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HIGH-ALTITUDE ELECTROMAGNETIC PULSE (HEMP) PROTECTION FOR GROUND-BASED C⁴I FACILITIES PERFORMING CRITICAL, TIME-URGENT MISSIONS

VOLUME I
FIXED FACILITIES

(METRIC)

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DEPARTMENT OF DEFENSE
Washington DC 20301

HIGH-ALTITUDE ELECTROMAGNETIC PULSE (HEMP) PROTECTION FOR FIXED GROUND-BASED C^4I FACILITIES PERFORMING CRITICAL, TIME-URGENT MISSIONS

1. This military standard is approved and mandatory for use by all departments and agencies of the Department of Defense in accordance with Department of Defense Directive 5000.2, 23 February, 1991.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: HQ AFC4A/TNAS, 607 Pierce Street, Room 303, Scott AFB IL 62225-5421 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FOREWORD

1. Originally, Military Standard 188 (MIL-STD-188) covered technical standards for tactical and long-haul communications, but later evolved through revisions (MIL-STD-188A, MIL-STD-188B) into a document applicable to tactical communications only (MIL-STD-188C).

2. The Defense Information Systems Agency (DISA) published DISA circulars (DISAC) promulgating standards and engineering criteria applicable to the long-haul Defense Communication System and to the technical support of the National Military Command System.

3. As a result of a Joint Chiefs of Staff action, standards for all military communications are now being published in a MIL-STD-188 series of documents. The MIL-STD-188 series is subdivided into a MIL-STD-188-100 series, covering common standards for tactical and long-haul communications; a MIL-STD-188-200 series, covering standards for tactical communications only; and a MIL-STD-188-300 series, covering standards for long-haul communications only. Emphasis is being placed on developing common standards for tactical and long-haul communications published in the MIL-STD-188-100 series.

4. This document contains technical standards and design objectives for High-Altitude Electromagnetic Pulse (HEMP) protection of ground-based facilities which are nodes in a HEMP-hardened network for performing critical and time-urgent command, control, communications, computer, and intelligence (C^4I) missions. The requirements are stringent in order to avoid both damage and functional upsets which prevent mission accomplishment within operationally prescribed timelines. The standards apply uniformally to all facilities in the end-to-end chain, since disruption of a single node may result in network failure.

5. This Volume I of MIL-STD-188-125A addresses HEMP hardening for fixed ground-based facilities which perform critical, time-urgent C^4I missions.

6. Use of the standard for HEMP protection of other ground-base communications-electronics facilities that require hardening is encouraged to the extent permitted by cost constraints.

7. Performance, acceptance, and verification requirements are contained in the body of the standard. HEMP-unique acceptance and verification test techniques are temporarily included as appendices A, B, and C.

8. Implementation of MIL-STD-188-125A, Volume I is supported by MIL-HDBK-423 "High-Altitude Electromagnetic Pulse (HEMP) Protection for Fixed and Transportable Ground-Based Facilities, Volume I, Fixed Facilities." The handbook also includes planning, management, logistics, and data requirements for critical, time-urgent fixed, ground-based facilities.

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1. SCOPE

1.1 Purpose. This standard establishes minimum requirements and design objectives for High-Altitude Electromagnetic Pulse (HEMP) hardening of fixed[1] ground-based facilities which perform critical, time-urgent command, control, communications, computer, and intelligence (C^4I) missions. Facilities required to fully comply with the provisions of the standard will be designated by the Joint Chiefs of Staff, a Military Department Headquarters, or a Major Command.

1.2 Scope. This standard prescribes minimum performance requirements for low-risk protection from mission-impacting damage or upset due to HEMP threat environments defined in DoD-STD-2169. This standard also addresses minimum testing requirements for demonstrating that prescribed performance has been achieved and for verifying that the installed protection subsystem provides the operationally required hardness for the completed facility.

1.3 Applications. This standard defines the design, engineering, fabrication, installation, and testing criteria of specifically designated fixed ground-based facilities in a HEMP-hardened, critical, time-urgent C^4I network. Such nodes include subscriber terminals and data processing centers, transmitting and receiving communications stations, and relay facilities. The standard applies to both new construction and retrofit of existing facilities. Although only local portions of facility interconnects are addressed, it is assumed that survivable long-haul communications paths, fiber optic links, or other hardened interconnects between facilities will be provided as required for mission accomplishment. Use of the standard for HEMP protection of other ground-based communications-electronics facilities that require hardening is also encouraged.

1.4 Objectives. Survivable C^4I capabilities are essential to a credible military deterrent. This standard supports nuclear survivability objectives by providing a standardized, low-risk protection approach for fixed ground-based facilities in a HEMP-hardened C^4I network. These uniform requirements ensure balanced HEMP hardening for all critical facilities in the network.

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[1]This version (Vol I) of the standard addresses fixed facilities only. Transportable Facilities HEMP hardening measures are contained in Vol II of this MIL-STD-188-125 series; publishing date of 1st Quarter, FY 94.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the effective issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto.

SPECIFICATIONS

MILITARY

MIL-Q-9858	Quality Program Requirements

STANDARDS

FEDERAL

FED-STD-368	Quality Control System Requirements
FED-STD-1037	Glossary of Telecommunication Terms

MILITARY

MIL-STD-100	Engineering Drawing Practices
MIL-STD-188-124B	Grounding, Bonding and Shielding for Common Long Haul/Tactical Communication Systems Including Ground Based Communications-Electronics Facilities and Equipments
MIL-STD-248	Welding and Brazing Procedure and Performance Qualification
MIL-STD-470	Maintainability Program Requirements
MIL-STD-480	Configuration Management
MIL-STD-785	Reliability Program for Systems and Equipment Development and Production
MIL-STD-1379	Military Training Program
MIL-STD-1388-1	Logistic Support Analysis
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment and Facilities
MIL-STD-2165	Testability Program for Electronic Systems and Equipments
DoD-STD-2169	High-Altitude Electromagnetic Pulse (HEMP) Environment (U) (document is classified Secret)

HANDBOOKS
MILITARY

MIL-HDBK-419	Grounding, Bonding, and Shielding for Electronic Equipment and Facilities
MIL-HDBK-423	High-Altitude Electromagnetic Pulse (HEMP) Protection for Fixed and Transportable Ground-Based Facilities, Volume I, Fixed Facilities
MIL-HDBK-729	Corrosion and Corrosion Prevention Metals

(Unless otherwise indicated, copies of Federal, and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, (ATTN: NPODS) 5801 Tabor Avenue, Philadelphia PA 19120-5099.)

2.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this standard to the extent specified herein.

DoD Instruction 5000.1	Major and Non-Major Defense Acquisition Programs
DoD Instruction 5000.2	Defense Acquisition Program Procedures
DoD Manual 5000.2M	Defense Acquisition Management Documentation and Reports
DoD Instruction 6055.11	Protection of DoD Personnel from Exposure to Radiofrequency Radiation, 20 August 1986
DI-NUOR-80928	Nuclear Survivability Test Plan
DI-NUOR-80929A	Nuclear Survivability Test Report
JCS Memorandum	CJCS High Altitude Electromagnetic Pulse Prioritization of C3 Nodes and Systems (effective)

FORMS

DD Form 2639	Hardness Critical Label
DD Form 2640	Hardness Critical Tag

(Copies of specifications, standards, handbooks, drawings, and publications required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted shall be those listed in the issue of the DODISS specified in the solicitation. The issues of documents which have not been adopted shall be those in effect on the date of the cited DODISS.

NFPA 101	Life Safety Code

(Applications for copies should be addressed to the National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.)

2.3 Source of documents. Copies of Federal and military standards, specifications, and associated documents listed in the DoDISS, should be obtained from the DoD Single Stock Point, Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia PA 19120. Single copies may be obtained on emergency basis by calling DSN 442-3321 or Area Code (215)697-3321. Copies of industry association documents should be obtained from the sponsor. Copies of all other listed documents should be obtained from the contracting activity or as directed by the contracting officer.

2.4 Order of precedence. In the event of a conflict between the text of this standard and the references cited herein, the text of this standard shall take precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Acronyms used in this standard. The acronyms used in this standard are defined as follows:

a. A - Amperes

b. C^4I - Command, Control, Communications, Computer, and Intelligence

c. CW - Continuous Wave

d. d c - direct current

e. dB - Decibel

f. DoDISS - Department of Defense Index of Specifications and Standards

g. $FGBC^4I$ - Fixed Ground-Based C^4I

h. ft - Foot

i. FWHM - Full Width at Half Maximum Amplitude

j. HAMS - Hardness Assurance, Maintenance, and Surveillance

k. HCI - Hardness Critical Item

l. HCP - Hardness Critical Process

m. HEMP - High-Altitude Electromagnetic Pulse

n. HM/HS - Hardness Maintenance and Hardness Surveillance

o. IAW - In Accordance With

p. IEEE - Institute of Electrical and Electronic Engineers

q. kHz - Kilohertz

r. m - Meter

s. MCS - Mission-Critical Systems

t. MHz - Megahertz

u. NFPA - National Fire Protection Association

v. PCI - Pulsed Current Injection

w. POE - Point-of-Entry

x. rf - radio frequency

y. SE - Shielding Effectiveness

z. SEm - Shielding Effectiveness (Magnetic)

aa. SEpw - Shielding Effectiveness (plane wave)

bb. SELDS - Shielded Enclosure Leak Detection System

cc. TEMPEST - A term used to describe a methodology for controlling radiated and conducted emanations

3.2 Sources for definitions. Sources for definitions of terms used in MIL-STD-188-125A, in order of decreasing priority, are as follows:

a. FED-STD-1037, "Glossary of Telecommunication Terms"

b. JCS Pub. 1, "Dictionary of Military and Associated Terms"

c. MIL-HDBK-423, Military Handbook High-Altitude Electromagnetic Pulse (HEMP) Protection for Fixed and Transportable Ground-Based Communications Electronics Facilities and Equipment.

d. MIL-STD-188-124A, Grounding, Bonding and Shielding for Common Long Haul/Tactical Communication Systems Including Ground Based Communications, Electronics Facilities and Equipment.

e. DI-NUOR-80928, Nuclear Survivability Test Plan

f. DI-NUOR-80929A, Nuclear Survivability Test Report

g. MIL-STD-100, Engineering Drawing Practices

3.3 Definitions. Definitions of terms used in this standard are taken from FED-STD-10371 where applicable.

3.3.1 Aperture POE HEMP shield surface. An intentional aperture POE provided for personnel and equipment entry and egress and for fluid flow (ventilation and piped utilities) through the electromagnetic barrier.

3.3.2 Conductive POE. An electrical wire or cable or other conductive object, such as a metal rod, which passes through the electromagnetic barrier. Conducting POE are also called penetrating conductors.

3.3.3 Continuous Wave Immersion. A test method for measuring the electromagnetic responses induced on an electromagnetic barrier or other item of interest, i.e., cables, conduit, etc., illuminated by an electric or magnetic field.

3.3.4 Corrective maintenance. All unscheduled maintenance actions. Such actions are undertaken, when excessive degradation or failure of a Hardness Critical Item (HCI) is detected, to restore the HEMP protection subsystem to a satisfactory condition and level of performance. Corrective maintenance includes removal, repair or replacement, reassembly, and checkout of the completed work.

3.3.5 Electromagnetic barrier. The topologically closed surface created to prevent or limit HEMP fields and conducted transients from entering the enclosed space. The main barrier consists of the facility HEMP shield and POE treatments, and it encloses the protected volume.

3.3.6 Electromagnetic stress. A voltage, current, charge, or electromagnetic field which acts on an equipment. If the electromagnetic stress exceeds the vulnerability threshold of the equipment, mission-impacting damage or upset may occur.

3.3.7 Facility HEMP shield. The continuous metallic housing that substantially reduces the coupling of HEMP electric and magnetic fields into the protected volume. The facility HEMP shield is part of the electromagnetic barrier.

3.3.8 HEMP acceptance test. An acceptance test of a system, subsystem, or component performed to ensure that specified performance characteristics have been met. HEMP acceptance tests, conducted near the conclusion of a hardening construction or installation contract, are tests for the purpose of demonstrating that at least minimum performance requirements of the HEMP protection subsystem have been achieved before the subsystem will be accepted by the Government from the contractor.

3.3.9 HEMP hardness. A quantitative description of the resistance of a system or component to malfunction (temporary or permanent) and/or degraded performance induced by HEMP. HEMP hardness is achieved through adhering to appropriate design specifications and is verified by one or more test and analysis techniques.

3.3.10 HEMP Hardness Assurance. Procedures and activities performed during the production phase to confirm the end product meets the HEMP hardness design specifications. Hardness assurance includes those aspects of Quality Assurance which deal with hardening, component and subassembly testing, acceptance testing, and initial verification testing which confirm the design specifications have been met.

3.3.11 HEMP Hardness Critical Item (HCI). An item at any assembly level having performance requirements for the purpose of providing protection. Nuclear HCIs provide protection from environments produced by a nuclear event or are specially designed to operate under nuclear weapon (device)-derived stresses. HEMP HCIs are the elements of the HEMP protection subsystem. A hardness critical assembly is a top-level definable unit of HEMP HCIs and other components that may not be hardness critical.

3.3.12 HEMP Hardness Critical Process (HCP). A process, specification, or procedure which must be followed exactly to ensure that the associated HCI attains its required performance.

3.3.13 Hardness Maintenance (HM). Preventive maintenance (e.g., adjustments or cleaning) and corrective maintenance (e.g., repairs or replacements) on the HEMP protection subsystem or its HCIs and assemblies. These HM activities are intended to eliminate faults or to preserve specified performance levels.

3.3.14 HEMP Hardness Maintenance and Hardness Surveillance (HM/HS). The combined preventive maintenance, inspection, test, and repair activities accomplished on a HEMP-protected operational facility to ensure that HEMP hardness is retained throughout the system life cycle. HM/HS, along with hardness assurance, constitute a total HAMS program.

3.3.15 HEMP protection subsystem. The electromagnetic barrier and all special protective measures installed for the purpose of hardening the MCS against the HEMP environment.

3.3.16 Hardness Surveillance (HS). Inspections and tests of the HEMP protection subsystem or its HCIs and assemblies. These HS activities are intended to observe and monitor the condition and performance of the hardening elements and to detect faults.

3.3.17 Low-risk HEMP hardening. A hardening technique that features a high-quality electromagnetic barrier with minimized and protected POE. Virtually all mission-critical communications-electronics and support equipment are placed in the protected volume enclosed by the barrier and operate in a relatively benign electromagnetic environment, isolated from the external HEMP stresses. The low-risk approach results in a well-defined HEMP protection subsystem configuration with inherent testability.

3.3.18 Main barrier. The topological closed surface comprised of electromagnetic barrier components that represent the smallest, protected interior volume. Special protective volume walls that impinge on the interior of a facility are an important part of this barrier.

3.3.19 Main barrier protective device. A protective device installed on an electrical conductor that penetrates from the system exterior, through the facility HEMP shield, and into the protected volume. Main barrier protective devices must meet the performance requirements of this standard (see 5.1.7).

3.3.20 Mission-Critical Systems (MCS). All communications-electronics and support equipment required to perform specified critical missions that are required trans and post nuclear attack. In the context of this standard, MCS refer to be hardened to perform missions specified to be accomplished in or after a HEMP environment.

3.3.21 Norton Source. Is a circuit consisting of a current source in parallel with an impedance which is electrically equivalent to another electrical circuit.

3.3.22 Penetrating conductor. Any electrical wire or cable or other conductive object, such as a metallic rod, which passes through the electromagnetic barrier. Penetrating conductors are also called conductive POEs.

3.3.23 Penetration entry area. That area of the electromagnetic barrier where long penetrating conductors (such as an electrical power feeder) and piping POEs are concentrated.

3.3.24 Point-of-Entry (POE). A location on the electromagnetic barrier where the shield is penetrated and HEMP energy may enter the protected volume unless an adequate POE protective device is provided. POEs are classified as aperture POEs or penetrating conductors according to the type of penetration. They are also classified as architectural, mechanical, structural, or electrical POEs according to the architectural-engineering discipline in which they are usually encountered.

3.3.25 POE protective device or POE treatment. The protective measure used to prevent or limit HEMP energy from entering the protected volume at a POE. Common POE protective devices include waveguides-below-cutoff and closure plates for aperture POEs, and filters and electrical surge arresters on penetrating conductors. The three categories of POE protective devices for installation on penetrating conductors are: main barrier protective devices, primary special protective devices, and secondary special protective devices (see 5.1.8.3).

3.3.26 Preventive maintenance. Scheduled maintenance actions. These actions are performed on a regular basis. Preventive maintenance includes scheduled adjustments, cleaning and replacement of items with limited lifetimes.

3.3.27 Primary special protective device. A protective device installed on an electrical conductor that penetrates from the system exterior into a special protective volume. A primary special protective device is designed to provide the maximum attenuation possible without interfering with the normal operational electrical signals that are routed on the penetrating conductor.

3.3.28 Protected volume. The three-dimensional space enclosed by the electromagnetic barrier, except for those spaces which are also within special protective volumes.

3.3.29 Pulsed current injection (PCI). A test method for measuring performance of a POE protective device on a penetrating conductor. A HEMP threat-relatable transient is injected on the penetrating conductor at a point outside the electromagnetic barrier and the residual internal transient stress is measured inside the barrier.

3.3.30 Residual internal stress. The electromagnetic fields, voltages, currents, or charges which originate from the HEMP environment and penetrate into the protected volume after attenuation by elements of the electromagnetic barrier.

3.3.31 Retrofit HEMP hardening. An action taken to modify in-service equipment. Retrofit HEMP hardening is the installation or substantial upgrade of the HEMP protection subsystem for an existing facility or equipment.

3.3.32 Secondary special protective device. A protective device installed on an electrical conductor that penetrates from a special protective volume into the main protected volume. It is used only when necessary to augment the attenuation provided by the primary special protective device and the connected equipment. The total attenuation through the primary special protective device, the connected equipment, and the secondary special protective device (see 5.1.8.3.2.2), must meet the performance requirements of this standard.

3.3.33 Shielded enclosure leak detection system (SELDS). Any of a class of commercially available instruments designed for checking shielding effectiveness in the magnetic field test regime. Most of these instruments operate at one or more discrete frequencies, often of the order of 100 kHz.

3.3.34 Special protective measures. All HEMP hardening measures required in addition to implementation of the electromagnetic barrier. Special protective measures are necessary for MCS outside the barrier, for MCS which are within the protected volume and experience damage or upset during verification testing, and in cases requiring a special protective volume.

3.3.35 Special protective volume. A region within the electromagnetic barrier where electromagnetic stresses due to HEMP may exceed the residual internal stress limits for the protected volume (see 5.1.8.3). The special protective barrier may be a separate shield with protected penetrations; more commonly, shielded cables or conduits and equipment cabinets and closed piping systems are used to provide the needed electromagnetic isolation from the protected volume.

3.3.36 Verification testing. Tests conducted for demonstrating that the installed HEMP protection subsystem provides the required HEMP hardness. These tests are performed after the construction and acceptance testing are complete and after the equipment is installed and functioning, to determine if the operational system suffers mission-aborting damage or upset due to simulated HEMP excitations. Verification is normally a Government-conducted test, and is not part of a facility construction contract.

3.3.37 Vulnerability threshold (of an equipment). The minimum stress level which causes the equipment to suffer definite degradation. In the context of this standard, the vulnerability threshold is the minimum electromagnetic stress which causes mission-impacting damage or upset.

3.3.38 Waveguide below cutoff. A metallic waveguide whose primary purpose is to attenuate electromagnetic waves at frequencies below the cutoff frequency (rather than propagating waves at frequencies above cutoff). The cutoff frequency is determined by the transverse dimensions and geometry of the waveguide and properties of the dielectric material in the waveguide.

3.3.39 Waveguide-below-cutoff array. An assembly of parallel waveguides-below-cutoff, with adjacent cells usually sharing common cell walls (see 5.1.5.2). A waveguide-below-cutoff array is used when the area of the shield aperture required to obtain adequate fluid flow within pressure drop limitations is larger than the permissible area of a single waveguide-below-cutoff.

