FACILITY REQUIREMENTS FOR NAVY AND MARINE CORPS CALIBRATION LABORATORIES

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FOREWORD

The requirements set forth in this document will be used to determine the adequacy of calibration facilities. When a facility is determined to be inadequate and upgrading or new construction is required but funding is not available, a waiver shall be requested from the responsible Systems Command (SYSCOM)/Sponsor until funding is available. The criteria herein will apply to all new construction, reconstruction, refurbishment, alteration, modification, and repairs of existing facilities.

Reference to the quality or suitability of any commercial test equipment herein is applicable only to its use in the Metrology and Calibration (METCAL) program and does not reflect on the suitability of the equipment for use elsewhere. Items of commercial equipment described in this document are cited as examples of instruments known to be available in Navy laboratories**.** There is no intentional implication of superiority of these instruments over those of other manufacturers. The information contained herein is intended solely for utilization in the United States Navy and Marine Corps METCAL programs.

This document will be revised, amended, and updated as required. Corrections or comments concerning this document are invited and should be addressed to:

Naval Surface Warfare Center, Corona
Measurement Science Directorate
Metrology Technology Division (MS30)
P.O. Box 5000
Corona, CA 92878-5000

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1 INTRODUCTION

1.1 Scope

1.1.1 This document prescribes environmental conditions that must be met within Navy and Marine Corps calibration laboratories to perform accurate measurements in accordance with OPNAVINST 3960.16. It also provides recommendations that serve as guidelines to the design, construction, and operation of calibration laboratories.

1.1.2 The environmental conditions outlined in this document are not applicable when performing on-site calibrations. Specific guidance with regards to environmental requirements or correction factors necessary to perform accurate on-site calibrations is given in the approved Navy calibration procedure and takes precedence over the requirements prescribed in this document.

1.1.3 This document does not prescribe environmental conditions for the Radiation Detection, Indication, and Computation (RADIAC) Program. In accordance with NAVSEAINST 4734.1A, the technical policy and facility requirements for RADIAC Program equipment are contained in NAVSEA SE700-AA-MAN-100/RADIAC.

1.2 Purpose

1.2.1 Previous facility requirements documents were written around a rigid hierarchical structure without regards to the specific mission of each laboratory and the level of uncertainty required in the measurements. The purpose of this document is to establish technical requirements for all Navy and Marine Corps calibration facilities. The requirements listed in this document are known to be conditions under which the environment will not have an appreciable effect upon calibration accuracy. However, due to the interaction between environment and precision measurements, it is almost impossible to state conditions that are suitable for every possible calibration without seriously exceeding practical constraints. Therefore, where possible, this document states differing levels of control required based upon the measurement and level of accuracy required.

1.2.2 In order to ensure the successful transfer of accuracy from calibration standard to test instrument this document is intended primarily as a quality assurance document for the audit of operational facilities. It should also be used during the design and construction of new facilities, or in the renovation of existing facilities. However, many of the essential details necessary for the design and construction of a complete facility are not provided. Additional facility design criteria is prescribed in various design manuals and should be consulted. Special precautions, equipment and facilities may be required to protect the health and safety of personnel or the integrity of calibration standards and equipment from hazards or unusual conditions which may be encountered.

1.3 Responsibilities

The Naval Surface Warfare Center (NSWC), Corona is responsible for designating and revising requirements for Navy and Marine Corps Calibration Laboratories in accordance with OPNAVINST 3960.16, NAVAIRINST 13640.1, NAVSEAINST 4734.1, MCO 4733.1, and SSPINST 4355.8. The responsible Systems Command/Sponsor should periodically review the applicable facilities under his cognizance for adherence to the requirements specified herein. The appropriate SYSCOM approval must be obtained prior to performing measurements outside of the requirements set forth in this document.

1.4 Safety

The safety of personnel is of the highest priority at all times. Throughout this manual, references are made to various documents that contain safety information concerning special hazards. This information is provided for the purpose of highlighting potential problem areas but is not intended to supplant or replace essential safety information, instructions, or procedures contained in OPNAVINST 5100.23. Safety considerations applicable to the design and construction of new facilities are provided in OPNAVINST 5100.24.

1.5 How To Use This Document

1.5.1 This document contains both requirements on environmental conditions, which must be maintained by operational labs and general discussion on laboratory design that is meant to be helpful for meeting these requirements. The document also identifies environmental conditions that are considered to be best practices for operational labs and design goals for new or refurbished labs. The following paragraphs will provide the user with a brief overview of the sections contained within as well as a guide on how to use the document to determine calibration facility requirements.

1.5.2 Section 2 contains discussion and recommended practices related to laboratory design for new or refurbished labs. Operational labs may also find the information in Section 2 useful, but it must be pointed out that satisfactory calibrations can be performed outside of the recommendations contained in this section, as long as the appropriate safety and equipment environmental requirements are met. Many of the recommendations in Section 2 are also listed in the sections covering specific measurement areas as requirements that must be maintained by operational labs.

1.5.3 Section 3 covers general environmental requirements for both calibration and non-calibration areas that need to be maintained by operational labs to avoid the necessity to make corrections for temperature deviations and/or other special considerations. This section also contains recommended best practices with regards to vibration and particle contamination proven to be satisfactory for performing the required measurements. These recommended best practices are provided primarily as a trouble-shooting tool to solve accuracy and repeatability problems within a particular measurement area if there are no specific requirements given in Section 4.

1.5.4 Section 4 covers environmental requirements that must be maintained for specific calibration areas. Section 4.2 covers the electrical/electronic calibration areas; Section 4.3 covers physical/mechanical; Section 4.4 covers dimensional/optical; and Section 4.5 covers electro-optical. Each of these sections is further broken down into specific measurement areas. At the top of each subsection is a table of specific environmental requirements for that measurement area. Some areas will have one set of requirements for all calibrations, while others will have multiple levels of control based on the accuracy of the required measurement. In each table, the leftmost column lists differing levels of measurement accuracy that are required within the specific measurement area. The second and third columns detail the temperature and humidity limits necessary to achieve the required measurement accuracy. The fourth and fifth columns detail the airborne particles and vibration limits that are applicable to a particular measurement. Some tables do not specify particle counts and vibration limits, since these particular parameters do not always have a direct influence on measurement accuracy.

1.5.4.1 It is important to state here that the first column represents the accuracy that satisfies the test accuracy ratio requirement for the test instrument uncertainty, not necessarily the standard's stated accuracy. For example, if gage blocks with an uncertainty of less than 4 microinches (µin) + 1 µin per inch of length are used to calibrate an electronic height gage with a range of 0.001 in and an uncertainty of 20 µin, then temperature limits of 68 ±1 °F would apply. However, if those same gage blocks were used to calibrate a 0-1 inch micrometer with an uncertainty of 1000 µin, then 68 ±8 °F would be acceptable.

1.5.4.2 Notes listed under a matrix represent additional requirements that must be met for particular types of equipment in use. Some sections may also contain a subsection titled *Discussion*. This subsection is meant to provide recommendations for effectively meeting the stated environmental conditions. It also provides other factors that must be considered during laboratory design.

1.5.5 Finally, the distinction must be made between the environmental requirements of calibration standards versus test instruments. Standards, being higher in accuracy than the instruments they calibrate, are usually more sensitive to environment. Occasionally however, the test instrument may be more sensitive to one or more environmental conditions than the standards due to less sophisticated design. Likewise, some models within a parametric category of standards (such as oscilloscopes, temperature indicators, etc.) may have different environmental requirements. It is impossible to list the requirements of every possible combination of standard and test instrument in this type of document. Therefore, the requirements in this document have been written around the most sensitive of the standards models common in Navy inventory.

1.5.6 Section 5 contains discussion related to environmental quality control requirements. Three facility operational situations are identified for monitoring and evaluating the effectiveness of services provided to and supporting the Fleet. A table is provided that summarizes these three operational situations and the environmental parameters that must be reviewed during each.

1.5.7 Appendix A lists several documents useful for the design and/or operation of a calibration facility. Included are commercial and military documents related to environmental effects upon

calibration and measurement; documents which are not directly written toward calibration facilities, but contain information useful for meeting calibration facility requirements; and policy/regulatory documents related to the Navy and Marine Corps METCAL program. The basic document number is provided in all cases, however the latest applicable revision or superceding document shall be used. Some of the documents listed in Appendix A are not specifically referenced in the body of this document but are included due to the potential usefulness of their subject matter.

1.5.8 Appendixes B and C contain requirements that are unique to shipboard laboratories and mobile facilities, respectively. The general requirements in Sections 2 and 3 apply unless changed or modified by the requirements set forth in the applicable appendix.

2 GENERAL LABORATORY DESIGN REQUIREMENTS

2.1 Introduction

This section includes items which may not directly affect measurements, but which must be considered in the design and operation of any facility. These considerations represent ideals for calibration labs, and should be design objectives for new and renovated facilities. However, it should be realized that it may not be possible or cost-effective to meet all of these goals in some cases, and compromises may have to be made, as long as calibration accuracies are not adversely compromised. It is widely recognized that no general set of environmental conditions may be stated that will absolutely assure adequate levels of measurement accuracy and at the same time, avoid the risk of over design or under design of the calibration facility.

2.1.1 Site Location

The building site or physical location of the calibration facility shall be isolated from sources of:

a. Vibration such as those induced from railroad lines, heavy vehicle traffic, crane or machine operations, foot traffic, aircraft operations, or similar disturbances such that vibration levels in calibration laboratory areas may be maintained or controlled when required by the criteria set forth in Sections 2.7 and 3.2.3.
b. Electromagnetic radiation such as high-power electrical transmission lines or transmitting antennas such that electromagnetic interference in calibration laboratory areas may be maintained and controlled when required by the criteria set forth in Section 3.2.6.

2.1.2 Building

The building or buildings housing the calibration facility shall be adequate to ensure the following:

a. Isolation from weather or other harmful or disturbing effects or conditions so that facility environmental conditions may be maintained or controlled when required by the criteria set forth in Sections 3.2.1 and 3.3.1.
b. Isolation and segregation of incompatible calibration areas or equipment maintenance, materials handling, or other process as specified herein.
c. Controlled access, including protection from unauthorized entry, and security for maintaining classified equipment and documents in accordance with the requirements of OPNAVINST 5530.14 and 5530.15.
d. Protection from toxicological, radiological, mechanical, electrical, electromagnetic, pyrotechnic, visual, and other special hazards as specified herein.
e. Utilities and services as specified in Sections 2.3 through 2.10.

2.1.3 Facility Work Areas

For the purposes of this document, a Calibration Facility shall be considered as being divided into one or more of the areas listed in Table 2-1.

Table 2-1. Calibration Facility Areas

General Areas	Special Purpose or Hazardous Areas
Electrical/Electronic Calibration	Equipment Cleaning
Physical/Mechanical Calibration	Oxygen-Clean Calibration
Optical/Dimensional Calibration	Nuclear-Clean Calibration
Electro-Optical Calibration	Electrostatic Discharge (ESD) Protection
	Electromagnetic Interference (EMI) Protection
	Meter Calibration
	Liquid Flow Calibration
	Mercury Handling

NOTE

The above areas are designated for the purpose of defining facilities requirements and are not necessarily representative of the capabilities, organizational structure, or physical layout of any one facility. Activities not supporting workload in one or more of the above areas need not consider the facilities requirements for that area. In addition to the calibration areas above, there are other areas normally included in facilities such as: administrative offices, computer terminal rooms, shipping and receiving areas, equipment or material storage or non-calibration work areas such as lunch rooms, rest rooms, etc. These areas are subject to the requirements listed in Section 3.2.

2.2 Floor Area and Laboratory Layout

A generally accepted guideline for the amount of floor area required by a lab is 60 square feet (sq ft) for each technician. However, space requirements may often be dependent upon the area required by the test equipment or the calibration standard and measuring equipment or required workbenches rather than the number of personnel. Therefore, when planning a new facility, careful consideration should be given to all factors applicable to the calibration facility. For new construction or remodeling, a minimum of 1,000 sq ft of floor space shall be allocated to any of the general calibration laboratory areas described above for use by up to 10 calibration technicians. For more than 10 technicians, space shall be increased at the rate of at least 60 sq ft per technician. Space for special purpose areas shall be allocated as required. For larger facilities, dedicated spaces should be allocated for support areas, such as receiving, storage, staging and administrative areas.

NOTE

Floor space requirements for special purpose areas, if different from the above, are specified in Section 2.10.

2.2.1 Floor Loading

No calibration standard or equipment installation shall cause the floor loading capacity of the structure housing it to be exceeded.

2.2.2 Ceilings and Walls

Interior ceilings and walls shall be constructed of fire retardant construction materials. Interior surfaces shall be finished in flat or semi-gloss finish, light-colored paint, or wall covering materials.

2.2.3 Floor Covering

Special flooring shall be required under the following circumstances and can be either a temporary (floor mats) or permanent installation:

a. Conductive flooring of more than 25 kΩ but less than 1 MΩ, shall be required in enclosed areas where there is a potential for igniting explosive vapors, gases, or dusts by sparks from discharging an accumulation of static electricity.

WARNING

Due to the increased danger to personnel from electrical shocks, conductive flooring should not be utilized in the Electrical/Electronic calibration laboratory or other area where it may be possible for personnel to come in contact with sources of high voltage.

b. Static-dissipative flooring of more than 1 MΩ but less than 1,000 MΩ shall be required in areas where there is a high potential for damage to microelectronic circuits and components from discharging accumulated static electric charge. This shall include ESD protection area described in Section 2.10.4.

