BY ORDER OF THE
SECRETARY OF THE AIR FORCE

AIR FORCE MANUAL 32-1094
1 NOVEMBER 1998

Civil Engineering

CRITERIA FOR AIR FORCE PRECISION MEASUREMENT EQUIPMENT LABORATORY DESIGN AND CONSTRUCTION

OPR: HQ AFCESA/CESM
(Mr Alvin L. Day)
Supersedes AFM 88-4CH10, 19 June 1974.

Certified by: HQ AFCESA/CES
(Col Lance C. Brendel)
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This manual implements AFPD 32-10, *Installations and Facilities*. It prescribes criteria for design and construction of Precision Measurement Equipment Laboratories (PMEL) on Air Force installations. Refer to TO 00-20-14 for operational procedures and operating environmental requirements. This manual does not apply to the Air National Guard. Users should send comments and suggested improve-ments on AF Form 847, **Recommendation for Change of Publication**, through major commands (MAJCOM) and HQ AFCESA/CESM, 139 Barnes Dr Suite 1, Tyndall AFB FL 32403-5319 to HQ USAF/ILEC, 1260 Air Force Pentagon, Washington DC 20330-1260.

SUMMARY OF REVISIONS

This is the initial publication of AFMAN 32-1094, which replaces AFM 88-4, Chapter 10.

Section A—Purpose and Responsibilities

1. Purpose. Many PMELs built or renovated in recent years have not met minimum operating environment standards. These facilities cannot be certified by the Air Force Metrology and Calibration Program, resulting in loss of calibration capability at the bases. This manual provides Air Force Civil Engineer standards for design and construction of Precision Measurement Equipment Laboratories. Use it as a guide for site selection and design of a new metrology laboratory, or for modification of an existing facility. Only those requirements which directly affect the accuracy and integrity of the measurements made and are unique to a calibration laboratory are addressed. Criteria in this manual must not be used as sole justification to improve an existing facility if the facility's condition does not adversely affect the environmental requirements for performing measurement traceability. Users should contact AFMETCAL DET 1/ML, 813 Irving-Wick Drive West Suite 4M, Heath OH 43056-6116, and HQ AFCESA, Tyndall AFB early in the design phase to ensure their facility will meet or surpass the basic design criteria.

2. Responsibilities:

2.1. Headquarters Air Force Civil Engineer Support Agency (HQ AFCESA):

2.1.1. Establishes standards and criteria for Air Force PMEL design and construction.

2.1.2. Provides technical assistance to the MAJCOMs and bases.

2.2. AFMETCAL DET 1/ML: Manages the Air Force Metrology and Calibration program, including the PMEL program.

2.3. Base Civil Engineer:

2.3.1. Ensures this manual is referenced in all PMEL project design documents, and reviews A&E Design Documents to ensure their compliance with this manual.

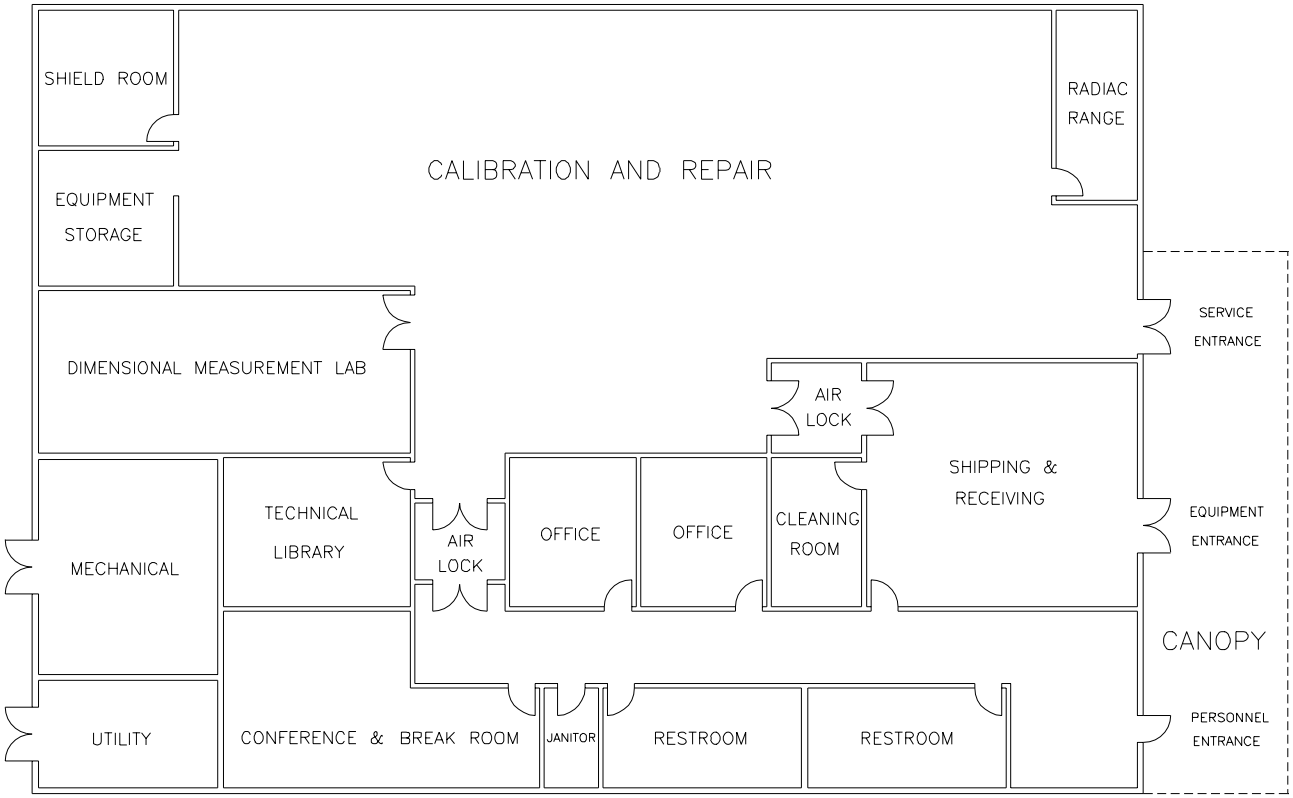
2.3.2. Hosts a pre-planning workshop prior to development of programming documentation for new construction, major rehabilitation, or major modification of the PMEL environmental system.

2.3.3. Invites representatives from AFMETCAL DET 1/ML, Base PMEL, the MAJCOM PMEL Functional Area Manager (FAM), and the MAJCOM CE functional manager to participate in the workshop.

Section B—Facility Design

3. Design Approach. The design approach described in this section simplifies construction or renovation of a wide variety of PMELs by including the basic calibration and administration area requirements which apply to any PMEL. It incorporates common area criteria with unique criteria to arrive at an overall space requirement. Figure 1 is an example layout showing relative locations of laboratory and administrative functions. Tables provided in attachment 2 should be carried over directly to the design documents, and incorporated into the commissioning process. Architectural features specified in this manual must be included in PMEL design. **NOTE:** Figure 1 is not to scale and does not show all facility requirements.

Figure 1. Example PMEL Layout.



4. Space Requirements. There are four basic sizes for the PMEL calibration/repair area, each based on the size of the inventory supported (Table 1). Some PMELs support more than a 10,000 item inventory. If the PMEL supports between 10,000 and 20,000 items, add the area for Plan D to the value obtained by multiplying the number of items over 10,000 by 0.5. The product will be the space requirement in square meters (square feet) for the calibration/repair area of the PMEL. For PMELs supporting an inventory over 20,000 items, add the space required to support the 20,000 items (3,141 square meters [10,185 square feet]) to the value obtained by multiplying the number of items over 20,000 by 0.4. In general, space required for measurement areas depends on the area needed per work station; space required for support/administrative areas is based on the number of personnel working in the PMEL. Support/administrative area figures are not included in Table 1.