4. GENERAL REQUIREMENTS

4.1 General.

4.1.1 HEMP protection overview. The need exists for uniform and effective hardening, hardness verification, and Hardness Maintenance and Hardness Surveillance (HM/HS) of Fixed Ground-Based Command, Control, Communications, Computer, and Intelligence ($FGBC^4I$) systems that require network interoperability during and after exposure to HEMP environments. In critical time-urgent applications where some momentary upsets, as well as damage, are mission-impacting, the hardening requirements include stringent shielding, POE protection, and special protective measures. Since normal operational experience may not indicate the condition of the HEMP protection subsystem(s), thorough verification testing and HM/HS after deployment are necessary. For additional information, refer to supporting handbook MIL-HDBK-423, Volume I, Fixed Facilities.

4.1.2 Integration with related requirements. Elements of the HEMP protection subsystem(s) can serve multiple purposes. For example, the electromagnetic barrier(s) can also be used to meet emanations security requirements. HEMP hardening measures should be integrated with those of other electromagnetic disciplines, such as electromagnetic interference/electromagnetic compatibility, lightning protection, and TEMPEST, and with treatments for other hardening requirements.

4.2 Hardness program management.

Hardness program management[2] for fixed ground-based systems being HEMP hardened IAW requirements of this standard shall implement the policy and procedures of DoD Directive 5000.1 and the accompanying DoD Instruction 5000.2. Design, engineering, fabrication, installation, and testing activities shall be managed to accomplish the following objectives:

a. To provide a HEMP-protected system design based upon verifiable performance specifications.

b. To verify hardness levels through a cost-effective program of testing and analysis.

c. During the acquisition process, to develop a maintenance/surveillance program that supports the operational phase of life cycle HEMP hardness.

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[2] HEMP planning, analysis, design, test procedures, test reporting documentation, and requirements for HM/HS program development and execution are described in MIL-HDBK-423, Volume I, Fixed Facilities.

4.3 HEMP hardening design. Facility protection against the HEMP threat environment specified in DoD-STD-2169 shall be achieved with an electromagnetic barrier and with additional special protective measures, as required. The electromagnetic barrier shall consist of the facility HEMP shield and protective devices for all POEs. Special protective measures shall be implemented for hardening MCS which must be placed outside the barrier and for other special cases. Reliability (MIL-STD-785), maintainability (MIL-STD-470), safety and human engineering (MIL-STD-1472), testability (MIL-STD-2165), and corrosion control (MIL-HDBK-729) shall be incorporated into the HEMP protection subsystem design.

4.3.1 Facility shield. The facility HEMP shield shall be a continuously welded or brazed metallic enclosure which meets or exceeds shielding effectiveness requirements of this standard (see 5.1.3.1).

4.3.2 POE. The number of shield POEs shall be limited to the minimum required for operational, life-safety, and habitability purposes. Each POE shall be HEMP protected with POE protective devices which satisfy performance requirements of this standard (see 5.1.4 through 5.1.7).

4.3.3 MCS. All equipment required to perform critical time-urgent missions during trans- and post-attack shall be designated as MCS. MCS includes such items as communications-electronic equipment, data processing subsystems, command and control equipment, local portions of hardened interconnects[3], and critical support subsystems such as power generation, power distribution, and environmental control.

4.3.3.1 MCS within the electromagnetic barrier. All MCS that will operate satisfactorily and compatibly shall be installed within the electromagnetic barrier. No HEMP-unique performance characteristics are required in design and selection of MCS that will be housed within the barrier.

4.3.3.2 MCS outside the electromagnetic barrier. MCS, such as a radio antenna or evaporative heat exchanger, that must be placed outside the electromagnetic barrier, shall be provided with special protective measures (see 5.1.8) as required to ensure HEMP hardness in the HEMP threat environment.

4.3.3.3 HEMP-hardened electrical power. The facility shall be provided with HEMP-hardened electrical power generation and distribution capability sufficient to

[3]Although they are not included within the scope of the document, HEMP-hardened local interconnects and survivable long-haul communication circuits to other hardened facilities in a network must be made available as required for mission accomplishment.

perform trans- and post-attack missions, without reliance upon commercial electrical power sources.

4.3.4 Special protective measures. Special protective measures shall be implemented in cases where HEMP hardness cannot be achieved with the electromagnetic barrier alone. Additional shielding, transient suppression/ attenuation devices, and equipment-level protection shall be provided as required to achieve HEMP hardness. The three categories of cases requiring special protective measures are as follows:

a. MCS that must be located outside the electromagnetic barrier and, therefore, is not protected by the barrier (see 5.1.8.1).

b. MCS that is enclosed within the electromagnetic barrier and experiences mission-impacting damage or upset during verification testing, even though the barrier elements satisfy all performance requirements (see 5.1.8.2).

c. Special protective volumes and barriers to provide supplementary isolation, when POE protective devices cannot satisfy the barrier requirements without interfering with facility operation (see 5.1.8.3).

4.4 HEMP testing. The HEMP testing program shall demonstrate that hardness performance requirements have been satisfied and that the required HEMP hardness has been achieved. This program shall include quality assurance testing during facility construction and equipment installation, acceptance testing for the electromagnetic barrier and special protective measures, and verification testing of the completed and operational facility.

4.4.1 Quality assurance program. A quality assurance program IAW FED-STD-368 and MIL-Q-9858 shall be implemented during system construction and installation to demonstrate that the HEMP protection subsystem materials and components comply with performance requirements of this standard. The quality assurance test procedures and results shall be documented for use as baseline configuration and performance data for the HM/HS program.

4.4.2 Acceptance testing. Acceptance of the HEMP protection subsystem shall be based upon successful demonstrations of compliance with hardness performance requirements of this standard. HEMP acceptance tests of the electromagnetic barrier and special protective measures shall be conducted after all related construction work has been completed. Acceptance test procedures and results shall be documented for use as baseline configuration and performance data.

4.4.3 Verification testing. After completion of the HEMP protection subsystem, installation, operational checks and acceptance testing of the facility equipment, HEMP hardness of the facility shall be verified through a program of tests and supporting analysis. The verification program shall provide a definitive statement on the HEMP hardness of critical time-urgent mission functions at the facility under test. Verification test procedures and results shall be documented for use as baseline configuration and performance data.

4.5 HM/HS.

4.5.1 HM/HS program development. HM/HS considerations shall be included in the facility planning and design phases to facilitate life cycle survivability and the development of an effective HM/HS program. The HM/HS program shall be designed to maintain the protection subsystem at a level of performance that meets the requirements in this standard.

4.5.2 HM/HS program implementation. During the verification phase, baseline data shall be obtained for the HM/HS program. The HM/HS program shall be implemented in the operation and support phase of the facility life cycle. Effectiveness of the HM/HS program for maintaining the HEMP protection subsystem performance at the required level shall be periodically reviewed, and program revisions shall be made when required.

5. DETAILED REQUIREMENTS

5.1 Fixed Systems.

5.1.1 HEMP protection subsystem topology.

5.1.1.1 Electromagnetic barrier topology. The electromagnetic barrier, consisting of the facility HEMP shield and POE protective devices, shall be configured to accomplish the following technical requirements:

a. To enclose all MCS except those equipments such as radio antennas, evaporative heat exchangers, or external security sensors, which will not function properly if placed within the protected volume.

b. To minimize the number of POEs.

c. To avoid requirements for special protective measures internal to the barrier .

d. To facilitate HEMP acceptance and verification testing.

e. To minimize requirements for scheduled HM.

5.1.1.2 Penetration entry area. As a design objective, there should be a single penetration entry area on the electromagnetic barrier for all piping and electrical POEs except those connected to external conductors less than 10 m (32.8 ft) in length. The penetration entry area shall be located as far from normal and emergency personnel and equipment accesses and ventilation POEs as is permitted by the facility floor plan.

5.1.2 Facility grounding.

5.1.2.1 Equipotential ground plane. Fixed ground-based C^4I facilities shall be grounded using the equipotential ground plane method IAW MIL-STD-188-124 and guidance in MIL-HDBK-419. The facility HEMP shield shall form a major portion of the equipotential ground plane.

5.1.2.2 Grounding to the facility HEMP shield. Grounds for equipment and structures enclosed within the protected volume shall be electrically bonded to the inside surface of the shield by the shortest practical paths, including via the raised floor structure. Grounds for equipment and structures outside the electromagnetic barrier shall be electrically bonded to the outside surface of the shield or to the earth electrode subsystem. Ground cables used to connect the facility shield (equipotential ground plane) to the earth electrode subsystem shall be electrically bonded to the outside surface of the shield, and at least one such ground cable shall be located at the penetration entry area. All grounding connections to the facility HEMP shield shall be made in a manner which does not create POEs.

5.1.3 Facility HEMP shield.

5.1.3.1 Shielding effectiveness. The facility HEMP shield, with all POE protective devices installed, shall provide at least the minimum shielding effectiveness shown on figure 1.

5.1.3.2 Shield construction. The facility HEMP shield, exclusive of its POEs, shall be a continuous conductive enclosure such as steel or copper, closed on all wall, ceiling, and floor surfaces. All seams and joints between adjacent panels shall be continuously welded (for steel shields) or continuously brazed (for copper shields). Welding and brazing shall be performed using procedures and personnel qualified in accordance with MIL-STD-248.

5.1.3.3 Shield monitoring capability. A built-in test capability to at least qualitatively monitor for electromagnetic shield leakage shall be provided (see 5.1.11).

5.1.3.4 Shield construction quality assurance.

5.1.3.4.1 In-progress inspection of welded and brazed seams. In-progress inspection of welded and brazed seams and joints shall proceed continuously in parallel with the shield fabrication and assembly activity. The quality of all shield seams and joints, including those used for installation of POE protective devices, shall be monitored with visual and magnetic particle inspection, SELDS measurements, or dye penetrant testing.

5.1.3.4.2 Shielding effectiveness survey. After the shield is closed but before interior equipments and finishes are installed, a shielding effectiveness survey shall be performed. SELDS testing and plane wave shielding effectiveness tests shall be employed. Shielding defects found during the survey must be corrected, retested, and shown to provide the required performance before the interior equipment and finishes are installed.

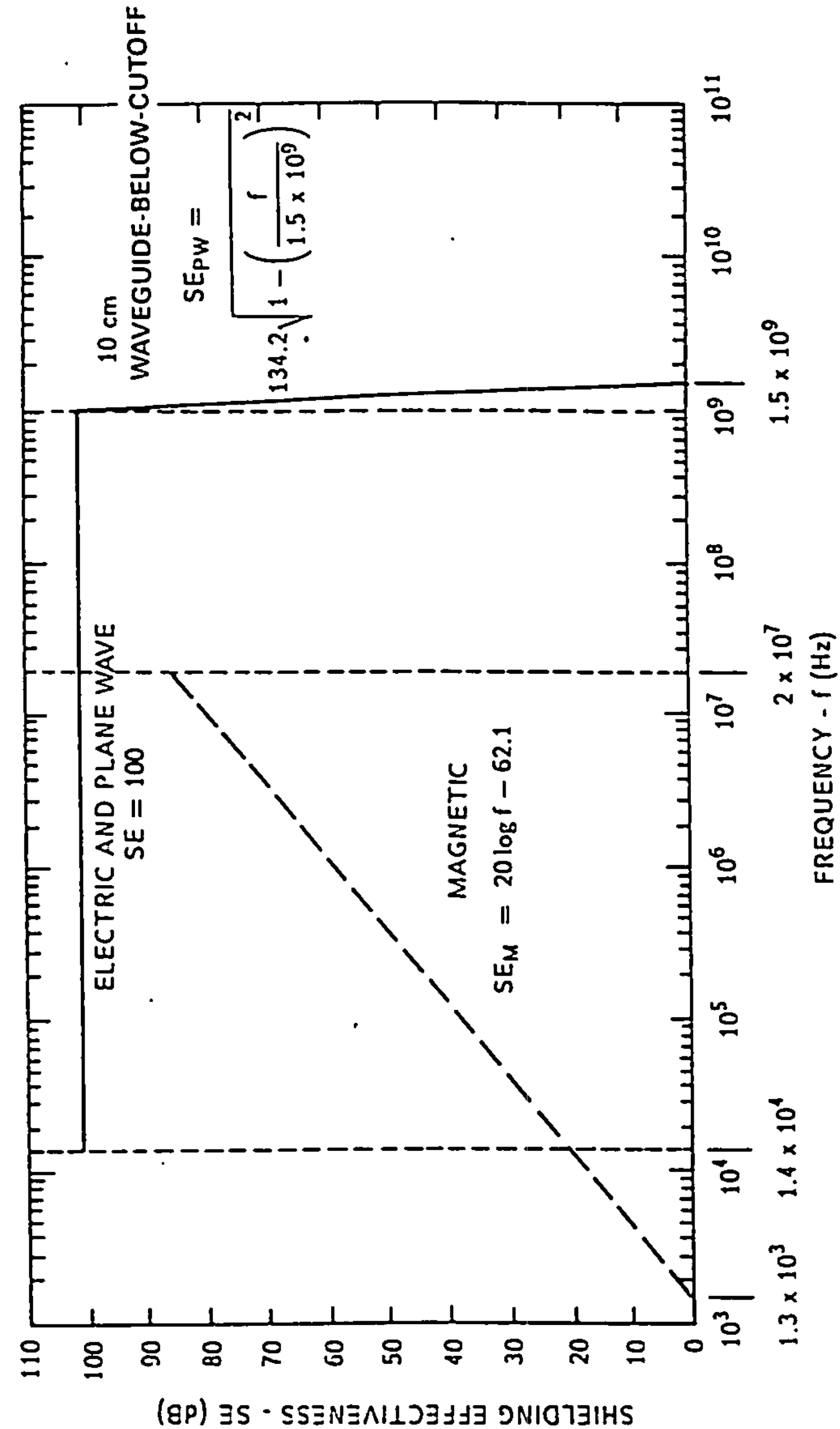
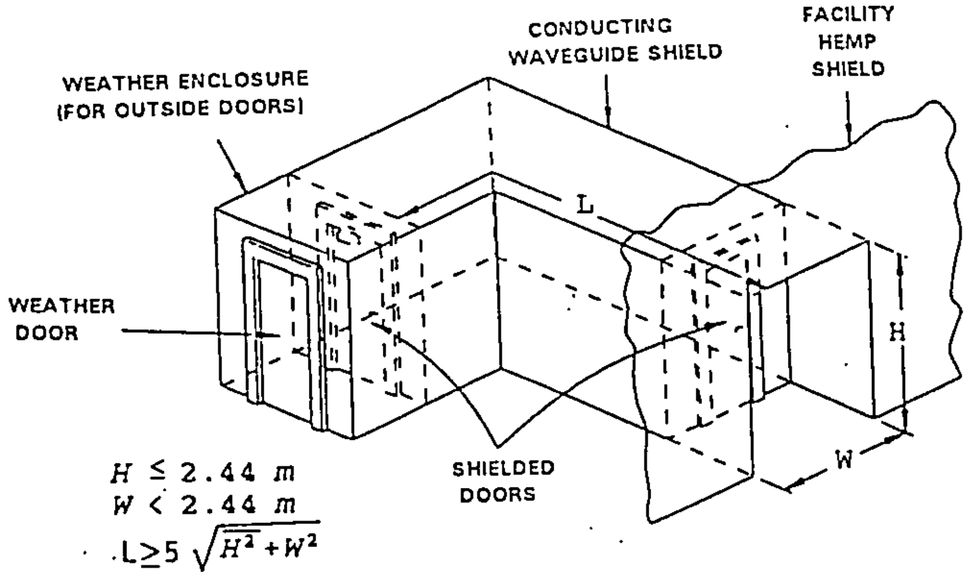
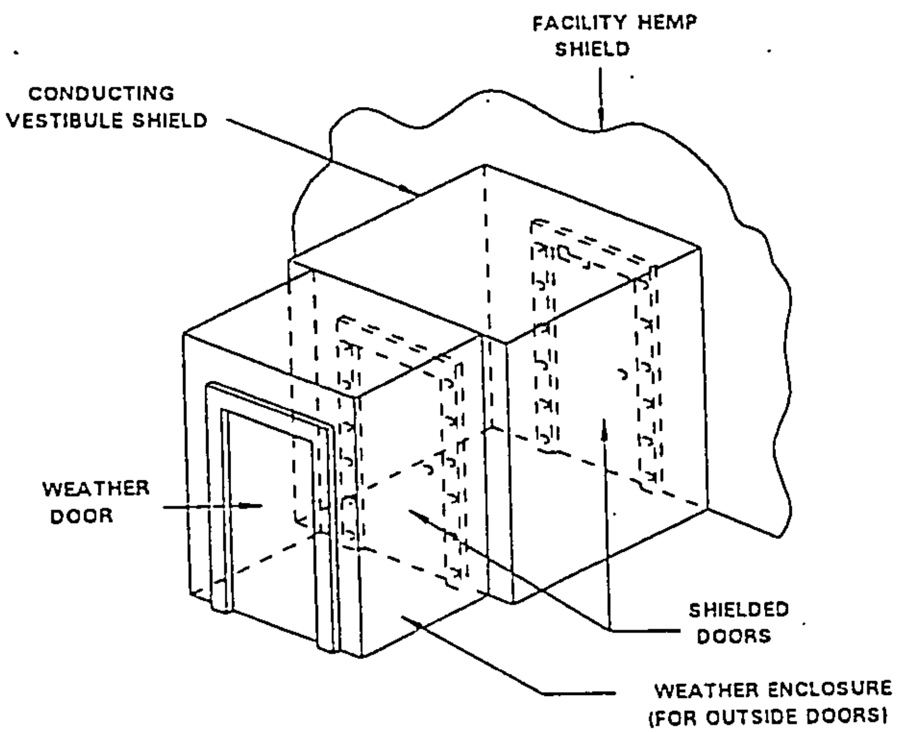


Figure 1 Minimum HEMP shielding effectiveness requirements (measured IAW procedures of Appendix A).



a. Waveguide entryway.



b. Vestibule entryway.

Figure 2 Typical waveguide and vestibule entryways

5.1.3.5 Shield acceptance testing. After completion of the shield and after installation of the POE protective devices, internal equipments, and finish work provided under the construction contract, the shield acceptance test shall be conducted to determine if the facility shield performs IAW minimum requirements of figure 1. The test shall be conducted with POEs and their protective devices in a normal operating configuration, using shielding effectiveness test procedures of appendix A. All defects found during the acceptance testing shall be corrected, retested, and shown to provide the required performance before the installation of communications-electronics equipment.

5.1.3.5.1 Facility shield modifications. If POEs are added or the facility HEMP shield is breached and repaired after acceptance, shield acceptance testing in the affected area shall be repeated.

5.1.4 Architectural POE.

5.1.4.1 HEMP protection for architectural POEs. HEMP protection for architectural POEs, including personnel entryways and exits and equipment accesses through the facility shield, shall be provided with electromagnetic closure, waveguide-below-cutoff techniques, or combinations of closure and waveguides-below-cutoff.

5.1.4.1.1 Quality assurance for architectural POE protective devices. All welded or brazed seams and joints required for installation of architectural POE protective devices shall be monitored under the program of in-progress inspection of welded and brazed seams (see 5.1.3.4.1). Shielded doors and other closure or access covers shall be subjected to electromagnetic and mechanical quality assurance tests to demonstrate acceptable performance.

5.1.4.1.2 Acceptance testing for architectural POE protective devices. Acceptance testing for architectural POE protective devices shall be conducted using shielding effectiveness test procedures of appendix A.

5.1.4.2 Personnel entryways and exits. HEMP protection for all normal and emergency personnel entryways and exits shall be provided with a two-door shielded waveguide-below-cutoff entryway or with a two-door shielded vestibule (figure 2). As design objectives, the number of personnel entryways and exits should be constrained to the minimum requirements of NFPA 101 and the main personnel entryway should be a waveguide-below-cutoff.

5.1.4.2.1 Waveguide entryway dimensions. When a waveguide-below-cutoff entryway is used, height and width of the waveguide shall each not exceed 2.44 m

(8 ft), and the length of the waveguide along its shortest path shall be at least five times the diagonal dimension of the cross-section. As a design objective, no electrical wiring, piping, or other conductors should run longitudinally inside the waveguide entryway. Where electrical wiring cannot be eliminated from the entryway, it shall be run in metal conduit. All conduits and other groundable conductors such as pipes or handrails in the waveguide entryway shall be electrically bonded to the entryway shield at intervals not exceeding 1 m (3.3 ft).

