/240 Vac single-phase 20 amp circuit hard-wired to a government- or contractor-supplied electronic drying oven with disconnect switch. This circuit should not be connected to the electrical distribution system serving the calibration area.
Lighting	100 foot-candles (1076 lux) ambient lighting using permanent overhead-recessed vapor-proof/dust-resistant fixtures sealed with gaskets to prevent air or moisture leakage and dust accumulation/intrusion from the interstitial area.
Communication	CCTV. None required. CATV/Internal Video. None required. PA/Audio. One speaker and an emergency call/alarm in the equipment cleaning room that sounds at the control counter in the event of an emergency. Telephone. None required. Data. None required. Security. None required.
Casework/Built-in Equipment	Install a cleaning unit and drying oven in the equipment cleaning room. Each cleaning unit or drying oven requires 15 ft ² (1.4 m ²) of floor space. See the Power and HVAC sections above for electrical and exhaust requirements.
Furnishings Fixtures & Equip. (FF&E)	Install a built-in eye-wash system for safety requirements. A vacuum port will be provided in the equipment cleaning room. Install a deep industrial sink and work bench with lipped stainless steel top that drains into the sink.
Special Req.	Locate the cleaning and washing area outside the calibration area. Supply utilities, services, furnishings, tools, and equipment, including the following: compressed air with oil-free compressor, cleaning system, drying oven, and exhaust vent system. Install a vacuum port in the equipment cleaning room.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers.
Min. net ft² (m²)	

Table 4-9. Copy/Work/Break Room

Description/ Usage	This space is used as a staff workroom for copying, meetings, breaks, and lunches.
Min. Ceiling Ht.	9 ft (2.74 m)
Finishes	Walls. Painted gypsum wall board with flush and smooth surface to reduce dust. Floor. Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. Static dissipative carpet may be added for copy/ work/break room. Ceiling. ACP; air-tight, dust-tight ceiling panels for environmental system balancing and required maintenance.
Plumbing	Two-compartment countertop sinks with hot and cold water supply. Floor drain. If an icemaker is desired, provide a cold water connection.
HVAC	Reference the most recent Air Force or installation policy on temperature set points for HVAC systems
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code; one additional outlet at counter height for convenience; additional outlets necessary to operate dedicated equipment such as the copier, fax machine, printers, coffee machine, refrigerator, time clocks, microwave, and various other office machines.
Lighting	100 foot-candles (1076 lux) lighting fixtures with dimmable lights.
Communication	CCTV. None required. CATV/Internal Video. None required. PA/Audio. One speaker. Telephone. One line. Data. Outlets as required for equipment. Security. None required.
Casework/Built-in Equipment	Two separate solid-surface countertops: one for food/break functions and one for administrative functions as required
Furnishings Fixtures & Equipment (FF&E)	Copier, fax machine, printers, table, chairs, microwave, coffee machine, refrigerator, bulletin board with tack surface, dry-erase board, and other office equipment as required.
Special Requirements	Locate copy/work/break room on exterior wall and provide windows for natural light admission. Provide a vision panel in the door.
For use during project execution by the appropriate Service agency	
Occupancy	Staff. Customers.
Min. net ft² (m²)	