WARNING

Static-dissipative flooring should not be utilized in the Electrical /Electronic calibration laboratory or other area where it may be possible for personnel to come in contact with sources of high voltage unless safety measures prescribed in MIL-HDBK-454 are applied.

c. Dielectric flooring meeting the criteria specified in MIL-DTL-15562 shall be required in the Electrical/Electronic calibration laboratory or any area where electrically powered equipment is opened for repairs or adjustments. This shall include the Electro-Optical (EO) calibration area but shall exclude the ESD protection area.

WARNING

Dielectric flooring meeting the criteria of MIL-DTL-15562 is intended to provide protection to personnel from exposure to sources of voltage of 3,000 volts or less. Additional protection and special safety precautions are required when working on or near exposed voltage sources exceeding 3,000 volts.

d. Dielectric flooring is required to be maintained in good physical condition; free of signs of excessive wear, accumulation of dirt, to remain unwaxed, and not to be damaged or contain defects which could substantially degrade insulation characteristics. Questionable areas are required to be replaced or covered with new runner-type mats conforming to MIL-DTL-15562, Type II or III.
e. Dielectric flooring is required to be continuous with no uncovered seams within three feet of a workbench or potentially hazardous location. Seams must be fused with adhesive or by heat to be considered continuous.
f. If the electrical properties of installed flooring cannot be determined, temporary mats with known electrical properties must be installed.

CAUTION

Dielectric tests of in-service flooring may be dangerous and could be destructive to flooring. Requirements for floor coverings may be satisfied by a visual inspection or by suitable evidence that floor coverings met or exceeded the requirements at the time of procurement and installation.

2.2.4 Laboratory Layout

2.2.4.1 It is good practice to separate calibration areas based upon different environmental requirements. Usually, this means having separate rooms for Electrical/Electronic, Physical/Mechanical, and Dimensional/Optical laboratory areas. Facilities servicing large amounts of workload or highly accurate workload will benefit from separate rooms for certain individual measurement areas, such as separate rooms for mass calibration and temperature calibration. Separate rooms are also needed for special purpose areas, such as EO calibration, instrument cleaning, oxygen-clean calibration, or mercury handling areas.

2.2.4.2 However, since it is not always possible to provide separate rooms for the distinct laboratory areas, compromises will have to be made. In particular, due to the 68 °F reference temperature for dimensional standards, and the 73 °F reference temperature for most other measurement areas, it may not be possible to perform accurate calibrations in both areas simultaneously. In these situations, careful workload management can lessen the impact of incompatible environments by scheduling calibrations that require a controlled 68 °F or 73 °F environment at different times. If the lab space contains high power equipment or equipment that produces a large heat load, that equipment should be located well away from the temperature sensitive areas and away from thermostats or sensors which control the heating, ventilation and air conditioning (HVAC) system. In addition, the ambient temperature and relative humidity must be monitored in each calibration area.

2.2.4.3 If there is more than one compartment within a calibration area, ambient temperature and relative humidity must be monitored within each compartment. If a large space with no distinct compartments acts as a calibration area, the quality assurance supervisor shall determine the appropriate placement of the ambient temperature and relative humidity devices used to monitor environmental conditions.

2.3 Electrical Power

2.3.1 Basic Electrical Service

2.3.1.1 All electrical service must meet the National Electrical Code, National Fire Protection Association (NFPA) Standard No. 70. All electrical power outlets, connectors, or receptacles in calibration areas shall be tagged or labeled to provide a technical description of the type of power source (voltage, frequency, power rating, and phase) or connection scheme as applicable. All electrical outlets shall be subject to special safety requirements as related to the laboratory workload where applicable.

2.3.1.2 Basic laboratory electrical service shall consist of a 480 V, 3-phase, 60 Hz supply installed and connected in accordance with the requirements of NFPA 70. Refer to MIL-HDBK-1028 and MIL-HDBK-1004/4 for further details. The following stepped down or converted sources of electrical power shall be required with respect to the calibration facility workload:

Phase	Frequency	Voltage
1	60 Hz	120/220 ± 5%
3	60 Hz	120/208 ± 5%
1	400 Hz	120/220 ± 5%
3	400 Hz	115/200 ± 5%
dc		28 ± 1 Volt

NOTE

If the test equipment and calibration standards are labeled as 50/60 Hz then 50 Hz power is authorized for use as required at overseas installations. However, in no case should 60 Hz (only) test equipment be calibrated at 50 Hz.

2.3.2 Voltage Regulation

Most measurement equipment used in calibration facilities will operate satisfactorily with voltage and frequency fluctuations of up to ± 5%. However, it is recommended that electrical feeds used to supply power to calibration equipment be isolated from those that provide power to other large current drain facility equipment. If it is known in advance that interference between loads on the same AC line; high speed AC line transients; and utility line harmonic distortion are a problem, the laboratory shall install AC line conditioners; isolation transformers; AC line filters; motor generators; or uninterruptable power supplies as applicable to provide the appropriate level of power and protection to the equipment. When necessary, portable equipment may be used to supply power to calibration equipment.

2.3.3 Power Distribution

The minimum requirements for power distribution is that safe and appropriate sources of power are available to the calibration technician, either as part of a workbench/workstation distribution system or

in the immediate proximity thereof for the purpose of supplying power to the calibration standards and workload items assigned to the area. This shall include installation, connection, outlets, overload protection, and emergency shut-off provisions required by NFPA 70 and MIL-STD-1310.

2.3.4 Grounding and Shielding

2.3.4.1 Electrical grounding shall be divided into two categories; the connecting of an electrical system to ground for electrical operating reasons, and the connecting of non-current carrying metal parts of equipment to ground for safety of personnel as follows:

a. Electrical systems shall be connected having a grounded-neutral conductor in accordance with the requirements of NFPA 70. A common point of connection to this ground shall be required in all calibration and special purpose areas. The DC resistance between the common point of connection and earth ground shall not exceed 3 ohms when measured in accordance with the requirements of MIL-STD-188-124 and MIL-HDBK-419.
b. Electrical conductor housings, equipment enclosures, and motor frames installed or utilized shall be interconnected by an equipment grounding system which will satisfy the requirements of NFPA 70. Safety grounds shall be re-verified on an annual basis or immediately following any repair or replacement of permanently installed electrical equipment or facility wiring.

2.3.4.2 To minimize electrical interference, all wiring should be installed in metal conduit. Unless the facility is located close to large sources of EMI such as high voltage power lines or radio transmission towers, adequate shielding can usually be achieved through simple means. For example, the shielding inherently provided by the facility structure, itself, can be used to isolate electromagnetic radiation (EMR) generating equipment from potentially susceptible devices and personnel. If necessary, auxiliary equipment rooms can be shielded by using grounded metal clad wallboard or fine copper mesh on the walls and ceiling. Additional shielding may be required in multi-floored facilities. Some very sensitive equipment may require the use of specially constructed screen rooms. Refer to MIL-HDBK-419 for screen room requirements and selection of shielding materials. MIL-STD-188-124 also discusses shielding requirements.

2.3.4.3 Although shielding is an important technique for reducing EMI effects, it is not the only technique available for this purpose. Application of shielding techniques should not be made without due regard to the roles which filtering, grounding, and bonding play in the interference suppression program.

2.4 Lighting

2.4.1 Lighting should be designed to provide comfortable light levels appropriate to the tasks being performed. Light fixtures shall be of a permanent type, consisting of overhead mounted fluorescent fixtures meeting the requirements of ANSI C78.2. Light fixtures shall be electro-magnetically shielded and filtered meeting the requirements of MIL-STD-461 for class A3 equipment, requirement RE101. Light fixtures shall be arranged in a manner to provide balanced lighting to minimize shadows, glare and spectral reflection, and to produce nominally uniform illumination. The overall requirement for light level in laboratory areas is 75 foot candles (ft-c) minimum, with a recommendation of a 100 ft-c at the

benchtop. Exceptions for this requirement apply in areas where computers or terminals are widely used (which generally need lower light levels), and where equipment is being repaired or fine detail work is performed (which generally need higher light levels.) Supplemental lighting (such as a desk lamp) may be used in areas where higher light levels are needed, but should not be used to achieve the overall light level of 75 ft-c minimum. In any case, overhead lighting should be distributed such that shadows are avoided in work areas. Refer to MIL-HDBK-1190 and MIL-STD-1472 for more information on lighting requirements.

2.4.2 EO calibration areas require lighting that is adjustable from 0 to 100 ft-c. In areas with a high sensitivity to temperature gradients, such as gage block calibration, care should be taken to avoid high heat loads and temperature gradients that could be caused by excessively high light levels.

2.5 Heating, Ventilation and Air Conditioning (HVAC)

2.5.1 The primary parameter, which must be controlled using the HVAC systems, is temperature. Measurement system accuracy is dependent upon the ambient temperature of the environment. Therefore, a good HVAC system is the most crucial element of calibration laboratory design. The system must not only regulate the nominal temperature, but must also keep temperature fluctuations within an acceptable limit. Special attention must be paid to the placement of HVAC control sensors and heat sources within the lab. Sensors should ideally be located close to critical work areas, but must be far enough away form heat sources, such as high power equipment, to prevent false readings. The air supply and return ducts should be designed to eliminate temperature gradients and areas of stagnant airflow.

2.5.2 The HVAC system also controls humidity and airborne particle counts. Humidity below 20% relative humidity (RH) can result in static buildup, which is hazardous to sensitive electronics, while humidity above 90 to 95%, can create condensation. In the presence of falling temperatures, or when equipment is moved from cooler to warmer areas, condensation can occur at much lower ambient humidity levels. To protect electronics from static discharge and condensation, humidity limits of 20 to 60% RH are listed for most areas. However, humidity above 50% RH can also cause rusting of steel and iron items, such as gage blocks and other dimensional standards. Therefore, limits of 20 to 45% RH are listed in areas where such standards are used. Refer to MIL-HDBK-1003/3 for HVAC humidification requirements for naval shore facilities.

2.5.3 Specific temperature, humidity, and particle limits are listed in the requirements section for each measurement area. However, beyond the effect on measurement equipment, the HVAC system also provides personnel comfort and therefore affects productivity. Even in calibration areas where the equipment is insensitive to temperature fluctuations comfort is achieved through having an adequate flow of conditioned air through the room. A generally accepted guideline is to provide between 5 and 20 room air changes per hour. MIL-HDBK-1003/3 recommends that the HVAC system be designed for 8 to 12 air changes per hour with a minimum supply airflow of 4 air changes per hour. Keep in mind that the location, type and size of the air supply and return air ducts not only affect room temperature gradients but also the number of air changes per hour. There are also several factors that influence the

requirements for fresh air such as the contaminants and odors to be controlled, room volume, number of people in the room, and the amount of foot traffic in the room. These factors should be considered when determining actual ventilation requirements. MIL-HDBK-1003/3 and ANSI/ASHRAE 62-1989 recommend 20 cubic feet per minute (CFM) of outdoor air per occupant for offices. A Navy Industrial Hygienist should be contacted for guidance when determining HVAC requirements within the laboratory. Other references include NEHC-TM91-2, OPNAVINST 5100.23, ANSI/AIHA Z9.5-1992, ACGIH Industrial Ventilation Manual, and the ASHRAE HVAC Handbook.

2.5.4 Some measurement equipment is more sensitive to drafts or temperature changes, than to the actual temperature. For example, force calibrations using proving rings take a long period of time. If the ambient temperature is not 73 °F, then corrections can be made, but the actual temperature must remain stable during the entire calibration in order for the corrections to be accurate. Pressure calibration using deadweight testers, and micro-volt measurements are two examples of measurements that are sensitive to strong air currents. Measurement areas with special environmental sensitivities such as these are noted below each matrix.

2.5.5 In some areas with tight temperature tolerances, the thermal mass of the standards and test instruments may allow for widening the tolerances if the temperature oscillations are rapid enough to attenuate the thermal effects of the ambient air. However, in optical calibration areas using autocollimators, and when using laser interferometers to measure distance, the standard is actually a beam of light with no thermal mass at all. In these areas, even slight air temperature fluctuations can reduce repeatability and accuracy, and rapid temperature oscillations must be avoided.

2.6 Particle Control

2.6.1 Clean room requirements are generally not necessary in most laboratories, however good housekeeping considerations should be maintained. Excessive airborne dust can contaminate mercury used in mercury manometers, and other fluids used in pressure, temperature, and flow calibration. It can create measurement errors during calibrations in these areas as well as during dimensional, optical, and dead-weight gage calibrations. It also accelerates corrosion in humid environments.

2.6.2 In general, airborne particles throughout the laboratory should be limited to less than 2.4×10^{10} particles per cubic meter, for particles over 0.5 micron (µm) in size, expressed in the requirements tables by "$<2.4 \times 10^{10}$ /m³ (>0.5 µm)." This requirement is based on an average dust concentration value normally expected in metropolitan areas. Some areas require more stringent particle control and the requirements tables for these areas list the allowable count of particles in two sizes: over 0.5 µm and over 1.0 µm. For these measurement areas, the quantitative values for particle count are based on the recommended allowable particles for standards laboratories as defined in ISA-RP52.1. In all areas, particles over 50 µm shall be filtered completely. This requirement can be assured by visual cleanliness of the area. Smoking and eating shall not be permitted in areas designated for particle control.