5.1.4.2.2 Entryway shield. The entryway shield shall comply with the same requirements applicable to the facility HEMP shield (see 5.1.3). All entryway POEs, either into the facility protected volume or to the outside, shall comply with the same requirements applicable to other POEs through the electromagnetic barrier (see 5.1.5 through 5.1.7).

5.1.4.2.3 Entryway shielded doors. Entryway shielded door frames shall be welded or brazed into the entryway shield. When installed, vestibule shield doors shall provide at least the minimum shielding effectiveness shown in figure 1. Waveguide entryway doors shall provide at least the minimum electric and plane wave shielding effectiveness shown on figure 1, but are not required to satisfy the magnetic shielding effectiveness criteria. A weather enclosure with appropriate environmental controls shall be provided to protect exterior shield doors from corrosion and exposure to blown dust and other natural elements.

5.1.4.2.4 Entryway interlocks and alarms. The entryway shield doors shall be provided with interlocks to ensure that at least one of the shield doors remains closed except during emergency evacuations. The entryway shield doors shall be provided with an alarm to indicate that the interlock has been overridden or that both shield doors are open.

5.1.4.3 Equipment accesses. A protected equipment access POE shall be provided only when movement of the equipment through a personnel entryway is not practical. HEMP protection for equipment accesses through the facility HEMP shield shall be provided with electromagnetic closure. The metal access cover shall be continuously seam welded in place, if anticipated usage is less than once per 3 years, and shall be radio frequency gasketed and secured by a closure mechanism which ensures a proper gasket seal, when expected usage is more frequent. When closed, the equipment access covers shall provide at least the minimum shielding effectiveness shown on figure 1. A weather enclosure shall be provided to protect exterior gasketed access covers from corrosion and exposure to blown dust and other natural elements.

5.1.5 Mechanical POE.

5.1.5.1 HEMP protection for mechanical POEs. HEMP protection for mechanical POEs, including piping and ventilation penetrations through the facility HEMP shield, shall be provided with waveguide-below-cutoff techniques. As a design objective, the number of piping POEs should be constrained to fewer than 20 and the number of ventilation POEs should be constrained to fewer than 10.

5.1.5.1.1 Quality assurance for mechanical POE protective devices. All welded and brazed seams and joints required for installation of mechanical POE protective devices, including those for piping and ventilation penetrations, shall be monitored under the program of in-progress inspection of welded and brazed seams and joints (see 5.1.3.4.1).

5.1.5.1.2 Acceptance testing for mechanical POE protective devices. Acceptance testing for mechanical POE protective devices, including those for piping and ventilation penetrations, shall be conducted using shielding effectiveness test procedures of appendix A.

5.1.5.2 Piping POEs. Piping shall penetrate the facility HEMP shield as a pipe section which is configured as a single waveguide-below-cutoff or a waveguide-below-cutoff array (figure 3). Dielectric hoses or pipes shall be converted to metal piping before penetrating the shield. The presence of the protected piping POE shall not degrade shielding effectiveness of the facility HEMP shield below the minimum requirements of figure 1.

5.1.5.2.1 Metallic piping waveguide dimensions. The inside diameter of a single wave-guide-below-cutoff and each of the transverse cell dimensions in a waveguide-below-cutoff array shall not exceed 10 cm (4 in), except where a special protective volume will be established (see 5.1.8.3.1). The length of the waveguide section shall be at least five times the inside diameter of a single waveguide-below-cutoff or at least five times the transverse cell diagonal dimension in a waveguide-below-cutoff array.

5.1.5.2.2 Metallic piping waveguide construction. All joints and couplings in the waveguide section shall be circumferentially welded or brazed, and the waveguide-below-cutoff shall be circumferentially welded or brazed to the facility HEMP shield at the POE. Cell walls of a waveguide-below-cutoff array shall be metallic, and there shall be continuous electrical bonds at all intersections and between the cell walls and the waveguide wall. No dielectric (glass, plastic, etc.) pipe lining shall be permitted in the waveguide section. External and internal piping shall be connected

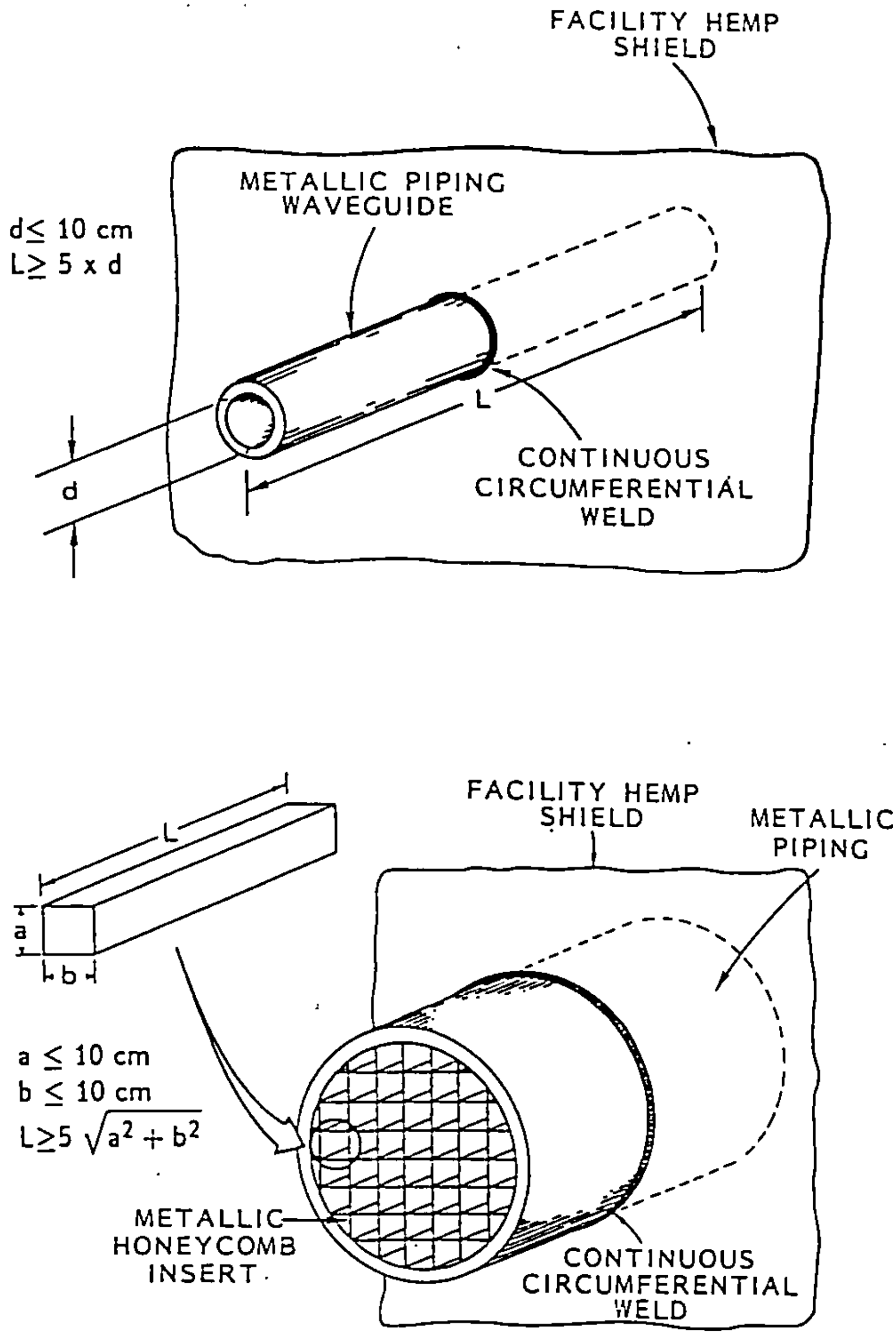


FIGURE 3. Typical waveguide-below-cutoff piping POE protective devices.

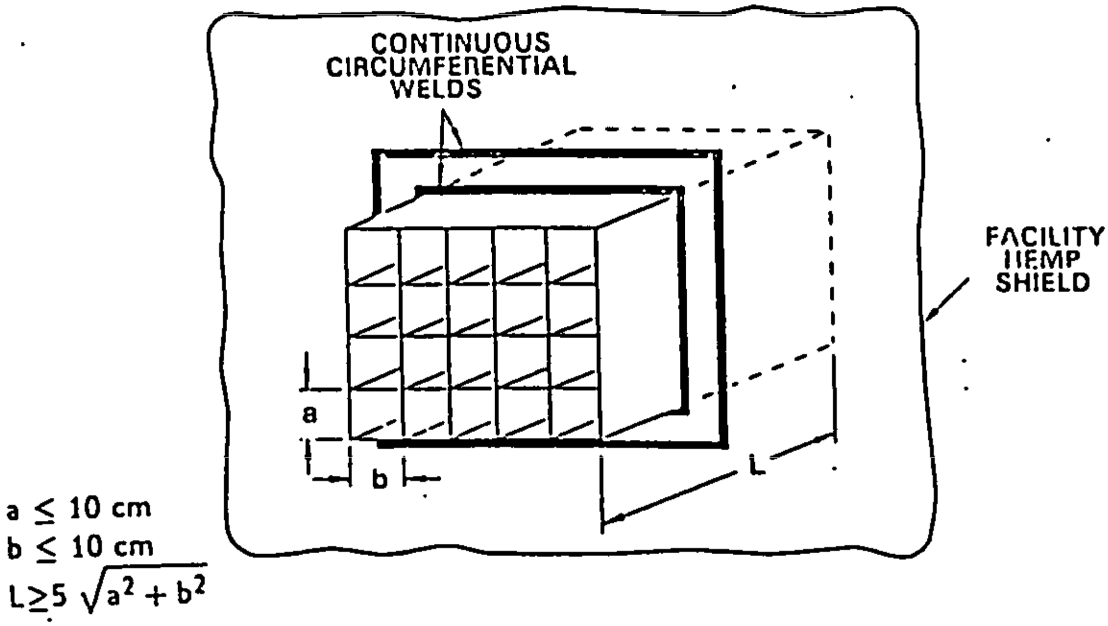


FIGURE 4. Typical waveguide-below-cutoff array ventilation POE protective device.

at the ends of the waveguide section; no HEMP-unique requirements apply to these couplings.

5.1.5.3 Ventilation POEs. Ventilation ducts shall penetrate the facility HEMP shield in a section of metallic ducting which is configured as a waveguide-below-cutoff array panel (figure 4). The presence of the protected ventilation POE shall not degrade shielding effectiveness of the facility HEMP shield below the minimum requirements of figure 1.

5.1.5.3.1 Waveguide array dimensions. Each of the transverse cell dimensions of the waveguide-below-cutoff array shall not exceed 10 cm (4 in). The length of the waveguide shall be at least five times the transverse cell diagonal dimension.

5.1.5.3.2 Waveguide array construction. The waveguide-below-cutoff array panel frame shall be circumferentially welded or brazed to the facility HEMP shield at the POE. Cell walls shall be metallic and there shall be continuous electrical bonds at all intersections and between the cell walls and the duct wall. No conductors shall be permitted to pass through the waveguide.

5.1.6 Structural POE.

5.1.6.1 HEMP protection for structural POEs. HEMP protection for structural POEs, including beams, columns, and other metallic structural elements which must penetrate the electromagnetic barrier, shall be provided with continuously welded or brazed seams and joints between the penetrating element and the facility shield. As a design objective, the facility should be configured to minimize the number of metallic structural elements required to penetrate the barrier. Nonmetallic structural elements shall not penetrate the electromagnetic barrier.

5.1.6.2 Quality assurance for structural POE protective treatments. All welded and brazed seams and joints required for structural POE treatments shall be monitored under the program of in-progress inspection of welded and brazed seams (see 5.1.3.4.1).

5.1.6.3 Acceptance testing for structural POE protective treatments. Acceptance testing for structural POE protective treatments shall be conducted using shielding effectiveness test procedures of appendix A.

5.1.7 Electrical POE.

5.1.7.1 HEMP protection for electrical POEs. HEMP protection for electrical POEs, including all power, communications and control penetrating conductors whether shielded or unshielded, shall be provided with main barrier transient suppression/ attenuation devices (except under conditions identified in 5.1.7.9).

5.1.7.1.1 Electrical POE main barrier protective device requirements. A main barrier transient suppression/attenuation device shall consist of an electrical surge arrester and additional linear and nonlinear elements, as required. The varistor voltage at 1 mA direct current d.c. (for a metal oxide varistor) or the d.c. breakdown voltage (for a spark gap) shall be 150 to 250 percent of the peak operating voltage on the line. The main barrier protective device shall limit the residual internal transient stress to the maximum prescribed for each class of electrical POE, when prescribed pulses are injected at its external terminal (see table I). Additionally, the main barrier protective device shall be rated to withstand at least 2000 short pulses at the prescribed peak injection current without damage or unacceptable performance degradation, as defined in test procedures of appendix B.

5.1.7.1.2 Electrical POE main barrier protective device installation. Electrical POE main barrier protective devices shall be installed in the configuration shown on figure 5. The external and internal conduits and compartment covers do not have

TABLE 1. Residual internal stress limits and injected pulse characteristics for classes of electrical POEs

a. Electrical POEs except RF Signal Line POEs

Class of Electrical POE	Residual Internal Stress Limits: Type of Measurement	Peak Response Current (A)	Peak Rate of Rise (A/s)	Root Action (A-√s)	Pulsed Current Injection Requirements[1]: Type of Injection	Peak Short Ckt Current (A)	Risetime (s)	FWHM[2] (s)
Commercial Power Lines (Intersite)								
Short Pulse	Bulk Current	10	$1x10^7$	$1.6x10^{-1}$	Comn mode	8000	$\leq 1 \times 10^{-6}$	$5x10^{-7}$ - $5.5x10^{-7}$
Short Pulse	Wire Current	10	$1x10^7$	$1.6x10^{-1}$	Wire-to-gnd	4000	$\leq 1 \times 10^{-6}$	$5x10^{-7}$ - $5.5x10^{-7}$
Intermediate Pulse	No damage or performance degradation				Comn mode	500	$\leq 1 \times 10^{-6}$	$\geq 5 \times 10^{-3}$
Intermediate Pulse	No damage or performance degradation				Wire-to-gnd	500	$\leq 1 \times 10^{-6}$	$\geq 5 \times 10^{-3}$
Long Pulse	No damage or performance degradation				Comn mode	200	≤ 0.5	≥ 100
Long Pulse	No damage or performance degradation				Wire-to-gnd	200	≤ 0.5	≥ 100
Other Power Lines (Intrasite)								
Short Pulse	Bulk Current	10	$1X10^7$	$1.6x10^{-1}$	Comn mode	8000	$\leq 1 \times 10^{-6}$	$5x10^{-7}$ - $5.5x10^{-7}$
Short Pulse	Wire Current	10	$1x10^7$	$1.6x10^{-1}$	Wire-to-gnd	4000	$\leq 1 \times 10^{-6}$	$5x10^{-7}$ - $5.5x10^{-7}$
Audio/Data Lines (Intersite)								
Short Pulse	Bulk Current	0.1	$1x10^7$	$1.6x10^{-3}$	Comn mode	8000	$\leq 1 \times 10^{-6}$	$5x10^{-7}$ - $5.5x10^{-7}$
Short Pulse	Wire Current	0.1	$1x10^7$	$1.6x10^{-3}$	Wire-to-gnd	[3]8000/√N or 500	$\leq 1 \times 10^{-6}$	$5x10^{-7}$ - $5.5x10^{-7}$
Intermediate Pulse	No damage or performance degradation				Comn mode	500	$\leq 1 \times 10^{-6}$	$\geq 5 \times 10^{-3}$
Intermediate Pulse	No damage or performance degradation				Wire-to-gnd	500	$\leq 1 \times 10^{-6}$	$\geq 5 \times 10^{-3}$
Long Pulse	No damage or performance degradation				Comn mode	200	≤ 0.5	≥ 100
Long Pulse	No damage or performance degradation				Wire-to-gnd	200	≤ 0.5	≥ 100
Control/Signal Lines (Intrasite)								
Low-Voltage Lines[4]								
Short Pulse	Bulk current	0.1	$1x10^7$	$1.6x10^{-3}$	Comn mode	8000	$\leq 1 \times 10^{-6}$	$5x10^{-7}$ - $5.5x10^{-7}$
Short Pulse	Wire current	0.1	$1x10^7$	$1.6x10^{-3}$	Wire-to-gnd	[3]8000/√N or 500	$\leq 1 \times 10^{-6}$	$5x10^{-7}$ - $5.5x10^{-7}$
High-Voltage Lines								
Short Pulse	Bulk current	1.0	$1x10^7$	$1.6x10^{-2}$	Comn mode	8000	$\leq 1 \times 10^{-6}$	$5x10^{-7}$ - $5.5x10^{-7}$
Short Pulse	Wire current	1.0	$1x10^7$	$1.6x10^{-2}$	Wire-to-gnd	[3]8000/√N or 500	$\leq 1 \times 10^{-6}$	$5x10^{-7}$ - $5.5x10^{-7}$
RF Antenna-Shields								
Buried[5]	Shld current	0.1	$1x10^7$	1.6×10^{-3}	Shld to ground	1000	$\leq 1x10^{-6}$	$5x10^{-7}$-$5.5x10^{-7}$
Nonburied	Shld current	0.1	$1x10^7$	1.6×10^{-3}	Shld to ground	8000	$\leq 1x10^{-6}$	$5x10^{-7}$-$5.5x10^{-7}$
Conduit Shields								
Signal and Low Current Power[6]								
Buried[5]	Bulk current	0.1	$1x10^7$	$1.6x10^{-3}$	Conduit to gnd	1000	$\leq 1x10^{-6}$	$5x10^{-7}$-$5.5x10^{-7}$
Nonburied	Bulk current	0.1	$1x10^7$	$1.6x10^{-3}$	Conduit to gnd	8000	$\leq 1x10^{-6}$	$5x10^{-7}$-$5.5x10^{-7}$
Medium Current Power[6]								
Buried[5]	Bulk current	1.0	$1x10^7$	$1.6x10^{-2}$	Conduit to gnd	1000	$\leq 1x10^{-6}$	$5x10^{-7}$-$5.5x10^{-7}$
Nonburied	Bulk current	1.0	$1x10^7$	$1.6x10^{-2}$	Conduit to gnd	8000	$\leq 1x10^{-6}$	$5x10^{-7}$-$5.5x10^{-7}$
High Current Power[6]								
Buried[5]	Bulk current	10	$1x10^7$	$1.6x10^{-1}$	Conduit to gnd	1000	$\leq 1x10^{-6}$	$5x10^{-7}$-$5.5x10^{-7}$
Nonburied	Bulk current	10	$1x10^7$	$1.6x10^{-1}$	Conduit to gnd	8000	$\leq 1x10^{-6}$	$5x10^{-7}$-$5.5x10^{-7}$

TABLE I. Residual internal stress limits and injected pulse characteristics for classes of electrical POEs - Continued

b. RF signal line POEs

PULSED CURRENT INJECTION REQUIREMENTS[9]					
Lowest Response Frequency[7]	Pulser Waveform	Type of Injection	Waveform Parameters[8]		
$f \le 2$ MHz ($L \ge 75$ M)	Double Exponential	Wire to Shield	Peak Current-I_p(A)	Risetime-T_r(s)	FWHM[2](s)
			8000[10]	$\le 1\times10^{-8}$	5×10^{-7}-5.5×10^{-7}
2 MHz $< f \le 30$ MHz (75 M $> L \ge 5$ M)	Damped Sine	Wire to Shield	Peak Current-I_p(A)	Center f-(MHz)	Decay Factor (Q)
			2500	2 ± 10%	5 ± 3
30 MHz $< f \le 200$ MHz (5 M $> L \ge 0.75$ M)	Damped Sine	Wire to Shield	900	30 ± 10%	5 ± 3
$f > 200$ MHz ($L < 0.75$ M)	Damped Sine	Wire to Shield	250	200 ± 10%	5 ± 3
RESIDUAL INTERNAL STRESS LIMITS					
Type of RF POE		Type of Measurement	Peak Response Current (A)	Peak Rate of Rise (A/s)	Root Action ($A\sqrt{s}$)
Receive Only		Wire Current	0.1	No Damage or Performance Degradation	
		Shield Current	0.1	1×10^{7}	1.6×10^{-3}
Transmit and Transceive		Wire Current	1.0	No damage or Performance Degradation	
		Shield Current	0.1	1×10^{7}	1.6×10^{-3}

[1]Pulse current injection requirements for electrical POEs, except RF signal lines, are in terms of Norton equivalent sources. Short circuit currents are double exponential waveshapes. Source impedances are ≥ 60 Ω for the short pulse, ≥ 10 Ω for the intermediate pulse, and ≥ 5 Ω for the long pulse.