4.1. Layout. 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 calibration/repair area when vibration may affect measurements. Moisture-generating areas such as restrooms and breakrooms should not be near the calibration/repair area. Limit outside walls in the calibration/repair area as much as possible. North exposures and east exposures are preferred. Ensure traffic from movement of equipment, technicians, and customers is isolated from the calibration/repair area. Where possible, design doors and air locks (paragraph 4.1.2) to allow movement of large PMEL equipment and appropriate material handling equipment within the facility. With the exception of the air lock doors, designate all exit doors as emergency exits only.

Table 1. PMEL Minimum Area Requirements Worksheet.

Workload per Year (Items):	**Plan A** *<3600*	**Plan B** *3601 to 5000*	**Plan C** *5001 to 7200*	**Plan D** *7201 to 10000*	**Current Project**
	m^2/ft^2	**m^2/ft^2**	**m^2/ft^2**	**m^2/ft^2**	
Calibration/Repair	207/2230	260/2800	362/3900	482/5185	
Additional from Table 2					
Scheduling/Receiving	69/740	86/924	121/1300	159/1711	
Air Lock	5/54	5/54	5/54	5/54	
Technical Library/Training	21/229	21/229	21/229	21/229	
Office Space					
Conference/Break Room					
Men's/Women's Toilets					
Janitorial/Supply Room					
Equipment Cleaning Room	9/98	9/98	16/175	16/175	
Other (corridors, etc.)					
Utility Room (15% of total)					
Total					

*Area requirements are based on the typical PMEL. Add square footage if the equipment in Table 2 will reside in the PMEL facility.

**Scheduling/receiving/equipment storage areas are estimated at 1/3 the calibration/repair requirement.

Table 2. Additional Equipment Area Requirements.

Equipment	**Additional Square Meters/Feet Required**	**Current Project**
RADIAC Low Intensity	17/180	
Temp Bath Hood	1.7/18	
Additional Force Presses	1.3/14	
Surface Plate: 0.6X0.9m (2X3 ft)	6.7/72	
0.9X1.8m (3X6 ft)	10/108	
1.2X2.4m (4X8 ft)	13/140	
Hoist (F-15 rock)	1.7/18	
Bullion Balance	2.8/30	
Photometric Bench	18/196	
High Voltage Calibrator	3.3/35	
Fiber Optic Cal System	4.5/48	
North Seeking Gyro Ped	1.5/16	
20 °C (68 °F) room	minimum 56/600	
Type IV (F15, 1 ESS)	152/1634	
Type IV (F15, 2 ESS)	208/2234	
Type IV (F16, 1 ESS)	97/1040	
Type IV (F16, 2 ESS)	149/1600	
Type IV (F16, 3 ESS)	204/2200	
Mobile PAMS per PAMS system	1.7/18	
PATEC/TFCU Cases (up to 8 cases)		
Total Additional Square Meters (Feet) in Calibration/Repair Area:		

4.1.1. Calibration/Repair Area. Floors, corners, aisles, and work areas must be clear and uncluttered for easy, frequent, thorough cleaning. Do not place exterior windows (except for optical windows, as required) in the calibration/repair area; however, sealed glass viewing ports may be installed in calibration areas to permit viewing without entering. Pass-through windows are not permitted. Minimize the number of doors in the calibration/repair area consistent with fire and safety regulations. Locate equipment to prevent disrupting airflow and heatflow patterns within the calibration/repair area. This will minimize temperature fluctuations in areas most affected, such as dimensional calibrations.

4.1.2. Air Lock. Use a minimum 1.8-meter (6-foot) wide air lock at the entrance to the calibration/repair area, with a door opening at least 1.5 meters (5 feet) wide to accommodate large equipment. The air lock must be at least 2.7 meters (9 feet) long to ensure both sets of doors are not open at the same time. Double doors are preferred (exception: a sliding door may be used). Do not position air lock doors in-line with building entry doors.

4.1.3. Mechanical and Electrical Equipment Rooms. Mechanical equipment is usually housed separate from electrical equipment. It is critical that equipment fits the space without crowding and allows adequate space for maintenance. Plan on a minimum of 15 percent of the total structure area. Utility rooms must be structurally (seismically) separate from the rest of the PMEL building. Overseas PMELs require additional space for 400- and 500-Hz motor generators with sound dampening walls between these generators and other areas.

4.1.4. Cleaning Room. The Test, Measurement, and Diagnostic Equipment (TMDE) cleaning room must be a separate room from the calibration/repair area, and supplied with utilities.

4.2. 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 predesign stages of the project, the PMEL Supervisor must provide the Design Agent with technical data for any equipment which requires special connections.

5. Acceptance Testing Criteria. To assure construction compliance, criteria for acceptance testing must be developed from the design and construction specifications, and appropriate test methods selected. Some tests must be conducted over a specific period of time, such as temperature and humidity variation in the calibration/repair areas during a seasonal change. Outside consultants may be hired to perform such tests as air balancing, air flow, and temperature gradients.

Section C—General Facility Requirements

6. Site Evaluation:

6.1. Vibration. The PMEL facility site must be isolated from sources of vibration such as railroads, heavy vehicle or aircraft traffic, cranes or machine operations, foot traffic, or similar disturbances. (An infrequently used option is constructing the facility below ground level.) Vibration level in the PMEL calibration/repair area must not exceed limits specified in Instrument Society of America (ISA) RP52.1, *Recommended Environments for Standards Laboratories*: 0.25 μm (10 microinches) between 0.1 and 30 Hz; and 0.0098 m/s^2 (0.001 g) between 30 and 200 Hz. Contact AFMETCAL DET 1/MLLE for assistance when excessive vibration is suspected at new PMEL sites.

6.2. External 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. With maximum currents of up to 243 amperes, average maximum field exposure is approximately 13.53 milligauses at zero meters (zero feet) and 2.48 milligauses at 30.5 meters (100 feet). These levels 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 DET1/MLLE.

7. Building.

7.1. Functional Requirements. The building must provide:

7.1.1. Protection from inclement weather or other atmospheric conditions to allow facility environmental conditions/ parameters to be maintained at the levels specified in this manual.

7.1.2. Controlled access, including protection from unauthorized entry, and security for maintaining classified equipment and documents.

7.1.3. Protection from toxicological, radiological, mechanical, electrical, electromagnetic, pyrotechnic, visual, and other special hazards.

7.1.4. Utilities and other services.

7.2. Construction. The building must be single-story, ground floor, concrete slab construction; exterior doors must not face prevailing winds.

7.3. Calibration/Repair Area Positive Pressure. A minimum positive static pressure of 12 pascals (0.05 inches of water) is required in the calibration/repair area to prevent infiltration of dust-laden air. Air should flow from the calibration/repair area through the grille of the inside air lock door and into the air lock, then out through the spaces around the outside air lock doors (normal construction tolerance), preventing infiltration of dust-laden air to the calibration/repair area. ***Note:*** The positive pressure requirement does not apply to Radioactivity Detection Indication and Computation (RADIAC) or liquid flow calibration areas in separate rooms.

7.4. Shoe Cleaners. Electrical and vacuum connections for shoe cleaners must be available at the entrance to the air lock. Provide a grounded touch pad at each shoe cleaner to dissipate electricity. Shoe cleaners are not required for Type IV PMELs.

7.5. Vacuum Cleaning System. A wet/dry vacuum cleaning system is required for cleaning TMDE, shoe cleaners, janitorial service of the calibration/repair area and other support areas. Install flush-mounted outlets in the walls approximately 0.6 meters (2 feet) above the finished floor. Outlets should be spaced so that hose length does not exceed 9.1 meters (30 feet) and each area can be reached by the hose intake fitting. At least four outlets should be operated simultaneously when using 38-millimeter (1½-inch) hoses and long sweep fittings. Install vacuum piping in the walls. Vacuum pressure at the end of each hose must be no less than 6221 pascals (25 inches of water). Vent system exhaust outside the building away from air inlets and other dust-sensitive areas.