2.6.3 The HVAC system is the primary means of controlling airborne particles, or dust. This is done by the use of filters. The types of filters required will depend on local conditions and on the allowable

particulate limits. The HVAC system should provide a slight positive pressure of 0.05 inches of water (in. H_2O) to aid particle control by preventing the intrusion of dust and unconditioned air into calibration areas. However, in some areas other factors may preclude the use of positive pressure. For example, sensitive low-pressure calibrations may be affected by changes in room pressure. And in liquid flow and solvent-cleaning areas, a slight negative pressure is required to contain vapors. The mission of the laboratory as well as other facility constraints must also be considered when designing for particle control.

2.6.4 Particle control can also benefit from the proper selection of fixtures and building materials. To eliminate spots for dust to accumulate, flush mounted lighting and electrical fixtures should be used wherever possible. Surface mounted electrical raceways should be avoided.

2.7 Vibration

2.7.1 The maximum allowable level of vibration is a velocity of 0.032 in/sec (rms) and acceleration of 0.046 g (peak) between 8 and 100 Hz. This dual recommendation takes into consideration the most significant parameter within this frequency range. This control is based on floor vibration levels normally tolerated in workshop-type environments as defined by the International Standards Organization (ISO). However, in calibration areas such as Dimensional, Optical, Pressure-Vacuum, Acceleration, Force, and Mass where high accuracy vibration-sensitive measurements are made tighter control limits are necessary. In these areas, the maximum acceptable condition for vibration is a displacement of less than 10 µin (25 µm) between 2 and 30 Hz and an acceleration of less than 0.001 g between 30 and 200 Hz. Refer to the ASME Mechanical Engineering Article “Designing Sensitive Equipment and Facilities” and ISA RP-52.1, respectively.

2.7.2 Like acoustic noise, vibration can impede worker performance by creating an uncomfortable work environment. The threshold of vibration perception for most humans is approximately 0.007 in/sec at frequencies below 100 Hz. New facilities shall take reasonable measures to provide this level of isolation from vibration.

2.7.3 Preventing excessive vibration depends as much on site selection as on actual laboratory design. This is because ground vibration is usually created by sources outside of the facility, such as highways, railways, and runways. Vibration from facility mechanical equipment can be reduced or eliminated by installing pumps, compressors, and HVAC systems on isolated pads or other reduction techniques. Some measurement areas including mass, dimensional/optical and electro-optical calibration require tighter vibration control. If it is not practical to provide this degree of isolation for the entire facility, then isolate the sensitive equipment through mounting on air bearings or on massive, isolated blocks. Refer to ARMY TM 5-805-4, which supercedes NAVFAC DM-3.10, for information on vibration control and isolation techniques.

2.7.4 When measuring vibration or specifying vibration limits keep in mind that the relationship between displacement, velocity and acceleration varies with frequency. Equipment sensitive to low frequency vibration is usually sensitive to displacement. An example of this is interferometers or optical

flats, where one fringe representing 10.7 µin can be completely washed out by a displacement as small as 6 µin. A displacement of 6 µin at 12 Hz represents a vibration level of 4.4×10^{-4} g. Other equipment may be more sensitive to velocity or acceleration levels at higher frequencies.

2.8 Acoustic Noise

2.8.1 The maximum noise exposure limit as specified in OPNAVINST 5100.23 is 84 dB(A) for 8 hours in a 24-hour period. Higher levels can be tolerated for shorter periods as long as the time-weighted average for the 8-hour workday remains below 84 dB(A). Although acoustic noise has little, if any, direct effect upon most measurements, it can greatly affect technician performance. OPNAVINST 5100.23 (Chapter 18), OPNAVINST 5100.19 (Chapter 4) and NAVMEDCOMINST 6260.5 all limit exposure to noise. Noise levels higher than 84 dB(A) can cause hearing damage. In areas where calibration standards and equipment produce high sound levels, such as in vibration and flow calibration areas, hearing protection is mandatory. Whenever potentially harmful conditions exist, refer all questions to the command industrial safety office.

2.8.2 Noise can impede the efficiency and productivity of workers at levels far below 84 dB(A). The degree of impediment is difficult to quantify, but depends upon the level of concentration and attention required to perform a task. Calibration labs shall limit background noise from continuously operating equipment to 55 dB(A). Reduction of noise caused by mechanical equipment such as pumps, compressors, and HVAC systems can often be achieved through careful layout of the facility. Reducing the noise from these sources can be further reduced by using isolation mountings and couplings and through the use of sound absorptive wall and ceiling materials.

2.9 Furnishings and Other Utilities

2.9.1 Workbenches

Workbenches shall be the standard Navy electronic workbench, type NEB-2 as described in NAVAIR engineering drawing package (DWG) 63A114 or shall be required to incorporate the important essential features of the NEB-2 as follows:

a. Workbench surfaces shall be required to have a working height of 36 inches, nominally, above the floor in accordance with the criteria specified in MIL-STD-1472, and shall provide a minimum of 6 lineal feet of workspace.

NOTE

Deviations to the workbench working height may be allowed to locate equipment at proper working levels.

b. Workbenches utilized in the Electrical/Electronic Laboratory or related areas, shall provide a 120 V, 60 Hz power distribution system which provides for a minimum of one 120 V, 15 A, 60 Hz, duplex outlet for every 2 lineal feet of workbench length. The workbench power distribution system shall incorporate a grounded neutral service and a safety ground wired in

accordance with National Electrical Code specifications. Any other electrical power outlets, receptacles or distribution system incorporated into a workbench shall be installed to NFPA 70 Standards and shall have a common ground with all other power sources available on the bench. Refer to NAVAIR 01-1A-512 for further guidance.

c. Workbenches, upon which electrically powered equipment is opened for repairs or adjustment, shall be constructed of or covered with non-conductive material. Alternatively, the workbenches shall be insulated and grounded through current limiting resistance or impedance to provide protection from electrical shock in accordance with the criteria for an ESD control program as specified in MIL-HDBK-263.
d. All workbenches in a single laboratory or area shall be electrically bonded together and connected to the facility ground at a common point. Workbenches shall not be connected to ground in series with one another. As a minimum, workbench bonding and grounds shall be checked on an annual basis.
e. Workbenches used in the Physical/Mechanical calibration laboratory or any area where oils or chemical are commonly used, shall require tops that are resistant to the absorption of these materials.

NOTE

Additional requirements may be necessary for overseas installations. Other workbench requirements are discussed in the Special Use Area requirements in Section 2.10 and should be considered during laboratory design.

2.9.2 Safety Screens

Safety screens or shields should be used in the immediate vicinity of force calibration equipment such as the Morehouse Universal Force Calibrating Machine for the purpose of protecting operators and other laboratory personnel from the possibility of flying projectiles or objects. The drawings MET D-508, MET D-511, and MET D-541 are maintained by NSWC Corona, Measurement Technology Division, Physical & Mechanical (MS 33) and are examples of the safety screens.

2.9.3 Shorebased Gravity Benchmark

A gravity benchmark shall be required in accordance with the specifications of Engineering Report ER-03 in facilities when weights or fluid columns are used to produce or measure calibration pressures exceeding ±0.1% accuracy, and where dead weight force machines are used in force calibrations. For less accurate needs, the local gravity can be estimated using the latitude and altitude of the lab, by the following equation:

$$g_L = 980.619 - 2.586 \cos(2\theta) - 0.003 \cos(4\theta) - 0.000094\ h$$

where g_L is local gravity in cm/s², q is the latitude in degrees, and h is the altitude in feet.

2.9.4 Fume Hoods

2.9.4.1 Fume hoods are required to remove noxious, toxic, or corrosive fumes and vapors from laboratory spaces. Separate, non-recirculating, slot-type exhaust systems as specified in MIL-HDBK-1003/17 shall be installed. Exhausted fumes must be ducted directly to outside spaces. The ducting should be capable of exhausting 100 CFM of air with less than 0.5 in. H_2O pressure drop. Typical areas that require the use of fume hoods include mercury handling areas, equipment washing and cleaning areas where toxic solvents are used, and in the temperature measurement area over temperature baths and furnaces.

2.9.4.2 A Navy Industrial Hygienist should be contacted for guidance and approval prior to installation of an exhaust ventilation system, or modification of existing systems. A routine performance test shall be conducted on each fume hood at least annually or whenever a significant change has been made to the operational characteristics of the system. Refer to 29 CFR 1910.1000 for exposure limits for airborne contaminants. General guidelines on types of hoods and their application are presented in the ACGIH Industrial Ventilation Manual. Other applicable references include ANSI Z9.2-1979 and ANSI/AIHA Z9.5-1992.

2.9.5 Other Considerations

Vibration calibration rooms with high power shakers may require air-cooling or water-cooling provisions for the shaker. Flow areas may require chilled and heated water, plus large volumes of compressed air. Dimensional/Optical calibration rooms with surface plates supported on air bearings also require compressed air service. Labs with a large amount of pressure workload will benefit from having a nitrogen supply hard-plumbed into the facility. This is usually done by installing a manifold for several nitrogen bottles in a service or storage room, with a high-pressure line running into the pressure calibration area. Nitrogen used for calibration purposes shall conform to MIL-PRF-27401D, Type 1, Grade A or B.

2.10 Special Use Areas

Requirements for specialized areas needed to ensure isolation of materials or processes that are potentially hazardous to personnel or incompatible with other calibrations or processes are specified in this section. When planning a new facility or remodeling, consideration shall be given to the layout of special use areas in order to limit transportation of potentially hazardous materials through the main calibration area.

NOTE

Unless otherwise stated, requirements in this section are intended to be additions or exceptions to the more general requirements provided in preceding sections.

2.10.1 Equipment Cleaning and Washing Area

2.10.1.1 In activities where the workload requires an equipment cleaning facility, a specially equipped and isolated area shall be required for solution cleaning and washing of mechanical, electrical and electronic workload items. Cleaning requirements for special purpose equipment are specified in MIL-STD-767. Routine washing of electrical and electronic test equipment is not recommended. However, air filter servicing and moderate cleaning should be a part of all calibration programs. Additionally, the cleaning of external surfaces does have a positive effect on the overall calibration effort.

CAUTION

Refer to TN 76-2 for specific information on approved cleaning methods for routine and extensive cleaning of electrical and electronic test equipment.

2.10.1.2 Minimum requirements for the equipment cleaning and washing area, as herein referred, are as follows:

a. This area shall be located externally to any environmentally controlled calibration laboratory.
b. This area shall require utilities and services equivalent to the following:

Utility or Service	Description
Power	120 volt, single phase, 60 Hz, 360 W (1480 W additional for drying oven)
Compressed Air	50 to 200 lb/in²
Water	Fresh water supply and drain
Exhaust Vent	Outside vent with 4-5 in. duct

2.10.1.3 Where extensive cleaning is required as defined in TN 76-2, the following additional requirements must be met:

a. This area shall require a minimum of one San-Del Model 16 Cleaning Unit (NSN 4940-00-422-1774) or equivalent and a minimum of one San-Del Model 46 Drying Oven (NSN 443-01-009-2371) or equivalent shall also be required.
b. Each cleaning unit shall require a minimum of 15 sq ft of floor space and each drying oven shall require a minimum of 10 sq ft of additional floor space.

2.10.2 Oxygen-Clean Calibration Area

2.10.2.1 With respect to the calibration facility workload and as authorized, a specially equipped and isolated area shall be required for cleaning, repair or calibration of instruments removed from, or intended for service in oxygen systems. This area shall require adherence to NAVSEA ST700-AM-GYD-020/OICR or NAVAIRINST 13640.1, as applicable.

WARNING

The scope of this document is limited to requirements for facilities. The safe processing, repair and calibration of oxygen-related instruments requires a complete program involving specialized knowledge, skills, equipment, accessories, materials, and workload control, as well as specialized facilities. Refer to NAVSEA ST700-AM-GYD-020/OICR, MIL-STD-1330, or EC-21, as applicable for specific instruction on cleaning, handling, and packaging of oxygen instruments.

2.10.2.2 Facility requirements for this area shall be in accordance with those specified for the general Physical/Mechanical calibration area with the following exceptions or additions:

a. This area shall require isolation from all sources of potential hydrocarbon contamination. This in part, shall require limiting access to the area to authorized personnel and prohibiting entry and storage of unrelated equipment items.
b. This area shall require at least one oxygen-clean workstation having a minimum work surface of nominally 3-by-6 ft. An oxygen-clean workstation is defined as a special purpose workbench or similar working enclosure which will provide air cleanliness levels that meet or exceed the requirements of Class 100,000 as defined in FED-STD-209.
c. This area shall provide the capability to clean closed-end systems, such as bourdon tube gages, with an approved cleaning solvent, and to detect through measurement, hydrocarbon contamination in the solvent to a level of 5 ppm or less.

CAUTION

Trichlorotrifluoroethane has been classified as an ozone depleting substance whose use is restricted. Refer to TN 88-1 for information on safe use of trichlorotrifluoroethane. Refer to the applicable Systems Command/Sponsor instructions for guidance on approved cleaning solvents and hydrocarbon contamination verification methods.

d. This area shall require a minimum of 40 sq ft of floor space for installation of each 3-by-6 ft oxygen-clean workstation, and proportionally more for larger workstations. In addition, the oxygen-clean calibration area may require at least one regular workbench.
e. This area shall require a source of clean, dry nitrogen gas conforming to MIL-PRF-27401D, Type 1, Grade A or B.