[2]FWHM is pulse full width at half maximum amplitude.

[3]Whichever is larger. N is the number of penetrating conductors in the cable.

[4]Low-voltage control/signal lines are those with maximum operating voltage < 90 V. High-voltage control/signal lines are those with maximum operating voltage ≥ 90 V.

[5]An antenna shield is considered buried when it terminates at a buried antenna and less than 1 m (3.3 ft) of its total length is not covered by earth or concrete fill. A conduit is considered buried when it connects two protected volumes and less than 1 m (3.3 ft) of its total length is not covered by earth of concrete fill.

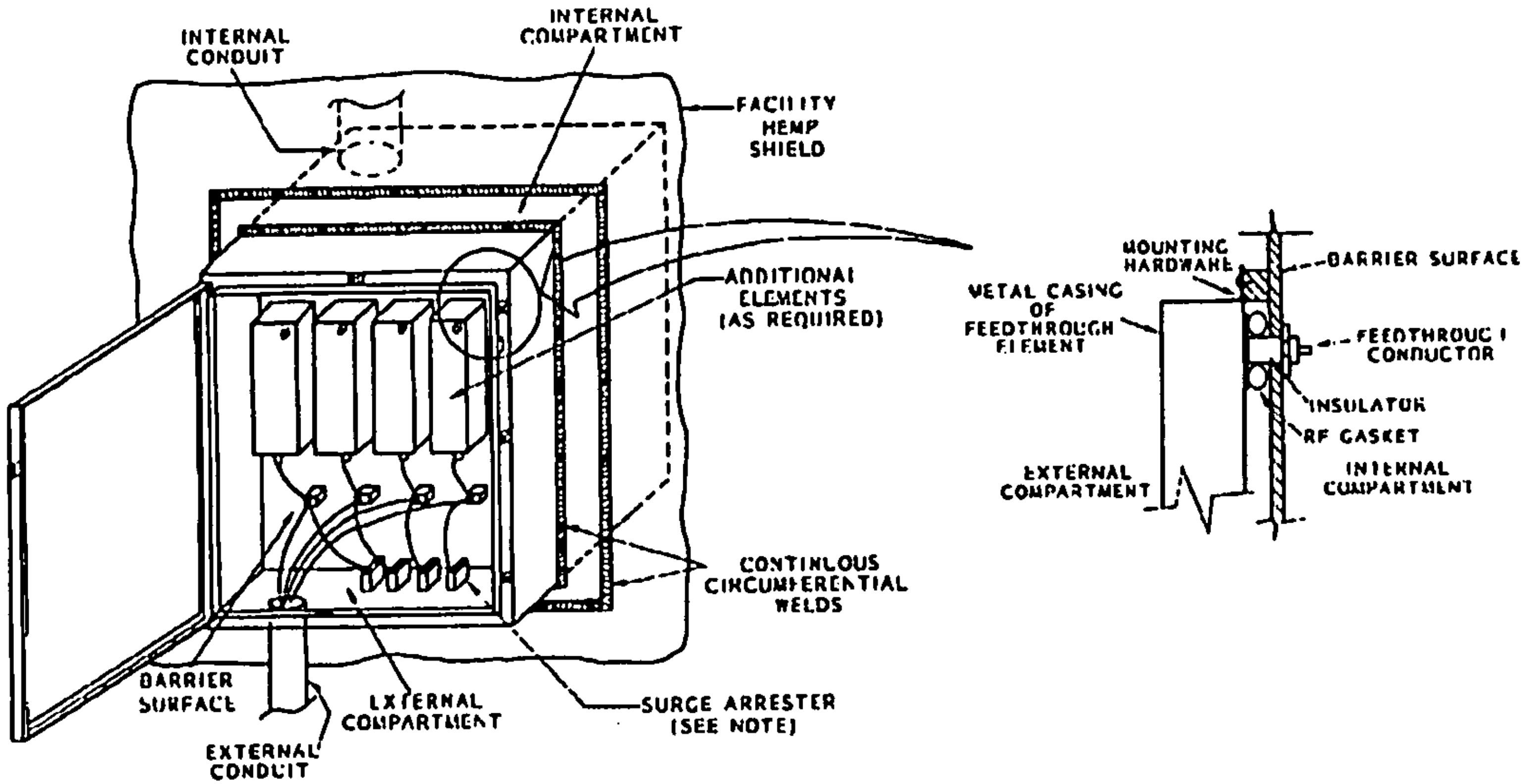
[6]High-current power lines have maximum operating current ≥ 10 A. Medium-current power lines have maximum operating current between 1 A and 10 A. Control/signal and low-current power lines have maximum operating current ≤ 1 A.

[7] f = 150/L MHz, where L is the largest dimension of the associated antenna in meters.

[8]These parameters of the injected current pulse are design objectives. Minimum injection requirements are contained in appendix B.

[9] For antennas mounted on towers taller than 25 m (82 ft), there is an additional pulsed current injection requirement. This requirement is a 2 (± 10%) MHz damped sinusoid of 500 A peak amplitude, and Q = 5 ± 3.

[10]For buried RF antenna lines, PCI of 1000 amps (peak current) is required.



NOTE: USE SHORT ELECTRICAL LEADS; CASE OF THE SURGE ARRESTER TO BE GROUNDED TO THE EXTERNAL ENCLOSURE

Figure 5 Typical electrical POE protective device.

shielding requirements as part of the electromagnetic barrier, but shielding may be necessary as a special protective measure (see 5.1.8) or to satisfy other electromagnetic requirements. The presence of the protected electrical POE shall not degrade shielding effectiveness of the facility HEMP shield below minimum requirements of figure 1.

5.1.7.2 Quality assurance for electrical POE main barrier protective devices. All welded and brazed seams and joints required for installation of electrical POE main barrier protective devices shall be monitored under the program of in-progress inspection of welded and brazed seams (see 5.1.3.4.1). Transient suppression/ attenuation devices shall be subjected to electrical quality assurance tests to demonstrate acceptable performance.

5.1.7.3 Acceptance testing of electrical POE main barrier protective devices. Acceptance testing of electrical POE main barrier protective devices shall be conducted using the pulsed current injection test procedures of appendix B.

5.1.7.4 Commercial electrical power feeder POEs. A main barrier transient suppression/attenuation device shall be provided on each penetrating conductor of a commercial electrical power feeder POE. The section of the commercial power feeder immediately outside the electromagnetic barrier shall be buried for a length of at least 15.2 m (50 ft). As a design objective, a maximum of two commercial electrical power feeders should penetrate the facility HEMP shield.

5.1.7.4.1 Commercial power POE main barrier protective device requirements. A Norton source, with a 8000 A short circuit current with ≤ 10 ns risetime and 500 ns FWHM, and source impedance ≥ 60 Ω, connected to a penetrating conductor at the POE main barrier protective device external terminal, shall produce a residual internal transient stress no greater than 10 A and shall not cause device damage or performance degradation.[4] A Norton source with a short circuit current of 500 A with ≤ 1 μs risetime and 5 ms FWHM, and source impedance ≥ 10 Ω, connected at the POE main barrier protective device terminal, shall not cause device damage or performance degradation.[4] A Norton source with a 200 A short circuit current with ≤ 0.5 s risetime and 100 s FWHM, and source impedance ≥ 5 Ω, connected at the POE main barrier protective device terminal, shall not cause device damage or performance degradation.[4] The E3 PCI pulser will be attached/installed on the primary side of the power transformer if one exists in series with the electrical POE being tested. If a POE main barrier protective device cannot be designed to satisfy

[4]Common mode PCI, waveform details of the injected pulses, and additional constraints on the residual internal transient stress are contained in table I. Circuit test configuration information is contained in the PCI test procedures of appendix B.

the residual internal stress limits without interfering with operation signals that it is required to pass, a special protective volume shall be established (see 5.1.8.3.2). As a design objective, each commercial power feeder should be provided with a device to disconnect the incoming lines automatically if a HEMP event occurs or manually during alert conditions.

5.1.7.5 Other electrical power feeder POEs. A main barrier transient suppression/ attenuation device shall be provided on each penetrating conductor of electrical power feeder POEs that supply internal power to equipment outside the electromagnetic barrier. As a design objective, internal power should be supplied only to MCS outside the electromagnetic barrier. Nonessential equipment outside the barrier should be powered from an external source.

5.1.7.5.1 Electrical power POE main barrier protective device requirements. A Norton source, with a 8000 A short circuit current with $\leq$ 10 ns risetime and 500 ns FWHM, and source impedance $\geq$ 60 Ω, connected to a penetrating conductor at the POE main barrier protective device external terminal, shall produce a residual internal transient stress no greater than 10 A and shall not cause device damage or performance degradation.[4] If a POE main barrier protective device cannot be designed to satisfy the residual internal stress limits without interfering with operational signals that it is required to pass, a special protective volume shall be established (see 5.1.8.3.2).

5.1.7.6 Audio and data line POEs.

5.1.7.6.1 Standard audio and data lines. All voice and data lines, whether shielded or unshielded, shall be converted to fiber optics outside the electromagnetic barrier and shall penetrate the facility HEMP shield on all-dielectric fiber optic cables. Electro-optic equipment outside the electromagnetic barrier shall be protected using special protective measures (see 5.1.8.1), if the associated audio or data line is mission essential. The fiber optic cable POE shall be protected with a waveguide-below-cutoff protective device.

5.1.7.6.1.1 Fiber optic waveguide-below-cutoff protective device. The inside diameter of a fiber optic waveguide-below-cutoff shall not exceed 10 cm (4 in). The length of the waveguide shall be at least five times the inside diameter of the waveguide-below-cutoff.

5.1.7.6.1.2 Fiber optic waveguide-below-cutoff protective device construction. All joints and couplings in the waveguide shall be circumferentially welded or brazed, and the waveguide-below-cutoff protective device shall be circumferentially welded or brazed to the facility HEMP shield at the POE. No conductors or conducting fluids shall be permitted to pass through the waveguide; the waveguide-below-cutoff protective device shall be filled or its ends shall be capped to prevent inadvertent insertion of conductors.

5.1.7.6.2 Nonstandard audio and data POE main barrier protective device requirements. A main barrier transient suppression/attenuation device shall be provided on each penetrating conductor of shielded or unshielded nonstandard audio or data lines that cannot be practically converted to fiber optics. As a design objective, a maximum of 20 such nonstandard audio or data lines are allowed to penetrate the facility HEMP shield.

5.1.7.6.2.1 Nonstandard audio and data POE main barrier protective device requirements. A Norton source, with an $8000/\sqrt{N}$ or 500 A short circuit current with ≤ 10 ns risetime and 500 ns FWHM (where N is the number of penetrating conductors in the audio or data cable and the larger amplitude is chosen), and source impedance ≥ 60 Ω, connected to a penetrating conductor at the POE main barrier protective device external terminal, shall produce a residual internal transient stress no greater than 0.1 A and shall not cause device damage or performance degradation.[4] A Norton source with a 500 A short circuit current with ≤ 1 μs risetime and 5 ms FWHM, and source impedance ≥ 10 Ω, connected at the POE main barrier protective device terminal, shall not cause device damage or performance degradation.[4] A Norton source with a 200 A short circuit current with a ≤ 0.5 s risetime and a 100 s FWHM, and source impedance ≥ 5 Ω connected at the POE main barrier protective device[5] terminal, shall not cause device damage or performance degradation.[4] If a POE main barrier protective device cannot be designed to satisfy the residual internal transient stress limits without interfering with operational signals it is required to pass, a special protective volume shall be established (see 5.1.8.3.2).

5.1.7.7 Electrical control and signal line POEs. A main barrier transient suppression/ attenuation device shall be provided on each penetrating conductor of electrical control and signal lines, whether shielded or unshielded. As a design objective, the number of control and signal lines penetrating the facility HEMP shield should be minimized. Nonmetallic fiber optic lines do not require a transient suppression/ attenuation device at the barrier.

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[5]When a transformer is in series and on the "dirty" side of the protective device/barrier, then the transformer is considered the main barrier POE protective device for E3 testing.

5.1.7.7.1 <u>POE main barrier protective device requirements for control and signal lines operating at voltages less than 90 V</u>. A Norton source, with an 8000/√N or 500 A short circuit current with ≤ 10 ns risetime and 500 ns FWHM (where N is the number of penetrating conductors in the control or signal cable and the larger amplitude is chosen), and source impedance ≥ 60 Ω, connected to a penetrating conductor at the POE main barrier protective device external terminal, shall produce a residual internal transient stress no greater than 0.1 A and shall not cause device damage or performance degradation.[4] If a POE main barrier protective device cannot be designed to satisfy the residual internal transient stress limits without interfering with operational signals it is required to pass, a special protective volume shall be established (see 5.1.8.3.2).

5.1.7.7.2 <u>POE main barrier protective device requirements for control and signal lines operating at greater than 90 V</u>. A Norton source, with an 8000/√N A or 500 A short circuit current with ≤ 10 ns risetime and 500 ns FWHM (where N is the number of penetrating conductors in the control or signal cable and the larger amplitude is chosen), and source impedance ≥ 60 Ω, connected to a penetrating conductor at the POE main barrier protective device external terminal, shall produce a residual internal transient stress no greater than 1 A and shall not cause device damage or performance degradation.[4] If a POE main barrier protective device cannot be designed to satisfy the residual internal transient stress limits without interfering with operational signals it is required to pass, a special protective volume shall be established (see 5.1.8.3.2).

5.1.7.8 <u>RF communications antenna line POEs</u>. A main barrier transient suppression/attenuation device shall be provided on signal-carrying conductors of all penetrating RF communications antenna lines. The antenna cable shields shall be circumferentially bonded to the facility HEMP shield at the POE.

5.1.7.8.1 <u>Antenna line POE main barrier protective device requirements</u>.

5.1.7.8.1.1 <u>Signal conductor injection for receive-only antennas</u>. A pulse of the prescribed waveform and amplitude, occurring on the signal-carrying conductor at the external terminal of a receive-only antenna line POE main barrier protective device, shall produce residual internal transient stresses no greater than 0.1 A on the signal-carrying conductor and shield and shall not cause device damage or performance degradation.[4] The pulse waveform and amplitude are determined by the lowest characteristic response frequency, f, which is 150/L MHz (where L is the largest dimension of the associated antenna in meters). The prescribed pulse is an 8000 A double exponential with 10 ns risetime and 500 ns FWHM, where the lowest characteristic response frequency is less than 2 MHz.[4] The prescribed pulse is a 2 MHz damped sinusoid with 2500 A peak current, where the lowest response frequency is 2 MHz to 30 MHz.[4] The prescribed pulse is a 30 MHz damped sinusoid with 900 A peak current, where the lowest response frequency is 30 MHz to 200 MHz, and a 200 MHz damped sinusoid with 250 A peak current, when the lowest response frequency is greater than 200 MHz.[4] For antennas mounted on towers taller than 25 m (82ft), there is an additional pulsed current injection requirement. A pulse with a double exponential waveshape, with 500 A peak amplitude, ≤ 10 ns risetime, and 500 ns FWHM shall be injected at the external terminal of the antenna line POE main barrier protective device. If a POE main barrier protective device cannot be designed to satisfy the residual internal transient stress limits without interfering with operational signals it is required to pass, a special protective volume shall be established (see 5.1.8.3.2).

5.1.7.8.1.2 Signal conductor injection for transmit antennas. A pulse of the prescribed waveform and amplitude, occurring on the signal-carrying conductor at the external terminal of a transmit-only or transceive antenna line POE main barrier protective device, shall produce residual internal transient stresses no greater than 1 A on the signal-carrying conductor[6] and 0.1 A on the shield and shall not cause device damage or performance degradation[4]. The pulse waveform and amplitude are determined by the lowest characteristic response frequency, f, which is 150/L MHz (where L is the largest dimension of the associated antenna in meters). The prescribed pulse is an 8000 A double exponential with ≤ 10 ns risetime and 500 ns FWHM, where the lowest characteristic response frequency is less than 2 MHz.[4] The prescribed pulse is a 2 MHz damped sinusoid with 2500 A peak current, where the lowest response frequency is 2 MHz to 30 MHz.[4] The prescribed pulse is a 30 MHz damped sinusoid with 900 A peak current, where the lowest response frequency is 30 MHz to 200 MHz, and a 200 MHz damped sinusoid with 250 A peak current, when the lowest response frequency is greater than 200 MHz.[4] For antennas mounted on towers taller than 25 m (82 ft), there is an additional pulsed current injection requirement. A pulse with a double exponential waveshape, with 500 peak amplitude, 10 ns risetime, and 500 ns FWHM shall be injected at the external terminal of the antenna line POE main barrier protective device. If a POE main barrier protective device cannot be designed to satisfy the residual internal transient stress limits without interfering with operational signals it is required to pass, a special protective volume shall be established (see 5.1.8.3.2).

[6] It may be difficult to design POE main barrier protective devices that can achieve the residual requirement of 1 A for RF transmit only or transceiver signal carrying conductors. Therefore, RF transmitters or transceivers will likely require placement in special protective volumes (see 5.1.8.3.2).

5.1.7.8.1.3 Shield Injection. A Norton source, with a 1000 A short circuit current with ≤ 10 ns risetime and 500 ns FWHM, and source impedance ≥ 60 Ω, connected to the shield of a buried antenna cable at a point outside the electromagnetic barrier, shall produce residual internal transient stresses no greater than 0.1 A on the signal-carrying conductor and shield and shall not cause POE protective device damage or performance degradation.[4] For a nonburied antenna cable, a Norton source, with an 8000 A short circuit current with ≤ 10 ns risetime and 500 ns FWHM, and source impedance ≥ 60 Ω connected to the shield at a point outside the barrier shall produce residual internal transient stresses no greater than 0.1 A on the signal-carrying conductor and shield and shall not cause POE protective device damage or performance degradation.[4] An antenna cable is considered buried when less than 1 m (3.3 ft) of its total length is not covered by earth or concrete fill and it terminates at a buried antenna. The cable is considered nonburied if at least 1 m (3.3 ft) of its total length is not covered.

5.1.7.9 Conduit shielding. Control/signal lines of interest are made of copper, aluminum or metal wrapped.

5.1.7.9.1 Buried and unburied control and signal line conduits. A control and signal cable run between two protected volumes may be HEMP-protected using a buried metal conduit, when the length of the run is less than 25 m (82 ft). A cable containing one (or more) control or signal lines or one (or more) power lines with maximum operating current below 1.0 A is considered to be a control and signal cable. A conduit is considered buried when less than 1 m (3.3 ft) of its total length is not covered by earth or concrete fill; unburied if 1 m (3.3 ft) or more of the cable's total length is not covered. Main barrier transient suppression/attenuation devices are not required on the penetrating conductors under these conditions.

5.1.7.9.2 Power line conduits. A cable run between two protected volumes and containing only power lines with operating currents above 10 A may be HEMP-protected using a buried metal conduit, when the length of the run is less than 2500 m (8200 ft). A cable run between two protected volumes and containing only power lines with operating currents above 10 A may be HEMP-protected using a nonburied metal conduit, when the length of the run is less than 312 m (1025 ft). For a cable run of power lines with operating currents between 1.0 A and 10 A, the maximum conduit length is 250 m (820 ft) for a buried conduit and 31.2 m (102 ft) for a nonburied conduit. Main barrier transient suppression/attenuation devices are not required on the penetrating conductors under these conditions.

5.1.7.9.3 Conduit requirements. HEMP protection conduits shall be rigid metal conduit, circumferentially welded or brazed at all joints and couplings, and circumferentially welded or brazed to the facility HEMP shields at POEs on both ends. Pull boxes in the conduit run shall be welded or brazed metal enclosures and shall be electromagnetically closed with welded, brazed, or RF gasketed and bolted covers. A Norton source, with a 1000 A short circuit current on a buried control and signal line conduit and an 8000 A short circuit current on a nonburied control and signal line conduit, with source impedance ≥ 60 Ω, with ≤ 10 ns risetime and 500 ns FWHM, shall produce a residual internal transient stress no greater than 0.1 A on the wire bundle inside the conduit.[4] The same sources connected on the outer surface of a power line conduit shall produce a residual internal transient stress no greater than 10 A, when the operating current on the lowest rated conductor in the wire bundle inside the conduit is above 10 A, and no greater than 1.0 A when the operating current is between 1.0 A and 10 A.[4]

5.1.8 <u>Special protective measures</u>. In special cases where HEMP hardness cannot be achieved with the electromagnetic barrier alone (see 4.3.4), special protective measures shall be implemented. Special protective measures shall not be used as a substitute for an electromagnetic barrier which satisfies the performance requirements of this standard.