Table 4-10. Public Toilets/Janitor's Closet

Description/ Usage	These toilet rooms are used primarily by visitors, PMEL staff, and customers checking in or picking up equipment. They should be located near the main laboratory entrance in the waiting room and equipment check-in and pickup area.
Min. Ceiling Ht.	9 ft (2.74 m)
Finishes	Walls. Epoxy or enamel painted moisture-resistant gypsum wall board with a ceramic tile wainscot. Consider full ceramic tile walls with integral patterns. Use a dark-colored epoxy grout. Floor. Ceramic tile with integral patterns. Use a dark-colored epoxy grout. Ceiling. Epoxy or enamel painted moisture-resistant gypsum board. None needed for janitor's closet.
Plumbing	Wall-hung water closets, wall-hung urinals and lavatories based on the applicable code for the calculated occupancy of the laboratory. Floor drain and a keyed hose bib.
HVAC	Ventilate exhaust to the outside per code. Provide 8 to 12 air changes per hour.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code.
Lighting	50 foot-candles (538 lux) lighting fixtures
Communication	CCTV. None required. CATV/Internal Video. None required. PA/Audio. One speaker. Telephone. None required. Data. None required. Security. None required.
Casework/Built-in Equipment	Solid-surface countertop with either underhung or integral sink. Solid composite toilet and urinal partitions. Consider permanent ceramic-tile partitions. Toilet accessories: toilet paper dispensers, paper towel dispenser with integral trash receptacle, robe hooks, grab bars, sanitary napkin disposal (female water closet stalls), seat cover dispensers, and soap dispensers. Mirror.
Furnishings Fixtures & Equipment (FF&E)	None required.
Special Req.	Janitor's closet associated with or in proximity of these toilets. This closet includes a floor mop sink with hot and cold water and a hose connection, a floor drain, and storage for pails, mops, vacuums, and related cleaning supplies and equipment. Include a lockable door (which can be opened from the inside) with a vision panel. Lockable cabinets for cleaning supplies. Exhaust ventilation in janitor's closet to remove chemical fumes.
For use during project execution by the appropriate Service agency	
Occupancy	Staff. Customers.
Min. net ft² (m²)	

Table 4-11. Night Vision Area

Description/ Usage	Night vision calibration area for testing under controlled conditions of lighting, temperature, and humidity. The night vision ANV-126 NVD Infinity Focus System should be calibrated in a room with ambient lighting levels of less than 0.1 foot-candles in the general area of the test set. The ANV-20/20, field deployable, low light level calibration system requires total darkness during the adjustment procedures for the night vision test to accomplish calibration.
Min. Ceiling Ht.	10 ft (3.05 m)
Finishes	Walls. Painted gypsum wall board with flush and smooth surface to reduce dust. Floor. Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. Ceiling. ACP; air-tight, dust-tight ceiling panels for environmental system balancing and required maintenance.
Plumbing	None required.
HVAC	73 ± 6 °F (22.8 ± 3.3 °C) and a RH of 35, +10/-15%. A minimum positive static pressure of 0.05 inch of water (12.5 pascals) compared to ambient pressure is required to prevent infiltration of dust-laden air.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code and additional outlets as necessary to operate any dedicated equipment.
Lighting	During non-test conditions, provide 100 foot-candles (1076 lux) ambient lighting. Night vision calibration lighting levels must meet minimum requirements of the test set being calibrated.
Communication	CCTV. None required. CATV/Internal Video. None required. PA/Audio. One speaker. Telephone. One line with internal two-way communication. Data. LAN internet connections and ensure WLAN signal is available, if required. Security. None required.
Casework/Built-in Equipment	Work bench(s) within the night vision area for equipment inspection and review. Secure storage area for equipment, tools, supplies, and test items. Include adequate shelving, bins, and open end cubicles to store equipment. Install additional areas as required for storage, depending on volume of workflow.
Furnishings Fixtures & Equipment (FF&E)	None required.
Special Requirements	None required.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers.
Min. net ft² (m²)	