2.10.3 Nuclear Clean Calibration Area

With respect to the calibration facility workload and as authorized, a specially equipped and isolated area shall be required where cleaning, repair and calibration of instruments removed from, or intended for service in testing or monitoring mechanical systems aboard nuclear powered vessels is performed. Facility requirements for this area shall be in accordance with those specified in MIL-STD-767.

2.10.4 Electrostatic Discharge (ESD) Protection Area

A specially equipped area shall be required where repair and calibration of equipment containing electro-statically sensitive components as defined in MIL-STD-1686, is performed. This area shall adhere to the requirements for the Electrical/Electronic calibration laboratory with additional requirements as specified in MIL-HDBK-263. The ESD protection area may consist of a dedicated workbench or workstation within the Electrical/Electronic calibration laboratory and need not be located in a separate compartment. Alternatively, standardized protective areas can be implemented throughout all of the Electrical/Electronic calibration area to provide an equal level of protection. Refer to MIL-PRF-87893 for details on ESD control workstations.

2.10.5 Electromagnetic Interference (EMI) Protection Area

With respect to the calibration facility workload, a specially equipped and isolated area shall be required where repair and calibration of equipment having emission or susceptibility to EMI as defined in MIL-STD-461 is performed. The area shall require adherence to the general requirements for an Electrical/Electronic calibration laboratory. Whenever possible, EMI shielding shall be afforded through the use of small bench-top type enclosures since these are more economical than the larger shielded rooms and frequently more effective in achieving the desired attenuation of electromagnetic radiation. Screen rooms or shielded enclosures shall only be required in special cases, since experience has demonstrated that in most instances screen rooms are either not required or over-designed. For further details, see MIL-STD-461.

2.10.6 Meter Calibration Area

Meter calibration facilities have traditionally been established outside the boundaries of the Electrical/Electronic calibration laboratory for the repair and calibration support of electrical switchboard and panel meters. More recently the meter calibration facility has been combined with and brought into the Electrical/Electronic calibration laboratory. If the Meter calibration facility is located in the calibration laboratory proper, facility requirements shall adhere to that of the surrounding work areas not to exceed the range of 68 to 85 °F. If the Meter calibration facility is located separately or in a separate compartment, temperature in the compartment shall be maintained between 68 and 85 °F.

2.10.7 Liquid Flow Calibration Area

Facilities that use jet fuel or other flammable liquids in flow calibration areas are required to meet other requirements and regulations due to the flammability and explosive potential of the fuel vapors. For use of flammable or combustible liquids, the flow facility shall meet the safety requirements specified in NFPA 70 for explosive environments. Detailed provisions are found in NFPA 30. In particular, any sources of ignition and sparks must be eliminated. All motors, light fixtures, and equipment must be specifically designed for use in potentially explosive atmospheres. Electrical outlets must be at least 24 inches above floor level. The room air should be exhausted directly to outside spaces, at a rate sufficient to maintain a safe atmosphere inside the room. The HVAC system supplying air to the liquid flow room shall produce a negative pressure of approximately 0.05 in. H_2O inside the room, to help prevent intrusion of vapors into other laboratory areas.

WARNING

Before using flammable or combustible liquids in flow calibration areas or when designing a liquid flow area for new construction or renovation of existing facilities, local safety authorities must be consulted to assure compliance with all safety and health regulations.

2.10.8 Mercury Handling Area

With respect to the calibration facility workload and as authorized, a specially equipped and isolated area shall be required for cleaning or repair of instruments containing mercury or compounds of mercury. Special care and handling is necessary when operating standards and instruments containing functional mercury in areas outside of the mercury handling area. Refer to EC-25 for instructions and guidelines when using these items. Specific requirements for the control of mercury shall be as prescribed in NAVSEAINST 5100.3. The maximum exposure limit for mercury vapor as specified in 29 CFR 1910 is 0.05 mg/m^3 for 8 hours in a 24 hour period. Further requirements for mercury handling areas are as follows:

WARNING

The scope of this document is limited to requirements for facilities. Mercury is a highly toxic substance requiring specialized knowledge, skills, safety equipment, decontamination procedures and process controls, as well as specialized facilities to limit exposure to personnel during routine handling and storage. Refer to EC-25 for specific instructions on care, handling and cleaning of mercury.

a. This area shall require a minimum of one King Nutronics, Model 3642-1-3 mercury workbench, or the equivalent.
b. Each mercury workbench shall require a minimum of 40 sq ft of floor space.
c. This area shall have smooth floors, impervious to the loss of mercury through cracks.
d. This area shall require a non-recirculating type environmental control system (HVAC system). It shall be capable of from 5 to 10 complete room air changes per hour while maintaining the minimum environmental conditions as specified in Section 4.3.1, with the exception that temperature be maintained below 75 °F.
e. This area shall require a mercury vapor monitor having an audible alarm and capable of detecting a mercury vapor concentration of 0.01 milligrams or less per cubic meter in continuous operation.

3 ENVIRONMENTAL CONTROL REQUIREMENTS

3.1 Introduction

3.1.1 Environmental controls are applicable in calibration facilities when it is necessary to ensure the stability of calibration standards and equipment, to maintain a set of nominal and readily reproducible reference conditions, and to reduce the potential for errors caused by vibration, dust, noise, electromagnetic radiation, and similar disturbances.

3.1.2 The need to provide environmental controls in Navy and Marine Corps METCAL Program facilities depends on the measurement capabilities, equipment allocation, and calibration workload applicable to a particular activity. Facilities where the most sensitive calibration standards and equipment are maintained require special environmental controls. Other facilities are required to remain within acceptable limits of temperature, humidity, or other pertinent environmental requirements.

3.1.3 Therefore caution should be used when relying on environmental control requirements specifications for operating laboratories that are derived from criteria set forth in various standards documents such as ISA RP52.1 and NCSL RP-7. The criteria set forth in these documents is meant to provide guidance in the selection of laboratory environments suitable for standards maintenance and calibration operations but is not intended to mandate a specific environment for a specific calibration. Consequently, many of the environmental parameters discussed below are to be considered as general requirements to ensure the repeatability and accuracy of the measurement.

3.1.4 The environmental controls specified do not pertain to on-site calibrations. Special environmental conditions that must be considered during these calibrations should be noted in the approved Navy calibration procedure. Similarly, if a special environmental requirement is stated in the approved procedure, the laboratory environment should either be adjusted accordingly or corrections calculated and applied to ensure the accuracy of the measurement.

3.2 General Environmental Control Requirements

The purpose of this section is to define the general facility environmental conditions including non-calibration areas such as storage and administrative areas that are adjacent and open to the calibration areas. These conditions are summarized in Table 3.1. Equipment that requires calibration in a more stringent environment is specified in the applicable measurement areas, in Section 4. Equipment should be maintained under the prescribed environmental conditions for a sufficient period of time to ensure stability prior to calibration. This stabilization time will vary depending on the type of equipment, environmental changes, and accuracy requirements. Questions concerning the applicability of environmental controls to any item should be directed to NSWC Corona, Measurement Science Directorate (MS 30).

NOTE

Storage and administrative areas that are not adjacent and open to the calibration areas should also remain within the requirements listed in Sections 3.2.1 through 3.2.5 since these guidelines form the basis of good facilities engineering practices but they are not governed by this document.

Table 3-1. Summary of General Facility Environmental Conditions

Parameter	**Acceptable Range**
Temperature	60 - 85 °F
Humidity	20 - 60% RH
Airborne Particles	≤ 2.4 x 10^{10} /m³ for >0.5 µm
Vibration	≤ 0.032 in/s and <0.046 g for 8 - 100Hz
Background Noise	≤ 55 dB(A)
Illuminance	≥ 50 ft-c

3.2.1 Temperature and Humidity

The maximum acceptable conditions for temperature and relative humidity are from 60 to 85 °F and 20 to 60% RH respectively.

NOTE

The maximum acceptable conditions provided above have been established in order to maintain a maximum level of safety in all calibration areas. There are some instances when calibrations may need to be performed outside of the conditions listed. Any measurement process conducted outside of the prescribed parameters must be evaluated in order to identify potential safety hazards and possible damage to measurement standards. For example, static discharge becomes a potential problem when humidity drops below 20%. This may cause problems with some measurements and pose shock hazards when working with electronic equipment. Conversely, high humidity may accelerate corrosion and condensation can cause possible shorts. Therefore, appropriate SYSCOM approval must be obtained prior to performing measurements outside of the requirements set forth in this document.

3.2.2 Particle Contamination

Particle counts are generally referenced in terms of particles greater than 0.5 µm in size. The best known recommended practice for laboratory airborne particle counts is a contamination level not exceeding 2.4 x 10^{10} particles per cubic meter greater than 0.5 µm in size. Particles over 50 µm shall be filtered completely. Particle count control is not required for measurement accuracy unless mandated by the requirements set forth in the tables in Section 4. However, good housekeeping practices must be maintained to ensure that dust does not accumulate on or under benches, cabinets, equipment and instrumentation. Accumulation of waste material or scrap shall be avoided. The primary intent of this

requirement is to preclude the use or storage of calibration standards and equipment in heavily dust-laden areas.

NOTE

A value of 2.4 x 10^{10} particles per cubic meter is based on an average dust concentration value normally expected in metropolitan areas.

3.2.3 Vibration

3.2.3.1 The best known recommended practice for general vibration levels within the laboratory is a velocity of 0.032 in/sec (rms) between 8 and 100 Hz and an acceleration of less than 0.046 g (peak) between 8 and 100 Hz. Vibration control is not required for measurement accuracy unless mandated by the requirements set forth in the tables in Section 4.

3.2.3.2 The primary intent of this recommended practice is to preclude the performance of calibrations in areas routinely affected by impacts, shocks, or abnormally high vibration levels, which would adversely affect calibration results or degrade the long-term performance of equipment. There are several calibration areas where this requirement is unacceptable such as in the Dimensional, Optical, Pressure-Vacuum, Acceleration, Force, and Mass areas where high accuracy vibration-sensitive measurements are made. For these calibrations, the maximum acceptable condition for vibration is a displacement of less than 10 µin (25 µm) between 2 and 30 Hz and an acceleration of less than 0.001 g between 30 and 200 Hz.

NOTE

An RMS velocity of approximately 0.007 in/s (or the equivalent in displacement or acceleration units) represents the threshold of human perception between 8 and 100 Hz while approximately 0.032 in/s would represent a tolerable level for workshop-type environments over the same frequency range.

3.2.4 Acoustic Noise

3.2.4.1 The maximum acceptable condition for background acoustic noise is a sound level of 55 dB(A) or less. For the purposes of this requirement, background noise is defined as noise from permanently installed and continuously operating equipment.

3.2.4.2 The maximum acceptable exposure limit for hazardous noise is 84 dB(A) for 8 hours in a 24 hour period as specified in OPNAVINST 5100.23. Higher levels can be tolerated for shorter periods as long as the time-weighted average for the 8-hour workday remains below 84 dB(A). For the purposes of this requirement, hazardous noise is defined as any intermittent or temporary noise emanating from either inside or outside the facility.

WARNING

The scope of this document is primarily limited to requirements for facilities. OPNAVINST 5100.23 governs limits for personnel exposure to acoustic noise.

3.2.5 Illuminance

The minimum acceptable condition for illumination level is 75 ft-c at workbench level in all calibration areas. The minimum acceptable condition for illumination level in all non-calibration areas that are not adjacent and open to the calibration areas is 50 ft-c. Light should be evenly distributed to minimize glare, spectral reflection, and radiant heat to a degree that calibrations are nominally unaffected by any of these parameters.

3.2.6 Electromagnetic Shielding

An EMI survey should indicate a field strength of less than 100 µV/m in the calibration area. The primary requirement is that the presence of EMR, from sources either internal or external to the facility, must not be of such levels as to cause interference with measurements or cause erroneous calibration results. Where tests demonstrate the presence of excessive EMR or when an area of containment is needed to perform calibration on interference producing equipment, requirements for some special type of shielded enclosure are indicated. Shielded areas or enclosures shall be furnished in accordance with the requirements specified in Section 2.10.5.

3.3 Calibration Area Environmental Control Requirements

The purpose of this section is to define the minimum performance capabilities of the facility environmental control system not the acceptable measurement control limits. The requirements that follow apply to all calibration areas, and are in addition to the requirements listed above. Additional requirements are also listed for individual measurement areas in Section 4.

3.3.1 Temperature and Humidity

Facilities shall require environmental controls or an environmental control system (HVAC system) having automatic temperature and relative humidity control capabilities to meet the following minimum requirements:

a. Maintain a nominal temperature of 73 °F (23 °C) or 68 °F (20 °C) in designated areas.
b. Control temperature excursions to within the specified tolerance limits in Section 4.
c. Maintain a spatially uniform temperature, such that the deviation between any two points in the working volume of a laboratory does not exceed the specified value for stability or temperature tolerance limits in Section 4 or 4 °F/hour if no stability requirement is given. The working volume is defined as any point where measurements are conducted or sensitive equipment located, or within ±3 ft elevation from the workbench level.
d. Limit temperature oscillations to a maximum of 60 cycles per hour.