5.1.8.1 <u>MCS outside the electromagnetic barrier</u>. Special protective measures shall be implemented to HEMP harden MCS that are placed outside the electromagnetic barrier IAW provisions of this standard (see 5.1.1.1). Special protective measures for MCS outside the main barrier may include:

a. Cable, conduit, and local volume shielding.

b. Linear and nonlinear transient suppression/attenuation devices.

c. Equipment-level hardening (reduced coupling cross-section, dielectric means of signal and power transport, use of inherently robust components).

d. Remoting sensitive circuits to locations within the protected volume.

e. Automatic recycling features or operator intervention schemes, when the mission timeline permits.

f. Other hardening measures appropriate for the particular equipment to be protected.

Performance requirements for the special protective measures shall ensure that the upper bound HEMP-induced peak time-domain current stresses at the equipment level are less than the vulnerability thresholds of the equipment.[7]

5.1.8.1.1 RF communications antennas outside the main electromagnetic barrier. Mission-essential RF antennas and any associated baluns or antenna cables located outside the main electromagnetic barrier shall be treated as MCS that are placed outside the electromagnetic barrier. Performance requirements shall ensure that the upper bound HEMP-induced peak time-domain current stresses at the antenna feed are less than the vulnerability thresholds of the MCS located outside the barrier.

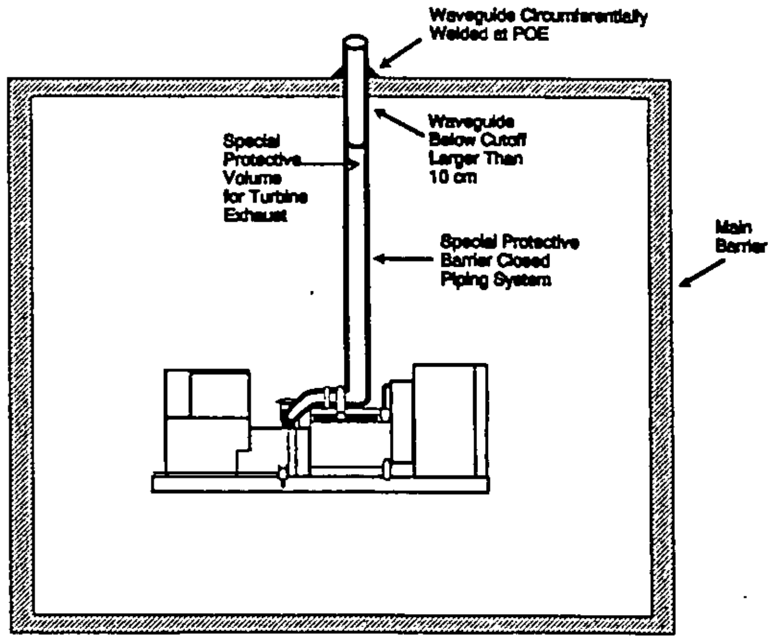
5.1.8.2 MCS inside the main electromagnetic barrier. Special protective measures shall be implemented to HEMP harden MCS that are within the main electromagnetic barrier, but experiences mission-aborting damage or upset during verification testing. Special protective measures for MCS inside the barrier may include cable, conduit, and volume shielding, transient suppression/attenuation devices, equipment-level hardening, automatic recycling, operator intervention features, and other hardening measures appropriate for the particular equipment to be protected. Performance requirements for the special protective measures shall ensure that the upper bound HEMP-induced peak time-domain current stresses at the equipment level are less than the vulnerability thresholds of the equipment.[6]

5.1.8.3 Special protective volumes.

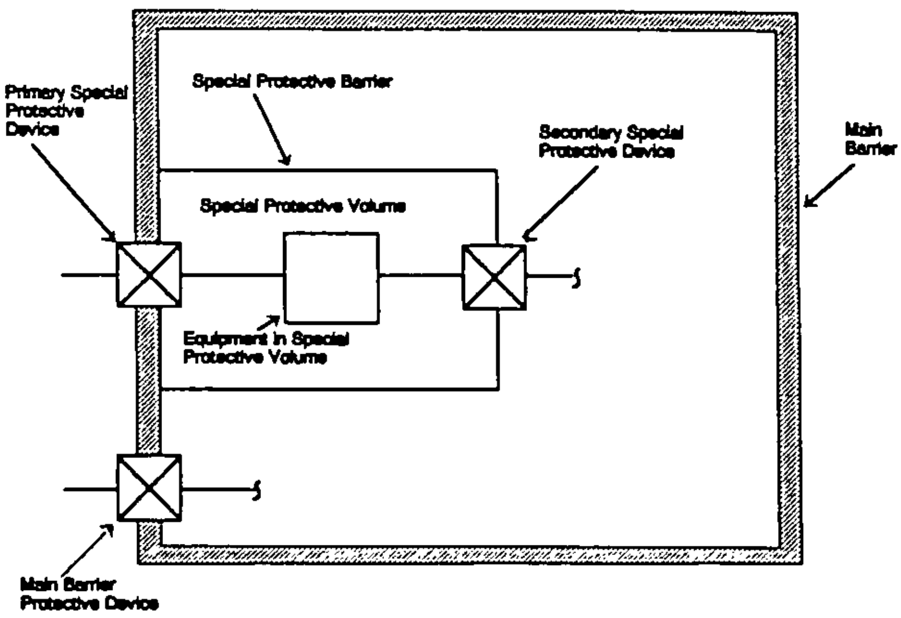
5.1.8.3.1 Special protective volumes for piping POEs. When a piping POE waveguide-below-cutoff must be larger that 10 cm (4 in) to provide adequate fluid flow and a waveguide-below-cutoff array insert cannot be used, a special protective volume shall be established inside the electromagnetic barrier (figure 6a).

5.1.8.3.1.1 Special waveguide requirements. A waveguide-below-cutoff which must be larger than 10 cm (4 in) shall be of the minimum inside diameter consistent with its functional requirements. The length of the waveguide section shall be at least five times the inside diameter. All joints and couplings in the waveguide section shall be circumferentially welded or brazed, and the waveguide shall be circumferentially welded or brazed to the facility HEMP shield at the POE. No dielectric lining shall be permitted in the waveguide section.

[7] See MIL-HDBK-423 for methods to determine the upperbound HEMP stresses and vulnerability thresholds.



6a. Special Protective Volume for Piping POE.



6b. Special Protective Volume for Electrical Equipment.

FIGURE 6. Typical special protective volumes

5.1.8.3.1.2 Special protective barrier for piping POEs. A special protective barrier shall completely enclose piping which is protected at its POE with a waveguide-below-cutoff larger than 10 cm (4 in) inside diameter. The special protective barrier may be a separate shield with protected penetrations, or it may be implemented using the metal walls of the piping system itself (see figure 6a). Performance requirements for the special protective barrier shall ensure that the total shielding effectiveness, measured through the main electromagnetic barrier and special protective barrier, satisfies at least the minimum requirements shown on figure 1.

5.1.8.3.2 Special protective volumes for electrical POEs. When a main barrier protective device cannot be designed to achieve the transient suppression/attenuation performance prescribed for the class of electrical POE (see 5.1.7) without interfering with operational signals it is required to pass, a special protective volume shall be established inside the main electromagnetic barrier (figure 6b). The special protective volume shall be enclosed by a special protective barrier with primary and secondary protective devices as required to meet the performance requirements prescribed in this standard.

5.1.8.3.2.1 Special protective barrier for electrical POEs. A special protective barrier shall completely enclose wiring and equipment directly connected to a primary special protective device. The special protective barrier may be a separate shield with electromagnetic barrier and shall satisfy at least the requirements of figure 1.

5.1.8.3.2.2 Primary special protective device requirements. A primary special protective device shall be substituted for a main barrier protective device that cannot achieve the prescribed transient suppression/attenuation performance (see table 1) without interfering with the operational signals it is required to pass. The primary special protective device shall be designed to provide the maximum transient suppression/attenuation consistent with its functional requirements. When the pulse prescribed for the class of electrical POE occurs at the external terminal (see table I), the primary special protective device shall perform its designed task(s) without damage or degradation.

5.1.8.3.2.3 Secondary special protective device requirements. When the combination of the primary special protective device and the directly connected equipment cannot be designed to achieve the transient suppression/attenuation performance prescribed for the class of electrical POE (see table I), a secondary special protective device shall be used (figure 6b). The secondary special protective device shall be designed so that the total transient suppression/attenuation, measured through the primary special protective device, the connected equipment, and the secondary special protective device, satisfies at least the minimum requirements of 5.1.7 for the prescribed class of POE.

5.1.8.3.2.4 MCS in a special protective volume. Special protective measures shall be implemented as necessary to harden MCS in a special protective volume to the HEMP-induced signals that will occur in that volume. Special protective measures for MCS in a special protective volume may include cable, conduit, and volume shielding, transient suppression/attenuation devices, equipment-level hardening, remoting sensitive circuits, automatic recycling, operator intervention features, and other hardening measures appropriate for the particular equipment to be protected. Performance requirements for the special protective measures shall ensure that the upper bound HEMP-induced peak time-domain current stresses at the equipment level are less than the vulnerability thresholds for the equipment.[6]

5.1.8.4 Quality assurance for special protective measures. Quality assurance tests shall be conducted to ensure that special protective measures comply with performance requirements for the particular installation.

5.1.8.5 Acceptance testing for special protective measures.

5.1.8.5.1 Special protective measures for MCS. Acceptance testing is not required for equipment-level special protective measures installed on MCS IAW with 5.1.8.1, 5.1.8.2, and 5.1.8.3.2.3. HEMP hardness provided by these special protective measures shall be demonstrated during the verification test program.

5.1.8.5.2 Special protective barriers. Acceptance testing for all special protective barriers shall be conducted using shielding effectiveness test procedures of appendix A. Additionally, acceptance testing for all special protective barriers required because of an electrical POE protective device shall include PCI IAW test procedures of appendix B.

5.1.9 Reliability and maintainability. The HEMP protection subsystem shall be designed and constructed to be rugged, reliable, and maintainable. Reliability and maintainability program tasks and requirements shall be included in the facility acquisition specifications to assure that reliability is considered in component selections, to reduce the frequency, complexity, and costs of design-dictated maintenance, and to provide adequate provisioning with spare HCI and maintenance tools and supplies.

5.1.10 Safety and human engineering. Safety and human engineering criteria, principles, and practices shall be applied in the design, selection, and placement of HEMP protection subsystem elements. Entryways shall be designed to accommodate expected traffic and shield doors shall operate simply with operating forces within limits imposed by MIL-STD-1472. Inspection covers shall be designed for safety and ease of removal and proper reinstallation. Electrical POE protective devices shall provide fail-safe features, such as capacitor discharge resistors, for protection of personnel during installation, operation, maintenance, and repair. Radiofrequency radiation protection for personnel shall be addressed IAW DoDI 6055.11.

5.1.11 Testability. The HEMP protection subsystem shall be designed and constructed to accommodate quality assurance, acceptance and verification testing, and HM/HS. The facility shield shall be accessible for visual inspection at all POEs. Access for periodic shielding effectiveness measurements shall be provided except on the floor shield of a bottom floor and on buried facilities. The built-in shield monitoring capability shall consist of a permanently installed large loop or a permanently installed shield injection point system, as described in MIL-HDBK-423, or other exciter and sensor elements which will detect significant changes in the electromagnetic barrier performance. Electrical POE protective devices shall be installed with accessible PCI drive points and measurement points.

5.1.12 Corrosion control. Corrosion protection measures shall be implemented in the design and construction of the HEMP protection subsystem. The facility shield and POE protective devices shall be constructed with inherently corrosion-resistant materials or metals shall be coated or metallurgically processed to resist corrosion. Pockets where water or condensation can collect shall be avoided and a crawl space shall be provided above the ceiling shield to allow inspection for roof leakage. Buried conduits or cables shall be coated with asphalt compound, plastic sheaths, or equivalent corrosion protection, and a means for detecting leakage shall be provided. Joints between dissimilar metals shall be avoided and, where required, shall be provided with corrosion preventive measures. Cathodic protection shall be provided, where required by environmental conditions.

5.1.13 Configuration management. A hardness configuration management program shall be implemented during design and construction of the HEMP protection subsystem. Hardness critical items and hardness critical processes shall be identified in the facility drawings IAW MIL-STD-100, and installed hardness critical items shall be distinctively marked with DD Form 2639, Hardness Critical Label or DD Form 2640, Hardness Critical Tag as appropriate. Facility design and installation changes shall be assessed for potential HEMP hardness impacts prior to approval. The affected portions of the HEMP protection subsystem shall be retested when configuration changes, MIL-STD-480, occur after acceptance testing.

5.1.14 Verification testing. After the HEMP protection system has been accepted and facility equipment is installed and operational, a verification test program shall be conducted. As a minimum, verification testing shall include CW immersion testing of the electromagnetic barrier, PCI tests at electrical POEs, and additional site-specific tests as needed to demonstrate effectiveness of special protective measures. All deficiencies identified by the verification test program shall be corrected, and retested until the required hardness is achieved.

5.1.14.1 CW immersion testing. CW immersion testing shall be performed IAW procedures of appendix C. At frequencies where the measurement dynamic range exceeds the attenuation required by figure 1, ratios of illuminating field strength to the internal field measurements shall be equal to or greater than the minimum shielding effectiveness requirement. Internal field measurements shall be below the instrumentation noise or operating signal level in frequency bands where measurement dynamic range is less than attenuation requirements of figure 1. Internal current measurements, when extrapolated to threat using equations defined in appendix C, shall be less than 0.1 A. No interference with mission-essential communications- electronics or support equipment shall occur.

When approved by the sponsoring agency for the verification test, a thorough program of shielding effectiveness measurements using procedures of appendix A and a thorough SELDS survey IAW MIL-HDBK-423 guidance may be performed in lieu of the CW immersion test.

5.1.14.2 PCI verification testing. PCI verification testing shall be performed IAW procedures of appendix B. Residual internal transient stress measurements shall not exceed maximum limits for the applicable class of electrical POE. POE protective devices shall not be damaged by the PCI excitations. No time-urgent, mission-impacting damage or upsets of MCS shall occur.[8]

5.1.14.3 Verification for special protective measures. Site-specific procedures for verification of special protective measures shall be developed based upon test approaches of 5.1.14.3.1 and 5.1.14.3.2. The verification testing shall demonstrate that HEMP-induced electromagnetic stresses resulting from facility

[8]The determination whether an observed interruption or upset is mission-aborting is the responsibility of the operational authority for the facility.

exposure to the threat environment of DoD-STD-2169 will not cause time-urgent, mission-impacting damage or upsets.[7]

5.1.14.3.1 Verification of special protective measures for MCS. Verification testing for MCS hardened with special protective measures shall generally include coupling measurements and PCI procedures. The coupling test shall be threat-relatable such as by pulse field illumination, PCI, or CW immersion (see appendix C). MCS cable currents shall be measured and extrapolated to the HEMP Environment Criteria [DoD-STD-2169 (current version)].

Long conductors that connect to the MCS and are directly exposed to the HEMP environment shall be PCI tested with injected pulses of the amplitudes and waveforms prescribed in appendix B.

Cables that connect or are internal to the MCS and are not directly exposed shall also be PCI tested. The injected pulse characteristics shall comply with one of the following requirements:

a. Amplitudes equal to the upper bounds of the HEMP-induced current stresses and waveforms similar to the measure data. For purposes of this standard, the upper bound shall be equal to 10 times the extrapolated coupling test results.

b. Amplitudes and waveforms prescribed in appendix B for the applicable class of electrical circuit.

These verification test excitations shall not cause time-urgent, mission-impacting damage or upset of MCS.[7]

5.1.14.3.2 Verification of special protective barriers. Verification of special protective barriers shall include PCI testing of all electrical POEs which penetrate into the special protective volume from outside the protective volume. Amplitudes and waveforms of the injected pulses shall be as prescribed in appendix B. In addition to functional observations and measurements required by 5.1.14.3.1, residual internal stresses shall be measured on conductors which penetrate from the special protective volume into the protected volume. Responses measured at test points within the protected volume shall not exceed maximum allowable limits, and the test excitations shall not cause time-urgent, mission-impacting damage or upset of MCS.

5.1.15 HM/HS program requirements. Logistics support analysis for the HEMP protection subsystem shall be performed IAW MIL-STD-1388-1 during the facility acquisition phase. The logistics support analysis shall define the HEMP protection subsystem HM/HS requirements, supply support requirements, training requirements, and technical data requirements.

5.1.15.1 HS/reverification test procedures. Detailed HS/reverification test procedures for the HEMP protection subsystem shall be developed and used. The HS tasks shall be performed on a periodic basis as described in the HM/HS program. The reverification test results shall be correlatable to verification test results and shall have the same pass/fail criteria. The procedures shall identify the tests to be performed, test equipment requirements, safety precautions, and other relevant information.

5.1.15.2 Maintenance and inspection procedures. Detailed procedures for maintenance and inspection and for repair and replacement of HEMP hardness critical assemblies or items shall be provided. Maintenance and inspection procedures shall be designed to be implemented at the organizational maintenance level and shall identify the tasks to be performed, frequency of performance, pass/fail criteria where applicable, safety precautions, and other relevant information. Repair and replacement procedures shall identify the tasks to be performed, hardness assurance requirements including pass/fail criteria, safety precautions, and other relevant information.

5.1.15.3 Supply support requirements. A parts list of the installed HEMP hardness critical assemblies or items and lists of recommended organizational HEMP protection subsystem spare parts, repair parts, supplies, special tools, and special test equipment shall be provided. The lists shall identify the nomenclature or description of each item, the manufacturer and manufacturer's part number, the federal stock number when assigned, the required quantity, and other relevant information. All hardness critical assemblies, items, cables, etc. shall be identified using either DD Form 2639, Hardness Critical Label, or DD Form 2640, Hardness Critical Tag as appropriate.

5.1.15.4 Training requirements. Training requirements for personnel assigned to a HEMP-hardened facility shall be defined. As a minimum, the training program shall include organizational HEMP awareness training for all site personnel and classroom and on-the-job training for HM/HS maintenance personnel. Training materials shall be provided for all training, MIL-STD-1379D, to be administered at the organizational level.

5.1.15.5 Technical data. A HEMP protection subsystem technical manual shall be provided. As a minimum, the technical manual shall include the following:

a. HEMP protection subsystem description and principles of operation.

b. Maintenance and inspection procedures, repair and replacement procedures, and hardness surveillance test procedures.

c. Supply support requirements.

d. Training requirements.

5.1.15.6 Delivery. The HEMP protection subsystem technical manual shall be delivered with the facility. Recommended organizational HEMP spare parts, repair parts, supplies, special tools, special test equipment, and training materials shall also be delivered with the facility.

5.1.15.7 Implementation. HEMP protection subsystem preventive maintenance, inspection, and Hardness Surveillance (HS)/reverification testing shall be performed IAW the technical manual. Corrective maintenance shall be performed if the HEMP protection subsystem performance degrades below the minimum requirements of this standard. Hardness Surveillance (HS)/reverification testing shall be performed at intervals not exceeding seven years.

6. NOTES

(THIS SECTION CONTAINS INFORMATION OF A GENERAL OR EXPLANATORY NATURE THAT MAY BE HELPFUL, BUT IS NOT MANDATORY.)

6.1 Intended use. The standard contains minimum requirements and design objectives for HEMP protection of fixed ground-based facilities which perform critical, time-urgent C^4I missions. The purpose is to standardize design, construction, and test of HEMP protection subsystems for these facilities and to thereby assure the quality and durability of the protection.