Table 4-12. Force and Pressure Measurement Area

Description/ Usage	The Force and Pressure Measurement area may require safety screens in the immediate vicinity of the force and calibration equipment to protect operators and other personnel from flying projectiles, high pressure gas, or fluids. This area is part of the C/R area, but can be part of the Dimensional Measurement lab.
Min. Ceiling Ht.	10 ft (3.05 m)
Finishes	Walls. Painted gypsum wall board with flush and smooth surface to reduce dust. Floor. Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. Ceiling. ACP; air-tight, dust-tight ceiling panels for environmental system balancing and required maintenance.
Plumbing	None required.
HVAC	73 ± 6 °F (22.8 ± 3.3 °C) for Type II and Type III PMELs. An optimum operational RH level is 35, +10/-15%. A minimum positive static pressure of 0.05 inch of water (12.5 pascals) compared to ambient pressure is required to prevent infiltration of dust-laden air.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code and additional outlets as necessary to operate any dedicated equipment.
Lighting	100 foot-candles (1076 lux) ambient lighting using permanent overhead-recessed vapor-proof/dust-resistant fixtures sealed with gaskets to prevent air or moisture leakage and dust accumulation/intrusion from the interstitial area.
Communication	CCTV. None required. CATV/Internal Video. None required. PA/Audio. One speaker. Telephone. One line with internal two-way communication. Data. One outlet per work bench. Ensure WLAN signal is available, if required. Security. None required.
Casework/ Built-in Equipment	Work bench(s) for equipment inspection and repair.
Furnishings Fixtures & Equipment (FF&E)	Safety screens to protect personnel, as required.
Special Requirements	If double doors are used, install a pair of 3-ft-wide double doors to allow movement of large pieces of equipment when necessary. Consider placing force and pressure measuring equipment in isolated parts of the room or space as an added measure for personnel and equipment protection.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers.
Min. net ft² (m²)	

Table 4-13. Technical Library

Description/ Usage	The library contains TOs, equipment descriptions, maintenance manuals, Air Force Manuals and Instructions. It is used by PMEL technicians, supervisors, and staff to provide data for precision measurement calibration activities, including library research and internet downloads of technical manuals.
Min. Ceiling Ht.	9 ft (2.74 m)
Finishes	Walls. Painted gypsum wall board with flush and smooth surface to reduce dust. Floor. Vinyl (non-conductive) plastic floor covering of continuous length or other suitable non-conductive material. Static dissipative carpet may be added to the technical library if located outside the C/R area.
Plumbing	None required.
HVAC	Reference the most recent Air Force or installation policy on temperature set points for HVAC systems.
Fire Protection	Refer to UFC 3-600-01 for fire protection requirements.
Power	Outlets per code; one additional outlet at counter height for convenience; additional outlets necessary to operate dedicated equipment such as a copier, fax machine, printer, and various other office machines.
Lighting	100 foot-candles (1076 lux). Consider dimmable lights.
Communication	CCTV. None required. CATV/Internal Video. None required. PA/Audio. One speaker. Telephone. One line. Data. Minimum of four LAN internet outlets for library research. Security. None required.
Casework/Built-in Equipment	Bookshelves to house technical library collection
Furnishings Fixtures & Equipment (FF&E)	Copier, fax machine, printers, table, chairs, bulletin board with tack surface, dry-erase board, and other office equipment as required.
Special Requirements	None required.
For use during project execution by the appropriate Service agency	
Occupancy	Staff, customers.
Min. net ft² (m²)	

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APPENDIX A REFERENCES

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS

www.ashrae.org

ANSI/ASHRAE 52.2-2012, *Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size*

ASHRAE Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*

ASHRAE Handbook: Fundamentals

AMERICAN NATIONAL STANDARDS INSTITUTE

<http://ansi.org>

ANSI/ASA S1.4, *American National Standard Electroacoustics – Sound Level Meters*

ANSI/ISA S7.0.01, *Quality Standard for Instrument Air*

ARCHITECTURAL WOODWORK INSTITUTE (AWI)

<http://www.awinet.org>

AWI Architectural Woodwork Standards

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

<http://www.nfpa.org>

NFPA 101, *Life Safety Code*®

NFPA 501.130B, *Standard on Manufactured Housing*

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*

NFPA 55, *Compressed Gases and Cryogenic Fluids Code*

NFPA 70, *National Electrical Code*®

CODE OF FEDERAL REGULATIONS (CFR)

<https://www.osha.gov/law-regs.html>

29 CFR 1910, *Occupational Safety and Health Standards*

DEPARTMENT OF DEFENSE

MIL-HDBK-419A, *Grounding , Bonding, and Shielding for Electronic Equipments and Facilities*