NOTE

Depending on the type of environmental control system and on its overall heating or cooling capacity, room temperature will typically oscillate between some high and low control limits in a nominally sinusoidal manner. Measurement standards and test instruments will attempt to come to equilibrium with the environmental temperature. However, the net effect tends to be lower in amplitude and out of phase with changes in the environment because of the greater heat capacity of the equipment. Higher rates of change (more oscillations per unit time) will ensure that the net temperature experienced by the equipment is close to the average temperature of the space, while lower rates will result in wider temperature excursions.

e. Maintain relative humidity to within the specified tolerance limits.

NOTE

Temperature and humidity are interrelated such that a change in one parameter can cause a change in the other parameter. For example, a 1 °C change in temperature can cause a 3.5% change in RH at 20 °C and 50% RH. In the past, certain humidity control systems were observed to have system reheat cycle failures which caused the system to generate a humidity level approaching 90% RH. This may not be a problem with modern humidity control systems.

f. Maintain the above conditions nominally at all times and for a period of 24 hours prior to any calibration conducted in the facility.

NOTE

The capability of the control system to hold the temperature to within acceptable limits for a period of 24 hours prior to performing calibrations does not limit calibration measurements should a temperature excursion occur. Generally speaking, measurements can be made if the laboratory temperature is in control and has remained so for a period of 4 hours. However, some standards and test instruments require a shorter or significantly longer period of temperature control depending on the accuracy of the required measurement, the thermal mass of the equipment and the magnitude of the thermal offset. Laboratory management discretion must be used to determine the significance of the temperature excursion and its likely impact on the intended measurement. Separate enclosures may be used to provide better environmental controls for particularly sensitive measurements.

NOTE

The maximum acceptable conditions provided above have been established in order to maintain a maximum level of safety in all calibration areas. There are some instances when calibrations may need to be performed outside of the conditions listed. Any measurement process conducted outside of the prescribed parameters must be evaluated in order to identify potential safety hazards and possible damage to

measurement standards. For example, static discharge becomes a potential problem when humidity drops below 20%. This may cause problems with some measurements and pose shock hazards when working with electronic equipment. Conversely, high humidity may accelerate corrosion and condensation can cause possible shorts. Therefore, appropriate SYSCOM approval must be obtained prior to performing measurements outside of the requirements set forth in this document.

3.3.2 Temperature and Humidity Monitoring

Since environmental conditions of temperature and humidity are of such basic importance to calibration, continual monitoring, and recording of the temperature and relative humidity of each laboratory area is a facility requirement. Thermo-humidigraphs and/or sensors used to monitor environmental conditions shall be placed within the working volume of the calibration area, as defined in Section 3.3.1.c, to represent accurately the area of coverage, i.e. out of drafts and away from heat sources, doors, windows, and vents. Records shall be maintained as specified in
Section 5.1.

NOTE

Portable hand-held devices having a sufficient accuracy may be used to monitor and record the temperature and humidity within the working volume. These devices may be preferred over conventional thermo-humidigraphs or sensors, particularly if they cannot be located within the working volume or when the temperature of the TI is required such as during artifact calibrations.

NOTE

Laboratory areas with HVAC systems that are designed to eliminate temperature variations and can control temperature and humidity within the working volume to the specified requirements for the measurement area require no additional instrumentation as long as the environmental quality control requirements in Section 5 are met. HVAC system instrumentation must be calibrated and routinely monitored for conformance to the requirements.

3.3.3 Ventilation and Air Pressure

Facilities shall require environmental controls providing the following minimum capabilities to:

a. Maintain a ventilation rate of between 5 and 20 room air changes per hour.
b. Maintain an average air velocity of 6 to 20 feet per minute.

NOTE

As an effective means to prevent infiltration of dust and untempered air, laboratories should maintain a positive air pressure of 0.05 in. H_2O (± 10%) in all environmentally controlled calibration laboratory areas (except in areas specifically noted). This should be considered when determining the requirements for the environmental control system.

3.3.4 Particle Contamination

Facilities shall require the control of airborne particles to less than 2.4×10^{10} particles per cubic meter for particles greater than 0.5 µm in size. Specific measurement areas with more stringent particle control requirements are listed in Section 4, with allowable counts of particles in two sizes: over 0.5 µm and over 1.0 µm. In all areas, particles over 50 µm must be filtered completely. Smoking and eating shall not be permitted in areas designated for particle control.

NOTE

Special consideration must be made for on-site calibrations when using standards or equipment that require particle control to ensure measurement accuracy. Refer to the approved Navy calibration procedure for specific guidance regarding particle control for these calibrations.

4 CALIBRATION AREA REQUIREMENTS TABLES

4.1 Introduction

4.1.1 Information is provided in the following tables to provide guidance for measurements being conducted in the measurement areas as defined below. To perform measurements to the accuracy listed in the *Required Accuracy* column, the temperature and humidity must be maintained within the ranges listed in the appropriate columns. If the temperature and/or humidity exceed these ranges and it is approved by the SYSCOM, it will be necessary to make corrections for temperature deviations and special considerations must be given to maintenance and safety conditions that exist when humidity levels exceed the specified range. Any time measurements are taken outside of the temperature and/or humidity ranges specified in the table, the out of specification condition shall be documented and appropriate steps must be taken to ensure that the measurements are accurate and repeatable and safety is not compromised.

NOTE

Specific guidance with regards to environmental requirements or correction factors may sometimes be given in the approved Navy calibration procedure and takes precedence over the requirements prescribed in this document.

4.1.2 The particle count and vibration information provided in the tables are the recommended practices that have proven to be satisfactory for performing these measurements. Some tables do not specify particle counts and vibration limits, since these particular parameters do not always have a direct influence on measurement accuracy. Other tables specify limits for only the most stringent accuracy requirements.

4.1.3 The *Notes* column is provided to identify additional guidance or requirements that must be met for particular types of equipment in use. The number listed in the table corresponds to the numbered item in the *Notes* subsection. Some tables may have an additional subsection titled *Discussion*. This subsection is used to provide additional recommendations to help laboratory personnel in meeting the stated environmental conditions or to provide additional factors that must be considered during laboratory design.

4.2 Electrical/Electronic Calibration Area Requirements

4.2.1 DC Voltage

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
2 ppm or better	73±2 °F	20% to 60% RH	Not applicable	Not applicable	
>2 to 90 ppm	73±9 °F	Same as above	Not applicable	Not applicable	
>90 ppm	60 to 85 °F	Same as above	Not applicable	Not applicable	

4.2.2 Resistance

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
4 ppm	73±2 °F	30% to 60% RH	Not applicable	Not applicable	1
>4 ppm	73±9 °F	Same as above	Not applicable	Not applicable	1

Notes:
1.) Low humidity can cause problems with resistance standards and should be avoided.

4.2.3 Frequency and Power

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
All	60 to 85 °F	20% to 60% RH	Not applicable	Not applicable	

4.2.4 General Application for other Electrical/Electronic measurements

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
All	73±9 °F	20% to 60% RH	Not applicable	Not applicable	

4.3 Physical/Mechanical Calibration Area Requirements

4.3.1 Pressure and Vacuum

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
0.01% or better					
- using mercury manometer	75±10 °F	20% to 60% RH	<4x10^7 (over .5 µm) <7x10^6 (over 1 µm)	<10 µin (0.1 to 30 Hz) <0.001 g (30 to 200 Hz)	1, 2, 3
- using dead weight tester	73±9 °F	Same as above	Same as above	<0.002 in/s and <0.003 g (8 to 100 Hz)	2, 4
>0.01%					
- using gauge standards	73±9 °F	20% to 60% RH	Not applicable	Not applicable	5, 6
- using transducer standards	60 to 85 °F	Same as above	Not applicable	Not applicable	

Notes:
1.) Temperature changes when using mercury manometers must be limited to less than 3 °F/hour.
2.) Local gravity must be known to within 0.001 cm/s² using a local gravity benchmark.

3.) Excessive vibration can distort the readings made by high accuracy mercury manometers. Where necessary, the manometer may require isolation from the surrounding floor surface.
4.) Drafts and strong air currents (over 20 ft/min) must not blow onto the standard. Use baffles or shielding where necessary.
5.) Particle count limits apply to hydraulic gauge standards. Pneumatic gauge standards have no particle count requirement.
6.) If the standard gauges are temperature-compensated, the temperature requirement is expanded to 60 to 85 °F.

4.3.1.1 Discussion

Schwien Engineering, Inc. has a seismic mass recommendation consisting of a concrete block 4 feet by 4 feet and 5 feet deep with a 2-inch thick sheet of cork on the four sides of the block and supported by a gravel bed. See also Army TM 5-805-4 for guidance on seismic masses.

4.3.2 Force and Torque

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
0.025% or better	73±6 °F	20% to 60% RH	Not applicable	<10 µin (10 to 30 Hz) <0.001 g (30 to 200 Hz)	1, 2, 4
>0.025% - using proving rings	73±9 °F	Same as above	Not applicable	Same as above	1, 2
- using load/torque cells	60 to 85 °F	Same as above	Not applicable	Same as above	3

Notes:
1.) When calibrating proving rings, the ambient temperature must be held stable within 2 °F for the duration of the calibration. Drafts and strong air currents (over 20 ft/min) must not blow onto the standard. Use baffles or shielding where necessary.
2.) If the proving ring was calibrated at a temperature other than 73.4 °F, then apply the appropriate temperature tolerances to the calibrated temperature.
3.) Sources of EMI must be shielded where load cell indicators are used.
4.) A local gravity benchmark, accurate to .001 cm/s² is required if the standard is a dead weight force machine.

4.3.2.1 Discussion

4.3.2.1.1 Safety shields should be used around all force machines when calibrating with proving rings or load cells. Three drawings, MET D-508, MET D-511 and MET D-541 are available from NSWC Corona, Measurement Technology Division to provide designs for safety equipment to be used with force machines.

4.3.2.1.2 The temperature of the proving ring itself is crucial to performing accurate measurements. A thermometer should be attached at the base of the proving ring or a thermometer may be inserted into a well drilled in a steel block and placed near the base of the proving ring, to measure the proving ring temperature. The thermometer should be shielded to protect the bulb end from drafts that may be prevalent where the proving ring is being used. The thermometer used to monitor the proving ring temperature may be either Fahrenheit or Centigrade scale with a resolution of 0.1 degree. The appropriate temperature correction formula must be applied to determine corrections for measurements taken when the temperature deviates from the reported calibration temperature as indicated on the report of calibration for the proving ring. Proving rings are normally calibrated at a reference temperature of 23 °C (73.4 °F). In order for the correction to be valid, the ambient temperature in the region of the proving ring must be uniform and stable during the duration of use.

4.3.3 Mass

NBS Circular 547

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
Classes S, M	68 to 73 °F	30% to 55% RH	$<4x10^7$ (over .5 µm) $<7x10^6$ (over 1 µm)	<10 µin (10 to 30 Hz) <0.001 g (30 to 200 Hz)	1
Class S1	68 to 73 °F	30% to 55% RH	$<4x10^7$ (over .5 µm) $<7x10^6$ (over 1 µm)	<10 µin (10 to 30 Hz) <0.001 g (30 to 200 Hz)	2
Classes P, Q, T	64 to 80 °F	30% to 60% RH	$<4x10^7$ (over .5 µm) $<7x10^6$ (over 1 µm)	<10 µin (10 to 30 Hz) <0.001 g (30 to 200 Hz)	3

ASTM E 617

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
Classes 0, 1, 1.1	68 to 73 °F	30% to 55% RH	$<4x10^7$ (over .5 µm) $<7x10^6$ (over 1 µm)	<10 µin (10 to 30 Hz) <0.001 g (30 to 200 Hz)	1
Classes 2, 3	68 to 73 °F	30% to 55% RH	$<4x10^7$ (over .5 µm) $<7x10^6$ (over 1 µm)	<10 µin (10 to 30 Hz) <0.001 g (30 to 200 Hz)	2
Classes 4, 5, 6	64 to 80 °F	30% to 60% RH	$<4x10^7$ (over .5 µm) $<7x10^6$ (over 1 µm)	<10 µin (10 to 30 Hz) <0.001 g (30 to 200 Hz)	3

NIST 105-1

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
Classes C, F	64 to 80 °F	30% to 60% RH	$<4x10^7$ (over .5 µm) $<7x10^6$ (over 1 µm)	<10 µin (10 to 30 Hz) <0.001 g (30 to 200 Hz)	3

Notes:

1.) The temperature must be held stable within 4 °F per hour with a maximum change of 1 °F per hour during calibration.
2.) The temperature must be held stable within 7 °F per hour with a maximum change of 2 °F per hour during calibration.
3.) The change in temperature must not exceed 4 °F per hour.

4.3.3.1 Discussion

Class designations for ASTM 617 and NIST 105-1 have superceded the class designation for NBS Circular 547.

The stability and uniformity of the temperature in the mass calibration room is more important than the actual temperature. Substitution techniques used in mass calibrations eliminate errors that might be caused by ambient temperatures other than 73 °F. However, balances are very susceptible to temperature gradients, fluctuations, and air currents. Most sensitive balances are enclosed in a cabinet to protect them from air currents. Nevertheless, temperature gradients and air currents in the region surrounding the balance can produce temperature gradients inside the cabinet, which in turn can create air movement inside the cabinet. Additionally, the mass standard's buoyancy in air requires temperature stability to attain certain class accuracies due to changes in air density.

4.3.4 Temperature

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
All	73±5 °F	20% to 60% RH	Not applicable	Not applicable	1, 2

Notes:

1.) The temperature requirement applies to ambient conditions surrounding the digital temperature indicators used with platinum resistance thermometers and thermocouples. Where digital indicators are not used, the requirement can be expanded to 60 to 85 °F.
2.) Sources of EMI must be shielded where digital temperature indicators are used.