7.6. Intercom System. An intercommunications system is required to allow two-way conversation between rooms in the PMEL facility. Normally, base communications personnel will provide and install the system; however, conduit runs and terminal boxes to support the intercom, telephone, and computer systems must be part of facility design.

7.7. Compressed Air. Oil-free, dry, compressed air for technical use in the calibration/repair area must be supplied from an oil-free compressor. Compressed air must conform to ANSI/ISA S7.3, *Quality Standard for Instrument Air*, with minimum pressure of 690 kPa (gage) (100 psig). Pressure of compressed air used at workbenches should be reduced with a precision valve and a 0-690 kPa gage. Compressed air quality for technical use in the calibration/repair 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 -40 ºC (-40 °F) atmospheric dew point. This quality may be achieved using dryers fitted with appropriate prefilters or coalescent air filters that remove oil and particulates. Provide an in-line oil monitor. Supply a refrigerated dryer for high flow requirements. Minimum filter requirement for an equipment cleaning area incoming air line 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 9.4 L/s (20 scfm) 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.

7.8. Dry Nitrogen. Water-pumped dry nitrogen (oil free) is required for technical use. It must conform to Federal Specification BB-N-411, *Nitrogen, Technical*, Type I, Class 1, Grade B; or MIL-P27401, *Propellant*

Pressurizing Agent, Nitrogen, Type I. Install dry nitrogen cylinders in the utility room. Piping run to the calibration/repair area must be rated at 4137 kPa (gage) (600 psig). Mark nitrogen lines to show pressure.

7.9. Exhaust Ventilation. Exhaust ventilation systems must accommodate the fume hoods over temperature calibration baths.

7.10. Fire Protection. The PMEL facility must have a complete sprinkler system conforming to National Fire Protection Association (NFPA) 13, *Sprinkler Systems*; and a manual fire evacuation system conforming to NFPA 72, *National Fire Alarm Code*.

7.11. Personnel Entrance Canopy. The personnel entrance to the building must be protected with an overhang. Where practicable, use a vestibule (two sets of doors), to prevent cold/hot air or dust from infiltrating the facility. Entrance doors should be recessed to prevent wind damage.

7.12. Service Entry. Provide an 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.

7.13. Oversized Equipment Entry. Where oversized equipment cannot be moved through the air lock, provide a set of tightly-sealed double doors between the precision dimensional area and the building exterior.

7.14. Communications. During development of the building layout, consult with Base Communications to identify space and functional requirements (usually a small, dedicated room with conduit and wiring) for telephone, computer, and other communication needs.

Section D—Materials and Methods of Construction

8. Type N Construction. Use standard construction materials and practices for permanent, Type N (non combustible) construction.

9. 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; and (3) comply with positive pressure requirements in the calibration/repair areas to duplicate the positive pressure in higher echelon laboratories that calibrate primary standards. 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.

10. Structural Elements. Use masonry walls, metal studs, steel joists, steel columns, and steel beams. Where possible, locate specially conditioned areas within the structure so the walls are interior partitions. These interior walls should be insulated and have as much thermal mass on the controlled (calibration/repair area and precision dimensional area) side of the wall as possible. For example, if the wall is stud construction, use two layers of 16-millimeter (5/8-inch) gypsum board on the controlled area side, with batt insulation, vapor barrier, and 13-millimeter (½-inch) gypsum on the outside. Good workmanship is essential in finishing each joint and seam of the walls to minimize air filtration and exfiltration. Interior partitions must extend above the vapor barrier of the ceiling.

11. Minimizing Vibration. To minimize vibration in the calibration/repair area:

11.1. 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.

11.2. Locate vibration-generating equipment such as blowers, compressors, heating and air conditioning units, vacuum pumps, and transformers on separate, isolated utility pads.

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

11.4. Mount air conditioning equipment (condenser/compressor or fan coil units) to the structure using steel spring type isolators which limit vibration transmission to 0.0098 m/s^2 (0.001 g) or less.

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

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

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

NOTE: 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. See paragraph 6.1 for more information on vibration control.

12. Vapor Barriers. 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 eliminate any possibility 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.

13. Finishes. 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, nonchalking, mildew-resistant semigloss 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.

14. Wainscots. Wainscots should be avoided because the top edge accumulates dust. If wainscotting is necessary, the top edge should be rounded or beveled.

15. Air Lock Doors. Air lock doors must have 610- by 760-millimeter (24- by 30-inch) shatterproof glass vision panels (or the closest standard size that fits) and bumpers to prevent equipment and cart damage. Door interlocking systems are not necessary. Doors closest to the calibration/repair area must have gasket-type stops, astragals, automatic door bottoms, and a properly-sized grille installed above the doors (not required on outside air lock doors). Joints between doors and frames must be sealed with gaskets.

16. Floor Covering in Calibration/Repair Areas and Air Locks. Use 1.8-meter- (6-foot-) wide non-conductive sheet vinyl flooring. Each joint must be routed and welded or bonded to form a seamless floor when installed according to manufacturer's recommendations. Sheet vinyl is recommended because its smooth, continuous surface simplifies daily cleanup, including chemical and mercury spills. At junctions of the floor and walls, install a wood or wax fillet strip, and turn up the sheet vinyl flooring to form a seamless "self-coved" base with the top edge fitted into a molding strip. Do not wax hard-surfaced flooring since waxed surfaces are highly resistive and prone to static generation. Wax also flakes and contributes to dirt accumulation. Do not install carpet in air locks because it interferes with door operation. Floor mounted thresholds are not permitted.

17. Ceilings. Install finished ceilings with clear ceiling height of not less than 2.74 meters (9 feet) throughout the PMEL (except in the utility and mechanical rooms) to provide a finished surface, conceal conduits, and provide an adequate thermal mass to stabilize temperatures. Where possible, the ceiling should be finished gypsum board with insulation. Drop-in ceiling panels cannot assure the same level of reduced vapor transmission and air exfiltration.
NOTE: Preferred ceiling and wall systems will add little to project costs, but will improve the thermal and humidity performance of the environmental control system.

17.1. Framing. Ceiling framing systems (if used) must be metal and support the required load without excessive deflection or vibration. The distance from floor to framing may dictate suspended or furred ceilings. Do not tie suspension systems to catwalks or mechanical and electrical equipment platforms.

17.2. Ceiling Access Panels. Provide air-tight, dust-tight ceiling access panels for environmental system balancing and required maintenance.

17.3. Calibration/Repair Area. The ceiling system for the calibration/repair area of the PMEL must provide a surface that will reduce air leakage, prevent dust infiltration, and not produce dust. Acceptable ceilings in order of preference are:

17.3.1. A monolithic surface of drywall or plaster construction with finished joints and corners.

17.3.2. Noncombustible acoustical units (mineral composition) secured to concealed metal runners with concealed fastenings and hold-down clips. Acoustical units must not shed particles, and must be installed with a joint system that will not leak due to the difference in air pressure above and below the ceiling. Do not use fissured or perforated units.

17.3.3. Lay-in panels, supported in a suspended exposed metal grid system. Securely fasten lay-in panels with concealed tape or clips to prevent movement or loss of air pressure and to prevent infiltration of dust. Use factory finished hardboard, vinyl faced and edged gypsum board, or acoustical units described above. Use lay-in panels only for renovation work where other options are not cost-effective.

Section E—Heating, Ventilation, and Air Conditioning (HVAC) for Calibration/Repair Areas

18. Standards for Facility Environmental Control. For environmental control purposes, each PMEL will have three areas: an administrative area; a main calibration area (can be broken up into separate rooms for specific purposes); and either a temperature/humidity sensitive (T/H S) area or a 68 degree room, depending on the purpose of the PMEL. T/H S rooms contain dimensional and other equipment which require more stringent environmental control. Design conditions for each area must be maintained on a continuous basis under varying loads, including periods when the laboratory is not in operation. Excluding the administrative area, reference AFM 88-29, *Engineering Weather Data*, for local outside temperature and humidity conditions using a 99 percent criterion for heating, and a 1 percent temperature and relative humidity criterion for air conditioning.