MIL-HDBK-423, *High-Altitude Electromagnetic Pulse (HEMP) Protection for Fixed and Transportable Ground-Based C4I Facilities*

MIL-STD-188-124B, *Grounding, Bonding and Shielding for Common Long Haul/Tactical Communication Systems Including Ground Based Communications-Electronics Facilities and Equipments*

MIL-STD-188-125-1, *Department of Defense Interface Standard: High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C4I Facilities Performing Critical, Time-Urgent Missions (Part 1 - Fixed Facilities)*

UNIFIED FACILITIES CRITERIA

http://www.wbdg.org/ccb/browse_cat.php?o=29&c=4

UFC 1-200-01, *General Building Requirements*

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

UFC 3-101-01, *Architecture*

UFC 3-120-01, *Design: Sign Standards*

UFC 3-120-10, *Interior Design*

UFC 3-201-02, *Landscape Architecture*

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

UFC 3-401-01, *Mechanical Engineering*

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

UFC 3-410-02, *Lonworks® Direct Digital Control for HVAC and Other Local Building Systems*

UFC 3-410-04, *Industrial Ventilation*

UFC 3-420-01, *Plumbing Systems*

UFC 3-501-01, *Electrical Engineering*

UFC 3-520-01, *Interior Electrical Systems*

UFC 3-530-01, *Interior and Exterior Lighting Systems and Controls*

UFC 4-010-01, *DoD Minimum Antiterrorism Standards for Buildings*

UFC 3-555-01N, *400 Hertz Medium Voltage Conversion/Distribution and Low Voltage Utilization Systems*

UFC 3-600-01, *Fire Protection Engineering for Facilities*

UNIFIED FACILITIES GUIDE SPECIFICATIONS

http://www.wbdg.org/ccb/browse_cat.php?c=3

UFGS 01 91 00.00 40, *Commissioning*

UFGS 23 07 00, *Thermal Insulation for Mechanical Systems*

UFGS 23 08 00.00 10, *Commissioning of HVAC Systems*

UNITED STATES AIR FORCE

<http://www.e-publishing.af.mil/>

AFI 32-1065, *Grounding Systems*

AFMAN 32-1084, *Facility Requirements*

AFMAN 32-1094, *Criteria for Air Force Precision Measurement Equipment Laboratory Design and Construction*

TO 00-20-14, *Technical Manual: Air Force Metrology and Calibration Program*
(<http://www.wpafb.af.mil/shared/media/document/AFD-120724-063.pdf>)

A7C Policy Memorandum, "Sustainable Design and Development (SDD) Implementing Guidance"
http://www.wbdg.org/ccb/browse_cat.php?c=265

DEFENSE LOGISTICS AGENCY

DLA A-A-59503A, *Nitrogen, Technical*

APPENDIX B GLOSSARY

°C	degrees Celsius
°F	degrees Fahrenheit
μin	microinch
μm	micrometer
A/E	Architect and Engineer
ACP	acoustical ceiling panels
AFCEC	Air Force Civil Engineer Center
AFI	Air Force Instruction
AFIMSC	Air Force Installation and Mission Support Center
AFMAN	Air Force Manual
AFMETCAL	Air Force Metrology and Calibration
ALC	Air Logistics Complex
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
AWI	Architectural Wordwork Institute
BCE	Base Civil Engineer
BIA	Bilateral Infrastructure Agreement
C/R	Calibration and Repair
CATV	community access television (cable)
CAV	constant air volume
CCP	clean construction protocol
CCTV	closed-circuit television
cfm	cubic feet per minute
CFR	Code of Federal Regulations