4.3.4.1 Discussion

Temperature baths and freezing point cells require large amounts of power, usually at 230 volts. These devices also produce very high heat loads. HVAC systems shall be sized accordingly to handle the heat load. When using triple-point cells and ice-baths, the ambient temperature should be kept as low as conveniently possible to maximize the duration over which the triple-point cell or ice-bath may be used.

4.3.5 Gas Flow

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
0.2% or better -using a bell prover	70±4 °F	20% to 60% RH	Not applicable	Not applicable	
0.2% or better -using a piston prover	70±4 °F	40% to 60%	Not applicable	Not applicable	1
>0.2%	60 to 85 °F	Same as above	Not applicable	Not applicable	

Notes:

1.) When a piston prover is equipped with a grounding strap for static electricity, the humidity can range from 20%-60% RH. The humidity requirement is provided to minimize the effect of static electricity buildup on the glass tube of a piston prover.

4.3.5.1 Discussion

Gas flow calibrators may also require large volumes of shop air or instrument quality air. High flow rate calibrators can also create large amounts of noise. Noise damping materials may be required on walls and ceiling.

4.3.6 Liquid Flow

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
All	60 to 85 °F	20% to 60% RH	Not applicable	Not applicable	1

Notes:

1.) If the liquid flow area uses fuels or other flammable or combustible liquids, then the HVAC systems serving this area should operate under a slight negative pressure (0.05 to 0.1 in. H_2O) to prevent intrusion of vapors into adjacent areas. Additional venting may also be required to prevent buildup of vapors inside the room.

4.3.6.1 Discussion

4.3.6.1.1 Facilities which use jet fuel or other flammable or combustible liquids in flow calibration areas are required to meet other requirements and regulations due to the flammability and explosive potential of the fuel vapors. In particular, any sources of ignition and sparks must be eliminated. All motors, light fixtures, and equipment must be specifically designed for use in potentially explosive atmospheres. Electrical outlets must be at least 24 inches above floor level. The room air should be exhausted directly to outside spaces, at a rate sufficient to maintain a safe atmosphere inside the room. The HVAC system supplying air to the liquid flow room should produce a negative pressure of approximately 0.05 in. H_2O inside to room, to help prevent intrusion of vapors into other laboratory areas. When designing a liquid flow area for new construction or renovation of facilities, local safety authorities must be consulted to assure compliance with all safety and health regulations.

4.3.6.1.2 Liquid flow calibrators may also have additional utility requirements such as 230 volt or three-phase power, large volumes of shop air or instrument quality air, or heated and/or chilled water. High flow rate calibrators can also create large amounts of noise and vibration, and should be isolated to minimize adverse effects on other calibration areas.

4.3.7 Vibration and Rotation

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes

All	60 to 85 °F	20% to 60% RH	Not applicable	<0.032 in/s and <0.046 g (8 to 100 Hz)	1

Notes:
1.) Provisions for water-cooling or air-cooling of some high power shakers may be required.

4.3.7.1 Discussion

Shakers can create high noise levels. Hearing protection should be provided. Noise damping materials may be required on walls and ceiling to reduce noise levels in adjacent areas. High power amplifiers used to drive shaker can also create large amounts of EMI. Instruments sensitive to EMI shall be shielded as necessary.

4.3.8 Viscosity and Specific Gravity

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
All	73±4 °F	20% to 60% RH	$<4x10^7$ (over .5 µm) $<7x10^6$ (over 1 µm)	Not applicable	

4.3.9 General Application for other Physical/Mechanical measurements

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
All	73±9 °F	20% to 60% RH	Not applicable	Not applicable	

4.4 Dimensional/Optical Calibration Area Requirements

4.4.1 Gage Block Calibration

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
See note 1 below					
- by comparison	68±0.5 °F	20% to 45% RH	$<2x10^6$ (over .5 µm) $<4x10^5$ (over 1 µm)	<10 µin (10 to 30 Hz) <0.001 g (30 to 200 Hz)	1, 2
- by interferometry	68±0.5 °F	Same as above	Same as above	<2 µin (10 to 30 Hz) <0.001 g (30 to 200 Hz)	1, 2

Notes:
1.) Uncertainties of gage block calibrations (including effects of environment) should always be determined by the servicing lab and reported to the customer on the report of calibration.
2.) Ventilation in the gage block room must be draft free. There must be no radiant heat sources that are strong enough to cause the temperature of the gage blocks or gage block comparator to exceed the limits above.

4.4.1.1 Discussion

4.4.1.1.1 Gage block calibration is one of the most demanding area of a calibration laboratory in terms of environment control required. Gage blocks are currently calibrated with uncertainties of less than 2 µin, and repeatability of less than 1 µin. This degree of repeatability requires a very tightly controlled environment. The length of a gage block is defined at a temperature of exactly 68 °F (20 °C). The temperature control becomes crucial because steel gage blocks have a thermal expansion coefficient of 6.4 ppm/ °F (or 11.5 ppm/ °C). This means that a 1 inch long gage block will grow in length by 6.4 µin for a 1 °F increase in temperature, a change that is much greater than the uncertainty of the gage block.

4.4.1.1.2 Although it is possible to apply a correction for the thermal expansion when using gage blocks at temperatures other than 68 °F, this practice is not recommended for very precise requirements, such as gage block comparisons. This is because the expansion coefficient can vary by several percent around the nominal value of 6.4 ppm/ °F, even with blocks of the same size and brand. The variances are especially common in blocks over 4 inches in length. This results in an additional uncertainty when the temperature correction is applied to the measured or calibrated length of a gage block. This additional uncertainty is proportional to the difference between the actual temperature and 68 °F. The problem is complicated further when gage blocks of one material are used to calibrate blocks of a different material. There are then two different expansion coefficients to account for, each with an associated uncertainty.

4.4.1.1.3 In addition to a nominal temperature of 68 °F, it is important to maintain a very uniform and stable temperature. Stable temperatures in the measurement area shall be maintained for a minimum of 8 hours prior to performing calibrations of gage blocks. A difference of even 0.2 °F between a master and test block is enough to affect the repeatability of calibrations. Although the calibration technique is designed to reduce differences between master and test blocks, these techniques depend upon stable, uniform environments. Also, the HVAC ducting and equipment in the gage block room should be designed to eliminate drafts and hot spots near the comparator. Temperature drift or gradients around the comparator can cause random errors that affect repeatability. In laboratories performing the most sensitive measurements, it is even possible for radiant energy from common, direct lighting to heat gage blocks or the comparator enough to affect repeatability. Normal HVAC systems commonly oscillate around a set temperature. The thermal mass of gage blocks will tend to attenuate this affect somewhat, but the HVAC system for the gage block calibration area should be specifically designed to produce as stable an environment as possible. If a temperature excursion outside of the limits should occur, there may be a substantial time lag before calibrations can resume. The amount of time for equilibrium to be restored depends upon the magnitude of the offset and the accuracy of the required measurement.

4.4.1.1.4 Humidity control for gage blocks, and other dimensional areas, is also critical. Oxidation or rust of clean steel surfaces begins at approximately 60% RH. The presence of air contaminates, dusts, and skin oils cause oxidation to occur at lower humidity, as low as 50% RH. The relationship between relative humidity and water vapor content of air changes with temperature. This means that a drop in temperature will increase the relative humidity, even without the addition of water vapor into the air.

Since humidity controls are slower to respond than temperature controls, it is important to keep humidity below 45% RH to provide a safe operating margin.

4.4.1.1.5 It is advantageous to locate gage block calibration equipment in its own room toward the center of the building. Locating the room away from exterior walls reduces seasonal heat loads and heat losses that can make the required level of control difficult.

4.4.2 Length (except by Laser Interferometry)

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
0.000010 in/in or better (10 µin/in or better)	68±1°F	20% to 45% RH	$<2x10^6$ (over .5 µm) $<4x10^5$ (over 1 µm)	<10 µin (under 30 Hz) <0.001 g (30 to 200 Hz)	1
>0.000010 to 0.000050 in/in (>10 to 50 µin/in)	68±2 °F	20% to 50% RH	Same as above	Same as above	1
>0.00005 in/in (>50 µin/in)	68±8 °F	20% to 60% RH	Not applicable	Not applicable	1

Notes:

1.) Proper attention must be given to maintaining standards and test instruments in high humidity environments. Rust can begin to occur at 50% RH per the discussion below.

4.4.2.1 Discussion

4.4.2.1.1 All length measurements are referenced to a standard temperature of 68 ºF (20 ºC). When temperatures deviate from the 68 ºF reference point in the measurement area, it may be necessary to apply corrections for dissimilar expansion caused by differences in material and mass. The rate of temperature change prior to and during measurements must be kept to a minimum to reduce the possibility of error caused by varying rates of thermal expansion. The measurement standards such as gage blocks, measuring machines, micrometers, and calipers often will be different in size than the item being measured and will change at a different rate due to the amount of material. The heat transfer will depend on the type of material, the mass of the material and the surface area available to transfer heat. To ensure accurate measurements the guidelines in the table should be followed for the accuracy required.

4.4.2.1.2 Similar to the discussion in Section 4.4.1 above, humidity control for length measurements is also critical. Oxidation or rust of clean steel surfaces begins at approximately 60% RH. The presence of air contaminates, dusts, and skin oils cause oxidation to occur at lower humidity, as low as 50% RH. The relationship between relative humidity and water vapor content of air changes with temperature. This means that a drop in temperature will increase the relative humidity, even without the addition of water vapor into the air. Since humidity controls are slower to respond than temperature controls, where possible, humidity should be kept below 45% RH to provide a safe operating margin. It should be emphasized that accurate measurements can be made when humidity excursions exceed the specified

ranges, however standards will require extra cleaning and maintenance to prevent damage caused by dirt and moisture.

4.4.3 Length by Laser Interferometry

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
1 ppm or better	68±5 °F	20% to 45% RH	<$2x10^6$ (over .5 µm) <$4x10^5$ (over 1 µm)	<10 µin (10 to 30 Hz) <0.001 g (30 to 200 Hz)	1
>1 ppm	68±5 °F	Same as above	Same as above	Same as above	2

Notes:
4.) The temperature must be held stable within 0.5 °F per hour during calibration.
5.) The temperature must be held stable within 1.0 °F per hour during calibration.

4.4.3.1 Discussion

The standard in a laser interferometer is the speed of light, which varies directly and instantly with changes in temperature. For this reason, temperature stability is of much more concern than the actual temperature. Even small fluctuations in the ambient temperature during a calibration can severely impact repeatability. Unlike length measurements made using mechanical standards (which have a high thermal mass to attenuate the effects of temperature oscillations), laser interferometers respond instantly to rapid temperature oscillations, creating random errors. It is therefore critical to eliminate sources of thermal gradients and drafts, and provide a uniform and stable environment.

4.4.4 Autocollimation

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
0.5 arcsec or better	68±1 °F	20% to 45% RH	<$2x10^6$ (over .5 µm) <$4x10^5$ (over 1 µm)	<10 µin (10 to 30 Hz) <0.001 g (30 to 200 Hz)	
>0.5 to 4.0 arcsec	68±2 °F	Same as above	Same as above	Same as above	
>4.0 arcsec	68±5 °F	Same as above	Same as above	Same as above	

4.4.4.1 Discussion

4.4.4.1.1 Like laser interferometry discussed above, the standard used in autocollimation is a beam of light. And for similar reasons, the autocollimator responds instantly to rapid temperature oscillations, creating random errors. It is therefore critical to eliminate sources of thermal gradients and drafts, and provide a uniform and stable environment.

4.4.4.1.2 The air path between the autocollimator objective lens or window and the associated reflector is an unavoidable part of the optical system. Any air turbulence can be regarded as a disturbing factor, with possible effects on image position and stability. Turbulence shows up as noise in photoelectric autocollimators. Temperature gradients can result in air stratification and cause mechanical twisting and warping of the instrument, reflector, and/or mounting surfaces. Severe temperature changes can affect optical alignment within the autocollimator, as well as between autocollimator and reflector. Vibration, even at moderate levels, can be a serious deterrent to the accurate measurement of angular displacement. It may cause deflections and perturbations of the autocollimator and/or reflector, introducing uncertainties in the instrument readout. It may also cause progressive misalignment in improperly supported systems, impairing accuracy and repeatability of measurement.

4.4.4.1.3 Finally, stray light which enters the front of the autocollimator may impair the accuracy of the instrument by reducing the quality of the return image in a visual autocollimator, or saturating the internal sensing devices of the photoelectric automatic type autocollimator. Stray light entering the eyepiece of an automatic instrument may also impair performance and accuracy of that autocollimator.

4.4.5 General Application for other Dimensional/Optical measurements

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
All	68±5 °F	20% to 45% RH	$<1x10^8$ (over .5 µm) $<2x10^7$ (over 1 µm)	<0.002 in/s and <0.003 g (8 to 100 Hz)	

4.5 Electro-Optical Calibration Area Requirements

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
All	73±5 °F	20% to 45% RH	Not applicable	Not applicable	1, 2

Notes:

1.) Vibration is generally not applicable to EO measurements unless performing boresight measurements. For these measurements, a displacement of less than 10 µin (25 µm) between 2 and 30 Hz and an acceleration of less than 0.001g between 30 and 200 Hz apply.