18.1. Administration Areas. Design the administrative area to normal comfort conditions using good commercial practice and ASHRAE standards for ventilation and air conditioning for administrative areas.

18.2. Main Calibration Lab. The environmental control system serving the main calibration area must maintain a temperature of 23 ± 1.1 ºC (73 ± 2 °F) dry bulb and a relative humidity of 40 percent, +5/–20 percent.

18.3. Temperature/Humidity Sensitive Area. The T/H S room environmental control system must maintain a temperature of 23 ± 1.1 ºC (73 ± 2 °F) and a relative humidity of 40 percent, +5/–20 percent. Though room temperature may vary 2.2 ºC (4 °F), the temperature may not vary more than 0.5 ºC (1 °F) in any one hour period during normal system operation. Maximum temperature gradient across the room is 1.1 ºC (2 ºF).

18.4. 68 Degree Room. Where a 68 degree room is required, the environmental control system shall maintain a temperature of 20 ± 0.5 ºC (68 ± 1 °F) dry bulb and a relative humidity of 40 percent, +5/–20 percent. Precise dimensional standards demand a 45 percent maximum acceptable relative humidity to preclude corrosion problems. The temperature may not change more than 0.5 ºC (1 °F) in any one hour period during normal system operation. A modular clean room may be provided to meet these requirements.

19. HVAC Design Considerations. A number of factors must be considered in the design of the environmental system to satisfy criteria. PMELs are issued restricted certification or decertified when the operating environment (temperature and humidity) is outside the required operating tolerances. This causes workloads to be transferred to other laboratories, resulting in costly delays until the condition is corrected. Although specific guidance is impractical due to the wide range of local conditions encountered at PMEL facilities, the following must be carefully considered:

19.1. Psychrometric analysis to determine the effect of local conditions on design. This analysis, including a review of past problems with similar facilities, will prevent designing an inadequate environmental system.

19.2 Equipment heat gain. The using agency must determine the electrical equipment load so that electrical apparatus heat gains can be considered in the air conditioning design. During the predesign stages of the project, the using agency will provide the agency responsible for design the maximum, minimum, and average heat gains for both PMEL-owned and PMEL-supported equipment that is expected to be connected to electrical power during a normal day's operation. Also provide the approximate equipment location.

19.3 Controls/instruments to record temperature and humidity data. Careful study of AFM 88-29 is essential. Design calculations should recognize the effect of brief deviations in outside temperature and humidity beyond those listed. Recording instruments, calibrated to National Institute of Standards and Technology (NIST)/International Standards, will be contractor-supplied and may be combined with the controller. The recording device must be capable of discerning 0.25 ºC (0.5ºF).

NOTE: The designer should optimize the selection of cooling equipment taking into account all aspects of performance, reliability, maintainability, and capital and maintenance costs.

20. Facility HVAC Design Features:

20.1. Building Layout (Figure 1). Whenever practical, locate the calibration/repair area adjacent to other conditioned areas. Lab space should always be covered with an attic or plenum loft space to reduce the effect of solar loads on the control requirements. When impractical to provide adjacent conditioned space, consider increasing the thermal mass of the envelope. Follow American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) fundamentals to determine the U values for building construction elements.

20.2. Chilled Water Systems. A chilled water system with reheat is usually the best option to maintain required temperature tolerances. A central building chilled water system with modulating control is most satisfactory for the required 4.4 ºC to 5.5 ºC (40 °F to 42 °F) water. Select compressors to be the most efficient over the range of anticipated loads. In humid regions, reciprocating compressors must have the maximum number of capacity steps to obtain adequate humidity control. Hot water reheat is recommended.

20.3. Single Zone Air Handling Units. Use single zone air handling units to isolate control requirements for each major PMEL area. Size calibration/repair area cooling coils to maintain nominal 40 percent relative humidity under the location design conditions listed in AFM 88-29. Determine the minimum acceptable room air change rate from ASHRAE Standard 62-1989, *Ventilation for Acceptable Air Quality*. The design requirement is to provide even temperature throughout the controlled space.

20.4. Air Distribution. Design the air distribution system to circulate air throughout the facility to prevent stratification. Use non-unidirectional air pattern control. Specifications apply within the space 0.9 meters to 1.5 meters (3 feet to 5 feet) above the floor (working area); air velocity in the working area must be 7.6 ± 3 meters (25 ± 10 feet) per minute. Keep noise level below 45 dB as measured by a meter meeting American National Standards Institute (ANSI) S1.4, *Sound Level Meters, Specification for*. 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 make-up air requirements do not adversely affect system operation.

20.5. 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 responds 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.

20.6. Condensate Discharge. Discharge condensate from cooling coils into a floor drain.

20.7. Recording Devices. The Air Force Metrology and Calibration Program requires permanent records of temperature and humidity data in calibration areas. The data must be provided by a contractor-supplied continuous recording system which uses self-contained sensor/recorders, or remote sensors with centrally-located recorders. Temperature and humidity sensors are required in each separate room in the calibration area, and a minimum of one set of sensors for every 186 square meters (2000 square feet) of calibration area. When selecting recording devices, consider accuracy and response time -- critical environments require immediate response and high accuracy. Mount sensors at bench level, as near as possible to the most critical area of measurement. If practicable, flush-mount recording devices with remote sensors within the walls. Calibrate recording instruments to NIST/International Standards. Recording device temperature resolution must be 0.1 degrees (Fahrenheit and Celsius) or better, and humidity sensor percent relative humidity resolution must be 0.5 percent relative humidity or better. An alarm will be relayed to the PMEL Computer System and the Base Energy Management and Control System (EMCS) when the calibration area environment is out of

tolerance or the HVAC system operating parameters are out of tolerance. Both the recording device and the alarm system will indicate real time. All temperature and humidity sensors, including wall-mounted assemblies, will be removable for calibration, and indicating devices will be capable of accepting new calibration data.

21. Calibration Area Environmental Control:

21.1. Makeup/Outside Ventilation Air. Use a separate system to supply a constant volume of preconditioned makeup/outside ventilation air to the HVAC systems serving the non-administrative 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 (22.8 ± 1.1 ºC [73 ± 2 °F]) 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 nonadministrative areas will be controlled by regulating the humidity in the outside/makeup air system. Coils must meet 99% design conditions. Discharge air from this system must be mixed with the return air from the calibration area. To facilitate inspection and cleaning, install access doors between coils, and ensure coils are no more than eight rows deep. In humid areas, the amount of dry outside air required to dehumidify the calibration area 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. Also consider using desiccants for the outside/makeup air in areas of high humidity.

21.2. Room Pressurization/Filtration. Use a self-reading magnahelic gauge to measure pressure differential between the calibration/repair area and surrounding spaces. Except for the 68 degree room, air filters will have 80-85% efficiency when tested by an acceptable atmospheric dust spot test (reference ASHRAE Standard 52.1-1992, *Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter*). Install roughing filters in the administrative area. The 68 degree room must have a filtration system which satisfies a particle count not exceeding 24,700 particles per cubic meter (700 particles per cubic foot) of atmosphere, 5 microns and larger; and 3,530,000 particles per cubic meter (100,000 particles per cubic foot) of atmosphere, 0.5 microns and larger. Accurately detail 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.

Section F—Electrical Power

22. Power Distribution. Safe and permanent sources of power must be available to calibration personnel, integral to or near each workstation, to supply power to the standards, comparators, and workload items assigned to the area.