6.2 Subject term (key word) listing.

Continuous wave (CW) immersion
Electrical surge arrester
Electromagnetic barrier
Facility HEMP shield
Hardening
Hardness verification
Low risk HEMP protection
Mission-critical systems
Nuclear survivability
POE
Protection device, POE
Pulsed current injection
Shielding effectiveness
Special protective measures
Survivability/vulnerability
Transient suppression/attenuation device
Waveguide-below-cutoff

6.3 Changes from previous issue. The margins of this standard are marked with vertical lines to indicate where changes, additions, modifications, or corrections from the previous issue were made. This was done as a convenience only and the Government assumes no liability whatsoever for any inaccuracies in these notations. Bidders and contractors are cautioned to evaluate the requirements of this document based on the entire content irrespective of the marginal notations and relationship to the last previous issue.

SHIELDING EFFECTIVENESS TEST PROCEDURES[9]

10. GENERAL.

10.1 Scope. This appendix is a mandatory part of the standard. The information contained herein is intended for compliance. This appendix establishes procedures for measuring the shielding effectiveness of the electromagnetic barrier required for low-risk HEMP protection of critical ground-based facilities with time-urgent missions. The procedures are applicable for testing other HEMP-hardened facilities, when specified by the procurement documentation.

10.2 Applications. These procedures shall be used for shielding effectiveness acceptance testing of the facility HEMP shield and aperture POE protective treatments, as required by the DETAILED REQUIREMENTS of MIL-STD-188-125A. The procedures shall also be performed for acceptance of repairs or installations of new POE protective devices after construction acceptance, except that only areas affected by the repair or installation shall be tested. Shielding effectiveness measurements may also be conducted as part of the verification test program.

20. REFERENCED DOCUMENTS.

20.1 Government documents. The following documents form a part of this appendix to the extent specified:

DI-NUOR-80928	Nuclear Survivability Test Plan
DI-NUOR-80929A	Nuclear Survivability Test Report
DNA-EMP-1	Electromagnetic Pulse (EMP) Security Classification Guide (U) (document is classified S-RD).

(Copies of specifications, standards, handbooks, drawings, and publications required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

[9] HEMP-unique test procedures are temporarily included as appendices to MIL-STD 188-125; it is intended that these procedures will ultimately be promulgated as separate standards outside of the MIL-STD 188-series.

20.1.1 Standards. The following document forms a part of this appendix to the extent specified:

IEEE-299-1991	IEEE standard for Measuring the Effectiveness of Electromagnetic Shielding Enclosures.

(Applications for copies should be addressed to the Institute for Electrical and Electronics Engineers, 445 Hoes Lane, Post Office Box 1331, Piscataway NJ 08855-1331.)

30. DEFINITIONS.

30.1 Shielding effectiveness (SE). (at a test area) For the purposes of this procedure, the ratio, expressed in decibels (dB), of the received signal when the receiving antenna is illuminated by electromagnetic radiation in the test calibration configuration (no shield present) to the received signal through the electromagnetic barrier in the test measurement configuration. Assuming that antenna voltage is detected

$$SE = 20 \log \left(\frac{V_c}{V_m} \right)$$

where V_m is the measured signal at the test area and V_c is the calibration signal at the same frequency and transmitting antenna polarization. Shielding effectiveness values are test method-dependent and different values may be obtained when time-domain or other frequency-domain measurement techniques are used.

40. GENERAL REQUIREMENTS

40.1 General. This HEMP shielding effectiveness test method is similar to IEEE-STD-299-1991 except that the requirements have been modified to evaluate the barrier performance over a narrower frequency range using a minimum set of test points and test frequencies. A transmitting antenna is placed on one side of the electromagnetic barrier in the center of each test area. The receiving antenna is centered on the test area at the opposite side of the barrier to obtain a stationary measurement. Additionally, the receiving antenna is swept over the entire test area and rotated in orientation until the maximum received signal strength is detected. Selection of test areas, test frequencies, and polarizations of the transmitting antennas are defined in this appendix.

40.2 Purpose. These procedures define shielding effectiveness, as used in MIL-STD-188-125A. The purpose of the measurements is to obtain shielding effectiveness data for demonstrating compliance with facility shield and aperture POE treatment performance requirements established by MIL-STD-188-125A.

40.3 HEMP protection subsystem test configuration. The shielding effectiveness acceptance test should be conducted near the conclusion of the construction contract, when the following prerequisite conditions are met. The facility shield assembly shall be completed. All POEs and their POE protective devices, required as part of the construction work, shall be installed and in a normal operating condition. Internal and external wiring to conductive POE protective devices, if provided under the construction contract, shall be in place and connected. Penetrating fiber optic cables, if provided under the construction contract, shall be installed. All interior equipment and finish work under the construction contract shall be completed. Installed equipment may be either operating or nonoperating. A visual shield inspection shall be performed before starting the measurements to assure that these configuration requirements have been met.

When these shielding effectiveness measurements are conducted as part of the verification test program, the facility shall be in a normal operating configuration and should be performing actual or simulated mission functions. The HEMP protection subsystem shall be intact.

40.4 Analysis requirements. There are no pretest or post-test analyses required for these procedures.

40.5 Test equipment requirements. Test equipment required for shielding effectiveness measurements is identified in table II.

40.6 Operational impact analysis and risk. Since the electromagnetic barrier must remain intact during conduct of the shielding effectiveness measurement sequence, and use of electrically noisy equipment must be restricted, construction activity or unusual operations (facility modification, maintenance) may be affected. Radiated signal levels are low and present no hazard to equipment, but frequency adjustments may be required to avoid self-interference with nearby facilities. Normal electrical safety precautions apply.

TABLE II. Shielding effectiveness test equipment requirements

Equipment	Characteristics
Oscillator(s)	15-30 kHz, 300-500 kHz, 1-20 MHz, 100-400 MHz, 900-1000 MHz
Power Amplifier(s)	15-30 kHz, 300-500 kHz, 1-20 MHz 100-400 MHz, 900-1000 MHz, power output as required for dynamic range
Preamplifier(s)	15-30 kHz, 300-500 kHz, 1-20 MHz, 100-400 MHz, 900-1000 MHz, amplification and noise figure as required for dynamic range
Receiver(s) and Spectrum Analyzer(s)	15-30 kHz, 300-500 kHz, 1-20 MHz, 100-400 MHz, 900-1000 MHz
Antenna Kit[1]	15-30 kHz, 300-500 kHz, 1-20 MHz, 100-400 MHz, 900-1000 MHz
Miscellaneous Cables and Attenuators	As required

[1] Any antennas which radiate at the prescribed frequencies may be used. However, antennas that require large clear space in the direction of wave propagation shall not be used where clear space is limited for testing. Examples of such antennas are log-periodic dipole and circularly polarized conical spiral antennas. Procedures are written assuming use of dipole or aperture antennas for plane wave measurements and loop antennas for magnetic field measurements.

40.7 Test plan and procedures. A shielding effectiveness test plan and detailed test procedures shall be prepared. These may be combined in a single document or two separate documents may be used. As a minimum, the documentation shall contain the following information:

a. A statement of test objectives.

b. Facility identification and description.

c. Plane wave test area identification. The entire surface (including the floor when both sides of the shield are accessible) of the electromagnetic barrier shall be divided into numbered plane areas not greater than 2.5m x 2.5m (8.2 ft x 8.2 ft), as illustrated by the example in figure 7. A plane wave transmitting antenna location exists at the center of each area. A list of POEs, by test area, shall be included.

d. Low frequency magnetic field test area identification. Each 2.5m x 2.5m plane wave test area which contains a POE shall also be designated as a magnetic field test area. Additional magnetic field test areas shall be chosen to survey the entire surface of the electromagnetic barrier in sections not greater than 7.5m x 7.5m

O – PLANE WAVE TRANSMITTING ANTENNA LOCATION
X – MAGNETIC FIELD TRANSMITTING ANTENNA LOCATION

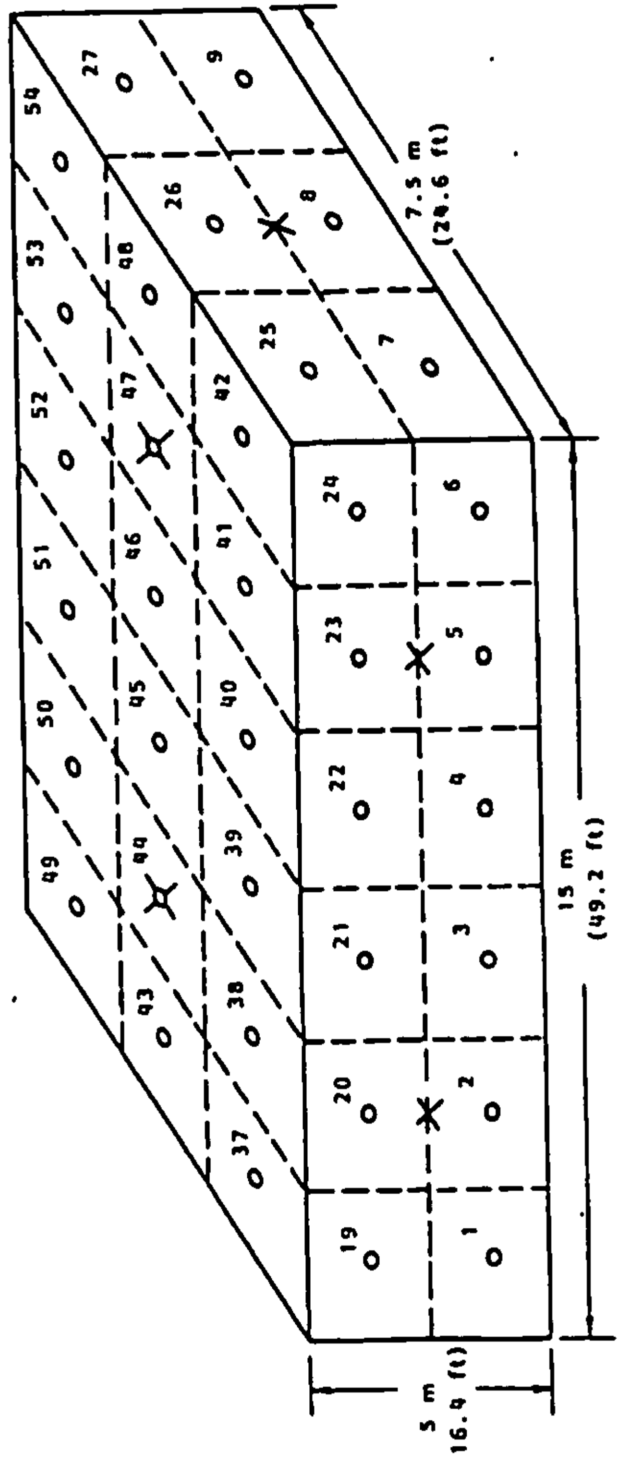


FIGURE 7. Sample test area assignments

(24.6 ft x 24.6 ft). A magnetic field transmitting antenna location exists at the center of each test area.

e. Electric field test area identification (when required by the procurement documentation).

f. Identification of test frequencies.

g. Test equipment identification by manufacturer, model, and serial number.

h. Any deviations from requirements of this appendix.

i. Procedures for marking, repair, and retest of defects.

j. Data management (including calibration and measurement data quality control procedures, data acceptability criteria, preservation of data records, and pass/fail criteria).

k. Safety.

l. Security. (see 40.9)

m. Test schedule (including priority of measurements).

Data item description DI-NUOR-80928, "Nuclear Survivability Test Plan," should be used.

40.8 Test report requirements. A shielding effectiveness test report shall be prepared. As a minimum, the report shall contain the following information:

a. Facility identification and test plan reference.

b. A discussion of any deviations from the test plan and requirements of this appendix.

c. Test calibration and measurement data (figure 8 illustrates a typical data sheet).

d. Pass/fail conclusions.

Data item description DI-NUOR-80929A, "Nuclear Survivability Test Report," should be used.

SHIELDING EFFECTIVENESS DATA SHEET

Facility: ____________
Test Date: ____________
Inspection: ____________

Test Area Number	Type of Test (Plane Wave or Magnetic)	Frequency/ Polarization	Distance from Antenna to Shield Wall	Type of Measurement (Stationary or Swept)	Calibration Signal (V_c) (V or dBV)	Measured Signal (V_m) or (V or dBV)	Shielding Effectiveness 20 log (V_c/V_m) or dBV_c - dBV_m)	Shielding Effectiveness Requirement (dB)	Pass/Fail

Comments: ____________

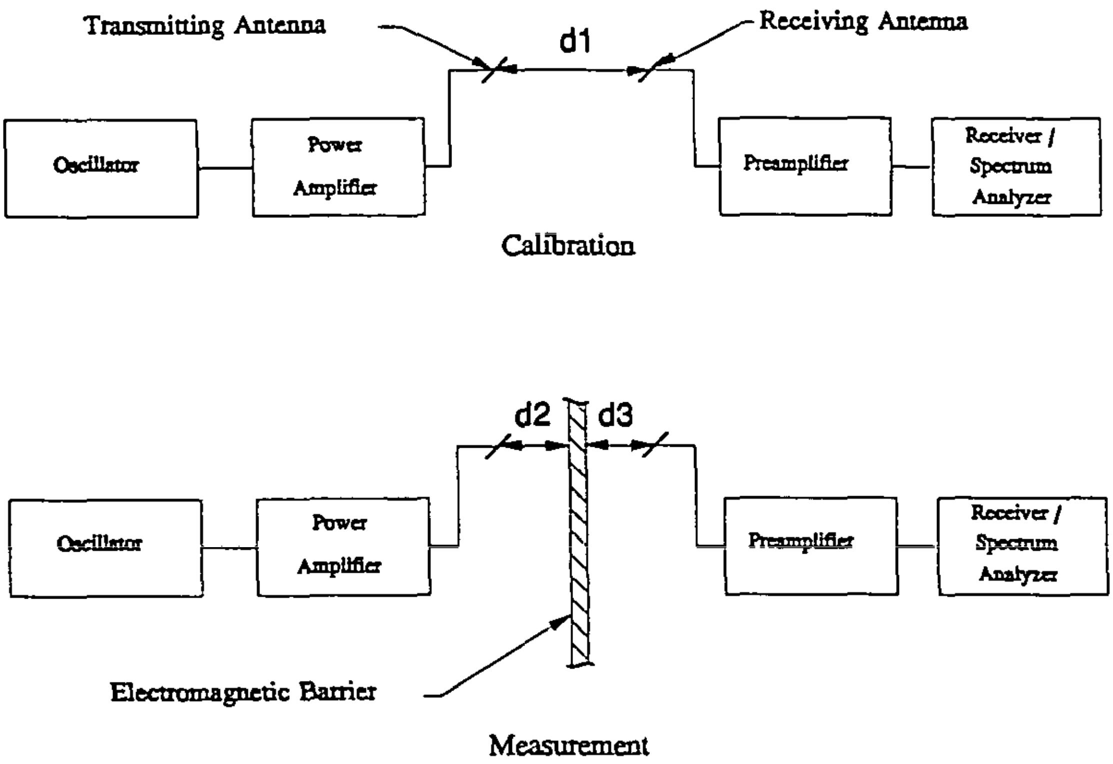
____

Signature

____

Title and Organization

FIGURE 8. Sample shielding effectiveness data sheet



d1 = as large as possible within dynamic range constraints and at least 2.5 m (8.2 ft)
d2 = d1 - 30 cm (1 ft)
d3 = 30 cm (1 ft) (Stationary measurement)
= 5 cm (2 in) to 60 cm (2 ft) (Swept measurement)

FIGURE 9. Plane wave test configurations

40.9 Data classification. Test data may be classified. DNA-EMP-1 and the classification guide for the specific facility or system should be consulted for guidance.

50. DETAILED REQUIREMENTS

50.1 Plane wave SE measurements.

50.1.1 Plane wave data requirements. For each plane wave test area (see 40.7c), eight shielding effectiveness measurements shall be made. Stationary and swept-in-space measurements shall be made at two frequencies for each of two transmitting antenna polarizations, as follows:

a. Frequencies - One frequency in the range of 100-400 MHz and one frequency in the range of 900-1000 MHz.

b. Antenna polarizations - Dipole (or antenna aperture) parallel to the test area surface in two orientations at 90 degrees to each other and parallel to the principle seams.

50.1.2 Plane wave calibration procedure. Plane wave calibration for each frequency and transmitting antenna polarization shall be performed IAW figure 9. The transmitting and receiving dipole antennas shall be parallel to each other (or aperture antenna planes parallel to each other). The distance between antennas shall be as large as possible, within dynamic range constraints, but shall be at least 2.5m (8.2 ft). The receiving antenna position shall be varied by ±30 cm (~1 ft) from its nominal location to ensure that it is not located at a minimum of the radiation pattern. Test equipment shall be chosen to provide a dynamic range at least 20 dB in excess of the shielding effectiveness requirement at the test frequency.

During calibration, no equipment or other electromagnetic reflectors (except ground) shall be closer than three times the antenna separation. The antennas shall be at least 1.5 - 2 m (6.6 ft) above ground.

The received signal strength for each frequency and transmitting antenna polarization shall be recorded as the calibration signal (V_c) for that configuration.

50.1.3 Plane wave measurement procedure. Plane wave shielding effectiveness measurements for each test area and at each required frequency and transmitting antenna polarization shall be performed as shown in figure 9. Identical equipment, antennas, cables, and equipment settings (except attenuator settings) shall be used in the calibration and measurement sequences.

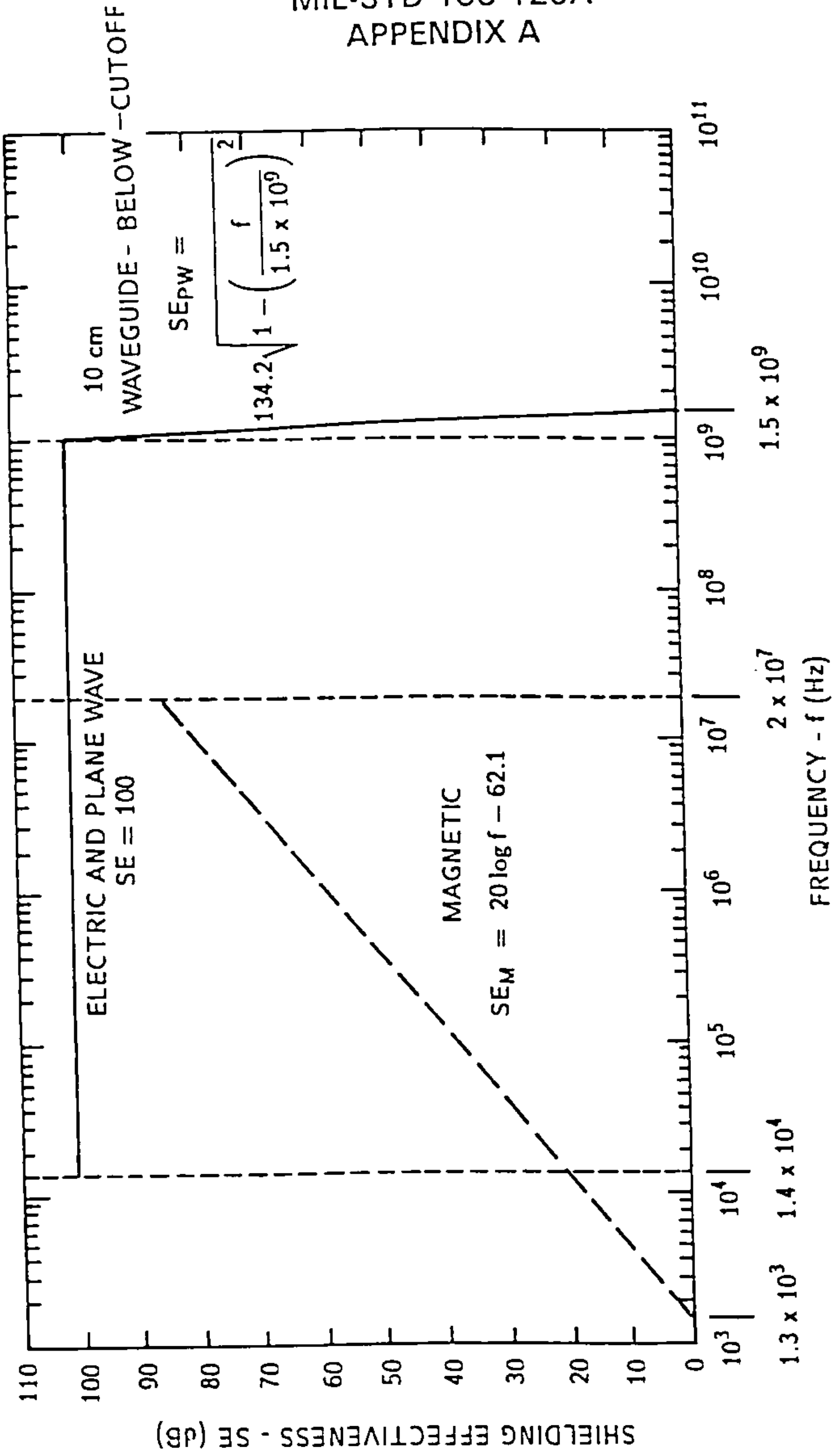


FIGURE 10. Minimum HEMP shielding effectiveness requirements (per MIL-STD-188-125A)

The transmitting antenna normally should be placed outside the electromagnetic barrier and it shall be centered on the test area. The transmitting dipole axis (or aperture antenna plane) shall be parallel to the test area surface and parallel to one of the two principle weld seam directions. The distance from the transmitting antenna to the test area surface shall be 30 cm (1 ft) less than the separation at which calibration was performed.