2.) For sealed optical systems, a humidity specification of 20% - 60% RH is acceptable.

4.6 Fiber Optic Calibration Area Requirements

Required Accuracy	Temperature	Humidity	Particle count /m³	Vibration	Notes
All	73±5 °F	30% to 70% RH	Not applicable	Not applicable	

5 ENVIRONMENTAL QUALITY CONTROL REQUIREMENTS

Navy and Marine Corps calibration facility environmental conditions shall be monitored and evaluated in order to gage the effectiveness of services provided to and supporting the Fleet as defined in NAVAIR 17-35QAC-01, NAVSEA 04-4734, and USMC TI-4733-35/23. Quality control of facility operation and environmental conditions is required at any one of three facility operational situations as discussed in Sections 5.1-5.3 below. The environmental requirements for these conditions are tabulated in Table 5.1.

5.1 Routine-Local.

5.1.1 Calibration facility environmental conditions shall be monitored on a qualitative routine basis at the local level. This requirement applies to all calibration, special purpose or hazardous areas defined within.

5.1.2 The environmental parameters of temperature and humidity shall also be monitored on a quantitative basis. These parameters shall be continuously monitored, recorded and verified to be within the limits specified herein. Records of environmental control shall be maintained for a period as specified in the laboratory quality manual. Charts and/or logbooks should be clearly marked and annotated with any relevant information when environmental conditions are out-of-tolerance.

5.2 Audit-Survey.

By direction or request of the applicable Type Commander/Sponsor, audit-surveys of calibration facility conditions or environmental controls will be performed as applicable and as a minimum at least once every three years for installed measurement areas. The audit survey will inspect and evaluate the facility in detail for the type of items listed in Table 5.1.

5.3 Design Review

By direction or request of the applicable Type Commander/Sponsor, NSWC Corona, Measurement Technology Division shall direct, conduct, or arrange for design review level tests of facility environmental controls and operations for any or all parameters required. Design reviews will be conducted as necessary to fully determine the adequacy of existing facilities or systems under harsh or adverse weather or other extreme environmental condition to establish a baseline of environmental control capabilities for existing facilities, or to evaluate newly constructed facilities for conformance to contractual requirements.

Table 5.1. Environmental Quality Control Requirements

	Routine-Local	**Audit-Survey**	**Design Review**
Temperature			
Nominal	X	X	X
Tolerance	X	X	X
Uniformity		X	X
Oscillations			X
Humidity	X	X	X
Airborne Particles	*	*	X
Ventilation			
Frequency			X
Velocity			X
Pressure			X
Noise			
Background			X
Hazardous			X
Vibration			
Velocity	*	*	X
Acceleration	*	*	X
Illumination			X
Shielding			X

* Investigations of these parameters shall be performed if there is adequate reason to suspect a problem requiring further investigation or corrective action in accordance with NAVAIR 17-35QAC-01.

APPENDIX A

REFERENCE DOCUMENTS

Document Designation	Title
29 CFR 1910	Code of Federal Regulations, Title 29, Chapter XVIII-Occupational Safety and Health Administration
ACGIH Industrial Ventilation Manual	Industrial Ventilation, A Manual of Recommended Practice
ANSI B89.6.2	Temperature and Humidity Environment for Dimensional Measurement
ANSI C78.2	Dimensional and Electrical Characteristics of Fluorescent Lamps-Preheat-Start
ANSI/LIA Z136.1	American National Standard for the Safe Use of Lasers
ANSI Z9.2-1979	Fundamentals Governing the Design and Operation of Local Exhaust Systems
ANSI/AIHA Z9.5-1992	American National Standard for Laboratory Ventilation
ANSI Z535.2	Environmental and Facility Safety Signs
ANSI/ASHRAE 62-1989	Ventilation for acceptable Indoor Air Quality
ANSI/NFPA 45-1991	Fire Protection for Laboratories Using Chemicals
ANSI/NCSL Z540-1	Calibration Laboratories and Measuring and Test Equipment
ARMY TM 5-805-4	Noise and Vibration Control
ASHRAE Handbook of Fundamentals	ASHRAE Handbook of Fundamentals
ASHRAE HVAC Handbook	ASHRAE Heating, Ventilating, and Air-Conditioning Applications Handbook
ASME B89 1.2M	Calibration of Gage Blocks by Contact Comparison Methods
ASTM E 617	Standard Specification for Laboratory Weights and Precision Mass Standards
EC-21	Cleaning, Handling, and Packaging of Oxygen Instruments
EC-25	Care, Handling, and Cleaning of Mercury
ER-03	Engineering Report, Calculated Corrections for Improved Force, Weight, and Mass Measurements When Using Force-Sensing Instruments
ER-13	The Effects of Temperature on Elastic Element Pressure Gages
FED-STD-209	Clean Room and Work Station Requirements, Controlled Environment
ISA RP52.1	Recommended Environments for Standards Laboratories
MCO 4733.1	Marine Corps Test, Measurement, and Diagnostic Equipment (TMDE) Calibration and Maintenance Program (CAMP)
MET D-508	Metrology Drawing, Safety Shield Assembly (Morehouse 100K Force Machine)

MET D-511	Metrology Drawing, Proving Ring Safety Retainer
MET D-541	Metrology Drawing, Safety Shield Assembly (Morehouse 300K Force Machine)
MIL-DTL-15562	Matting or Sheet, Floor Covering, Insulating for High Voltage Application
MIL-F-16377	General Specifications for Fixtures, Lighting, and Associated Parts; Shipboard Use.
MIL-HDBK-263	Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies, and Equipment (Excluding Electrically Initiated Explosive Devices)
MIL-HDBK-419 (Vol. 1)	Grounding, Bonding, and Shielding for Electronic Equipment and Facilities Basic Theory
MIL-HDBK-1003/3	Heating, Ventilating, Air Conditioning, and Dehumidifying Systems
MIL-HDBK-1003/17	Industrial Ventilation Systems
MIL-HDBK-1004/4	Electrical Utilization Systems
MIL-HDBK-1028/1	Aircraft Maintenance Facilities
MIL-HDBK-1190	Facility Planning and Design Guide
MIL-PRF-27401	Nitrogen, Propellant Pressurizing Agent
MIL-PRF-87893	Electrostatic Discharge (ESD) Control Workstation
MIL-STD-188-124	Grounding, Bonding and Shielding
MIL-STD-461	Requirements for the Control of Electromagnetic Interference Emissions and Susceptibility
MIL-STD-462	Measurement of Electromagnetic Interference Characteristics
MIL-STD-767	Cleaning Requirements for Special Purpose Equipment, Including Piping Systems
MIL-STD-1310	Standard Practice for Shipboard Bonding, Grounding, and Other Techniques for Electromagnetic Compatibility and Safety
MIL-STD-1330	Standard Practice for Precision Cleaning and Testing of Shipboard Oxygen, Helium, Helium-Oxygen, Nitrogen, and Hydrogen Systems
MIL-STD-1399	Interface Standard for Shipboard Systems
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment, and Facilities
MIL-STD-1686	Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)
NAEC-AWS-621	An Analysis of Spatial Requirements for Field Calibration Activities of LPH, LHA, and CV/CVN Type Ships (Revised)

NAVAIR 01-1A-512	Design Guide for Avionics Shop Power Distribution
NAVAIR 17-35HBK-3-1	Guide for Establishment of a Local Calibration Program
NAVAIR 17-35MTL-1	Metrology Requirements List (METRL)
NAVAIR 17-35NCE-1	Navy Calibration Equipment List (NCE)
NAVAIR 17-35QAC-01	Naval and Marine Corps Calibration Laboratory Audit/Certification Manual
NAVAIR 17-35QAL-11	Oxygen Instrument Cleaning for Calibration
NAVAIR DWG 63A114	Electronic Workbench, Type NEB-2
NAVAIRINST 13640.1	Naval Aviation Metrology and Calibration (METCAL) Program
NAVFACINST 11012.146	Department of Defense Construction Criteria
NAVMEDCOMINST 6260.5	Occupational Noise Control and Hearing Conservation
NAVSEA 04-4734	Naval and Marine Corps Calibration Laboratory Audit/Certification Manual
NAVSEA S9086-CL-STM-010/CH-077	Naval Ships Technical Manual (NSTM) Chapter 77, Personnel Protection Equipment
NAVSEA S9086-C6-STM-000/CH-096	Naval Ships Technical Manual (NSTM) Chapter 96, Weights and Stability
NAVSEA S9086-KY-STM-000/CH-320	Naval Ships Technical Manual (NSTM) Chapter 320, Electric Power Distribution Systems
NAVSEA S9086-K9-STM-000/CH-330	Naval Ships Technical Manual (NSTM) Chapter 330, Lighting
NAVSEA S9086-RK-STM-010/CH-505	Naval Ships Technical Manual (NSTM) Chapter 505, Piping Systems
NAVSEA S9086-RQ-STM-010/CH-510	Naval Ships Technical Manual (NSTM) Chapter 510, Heating, Ventilating, and Air Conditioning Systems for Surface Ships
NAVSEA S9086-SD-STM-000/CH-532	Naval Ships Technical Manual (NSTM) Chapter 532, Liquid Cooling Systems for Electronic Equipment
NAVSEA S9086-SX-STM-010/CH-550	Naval Ships Technical Manual (NSTM) Chapter 550, Industrial Gases - Generating, Handling, and Storage
NAVSEA S9086-SY-STM-010/CH-551	Naval Ships Technical Manual (NSTM) Chapter 551, Compressed Air Plants and Systems
NAVSEA S9086-S3-STM-010/CH-555	Naval Ships Technical Manual (NSTM) Chapter 555, Shipboard Firefighting
NAVSEA S9086-VG-STM-000/CH-634	Naval Ships Technical Manual (NSTM) Chapter 634, Deck Coverings
NAVSEA S9086-VH-STM-010/CH-635	Naval Ships Technical Manual (NSTM) Chapter 635, Thermal, Fire, and Acoustic Insulation
NAVSEA SE700-AA-MAN-100/RADIAC	RADIAC Policy and Procedures, Vol. 1

NAVSEA ST000-AG-IDX-010/TMDE	Test Measurement Diagnostics Equipment (TMDE)
NAVSEA ST700-AM-GYD-010/METCAL	Metrology and Calibration (METCAL) Laboratory Requirements and Certification Guide
NAVSEA ST700-AM-GYD-020/OICR	Oxygen Instrumentation Calibration Room (OICR) Requirements and Operations Guide
NAVSEAINST 4734.1	Metrology and Calibration (METCAL) Program
NAVSEAINST 5100.3	Control of Mercury, Mercury Compounds and Components Containing Mercury, and Mercury Compounds
NBS Circular 547	Precision Laboratory Standards of Mass and Laboratory Weights
NCSL RP-7	Laboratory Design
NCSL RP-14	Guide to Selecting Standards-Laboratory Environments
NEHC-TM91-2	Industrial Hygiene Field Operations Manual
NFPA 30	Flammable and Combustible Liquids Code
NFPA 70	National Electrical Code
NIST Handbook 105-1	Specifications and Tolerances for Field Standard Weights
NIST Monograph 180	The Gage Block Handbook
OPNAVINST 3960.16	Navy Test and Monitoring Systems (TAMS)
OPNAVINST 5100.19	Navy Occupational Safety And Health (NAVOSH) Program Manual For Forces Afloat
OPNAVINST 5100.23	Navy Occupational Safety and Health (NAVOSH) Program Manual
OPNAVINST 5100.24	Navy System Safety Engineering and Management
OPNAVINST 5530.14	Navy Physical Security and Loss Prevention
OPNAVINST 5530.15	Navy Physical Security
OPNAVINST 9640.1	Shipboard Habitability Program
SSPINST 4355.8B	Trident Calibration Support Responsibilities for Test and Measurement Equipment at Submarine Base Bangor and Kings Bay
TN 76-2	Technical Note, Electronic Test Equipment Cleaning and Washing
TN 82-1	Technical Note, Electro-Optical Facilities Recommendations
TN 88-1	Technical Note, Use of Trichlorotrifluoroethane
USMC TI-4733-35/23	Naval and Marine Corps Calibration Laboratory Audit/Certification Manual

APPENDIX B

SHIPBOARD REQUIREMENTS

B.1 Shipboard General Requirements

B.1.1 Laboratory Designations

A shipboard calibration facility shall consist of one or more spaces having the following designation and purpose:

Calibration Laboratory Spaces	Special Purpose or Hazardous Spaces
Optical/Dimensional	Oxygen-Clean Calibration
Physical/Mechanical	Meter Calibration
Electrical/Electronic	Electrostatic Discharge Protection

NOTE

Activities not supporting workload in one or more of the above areas need not consider the facilities requirements for that area. The Shipboard Gage and Calibration Program (SGCP) does not have facility requirements due to the on-site and in-place nature of SGCP calibrations. A secure non-condensing storage space shall be provided for the SGCP calibration standards and equipment.

B.1.2 Physical Isolation

Physical isolation and separation of shipboard calibration facilities is required as follows:

a. The calibration laboratory spaces shall require location in compartments dedicated solely for the purposes of calibration or activities directly related such as incidental instrument repair work or laboratory administration.

b. Electrical/Electronic calibration functions require isolation and separation from Physical/Mechanical and Optical/Dimensional calibration functions by a minimum of at least one watertight bulkhead.