22.1. Types of Electrical Power. Normally, electric service will be provided at 480 Vac, 3-phase, 60 Hz. Listed below are 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.

Nominal System Voltage*	Phase	Frequency
277/480	1&3	60 Hz ± 1 Hz
120/240	1&3	60 Hz ± 1 Hz
120/208	1&3	60 Hz ± 1 Hz
208 or 240	1	60 Hz ± 1 Hz
120/240	1&3	400 Hz ± 10Hz
120/208	1&3	400 Hz ± 10Hz
28	DC	N/A

*CONUS installations

22.2. Voltage Regulation. Voltage drop of the building wiring system will not exceed 3 percent 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 ±3 percent. Time constant (response time) of the

voltage regulators should not exceed 0.3 seconds, and total harmonic distortion must not exceed 5 percent. Power conditioning and continuation interface equipment (PCCIE) must be supplied by the using agency.

22.3. Tagging/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.

22.4. 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 calibration and repair 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.

23. 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 will be provided by the using agency and installed by the contractor. Follow applicable portions of National Electrical Code (NEC) and Occupational Safety and Health Administration (OSHA) Standards. Pay particular attention to derating electrical equipment if boilers or other heat-generating equipment are present. Provide Power Conditioning and Continuation Interface Equipment (PCCIE) for testing and powering sensitive electronic equipment. The using agency (PMEL) must obtain PCCIE through the PCCIE Program Office, SM-ALC/LIET, McClellan AFB CA 95652, DSN 633-0181, or (916) 643-6570/6777/0901. PCCIE maintenance is the responsibility of the using agency.

24. 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.

25. Antenna Ports. The PMEL requires an antenna port installed during construction. Port location is dependent on the location of such instruments as precise time (GPS) receivers. Antenna port penetrations through calibration walls should be properly finished and sealed to prevent loss of calibration area positive pressure.

26. Grounding. Install grounding in accordance with the NEC and the National Electrical Safety Code, except that the grounding system must have a resistance to ground of less than 10 ohms. If less than 10 ohms cannot reasonably be attained, a waiver must be sought from the MAJCOM electrical engineer and the PMEL Flight Chief. Power the calibration/repair area from (an) isolation transformer(s) with the electrostatic shield between the primary and secondary windings installed as a separately derived system as close as practical to the loads. Provide an equipotential plane for the calibration/repair area where sensitive electronic equipment will be used.

27. 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.*

28. Electrical Receptacles. Actual location and type of electrical receptacles must be considered, such as: receptacles high on the wall for wall clocks or portable emergency lights; receptacles at mid-wall level for connecting to work benches located along the walls. Do not use the common 60 Hz, 120 Vac receptacle for 28 Vdc, 50 Hz, or 400 Hz services. The electrical contractor can provide the approved type based on the NEC. Install enough receptacles to allow for future changes in layout due to personal preferences, relocation of measurement systems to balance heat load and air balance, or the addition of new measurement systems.

Recommend placing two duplex receptacles every six feet along each wall. Explosion-proof receptacles may be required in areas where flammable materials are used.

29. Electrical Feeds. Separate electrical feeds are recommended for the calibration areas.

30. Main Power Panels and Main Electrical Feeds. If possible, especially in areas of inclement weather, locate access to main power panels inside the facility. Main power panels should be marked as discussed in paragraph 22.3.

31. Internal Electromagnetic Interference (EMI)/Radio Frequency Interference (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 MIL STD 188-124, *Grounding, Bonding, and Shielding for Common Long HaulTactical Communications Systems Including Ground Based Communication,* and MIL STD 188-125, *High-Altitude Electromagnetic Pulse (HEMP) for Ground-Based C4I Facilities Performing Critical, Time-Urgent Missions,* Volume 1, *Fixed Facilities (Metric)*; and 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.*

Section G—Lighting

32. Calibration/Repair Area. Use permanent overhead-recessed fluorescent fixtures sealed with gaskets to prevent air or moisture leakage and dust accumulation/intrusion from the interstitial area, satisfying ANSI C78.2, *Fluorescent Lamps - Preheat Start Types - Dimensional and Electrical Characteristics.* Light fixture electrical circuits should be on separate electrical feeds from instrumentation circuits. Individual light controls are required for areas where radiant energy can affect measurements. If recessed fixtures can't be used during renovation of an existing PMEL, light fixtures surface-mounted on the ceiling may be used, providing the fixtures are streamlined to avoid catching dust particles.

33. Illuminance. Facilities shall require a minimum uniform illumination of 100 foot-candles calculated at the midlife of the tubes as measured at bench level in the calibration/repair 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. Other areas must conform to the Illuminating Engineering Society (IES) Lighting Handbook. Zone lighting by work area and provide switches near the air lock entrance.

34. Emergency Lighting. Emergency lighting is required by NFPA Standard 101, *Life Safety Code*. 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. If a generator set is included, wire emergency lights to automatically transfer from normal supply to the generator set. If portable lights are mounted on the wall, locate an electrical receptacle near the light.

35. Explosion Proof Lighting. Regardless of the type of lighting, Class 1 Division 2 light fixtures should be used in rooms housing pressurized flammable liquids.

Section H—Support Areas

36. Design Considerations. Quantities of workload, physical size of workload, proposed workload, or expansion of workload are the primary factors determining 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. Locate these areas adjacent to the calibration and repair areas when possible, to reduce the distance delicate test equipment must be moved. Equipment storage areas must be isolated from visitors for security and to prevent unauthorized movement of equipment. A custom-built customer service counter effectively isolates the customer

from equipment storage and processing areas. Typical support areas include: scheduling/receiving/equipment storage with customer service counter; equipment cleaning room; technical library (if not in calibration area); office space; conference room; janitorial supply room. **NOTE:** Hazardous materials used in the laboratory must be considered in the design. The user will provide the designer a list of hazardous materials, including quantity, use, and location in the laboratory.

36.1. Mechanical. A temperature of 22.8 ± 3 °C (73 ± 6 °F) is recommended to allow equipment in the work queue to pre-stabilize near the calibration laboratory temperature (pre-soak period). HVAC air supply distribution to the support areas should not be on the same zone as the laboratory calibration areas.

36.2. Electrical. 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 door bell should be installed on the customer entry door. Electrical power loads should not be on the same circuits providing electricity to the calibration areas.

36.3. Cleaning Room. A specially-equipped and isolated area is required for cleaning and washing mechanical, electrical, and electronic equipment. Requirements for the area are determined by the types of equipment to be serviced. Each cleaning unit and drying oven requires a minimum of 1.4 square meters (15 square feet) additional floor space. A stainless steel sink and drain board with hot and cold water and exhaust hood is required. Locate the cleaning and washing area outside the calibration area. Supply utilities, services, furnishings, tools, and equipment equivalent to the following:

36.3.1. Power: 120/240 Vac single-phase 20 amp circuit hard-wired to a government- or contractor-supplied electronic drying oven with disconnect switch. These circuits should not be connected to electrical distribution serving the calibration area.

36.3.2. Compressed Air: Use an oil-free compressor to provide oil-free and clean dry instrument air at 344 to 1379 kPa (50 to 200 psi), with 0.0017 m^3/s @ 344 kPa (3.5 cfm @ 50 psi). Compressed air supplied to the cleaning station must have an adjustable regulator with a 0-35 psig range at the station.

36.3.3. Cleaning System: Fresh hot and cold water supply and drain with mercury trap to be connected to the government supplied cleaning system and deep utility sink. Provide floor drain.

36.3.4. Exhaust Vent: The cleaning area needs a canopy type fume hood with power exhauster for fume and vapor removal (see OSHA Standards 1910.94, *Ventilation*, and 1910.1000, *Air Contaminants*). The drying oven requires 6 cubic meters (212 cubic feet) per minute of room air for the purge blower intake and exhaust. The maximum temperature of the oven is 72 °C (163°F).