CONUS	continental United States
dB	decibel
DLA	Defense Logistics Agency
DOAS	Dedicated Outdoor Air System
DoD	Department of Defense
DVD	digital versatile disk
EMCS	energy management and control system
EMI	electromagnetic interference
FC	Facility Criteria
FF&E	furnishings, fixtures, & equipment
ft	feet
ft ²	square feet
ft ³	cubic feet
fpm	feet per minute
g	gravitational acceleration (9.81 m/s ² , 32.2 ft/s ²)
gpm	gallons per minute
GPS	Global Positioning System
HEMP	high-altitude electromagnetic pulse
HNFC	Host Nation Funded Construction
HQ USACE	Headquarters United States Army Corps of Engineers
Ht	height
HVAC	heating, ventilation, and air conditioning
Hz	hertz
ISA	Instrument Society of America
kPa	kilopascal

L/min	liters per minute
L/s	liters per second
LAN	local area network
m	meter
mm	millimeter
m/min	meters per minute
m/s ²	meters per second squared
m ²	square meter
m ³	cubic meter
m ³ /min	cubic meter per minute
MERV	minimum efficiency reporting value
MIL HDBK	Military Handbook
MIL STD	Military Standard
NAVFAC	Naval Facilities Engineering Command
NEC	National Electrical Code
NFPA	National Fire Protection Association
OCONUS	outside continental United States
OSHA	Occupational Safety and Health Administration
PA	public address
PCCIE	Power Conditioning and Continuation Interface Equipment
PMEL	Precision Measurement Equipment Laboratory
ppm/wt	parts per million per weight
PSU	Primary Subordinate Unit
PWC	Performing Work Center
RPIE	Real Property Installed Equipment

psig	pounds per square inch gage
RFI	radio frequency interference
RH	relative humidity
scfm	standard cubic feet per minute
SDD	Sustainable Design and Development
SES	Senior Executive Service
SOFA	Status of Forces Agreement
STC	sound transmission coefficient
T/H S	Temperature/Humidity Sensitive
TMDE	Test, Measurement, and Diagnostic Equipment
TO	Technical Order
U.S.	United States
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification
UL	Underwriter's Laboratory
Vac	volts alternating current
VAV	variable air volume
VCR	video cassette recorder
Vdc	volts direct current
WLAN	wireless local area network

APPENDIX C DEFINITION OF TERMS

For additional definitions, reference TO 00-20-14, *Air Force Metrology and Calibration Program*.

Air Force Metrology and Calibration Program (AFMETCAL Program): An Air Force program that provides measurement standards and equipment, professional and technical metrologists, performing work centers (PWCs), a system of worldwide Precision Measurement Equipment Laboratory (PMEL) facilities, measurement equipment users, calibration data, and integrated planning. This program ensures the reliability and accuracy of systems, subsystems, and equipment. The program provides for the calibration and repair of Test, Measurement, and Diagnostic Equipment (TMDE).

Calibration: A comparison between equipment items, one of which is a measurement standard of known accuracy, to detect, correlate, adjust, and report any variation in the accuracy the other item(s).

Metrology: The science or system of weights and measures used to determine conformance to technical requirements. This includes the development of standards and systems for absolute and relative measurements.

Precision Measurement Equipment Laboratory (PMEL): The base-level AFMETCAL Program focal point. It is the activity authorized to possess and use base measurement standards. PMELs use base measurement standards to maintain working standards. The working standards are used to maintain (troubleshoot, align, repair, and calibrate) TMDE designated as PMEL responsibility. Authorizations for PMEL equipment and facility requirements are tailored to meet specific requirements for supported missions. PMELs are the base-level link for measurement transfer and maintenance self-sufficiency for all systems in the Air Force. PMEL types include:

Type IIA. A base-level PMEL with a 68 degree room providing support to an Air Logistics Complex (ALC) and/or a large geographical area.

Type IIB. A base-level PMEL established to support aircraft, missiles, ground systems and/or other equipment on base or in the local area.

Type IIC. A base-level PMEL with a 68 degree room supporting research, development, test or evaluation programs, as well as other operational and support functions.

Type III. A PMEL supporting a specific mission. It normally receives calibration support from a Type II PMEL.

Type IV. A PMEL that supports a specific weapon system. It uses a transportable measurement system in fixed and deployed locations. A Type IV PMEL receives calibration support from a Type II PMEL.