The receiving antenna should normally be inside the barrier. To obtain the stationary measurement, the receiving antenna shall be centered on the test area and the dipole axis (or aperture antenna plane) shall be parallel to the transmitting antenna axis (or plane). Distance from the receiving antenna to the test area surface shall be 30 cm (1 ft). The received signal strength shall be recorded as the stationary measured signal (V_m) for that test area, frequency, and transmitting antenna polarization.

To perform the swept-in-space measurement, the receiving antenna shall be swept over the entire test area at distances of approximately 5 cm (2 in) to 60 cm (2 ft) from the test area surface and shall be rotated in orientation until a maximum received signal is obtained. The maximum received signal strength shall be recorded as the swept measured signal (V_m) for that test area, frequency, and transmitting antenna polarization.[10]

50.1.4 Plane wave pass/fail criteria. The pass/fail criteria for plane wave shielding effectiveness are shown as a function of frequency by figure 10.

50.2 Low frequency magnetic field shielding effectiveness measurements.

50.2.1 Magnetic field data requirements. For each 2.5 m x 2.5 m magnetic field test area (see 40.7d), twelve shielding effectiveness measurements shall be made. Stationary and swept measurements shall be made at three frequencies for each of two transmitting antenna polarizations, as follows:

a. Frequencies. One frequency in the range of 10-30 kHz, and one frequency in the range of 300-500 kHz, and one frequency in the range of 1-20 MHz.

b. Antenna polarizations - Plane of the loop antenna normal to the test area surface in two orientations at 90 degrees to each other and parallel to the principle weld seams in the shield.

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[10] When the test area contains an aperture or conductive POE which requires a special protective volume inside the electromagnetic barrier, the receiving antenna must also be swept over the entire outer surface of the special protective barrier, at distances from approximately 5 cm to 60 cm from the barrier surface, and rotated in orientation. Pass/fail criteria for these readings are the same as the pass/fail criteria for other shielding effectiveness measurements.

For each 7.5 m x 7.5 m magnetic field test area, six shielding effectiveness measurements shall be made. Stationary measurements shall be made at three frequencies for each of two transmitting antenna polarizations, as described above.

50.2.2 Magnetic field calibration procedure. Magnetic field calibration for each frequency and transmitting antenna polarization shall be performed IAW figure 11.

The loops of the transmitting and receiving antennas shall be in the same plane. The distance between antennas shall be as large as possible, within dynamic range constraints, but shall be at least two loop diameters and at least 1.25 m (4.1 ft). The receiving antenna position shall be varied by ±30 cm (1 ft) from its nominal location to ensure that it is not located at a minimum of the radiation pattern. Test equipment shall be chosen to provide a dynamic range at least 20 dB in excess of the shielding effectiveness requirement at the test frequency.

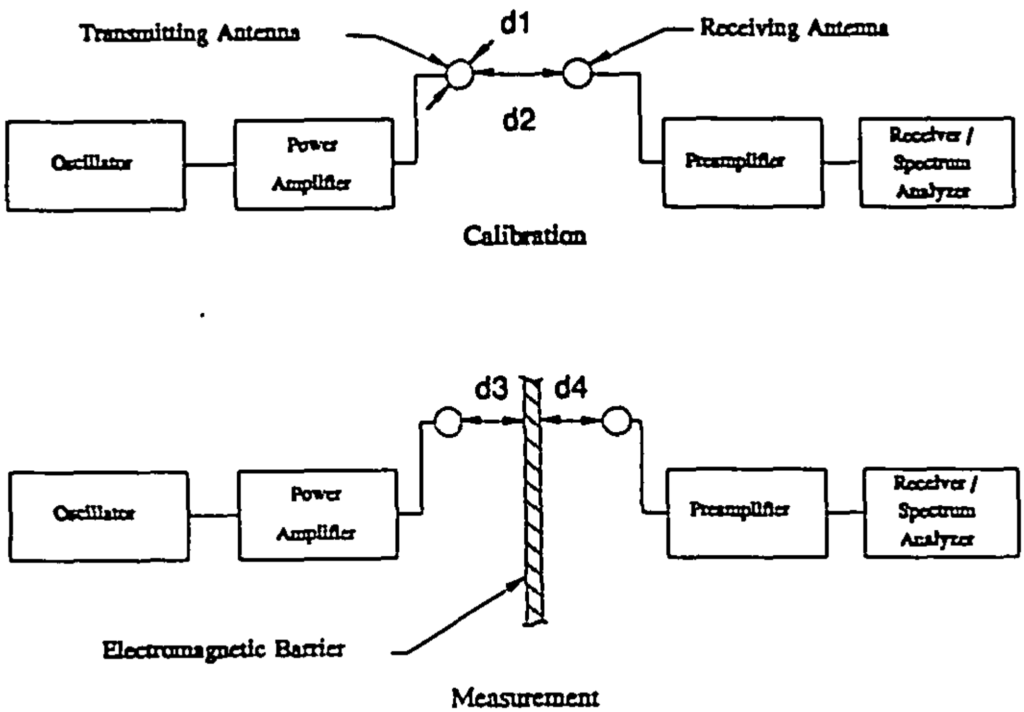
During calibration, no equipment or other electromagnetic reflectors (except ground) shall be closer than three times the antenna separation. The antennas shall be at least 1 m (6.6 ft) above ground.

The received signal strength for each frequency and transmitting antenna polarization shall be recorded as the calibration signal (V_c) for that configuration.

50.2.3 Magnetic field measurement procedure. Magnetic field shielding effectiveness measurements for each test area and at each required frequency and transmitting antenna polarization shall be performed as shown in figure 11. Identical equipment, antennas, cables, and equipment settings (except attenuator settings) shall be used in the calibration and measurement sequences.

The transmitting antenna shall normally be placed outside the electromagnetic barrier, and it shall be centered on the test area. The plane of the transmitting loop antenna shall be normal to the test area surface and parallel to one of the two principal weld seam directions. The distance from the transmitting antenna to the test area surface shall be 30 cm (~1 ft) less than the separation at which calibration was performed.

The receiving antenna shall normally be inside the barrier. To obtain the stationary measurement, the receiving antenna shall be centered on the test area and its loop shall be in the same plane as that of the transmitting antenna. Distance from the receiving antenna to the test area surface shall be 30 cm (1 ft). The received signal strength shall be recorded as the measured signal (V_m) for that test area, frequency, and transmitting antenna polarization.



d1 = Loop Diameter
d2 = As large as possible, within dynamic range constraints, and at least 2 x d1 or 1.25 m (4.1 ft) whichever is larger
d3 = d2 - 30 cm (1 ft)
d4 = 30 cm (1 ft) (Stationary measurement)
= 5 cm (2 in) to 60 cm (2 ft) (Swept measurement)

FIGURE 11. Magnetic field test configurations

To perform the swept measurement, when required, the receiving antenna shall be swept over the entire test area at a distance of approximately 5 cm (2 in) to 60 cm (2 ft) from the test area surface and shall be rotated in orientation until a maximum received signal is obtained. The maximum received signal strength shall be recorded as the swept measured signal (V_m) for that test area, frequency, and transmitting antenna polarization.[9]

50.2.4 Magnetic field pass/fail criteria. The pass/fail criteria for magnetic field shielding effectiveness are shown as a function of frequency by figure 10.

PULSED CURRENT INJECTION (PCI) TEST PROCEDURES[11]

10. GENERAL.

10.1 Scope. This appendix is a mandatory part of the standard. The information contained herein is intended for compliance. This appendix establishes PCI test procedures for electrical POE protective devices required for low-risk HEMP protection of critical ground-based facilities with time-urgent missions. The procedures are applicable for testing other HEMP-hardened facilities, when specified by the procurement documentation.

10.2 Applications. These procedures shall be used for acceptance testing after construction of the HEMP protection subsystem and for verification testing of electrical POE protective treatments after the facility is completed and operational, as required by DETAILED REQUIREMENTS of MIL-STD-188-125A.

20. REFERENCED DOCUMENTS.

20.1 Government documents. The following document forms a part of this appendix to the extent specified:

DI-NUOR-80928 -	Nuclear Survivability Test Plan
DI-NUOR-80929A -	Nuclear Survivability Test Report
DNA-EMP-1 -	Electromagnetic Pulse (EMP) Security Classification Guide (U) (document is classified S-RD)

(Copies of specifications, standards, handbooks, drawings, and publications required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

30. DEFINITIONS.

30.1 Norms. Scalar quantities which characterize the features of a complicated waveform. Norms used as pass/fail criteria for PCI test residual internal stresses

[11] HEMP-unique test procedures are temporarily included as appendices to MIL-STD 188-125A; it is intended that these procedures will ultimately be promulgated as separate standards outside of the MIL-STD 188-series.

are peak current, peak rate of rise, and root action. These quantities apply to short pulse only.

30.2 Peak current norm. The maximum absolute value of a current waveform, *I(t)*, expressed in units of amperes, measured from time $t = 0$ to $t = 5 \times 10^{-3}\ s$.

30.3 Peak rate of rise norm. The maximum absolute value of the first derivative of a current waveform *I(t)* with respect to time, *dI/dt* expressed in units of amperes per second, measured from time $t = 0$ to $t = 5 \times 10^{-3}\ s$.

30.4 Root action. The root action norm of a current waveform *I(t)*, in units of $amperes\text{-}\sqrt{seconds}$, is defined by the equation

$$\text{Root action} = \sqrt{\int_0^{5\times10^{-3}s} I^2(t)\ dt}$$

where $t = 0$ at the start of the PCI drive pulse.

40. GENERAL REQUIREMENTS.

40.1 General. PCI acceptance testing is used to demonstrate that electrical POE protective devices, as-installed, perform IAW MIL-STD-188-125A transient suppression/attenuation requirements. PCI verification testing confirms the transient suppression/attenuation performance in operational circuit configurations and demonstrates that MCS are not damaged or upset by residual internal transient stresses.

The test method couples threat-relatable transients to penetrating conductors at injection points *outside the electromagnetic barrier*. Injections in both common mode (all penetrating conductors of a cable simultaneously driven with respect to ground) and individual wire-to-ground configurations are required. For purposes of this procedure, ground is a point on the facility HEMP shield in the vicinity of the POE protective device under test. Residual internal responses are measured, and operation of the MCS is monitored during the verification test to determine if mission-impacting damage or upsets occur.

The required tests are performed on each penetrating conductor and cable, RF antenna shield, and conduit shield. Simultaneous injection of all electrical POE protective devices, if practicable, is desirable for verification testing.

40.2 Purpose.

40.2.1 Purposes of PCI acceptance testing. The purposes of PCI testing, as an acceptance test procedure, are as follows:

a. To measure the performance of as-installed conductive POE protective devices.

b. To demonstrate through post-test inspection, surge arrester performance checks, and response data analysis that the protective devices will not be damaged or degraded by threat-relatable transients.

c. To identify defective devices or faulty installation practices, so that repairs or replacements can be made.

40.2.2 Purposes of PCI verification testing. The purposes of PCI testing, as part of a verification test program, are as follows:

a. To measure the performance of conductive POE protective devices in operational circuit configurations.

b. To demonstrate, through post-test inspection, surge arrester performance checks, and response data analysis, that the protective devices will not be damaged or degraded by threat-relatable transients.

c. To identify defective devices or faulty installation practices, so that repairs of replacements can be made.

d. To characterize the residual internal transient stresses.

e. To demonstrate that residual internal transient stresses will not cause mission-impacting damage or upsets of the MCS in its various operating states.

f. To provide data for HEMP hardness assessment of the facility and baseline data for the HM/HS program.

40.3 HEMP protection subsystem test configuration.

40.3.1 Acceptance test subsystem configuration. PCI testing for acceptance is performed after the POE protective devices have been installed in the facility. The electromagnetic barrier is not required to be complete, but it must be recognized that an incomplete barrier may result in degradations of the POE protective device performance and the instrumentation signal-to-noise ratio. Equipment which, in the facility operation, will electrically connect to the POE protective device under test is not required to be powered or installed.

40.3.2 Verification test facility configuration. When PCI verification testing is conducted, the facility shall be in a normal operating configuration and shall be performing actual or simulated missions. The HEMP protection subsystems shall be intact. Equipment which electrically connects to the POE protective device under test shall be powered and operating, except as otherwise specified in this procedure.

40.4 Pretest analysis requirements. There are no pretest analyses required for PCI acceptance testing. Pretest analysis for PCI verification testing shall be performed to determine operating states in which the MCS will be tested. An equipment should be tested in multiple states when the switching produces significantly different propagation paths for the residual internal transient, significant changes in the equipment vulnerability threshold, or significant changes in the function being performed. A mission-essential transceiver, for example should be tested in at least two states -- transmitting and receiving -- and a digital interface should be tested in both the low and high signal states.

40.5 Test equipment requirements. Test equipment required for PCI testing is identified in table III. Current injection pulse generators for all POEs except RF signal line POEs are defined as Norton equivalent generators. Therefore, pulse generator requirements are defined in terms of short circuit current and source impedance. Short circuit current is defined as current driven through a short circuit connected to the generator output. Source impedance is defined to be the generator peak open circuit voltage divided by the peak short circuit current. RF POE current injection pulse generators are defined in terms of current delivered at the external terminal of the POE protective device.

40.6 Operational impact analysis and risk.

40.6.1 Acceptance testing impact. When PCI testing is performed as an acceptance test procedure, the electromagnetic barrier must remain reasonably intact, such that POE protective device performance and instrumentation signal-to-noise ratio are not excessively degraded, and use of electrically noisy equipment must be restricted in order to achieve the required measurement sensitivity. Construction activity may, therefore, be affected.

40.6.2 Verification testing impact. During PCI verification testing, the barrier must remain intact and use of electrically noisy equipment which is not part of the normal site equipment complement must be restricted; unusual operations (facility modification, maintenance) may be affected. Mission operations can continue normally, except as follows:

a. The circuit and POE protective device under test may be unavailable for normal use; it may be necessary to disconnect unprotected equipment outside the barrier, and the circuit may be periodically deenergized.

b. A special sequence of activities may be required so that the circuit and facility can be tested in their various operating states.

40.6.3 Risk. PCI testing requires application of high voltages and large currents. Special high-voltage electrical safety precautions apply. Because of the high injection levels, the risk of POE protective device or equipment damage cannot be completely eliminated. However, the procedures are designed to minimize this risk.

40.7 Test plan and procedures.

40.7.1 Acceptance test plan. A comprehensive, site-specific test plan and detailed test procedures for PCI acceptance testing shall be prepared. These may be combined in a single document or two separate documents may be used. As a minimum, the documentation shall contain the following information:

a. A statement of the test objectives.

b. Facility identification and description (including a site plan, floor plan of the shielded volume, list of shield POEs, and a description of the HEMP protective subsystems).

c. Identification of circuits and POE protective devices to be tested (including circuit functions and manufacturers' data sheets and specifications for the protective devices).

d. Identification of test points and injection levels (see table IV).

e. HEMP simulation and data acquisition equipment description (including manufacturer, model and serial numbers, characteristics, and detailed calibration procedures).

TABLE III. PCI test equipment requirements

Equipment	Characteristics		
	Short Pulse[1]	Intermediate Pulse[1]	Long Pulse[1]
Pulse Generators[2]	Up to 8000 A short circuit current, double exponential waveform, source impedance at least 60 Ω, and damped sinusoidal waveform	Up to 500 A short circuit current, source impedance at least 10 Ω, double exponential waveform	Up to 200 A short circuit current, source impedance at least 5 Ω, double exponential waveform
Current Sensors (Injected Transient)	10 Khz-750 MHz, 0-8000 A	dc - 10 MHz, 0-500 A	dc - 10 kHz, 0-200 A
Current Sensors (Residual Internal Transient)	100 Hz-750 MHz, 0-100 A, transfer impedance as required for measurement sensitivity	dc - 10 MHz, 0-500 A	dc - 10 kHz, 0-200 A
Oscilloscopes or Transient Digitizers[3]	100 Hz-750 MHz, minimum sensitivity as required for measurement sensitivity	dc - 10 MHz	dc - 10 kHz
Data Recorder[3]	0-5 ms	0-50 ms	0-100 s
Preamplifier(s)	100 Hz-750 MHz, amplification and noise figure as required for measurement sensitivity	—	—
Instrumentation Shield and Power Supplies	As required for isolation from pulse generator	As required for isolation from pulse generator	As required for isolation from pulse generator
Miscellaneous Cables, Attenuators, and Dummy Load Resistors	As required	As required	As required

[1]See 50.2.1 for characteristics of the short, intermediate, and long pulses.

[2]Pulse generator short circuit current requirements are stated in terms of current delivered through a short circuit at the generator output terminals. Source impedance is the ratio of the generator peak open circuit voltage to the peak short circuit current. The method of coupling the pulse generator output to the penetrating conductor is not specified. However, connection of the pulse generator into the circuit under test must not interfere with normal circuit operation.

[3]Use of a personal computer with an IEEE-488 general purpose interface bus (GPIB) to control instrumentation and store test data on magnetic disk is strongly recommended.

f. Any deviations from the requirements of this appendix.

g. Data management (including data quality control procedures, data acceptability criteria, data processing requirements, annotation and presentation of data records, and pass/fail criteria).

h. Safety.

i. Security (see B 40.10).

j. Test schedule (including priority of measurements).

Data item description DI-NUOR-80928, "Nuclear Survivability Tests Plan," should be used.

40.7.2 Verification test plan. A comprehensive, site-specific test plan and detailed test procedures for PCI verification testing shall be prepared. These may be combined in a single document or two separate documents may be used. As a minimum, the documentation shall contain the following information:

a. A statement of the test objectives.

b. Facility identification and description (including a site plan, floor plan of the shielded volume, list of shield POEs, list of MCS inside and outside the electromagnetic barrier, and a description of the HEMP protective subsystem).

c. Identification of circuits and POE protective devices to be tested (including circuit functions and manufacturers' data sheets and specifications for the protective devices).

d. Identification of test points.

e. HEMP simulation and data acquisition equipment description (including manufacturer, model and serial numbers, characteristics, and detailed calibration procedures).

f. Detailed test procedures (including system and circuit configuration requirements, equipment operating states, diagrams of the data acquisition system, injection levels (see table IV), data requirements, and step-by-step procedures).