36.3.5. Furnishings: Deep industrial sink, work bench with lipped stainless steel top that drains into the sink, storage cabinet for cleaning materials, trash cans, safety signs, fire extinguisher, storage for hand tools, stool, supplemental lighting.

36.3.6. Vacuum: Vacuum port will be provided in the equipment cleaning room.

36.4. Office. Locate the office for the PMEL manager and the administrative staff near the main laboratory entrance to control building access and receive visitors. Allow a maximum 9.3 square meters (100 square feet) per office occupant. Typical laboratory functions requiring office and administrative space include:

36.4.1. Flight Chief.

36.4.2. Laboratory Chief.

36.4.3. Secretary, receptionist, word processor.

36.4.4. Quality Assurance Supervisor.

NOTE: A separate entrance should be provided for customers picking up or delivering workloads.

36.5. Training and Conference Room. Allow 1.9 square meters (20 square feet) per projected room occupant. In sizing the room, consider: number of personnel that will use the room; and training aids and furnishings required. Recommend a small conference and training room be located near the laboratory manager's office; and the laboratory break and lunch (or other) rooms be used for larger meetings and training sessions. A smaller room near the Flight Chief’s office can also provide supplemental space for the lab manager for laying out special projects on a conference table during development stages.

Section I—68 Degree Rooms and Other Special Requirements

37. Modular Prefabricated PMEL Rooms. Modular environmental enclosure systems are available as controlled laboratories for high precision metrology. Typically they are more cost effective than a 68 degree room built as part of the facility. Their 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. Before contracting construction of a modular environmental enclosure, consider: (1) environmental specifications for the 68 degree room calibration laboratory 20 °C± 0.5 °C (68 °F±1 °F); (2) life cycle costs; (3) size (fits the space?); (4) possible vibration and electromagnetic interference; and (5) volume and type of work to be processed. If an environmental enclosure system is feasible, the design should include:

Design Features of Environmental Enclosure System
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 a 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 9.5 millimeters (3/8-inch).
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.
If required for the HVAC system condenser cooling coil, a year-round supply of water of the necessary minimum pressure, temperature, and flow-rate.
Possible use of an independent power supply for standby or to meet future load requirements.

37.1. Module Sizes. Following are sizes of various enclosures/modules available:

Enclosure Type*	Internal Size (Meters/Feet)	Max. No. of People	Intermittent kW**
1	6.1 x 12.2/20 x 40	8	10
2	11 x 12.2/36 x 40	16	12
3	20.7 x 12.2/68 x 40	28	25
5	6.1 x 12.2/20 x 40	8	10
6	11 x 12.2/36 x 40	16	12
9	6.1 x 12.2/20 x 40	8	10
10	11 x 12.2/36 x 40	16	12
11	6.1 x 15.8/20 x 52	10	10

* Term used by enclosure manufacturers.

** Maximum internal heat from equipment, excluding lights.

37.2. Modular Laboratory Control Conditions. The control conditions shown below can be achieved in modular laboratories. They can also be provided with less demanding conditions with the use of smaller capacity ancillaries, such as the HVAC, filtration, and control equipment.

Temperature	20°C± 0.5°C (68 ± 1 °F)
Relative humidity	40%, +5/-20%
Contamination level	Class 10,000*
Pressurization	12.4 to 24.9 Pa (0.05 to 0.10 inches H_20)
Air changes	20/hr
Air volume	0.85 m^3/s (1800 cfm)**
Lighting level	1076.4 lx (100 fc)
Sound level	45 dBA max
Allowable room heat load	3 kW**

* Can be controlled to Class 100,000 for 0.5 and 5.0 micron levels (per FED-STD-209, *Airborne Particulate Cleanliness Classes in Clean Rooms and Clean Zones*)

** Typical for a Type 1 enclosure (6.1 x 12.2 meters [20 x 40 feet])

37.3. Manufacturer's Information. For further information and examples of manufacturers of prefabricated PMELs, contact AFMETCAL/DET 1/MLEE, 813 Irving-Wick Drive West, Suite 4M, Heath OH, 43056-6116.

38. RADIAC Calibration Areas. Radioactive materials, such as Americium 241, Cesium 137, Krypton 85, Plutonium 239 and Thorium 232, are used in devices calibrated in selected licensed PMELs. These isotopes are also used as calibration standards. When not properly shielded or used, these materials can generate dangerous levels of radioactivity. Positive pressure is not required in RADIAC calibration areas; neutral or negative pressures are acceptable. Also, most Type IIB laboratories are calibrating only low-level radiation instruments and do not require special construction. Special shielding needs to be considered in facility design only when using RADIAC sources which emit more than 2.6×10^{-4} coulombs per kilogram of air (1 roentgen) per hour. Currently, only laboratories using the J.L. Shepherd 81-10 source qualify as using high-intensity sources. Reference Nuclear Regulatory Commission (NRC) Title 10 CFR 20, *Standards for Protection Against Radiation.* Calibration, leak testing, and otherwise processing these devices can be accomplished only in those activities authorized to do so, and by trained personnel. Storage, calibration, maintenance, shipping, and disposal of devices containing radioactive material is subject to detailed control, such as that specified by the NRC and the U. S. Air Force Radioisotope Committee, Brooks AFB, Texas. NRC and Agreement States have requirements for facility construction to house radioactive sources and RADIAC equipment. Recommend these requirements be identified through the A/E firm or builder.

39. Force and Pressure Measurement Areas. 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. Consider placing such equipment in isolated areas or separate rooms as an added measure for personnel and equipment protection.

40. Liquid Flow Calibration Area. A specially-equipped, isolated area is required in PMELs which perform liquid flowmeter calibration involving flammable liquids. The building housing a liquid flow calibration area must be constructed of non-combustible or fire resistive materials as defined by the National Fire Protection Association. 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.

40.1. Floor Space. Determine floor space by considering the type and number of flow calibrators necessary to accommodate the workbench. Allocate additional space as necessary for workbenches and for storage of tools, ancillary equipment, and for walkways.

40.2. Ceiling Height. Ceiling height must be adequate for housing flow calibrators and for performing in-place maintenance. Ceiling and wall finish will be in accordance with the requirements specified in paragraph 13.

40.3. Flooring. Use conductive flooring for installation in NFPA 70, *National Electrical Code*, Class I, Group D, Division 2 hazardous classified locations as specified.

40.4. Water Supply. Supply hot and cold water considering the requirements of flow calibrator heat exchangers. Minimum service will consist of 1.26 L/s (20 gpm) of 4.4 ± 2.7 °C (40 ± 5 °F) chilled water and 1.26 L/s of 71.1 ± 11.1 °C (160 ± 20 °F) heated water. Service must be adequate to support the simultaneous operation of all major systems in the facility.

40.5. Compressed Air and Nitrogen. 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 shall be of instrument quality conforming to the requirements of ANSI/ISA S7.3. Compressed nitrogen shall conform to the requirements of Federal Specification BB-N-411, Type I, Class I grade B or MIL-P-27401. Service shall be adequate to support the simultaneous operation of all major systems in the facility.

40.6. Fluid Waste. Use drip pans, barriers, or other suitable methods of containment to prevent spills of flammable, contaminated, caustic or waste fluids other than water from entering drain pipes or sewer systems.

40.7. Wastewater. Provide wastewater considering the requirements of the flow calibrators.

40.8. Ventilation. Ventilate the facility in accordance with the requirements of Title 29 CFR 1910, *Occupational Safety and Health Standards* . This includes a ventilation rate of not less than 4.25 liters per second per square meter (1 cubic foot per minute per square foot) of solid floor area.

40.9. Environmental Controls. Facilities housing temperature-controlled flow calibrators do not require environmental controls. All other facilities shall respect extremes in environmental conditions below 18.3 °C (65 °F) and above 29.4 °C (85 °F) or rapid changes in environmental temperature exceeding 2.2 °C (4 °F) per hour.