NOTE

Activities with only low accuracy Physical/Mechanical workload (such as pressure gages, torque wrenches and thermometers) are exempt from the above requirement, provided the ambient temperature range specified in Section 4.3 for that workload is no tighter than that specified in Section 4.2 for the Electrical/Electronic workload. Low accuracy dimensional workload (with 0.0005 inch or greater TI tolerance) may be supported in this combined calibration area, but only if the temperature is held within 64 to 76 °F for at least 24 hours before performing any dimensional calibrations. Also, if dimensional capability is included in this combined calibration area, the humidity should be held below 45% RH if possible to prevent rusting of the dimensional equipment.

c. Isolation and separation of other calibration functions, such as Optical/ Dimensional from Physical/Mechanical, is required only to the extent that the respective environmental control requirements can be achieved as specified in Section 4.
d. Isolation and separation of special purpose and hazardous spaces is required to the extent specified in Section 2.10.
e. Shipboard thermal, fire, and acoustic insulation shall be in accordance with NAVSEA S9086-VH-STM-010/CH-635.NAVSEA S9086-VH-STM-010/CH-635.

B.1.3 Deck Space

The allocated laboratory space shall be adequate to accommodate the laboratory staff during performance of expected peak calibration workloads without crowding. An area shall be provided for the safe storage of laboratory standards and accessories and for incoming/outgoing workload.

NOTE

The workload storage area in accordance with NAVSEA ST000-AG-IDX-010/TMDE shall be large enough to preclude use of the laboratory deck for workload storage. Six linear feet of workbench is recommended for each technician. The minimum space recommended for electrical/electronic areas and for physical/mechanical areas is 960 sq ft each for 10 or less technicians including 60 sq ft for workload storage. Add 40 sq ft for every technician above ten plus 30 sq ft of workload storage for each additional 10 technicians. Storage racks for workload shall be provided. Typically, the racks should be two to three feet deep, six feet high, as wide as space allows, and have shelf spacing from 30 inches at the bottom to 15 inches at the top. Equipment shall be secured using tie-down straps or other acceptable means during underway periods.

B.1.4 Deck Loading

No calibration standard or equipment installation shall cause the deck loading capacity of the structure housing it to exceed the requirements of NAVSEA S9086-C6-STM-000/CH-096.

B.1.5 Overheads and Bulkheads

Overheads and bulkheads shall be constructed of fire retardant construction materials. Interior surfaces shall be finished in flat or semi-gloss finish, light-colored paint, or wall covering materials.

B.1.6 Deck Covering

Special deck covering shall be required in accordance with the requirements of NAVSEA S9086-VG-STM-010/CH-634.

B.2 Shipboard Utility Requirements

B.2.1 Electrical Power

a. A shipboard calibration facility shall require a standard electrical power service consisting of a 440/115 volt, 3-phase, 60 Hz, Type I source, furnished by the ship's electric power plant or the equivalent from a shore based source, as specified in NAVSEA S9086-KY-STM-000/CH-320.

b. The Electrical/Electronic calibration laboratory space shall require additional electrical power service consisting of a 440/115 volt, 3-phase, 400 Hz, Type III source, furnished by the ship's electric power plant or the equivalent from a shore based source as specified in NAVSEA S9086-KY-STM-000/CH-320.

c. Both Type I and Type III sources shall require special reconfiguration in calibration facilities such that all 115-volt power outlets are furnished with a grounded neutral service meeting requirements of NAVSEA S9086-KY-STM-000/CH-320.

d. Voltage, waveform, frequency, and power continuity shall be in accordance with the requirements of NAVSEA S9086-KY-STM-000/CH-320.

e. Electrical/Electronic calibration laboratory spaces shall require additional regulation, filtering, and isolation of Type I electrical power to achieve voltage, waveform, frequency, and power continuity equivalent to Type III power with the exception that the nominal frequency shall be 60 Hz vice 400 Hz.

f. Electrical power outlets, connectors, or receptacles shall be tagged or labeled to provide a technical description of the type of power source (voltage, frequency, power rating and phase) or connection scheme as applicable.

NOTE

The grounded neutral electrical service specified in B.2.1.c can be achieved through the use of isolated line conditioners such as the Elgar 6006B series for 60 Hz or the Elgar 6004B series for 400 Hz.

B.2.2 Power Distribution

The minimum requirements for power distribution is that safe and appropriate sources of power are available to the calibration technician, either as part of a workbench/workstation system or in the immediate proximity thereof for the purpose of supplying power to the calibration standards and workload items assigned to the area. This shall include installation, connection, outlets, overload protection, and emergency shut-off provisions as required by NAVSEA S9086-KY-STM-000 /CH-320.

B.2.3 Grounding

Electrical grounding shall be in accordance with the requirements of NAVSEA S9086-KY-STM-000/CH-320.

B.2.4 Lighting

Lighting in calibration laboratory spaces shall be governed by the requirements of NAVSEA S9086-K9-STM-000/CH-330.

a. General illumination shall be provided by fluorescent fixtures meeting the requirements of MIL-F-16377/13, Symbol 174, or the equivalent.
b. Light fixtures shall be electromagnetically shielded and filtered meeting the requirements of MIL-STD-461 for Class A3 equipment, requirement RE101.
c. Light fixtures shall be arranged in a manner to provide balanced lighting to minimize shadows, glare and spectral reflection, and to produce nominally uniform illumination in all spaces specified in paragraph 2.4. Light fixtures shall be capable of providing illumination levels in accordance with the requirements specified in Section 3.2.5.

B.2.5 Compressed Gas

a. Nitrogen gas conforming to MIL-PRF-27401D, Type 1, Grade A or B NAVSEA S9086-SX-STM-010/CH-550, NAVSEA S9086-SD-STM-000/CH-532, and S9086-SY-STM-010/CH-551 at a minimum regulated delivery pressure of 1,000 psi shall be required in the Physical/Mechanical calibration laboratory and in other spaces as necessary.
b. All permanently installed compressed gas outlets, connectors, or receptacles shall be tagged or labeled to provide a technical description of the type of gas, pressure, and flow capacity.
c. Shipboard piping systems shall conform to Naval Ships Technical Manual S9086-RK-STM-010/CH-505.

B.2.6 Fire Detection and Protection

a. Design, installation, use, maintenance, and testing of fixed fire suppression and detection equipment shall be in compliance with 29 CFR 1910 and NAVSEA S9086-S3-STM-010/CH-555.
b. Placement, use, maintenance, and testing of portable fire extinguishers shall be in compliance with 29 CFR 1910.

B.2.7 Heating, Ventilation, and Air Conditioning

Shipboard HVAC systems shall be in accordance with the requirements of OPNAV 9640.1 and OPNAVINST 5100.19. In surface ships, minimum replenishment with outside air shall be 5 CFM per person. Exhaust ventilation systems shall be designed, constructed, installed, and maintained in accordance with the requirements of MIL-HDBK-1003/17.

B.2.8 Workbenches

Workbenches shall be built according to NAVSEA S9086-KC-STM-10/CH 300 and as follows:

a. Workbench surfaces shall be required to have a working height of 36 inches, nominally, above the floor in accordance with the criteria specified in MIL-STD-1472, and shall provide a minimum of 6 lineal feet of workspace.

NOTE

Deviations to the workbench working height may be allowed to locate equipment at proper working levels.

b. Workbenches utilized in the Electrical/Electronic Laboratory or related areas, shall provide a 120 V, 60 Hz power distribution system which provides for a minimum of one 120 V, 15 A, 60 Hz, duplex outlet for every 2 lineal feet of workbench length. The workbench power distribution system shall incorporate a grounded neutral service and a safety ground wired in accordance with NAVSEA S9086-KC-STM-10/CH 300. Any other electrical power outlets, receptacles or distribution system incorporated into a workbench shall be installed to NAVSEA S9086-KC-STM-10/CH 300 and shall have a common ground with all other power sources available on the bench. Refer to NAVSEA S9086-KY-STM-000/CH320 for further guidance on shipboard power distribution.
c. Workbenches, upon which electrically powered equipment is opened for repairs or adjustment, shall be constructed of or covered with non-conductive material. Alternatively, the workbenches shall be insulated and grounded through current limiting resistance or impedance to provide protection from electrical shock in accordance with the criteria for an ESD control program as specified in MIL-HDBK-263.
d. All workbenches in a single laboratory or area shall be electrically bonded together to a ground bus as described in NAVSEA S9086-KC-STM-10/CH 300 and connected to the ship's hull at a common point. Workbenches shall not be connected to ground in series with one another. As a minimum, workbench bonding and grounds shall be checked on an annual basis.
e. Workbenches used in the Physical/Mechanical calibration laboratory or any area where oils or chemical are commonly used, shall require tops that are resistant to the absorption of these materials.

APPENDIX C

MOBILE FACILITY REQUIREMENTS

C.1 Mobile Facility General Requirements

A mobile calibration facility is used to meet the needs of the Marine Corps. The ground Marine Corps facility known as the Calibration Facility (CF), AN/TSM-198, and the NAVAIR facility known as a Mobile Facility (MF), are a group of all weather, standardized shelters designed to ISO specifications. Modules provide the user with flexibility to configure the interior of each shelter, or groups of shelters (complexes), to satisfy specific mission needs. Internal furnishings are configured to meet calibration requirements for various measurement characteristics and calibration support functions. The goals of the system are to reduce manpower, system costs, and shipping space requirements. The shelters are easily assembled and relocated and are transportable by helicopter and amphibious shipping. They are compatible with both tactical and commercial material handling equipment. The shelters have a weight restriction of 10,000 lbs. Or 11,200 lbs. depending on the shelter and have an outside dimension of 8 ft. wide, 8 ft. high, and 10 ft. or 20 ft. in length.

C.1.1 Site Location

The site for setting up a CF, AN/TSM-198 or a MF has some important considerations. Those that are necessary for proper installation but not previously discussed in Section 2 of this document include:

a. Installation on a fairly flat, well-drained surface that slopes gently to avoid accumulation of drainage water. Shelters can also be installed on paved asphalt or concrete, if available or hard packed ground.
b. Preparation, positioning, and leveling should be completed as described in the appropriate technical manual for the CF, AN/TSM-198 or the MF.

C.1.2 Laboratory Spaces

For the purposes of this document, the calibration laboratory shall be considered as being conceptually and physically divided into one or more shelters. Calibrations performed within a shelter must be compatible with other calibrations and tasks since a variety of measurement parameters may be performed within each shelter. However, the shelters environmental specifications must meet the requirements listed for individual measurement areas as specified in Section 4 to achieve the accuracy of the required measurement.

C.1.3 Deck Space

Shelters are configured with a variety of modules based on workload requirements. However, due to their size limitations, space requirements are determined by the area required for the test equipment, standards and workbenches rather than by the number of personnel. The allocated laboratory space shall be adequate to accommodate the laboratory staff during performance of expected peak calibration workloads without crowding. An area immediately adjacent to the entrance should be provided for logistics purposes with sufficient space for processing equipment, racks or cabinets for storing test

equipment awaiting disposition and for storing spare parts or equipment. Also, where applicable, space should be provided for maintaining an active and inactive test equipment pool.

NOTE

A minimum of 10 sq ft of floor space is recommended for workload storage for each calibration phase package supported.

C.2 Mobile Facility Utility Requirements

Each MF shall have voltage and power capabilities required by the calibration phase packages supported. Power connections and requirements defined in U.S. Marine Corps Technical Manual TM5410-14/1, Intermediate Maintenance Instructions, Electronic Maintenance Complex, will be used for the CF, AN/TSM-198 shelters.

NOTE

It is recommended that MF power be provided by means of a Wye–connected transformer secondary system using a grounded common with 115 V between each phase leg and common. MF power, both shipboard and shorebased should be provided directly from the source on an unshared line to minimize line fluctuations caused by high current equipment. A single–point ground connection for all workbench receptacles should be provided at the facility power distribution panel. The 60–Hz power distribution system for shorebased facilities and vans should be single–phase three–wire, grounded–neutral service. Navy shipboard safety requirements impose restriction upon users equipment to prevent connection (or bonding) of the ship's power carrying conductors to the ship's hull (ground). Therefore, whenever MF equipment would cause a power–carrying conductor to be connected to the personnel safety ground (such as in some commercial test equipment in which one of the power–carrying conductors and personnel safety ground are connected to the equipment chassis), portable line isolation transformers shall be provided and used.

C.2.1 Grounding and Shielding

The DC resistance of the neutral conductor, and the safety ground wire from all receptacles to a reference ground point for the facility, shall be minimized. A DC resistance of 0.2 ohms or less shall be maintained.

NOTE

Navy calibration techniques and procedures are developed using a grounded–neutral power distribution system, and include methods to reduce or eliminate, under normal circumstances, the effects of ground loops and stray signal pickup. In view of this, special ground bars or buses are generally not required except at specific locations where measurements of extremely small DC signal levels are made (e.g., comparison of standard cells). When a higher quality ground is to be used in a calibration process,

then a 3/4” x 1/4” copper bus is recommended. This bar shall be connected to ship’s ground at only one point, or to the power distribution system earth ground. In either case the bus is connected to ground utilizing a flexible connector, such as SR–1–9 cable. The DC resistance between the ground bus and the ship’s ground or the earth ground electrode should be 0.1 ohms or less. To achieve this, the connections between the flexible cable and the copper bus bar, and between the flexible cable and the ship’s ground or the earth ground electrode, may require soldering as well as mechanical bonding.