40.10. Flammable Liquids. Flammable liquid storage and handling shall be in compliance with 29 CFR 1910.

41. Azimuth Reference:

41.1. Azimuth Station Locations. The Air Force has established eight North Seeking Gyrocompass Verification Facilities to support the calibration requirements of gyrocompass units. The purpose of these facilities is to provide accurate astronomical azimuth or directional standards for verifying the accuracy of the gyrocompass units. Equipment such as fixtures, plates, optical elements, stands, and other related items used in the calibration have been assembled in the Azimuth Reference System (ARS-1), NSN 4920-01-149-6391. Customers having requirements to set up a verification facility for supporting gyrocompass calibration requirements should contact AFMETCAL DET 1/MLEE, 813 Irving-Wick Drive West, Suite 4M, Heath OH 43056-6116, for technical assistance in establishing new verification facilities. The methodology for supporting critical azimuth requirements varies depending on accuracy requirements for items being supported..

41.2. Azimuth Reference Details. Each facility has an external azimuth reference line terminating at a target monument. The line ranges in length up to one mile, depending on location. 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. Stable piers are provided for the optical reference collimator and temperature is maintained at 22.2 ± 3.3 °C (72 ± 6 °F) through the year. A precision optical window assembly is located on the external wall of the PMEL to permit external observations of Polaris, the indoor reference collimator, and the target monument. This design permits direct, single-azimuth transfers between Polaris, the indoor target collimator, and the external azimuth reference line.

41.3. Updates. Determination of the direction of the reference line does not stop after the facility becomes operational. Observations will be made by the Defense Mapping Agency geodetic surveyors annually.

Section J—Commissioning

42. Standards. The designer must follow Army Corps of Engineers Engineer Regulation 1110-345-723, *Systems Commissioning Procedures*, in developing commissioning standards. The end result must be a facility where the primary emphasis is to design, construct, inspect, and accept a complete and operational facility.

WILLIAM P. HALLIN, Lt General, USAF
DCS/Installations & Logistics

Attachment 1

GLOSSARY OF REFERENCES AND SUPPORTING INFORMATION

References

Note: The most recent edition of referenced publications apply, unless otherwise specified.

Public Laws

Title 10 CFR 20, Nuclear Regulatory Commission,*Standards for Protection Against Radiation*
Title 29 CFR 1910, *Occupational Safety and Health Standards*

DoD Directives, Instructions, and Standards

MIL STD 188/124B, *Grounding, Bonding, and Shielding for Common Long Haul/Tactical Communications Systems Including Ground Based Communications-- Electronic Facilities and Equipments*
MIL STD 188/125A, *High-Altitude Electromagnetic Pulse (HEMP) for Ground-Based C4I Facilities Performing Critical, Time-Urgent Missions, Volume I, Fixed Facilities (Metric)*
MIL HDBK 419A, *Grounding, Bonding, and Shielding for Electronic Equipment and Facilities*
MIL HDBK 423, *High-Altitude Electromagnetic Pulse (HEMP) Protection for Fixed and Transportable Ground-Based C41 Facilities*

Air Force Publications

AFM 88-29, *Engineering Weather Data*

Army Corps of Engineers

Engineer Regulation (ER) 1110-345-723,*Systems Commissioning Procedures*

Other Government Publications

OSHA Std 1910.1000, *Air Contaminants*
OSHA Std 1910.94, *Ventilation*

Federal Standards and Specifications

Federal Standard 209, *Airborne Particulate Cleanliness Classes in Clean Rooms and Clean Zones*
Federal Specification BB-N-411C,*Nitrogen, Technical*

Military Specifications

MIL-P-27401C, *Propellant Pressurizing Agent, Nitrogen*

National Fire Protection Association

NFPA 13, *Sprinkler Systems*
NFPA 70, *National Electrical Code*
NFPA 72, *National Fire Alarm Code*
NFPA 101, *The Life Safety Code*

Miscellaneous

ANSI C78.2, *Fluorescent Lamps - Preheat Start Types - Dimensional and Electrical Characteristics*
ANSI S1.4, *Sound Level Meters, Specification for*
ANSI/ISA S7.3, *Quality Standard for Instrument Air*
ASHRAE 52.1-1992, *Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter*
ASHRAE 62-1989, *Ventilation for Acceptable Indoor Air Quality*
Illuminating Engineering Society (IES) of North America,*Lighting Handbook*
Instrument Society of America ISA RP52.1,*Recommended Environments for Standards Laboratories*

National Electrical Code (NEC) 250-5(d), *Alternating-Current Circuits and Systems to Be Grounded, Separately Derived Systems*

Additional References

DoD Directives, Instructions, and Standards

MIL STD 285, *Military Standard Attenuation Measurements for Enclosures, Electromagnetic Shielding, for Electronic Test Purposes, Method of*

MIL STD 461B, *Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference*

MIL STD 462, *Measurement of Electromagnetic Interference Characteristics*

MIL HDBK 1190, *Facility Planning and Design Guide*

Defense Logistics Agency DLAH4145.6, *Hazardous Materials - Storage and Handling Handbook*

Missile Command Specification MIL-35236A, *Environmental Enclosure Laboratory System*

Air Force Publications

AFI 21-113, *Air Force Metrology and Calibration (AFMETCAL) Program*

AFI 32-1065, *Grounding Systems*

AFOSH 127-90, *Precision Measurement Equipment Laboratory (PMEL)*

TO 00-20-14, *Air Force Metrology and Calibration Program*

Other Government Publications

Department of Health, Education and Welfare (FDA) 76-8005,*Radiation Safety Handbook*

Environmental Protection Agency EPA1530-SW-90-036, *RCRA Orientation Manual*

Environmental Protection Agency EPA 530-SW-85-006, *Requirements for Small Quantity Hazardous Waste Generators: New Resource Conservation and Recovery Act Requirements*

Miscellaneous

ASHRAE Applications Handbook, Chapter 17, "Clean Spaces"

National Conference of Standards Laboratories (NCSL) Recommended Practice RP-7,*Laboratory Design*

National Institute for Occupational Safety and Health (NIOSH)*Pocket Guide to Hazardous Chemicals*

National Physical Laboratory Report MOM 22, *Recommendations for the Design and Equipping of Engineering Metrology Laboratories*

Sandia Report SANDGO - 1962. UC - 906, *Standard Laboratory Environments*, David W. Braudaway, September 1990

The Design of Air Conditioning Systems for Metrology and Testing Laboratories, W. Schollmeir, Physicalisch - Bundesanhalt, Braunschweig, Bulletin OIML No. 118, March 1990

Planning of Metrology and Testing Laboratories, OIML, July 1989, Bureau International de Metrologie Legale, 11 Rue Turgot 75009 Paris, France

"Magnetic Fields Near Overhead Distribution Lines, Measurements and Estimating Techniques," T. Vinh, T.L. Jones, C.H. Shih, *IEEE Transactions on Power Delivery*, Volume 5, No. 2, April 1991

"Selecting ESD-Protective Floor Materials," Michael T. Brandt,*EDS/ESD Technology*, pp 12 - 16, Oct/Nov 1990 SS-T-312B

Abbreviations and Acronyms

A&E—Architect and Engineer

AFMETCAL—Air Force Metrology and Calibration

ANSI—American National Standards Institute

ARS—Azimuth Reference System

ASHRAE—American Society of Heating, Refrigerating, and Air Conditioning Engineers

CCP—Clean Construction Protocol
CE—Civil Engineer
CFR—Code of Federal Regulations
EMCS—energy management and control system
EMI—electromagnetic interference
ESD—electrostatic discharge
ESS—electrical standards set
FAM—Functional Area Manager
GPS—Global Positioning System
HEMP—High-Altitude Electromagnetic Pulse
HQ AFCESA—Headquarters Air Force Civil Engineer Support Agency
HVAC—heating, ventilation, and air conditioning
IEEE—Institute of Electrical & Electronic Engineers
IES—Illuminating Engineering Society
ISA—Instrument Society of America
MAJCOM—Major Command
NCSL—National Conference of Standards Laboratories
NEC—National Electrical Code
NFPA—National Fire Protection Association
NIOSH—National Institute of Occupational Safety and Health
NIST—National Institute of Standards and Technology
NRC—Nuclear Regulatory Commission
NSN—National Stock Number
OSHA—Occupational Safety and Health Administration
PAMS—PMEL Automated Management System
PATEC/TFCU—Portable Automatic Test Equipment Calibrator/Transportable Field Calibration Unit
PCCIE—Power Conditioning and Continuation Interface Equipment
PID—proportional integral differential
PMEL—Precision Measurement Equipment Laboratory
ppm—parts per million
RADIAC—Radioactivity Detection Indication and Computation
RF—radio frequency
RFI—radio frequency interference
T/H S—Temperature/Humidity Sensitive
TMDE—Test, Measurement, and Diagnostic Equipment
wt—weight

Terms

Air Force Metrology and Calibration Program (AFMETCAL Program)—The composite of measurement standards, metrologists, a system of world-wide laboratory facilities (commonly known as PMELs), calibration data, and integrated planning to provide a disciplined Air Force program to assure the optimum reliability and accuracy of systems, subsystems, and equipment.

Precision Measurement Equipment Laboratory (PMEL)—PMELs use base measurement standards to maintain working standards. The working standards are used to maintain (troubleshoot, align, repair, and calibrate) Test, Measurement, and Diagnostic Equipment (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.

Attachment 2

TABLES OF DESIGN/COMMISSIONING CRITERIA

Table A2.1. Architectural Features.

Project Success Assurance		
Tables made part of the A&E documents?		
Design Team has met?		
Space requirements identified?		
Table 1 completed?		
Table 2 completed?		
Layout meets requirements?		
Commissioning criteria defined?		
Site Selection and Building Items		
Proposed PMEL >305 m (1000 ft) from flightlines and major highways?		
PMEL site located away from major overhead transmission lines or antennas?		
PMEL calibration/repair area oriented away from direct sunlight?		
Vibration Isolation--New Facility		
Location of vibration generating equipment		
Mechanical (utility) room isolated from main structure?		
Vibration Isolation--Existing Facility		
Vibration isolators?		
Location of vibration generation equipment?		
Location of dimensional lab?		
Other Architectural Features Used/Provided:		
Air lock?		
Utility room?		
Equipment cleaning room?		
Entrance canopy?		
Vapor barriers?		
Vibration isolated compressors, pumps?		
Vacuum source?		
Intercom?		
Compressed air, 690 kPa (gage) (100 psig)?		
Dry nitrogen?		
Exhaust ventilation?		
Clean construction protocol?		

Table A2.2. Heating, Ventilation, and Air Conditioning (HVAC) for Calibration/Repair Areas.

General Requirements	
Temperature stability	22.8 ±1.1 ºC (73±2 °F)
T/H S room and 20 ºC (68 °F) room	Maximum change: 0.5 ºC/hr (1 °F/hr)
20 ºC (68 °F) room	20±0.5 ºC (68±1 °F)
Temperature gradient	
T/H S room	Maximum 1.1 ºC (2 °F) between any two points
20 ºC (68 °F) room	Maximum 0.5 ºC (1 °F) between any two points
Humidity	40% relative humidity nominal, +5/-20 percent
Dust particles (ASHRAE 80-85 % efficiency)	
20 ºC (68 °F) room	24,700 pt/m^3 (700 pt/ft^3) 5+microns; 3,530,000 pt/m^3 (100,000 pt/ft^3) 0.5+ microns
Room air pressure	12 pascals (0.05 inches of water) minimum
Heat Load, Weather	
Site weather history	
Average, peak, and low temperature	
External temperature fluctuations	
Facility site layout v. prevailing winds	
Personnel heat load	
Installed equipment heat load	
Portable equipment heat load	
Measurement Accuracy and Interaction Design Factors	
Critical calibration areas located away from outside walls (optical & dimensional measurements)	
HVAC Control Systems	
PID controls	
Sensor location	
Sensors removable for calibration	
Control system accepts new calibration constants for sensors	
Out-of-tolerance alarms	
Sensitivity and response time	
Accuracy and range	
Dust Particle Control and Air Locks	
Electronic air filters	
Mechanical air filters	
Shoe cleaner located near air lock	
Calibration/repair area positive pressure	
Differential pressure gauge installed to measure positive pressure	
Proper air lock design	
Air Supply Distribution	
Elimination of hot and cold spots (temperature gradient)	
Air changes per hour	
Airflow balance	

Table A2.3. Electrical Power.

Electrical Power Requirements Analysis
Voltage type
Amplitude and phase
Current
Receptacle style
Future expansion
Equipment location
Receptacle location and mounting height
Centralized power distribution
Type of power cables
Flexibility of power distribution
Cable length
Voltage Regulation and Conditioning
Degree of protection needed
Types:
Voltage regulators
Line conditioners
Uninterruptible power sources
Power line noises (transients, sags)
Emergency Electrical Power
Automatic operation
Clean on/off operation
Length of time to start
Length of emergency coverage required
Electrical Power Conduit
Flush, wall-mounted metal conduits
Third-wire ground
Emergency Electrical Power Switches
Central location
Each room
Lock-out feature
Leaves overhead lights on

Table A2.3. Continued.

Electrical Receptacles
Proper amperage
Proper style/type
Locations to shorten power cord runs and dangling cables
Identification plates
Sufficient receptacles to allow expansion or relocation of measurement systems
Explosive proof
Electrical Feeds
Separate for calibration/repair areas
Electrical Power Requirements (Load Voltages)
115/117 V(ac)
230 V(ac)
60 Hz
400 Hz
50 Hz
Single-phase
Three-phase
28 V(dc)
Main power panels and main electrical feeds
Panel internal access
Feeds marked
Emergency shutoff
Lock-out feature
Service amperage
Circuit breaker size
Main feed regulation
Main feed conditioning
Main feed conversion
Wall Penetrations
Finished
Sealed
Antenna Ports
Location
Sealed and finished ports

Table A2.4. Electromagnetic Interference.

External EMI/RFI Input
Grounding Cable Layout
Grid Isolated
Laboratory Interference Suppression
Shielded Lighting Fixtures
Power Line Filters
Utility Room Shielding

Table A2.5. Lighting.

Calibration/Repair Area
Type of lighting fixture
Light level [1076 lux (100 footcandle) minimum]
Interference suppression
Separate electrical feeds for lights
Supplemental
Interference suppression
Heat suppression
Emergency
Location
Flush wall-mounted
Light Fixtures and Switching
4-bulb, 0.6 by 1.2 meter (2 by 4 foot), lay-in fluorescent panels

Table A2.6. Fire Protection.

Item:	*Complies with:*
Egress	NFPA 101, *The Life Safety Code*
Manual fire evacuation system	NFPA 72, *National Fire Alarm Code*
Sprinkler system	NFPA 13, *Sprinkler Systems*

Table A2.7. PMEL Support Areas.

Receiving, Customer Service, Cleaning Room, Equipment Storage
HVAC air supply zone separate from calibration/repair area
Computer network
Intercom
Telephones
FAX
Door bell
Exit door
Service entry; drive-through, roll-up doors
Cleaning Rooms
Drying oven
Equipment washer
Utility sink
Power
Compressed air
Water
Ventilation and exhaust
Work bench
Safety equipment
Waste containers
Storage
Vacuum

Table A2.8. Modular Pre-Fabricated Laboratories.

Analysis to determine economic use
Site survey
Environmental specifications
Volume of work justifies expense
Electrical requirements
Availability of utility hook-ups
Size required