TABLE IV. PCI source parameters, waveforms, and acceptance test loads

a. Electrical POEs except RF signal line POEs-double exponential waveforms (figure 12)

Class of Electrical POE	Type of Injection	Peak Short Circuit Current $\hat{I}$ (A)	Source Impedance[2] Z_s (Ω)	Risetime - τ_R (s)	FWHM (s)	Acceptance Test Load Impedance (Ω)
Commercial Power Lines (Intersite)						
Short Pulse	Common mode[1]	8000	≥ 60	$\leq 1\times10^{-8}$	5×10^{-7}-5.5×10^{-7}	Not applicable[1]
Short Pulse	Wire-to-ground[3]	4000	≥ 60	$\leq 1\times10^{-8}$	5×10^{-7}-5.5×10^{-7}	[4] 2 or V_{rated}/I_{rated}
Intermediate Pulse	Common mode[1]	500	≥ 10	$\leq 1\times10^{-6}$	$\geq 5\times10^{-3}$	Not applicable[1]
Intermediate Pulse	Wire-to-ground[3]	500	≥ 10	$\leq 1\times10^{-6}$	$\geq 5\times10^{-3}$	50
Long Pulse	Common mode[1]	200	≥ 5	≤0.5	≥100	Not applicable[1]
Long Pulse	Wire-to-ground[3]	200	≥ 5	≤0.5	≥100	50
Other Power Lines (Intrasite)						
Short Pulse	Common mode[1]	8000	≥ 60	$\leq 1\times10^{-8}$	5×10^{-7}-5.5×10^{-7}	Not applicable[1]
Short Pulse	Wire-to-ground[3]	4000	≥ 60	$\leq 1\times10^{-8}$	5×10^{-7}-5.5×10^{-7}	[4]2 or V_{rated}/I_{rated}
Audio/Data Lines (Intersite)						
Short Pulse	Common mode[1]	8000	≥ 60	$\leq 1\times10^{-8}$	5×10^{-7}-5.5×10^{-7}	Not applicable[1]
Short Pulse	Wire-to-ground[3]	[5]8000/√N or 500	≥ 60	$\leq 1\times10^{-8}$	5×10^{-7}-5.5×10^{-7}	50
Intermediate Pulse	Common mode[1]	500	≥ 10	$\leq 1\times10^{-6}$	$\geq 5\times10^{-3}$	Not applicable[1]
Intermediate Pulse	Wire-to-ground[3,6]	500	≥ 10	$\leq 1\times10^{-6}$	$\geq 5\times10^{-3}$	50
Long Pulse	Common mode[1]	200	≥ 5	≤0.5	≥100	Not applicable[1]
Long Pulse	Wire-to-ground[3,6]	200	≥ 5	≤0.5	≥100	50
Control/Signal Lines (Intrasite)						
Short Pulse	Common mode[1]	8000	≥ 60	$\leq 1\times10^{-8}$	5×10^{-7}-5.5×10^{-7}	Not applicable[1]
Short Pulse	Wire-to-ground[3]	[5]8000/√N or 500	≥ 60	$\leq 1\times10^{-8}$	5×10^{-7}-5.5×10^{-7}	[4]2 or V_{rated}/I_{rated}
RF Antenna Lines--Shield						
Buried[9]	Shield-to-ground[10]	1000	≥ 60	$\leq 1\times10^{-8}$	5×10^{-7}-5.5×10^{-7}	[9] 50
Nonburied	Shield-to-ground[10]	8000	≥ 60	$\leq 1\times10^{-8}$	5×10^{-7}-5.5×10^{-7}	[9] 50
Conduit Shields						
Buried[9]	Conduit-to-ground[11]	1000	≥ 60	$\leq 1\times10^{-8}$	5×10^{-7}-5.5×10^{-7}	[12] 2
Nonburied	Conduit-to-ground[11]	8000	≥ 60	$\leq 1\times10^{-8}$	5×10^{-7}-5.5×10^{-7}	[12] 2

TABLE IV. PCI source parameters, waveforms, and acceptance test loads - Continued

b. RF signal line POEs

PULSED CURRENT INJECTION REQUIREMENTS[14]						
Lowest Response Frequency[7]	Pulser Waveform	Type of Injection	Waveform Parameters[8]			Acceptance Test Load Impedance (Ω)
$f \le 2$ MHz ($L \ge 75$ M)	Double Exponential (fig. 12)	Wire to Shield	Peak Current-I_p(A)	Risetime-T_r(s)	FWHM[1](s)	[6]50
			8000	$\le 1\times10^{-8}$	5×10^{-7}-5.5×10^{-7}	
2 MHz $< f \le 30$ MHz (75 M $> L \ge 5$ M)	Damped Sine[13] (fig. 13)	Wire to Shield	Peak Current-I_p(A)	Center f-(MHz)	Decay Factor (Ω)	[6]50
			2500	2 ± 10%	5 ± 3	
30 MHz $< f \le 200$ MHz (5 M $> L \ge 0.75$ M)	Damped Sine[13] (fig. 13)	Wire to Shield	900	30 ± 10%	5 ± 3	[6]50
$f > 200$ MHz ($L < 0.75$ M)	Damped Sine[13] (fig. 13)	Wire to Shield	250	200 ± 10%	5 ± 3	[6]50

[1] For a common mode test, all penetrating conductors in the cable are simultaneously driven with respect to ground, where ground is a point on the facility HEMP shield in the vicinity of the POE protective device. Common mode tests are required for verification but they are not required for acceptance.

[2] Source impedance, Z_s, is defined as the peak time domain pulser open circuit voltage divided by the pulser peak time domain short circuit current.

[3] For a wire-to-ground test, each penetrating conductor in the cable is driven with respect to ground, where ground is a point on the facility HEMP shield in the vicinity of the POE protective device

[4] Whichever is smaller. V_{rated} and I_{rated} are the maximum voltage and current ratings of the POE protective device, respectively.

[5] Whichever is larger. N is the number of penetrating conductors in the cable.

[6] Intermediate and long pulse wire-to-ground tests of audio/data lines are required for acceptance, but they are not required for verification.

TABLE IV. PCI source parameters, waveforms, and acceptance test loads-Continued

c. Notes to TABLE IV

[7] f = 150/L MHz, where L is the largest dimension of the associated antenna in meters. When f ≤ 2 MHz, a double exponential pulse is required. When f > 2 MHz, a damped sinusoidal waveform is specified.

[8] Signal conductor terminated to the shield with 50 Ω. The shield conductor is electrically bonded to the facility HEMP shield.

[9] An antenna shield is considered buried when it terminates at a buried antenna and less than 1 m (3.3 ft) of its total length is not covered by an earth or concrete fill. A conduit is considered buried when it connects two protected volumes and less than 1 m (3.3 ft) of its total length is not covered by earth or concrete fill.

[10] For a shield-to-ground test, maximum feasible length of the antenna line shield is driven with respect to ground, where ground is a point on the facility HEMP shield in the vicinity of the POE protective device.

[11] For a conduit-to-ground test, maximum feasible length of the conduit is driven with respect to ground, where ground is a point on the facility HEMP shield in the vicinity of the conduit penetration.

[12] Wiring internal to the conduit is terminated at the installed equipment, if present, Other internal wiring is bundled together and terminated in common 2 Ω resistors at each end. The conduit is welded to the facility HEMP shields at both ends.

[13] The damped sinusoidal waveform is a design objective. The minimum requirement is to inject the current output from a PCI source with ≥ 50 Ω source impedance and short circuit current I(t) which satisfies the following:

$$a.\ \int_0^T I(t)\,dt \geq 0.3\frac{\hat{I}}{f_c} \qquad b.\ |I(t)| \leq K_{DS}\hat{I}e^{-\frac{\pi f_c t}{10}}\ \text{for all } t > T$$

where t is time in seconds, $\hat{I}$ is the prescribed peak current in amperes, f_c is the prescribed center frequency, K_{DS} is a scaling constant which can be determined based on initial conditions (see fig.13) and T is the time of the first zero crossing or $1/f_c$ which ever occurs earlier.

[14]For antennas mounted on towers taller than 25 m (82 ft), there is an additional pulsed current injection requirement. This requirement is a 2 (±10%) MHz damped sinusoid of 500 A peak amplitude, and Q = 5±3.

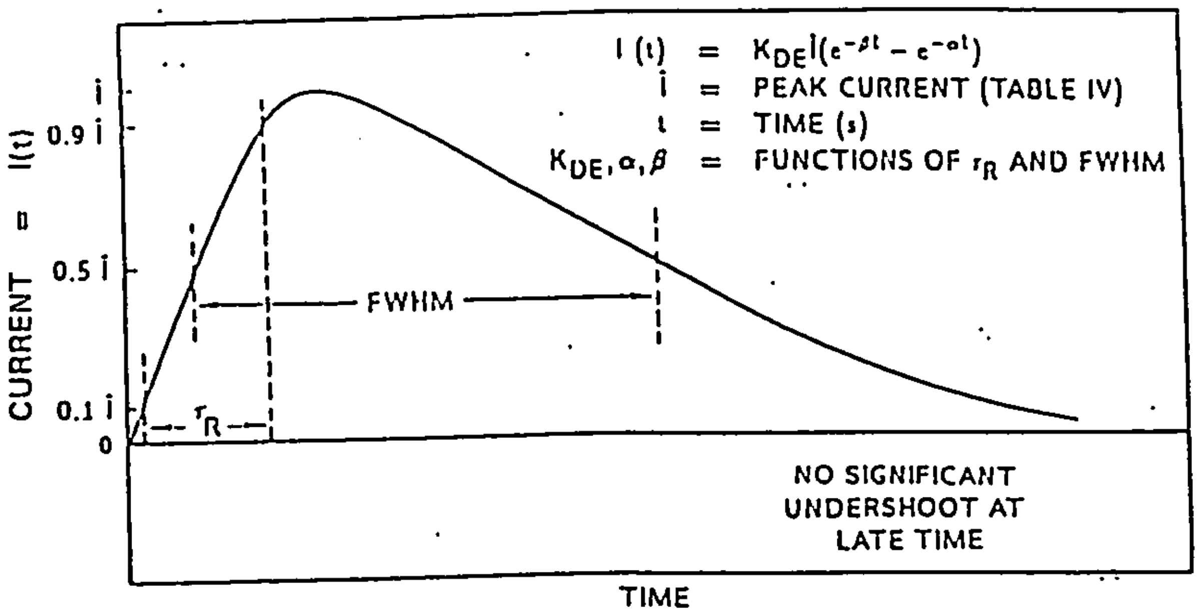


FIGURE 12. Double exponential waveform

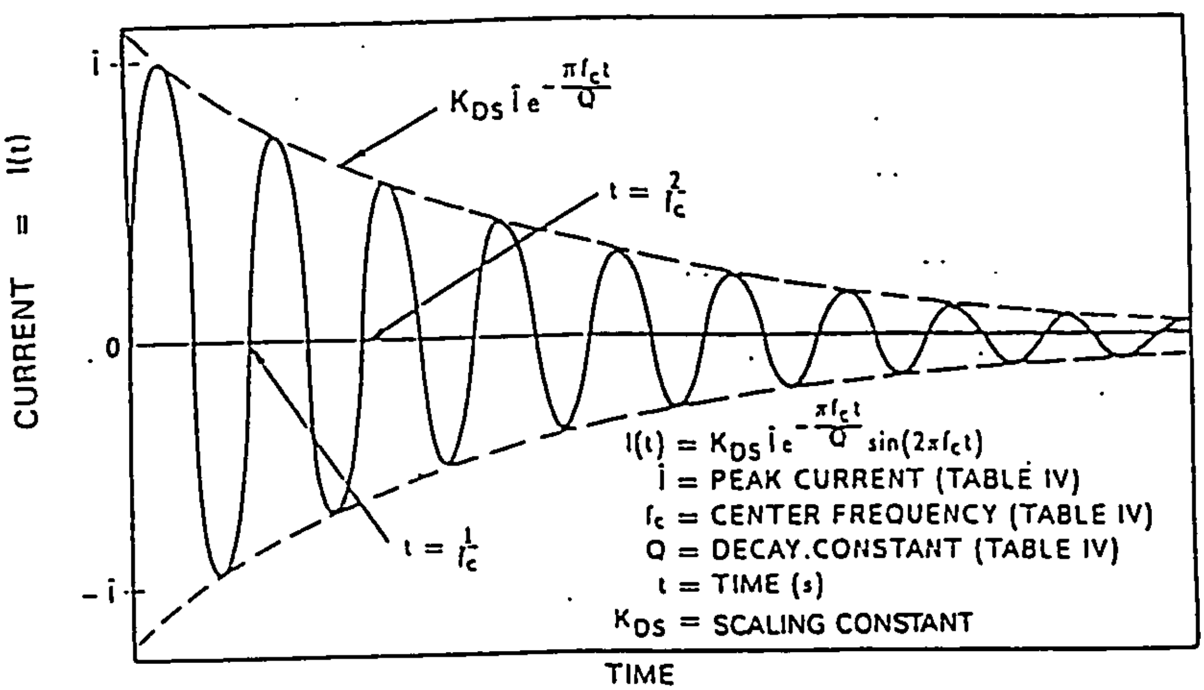


FIGURE 13. Damped sinusoidal waveform

TABLE V. Maximum allowable residual internal response characteristics for electrical POEs

Class of Electrical POEs	Type of Injection	Type of Measurement	Peak Current (A)	Peak Rate of Rise (A/s)	Root Action ($A\sqrt{s}$)
Commercial Power Lines (Intersite) Short Pulse Short Pulse	Common Mode Wire-to-ground	Bulk current Wire current	10 10	1×10^7 1×10^7	1.6×10^{-1} 1.6×10^{-1}
Intermediate Pulse Intermediate Pulse Long Pulse Long Pulse	Common mode Wire-to-ground Common mode Wire-to-ground	Bulk current Wire current Bulk current Wire current	No damage or performance degradation[1] No damage or performance degradation[1] No damage or performance degradation[1] No damage or performance degradation[1]		
Other Power Lines (Intrasite) Short Pulse Short Pulse	Common mode Wire-to-ground	Bulk current Wire current	10 10	1×10^6 1×10^4	1.6×10^{-1} 1.6×10^{-1}
Other Power Lines (Intrasite) Short Pulse Short Pulse	Common mode Wire-to-ground	Bulk current Wire current	10 10	1×10^6 1×10^6	1.6×10^{-1} 1.6×10^{-1}
Audio/Data Line(Intersite) Short Pulse Short Pulse	Common mode Wire-to-ground	Bulk current Wire current	0.1 0.1	1×10^6 1×10^6	1.6×10^{-1} 1.6×10^{-1}
Intermediate Pulse Intermediate Pulse Long Pulse Long Pulse	Common mode Wire-to-ground Common mode Wire-to-ground	Bulk current Wire current Bulk current Wire current	No damage or performance degradation[1] No damage or performance degradation[1] No damage or performance degradation[1] No damage or performance degradation[1]		
Control/Signal Lines (Intrasite) Low-Voltage Lines[2] Short Pulse Short Pulse	Common mode Wire-to-ground	Bulk current Wire current	0.1 0.1	1×10^4 1×10^6	1.6×10^{-1} 1.6×10^{-1}
High-Voltage Lines[2] Short Pulse	Common mode Wire-to-ground	Bulk current Wire current	1.0 1.0	1×10^6 1×10^6	1.6×10^{-1} 1.6×10^{-1}

[1]Pass/fail criteria on internal response waveform norms are not specified for intermediate or long pulse current injection test sequences. Pass/fail criteria on the peak rate of rise, rectified impulse, and action norms are not specified for RF antenna line signal conductors. The pass/fail criteria of no POE protective device damage or performance degradation also applies to PCI test sequences where this note does not appear in the table.

[2]Low voltage control/signal lines are those with a maximum operating voltage <90 V. High voltage control/signal lines are those with maximum operating voltage ≥90 V.

TABLE V. Maximum allowable residual internal response characteristics for electrical POEs-Continued

Class of Electrical POE	Type of Injection	Type of Measurement	Peak Current (A)	Peak Rate of Rise (A/s)	Root Action ($A\sqrt{s}$)
RF Antenna Lines *Receive Only* Signal Conductor Drive	Wire-to-shield	Wire Current	0.1	No damage or performance degradation[1]	
		Shield current	0.1	$1x10^7$	$1.6x10^{-3}$
Receive Only Shield Drive	Shield-to-ground	Wire Current	0.1	No damage or performance degradation[1]	
		Shield current	0.1	$1x10^7$	$1.6x10^{-3}$
Transmit and Transceive Shield Conductor Drive	Wire-to-shield	Wire Current	1.0	No damage or performance degradation[1]	
		Shield current	0.1	$1x10^7$	$1.6x10^{-3}$
Transmit and Transceive Shield Drive	Shield-to-ground	Wire Current	0.1	No damage or performance degradation[1]	
		Shield current	0.1	$1x10^7$	$1.6 x10^{-3}$
Conduit Shields Signal and Low Current Power[3] Buried or Nonburied	Conduit-to-ground	Bulk current	0.1	$1 x 10^7$	$1.6 x 10^{-3}$
Intermediate Current Power[3] Buried or Nonburied	Conduit-to-ground	Bulk current	1.0	$1 x 10^7$	$1.6 x 10^{-2}$
High Current Power[3] Buried or Nonburied	Conduit-to-ground	Bulk current	10	$1 x 10^7$	$1.6 1x 10^{-1}$

[3] Low current power lines are those with a maximum operating current ≤1 A. Intermediate current power lines are those with maximum operating current between 1 A and 10 A. High current power lines are those with maximum operating current ≥10 A.

g. Data management (including data quality control procedures, data acceptability criteria, data processing requirements, annotation and preservation of data records, and pass/fail criteria).

h. Safety.

i. Security (see B 40.10).

j. Test schedule (including priority of measurements).

Data item description DI-NUOR-80928, "Nuclear Survivability Tests Plan," shall be used.

40.8 Test report requirements.

40.8.1 Acceptance test report. A PCI acceptance test report shall be prepared. As a minimum, the test report shall contain the following information:

a. Facility identification and test plan reference.

b. A discussion of any deviations from the test plan and requirements of this appendix.

c. Copies of the measured results, along with sensor calibrations and instrumentation settings required to convert the data to engineering units.

d. A summary table of the norms of the measured internal responses and comparison to the maximum allowable residual internal response characteristics (see table V).

e. Pass/fail conclusions.

Data item description DI-NUOR-80929A, "Nuclear Survivability Test Report," shall be used.

40.8.2 Verification test report. A PCI verification test report shall be prepared. As a minimum, the test report shall contain the following information:

a. Facility identification and test plan reference.

b. A discussion of any deviations from the test plan and requirements of this appendix.

c. Copies of the measured results, along with sensor calibrations and instrumentation settings required to convert the data to engineering units.

d. A summary table of the norms of the measured internal responses and comparison to the maximum allowable residual internal response characteristics (see table V).

e. Test conclusions (including a definitive statement of HEMP hardness of mission functions, based on the continuous wave immersion (see appendix C) and PCI test results and supporting analysis).

f. Test chronology (including a sequence of events and identification of failures, upsets, or interference observed and the conditions under which they occurred).

Data item description DI-NUOR-80929A, "Nuclear Survivability Test Report," shall be used.

40.9 Post-test analysis requirements.

40.9.1 Analysis of acceptance test data. Post-test analysis of PCI acceptance measured data is required for data corrections for probe and instrumentation response characteristics and conversion of results into norms in engineering units.

40.9.2 Analysis of verification test data. Post-test analysis of PCI verification measured data is required for data corrections for probe and instrumentation response characteristics and conversion of results into norms in engineering units. Additional analysis of measured data shall be performed to assist in developing a definitive statement of facility HEMP hardness. Detailed requirements for post-test analysis of PCI verification test results shall be established by the sponsoring agency for the test. They will generally include calculations of threat responses from CW immersion and PCI test data, analysis of verification test adequacy, development of hardness conclusions, and recommendations for corrective actions, if required.

40.10 Data classification. Test data may be classified. DNA-EMP-1 and the classification guide for the specific facility or system should be consulted for guidance.

40.11 Alternative test methods. When approved by the sponsoring agency, cable shield injection may be used for verification testing on shielded intrasite control or signal lines in lieu of the common mode PCI requirement. Maximum required current amplitude and the prescribed waveform for cable shield injection shall be as shown in table VI. Intrasite cable shields shall be driven over their entire length by removing or buffering/isolating intermediate grounds and other low-impedance paths to ground along the cable run. Internal response measurements shall be made on the bulk cable. Pass/fail criteria of table V apply.

TABLE VI. Cable shield PCI amplitudes and waveforms

Class of Electrical POE	Double Exponential Waveform (Fig. 12)		
	Peak Current = $\hat{I}$ (A)	Risetime = τ_R (s)	FWHM (s)
Control/Signal Lines (Intrasite)	8000	[1] $\leq 1 \times 10^{-8}$	[2] 5×10^{-7} - 5.5×10^{-7}

[1] $\tau_R \leq 1\times10^{-7}\ s$ is a design objective. The minimum requirement is $\tau_R \leq 5\times10^{-7} s$.

[2] FWHM = 5×10^{-8} s to 5.5×10^{-7} s is a design objective. The minimum requirement is FWHM > 2.5×10^{-8} s.

50. DETAILED REQUIREMENTS.

50.1 Test configuration. Typical PCI test configurations are illustrated in figure 14, and a typical data recording system is illustrated in figure 15. The pulse generator output may be directly coupled to the circuit under test, or it may be capacitively or inductively coupled. All injection current amplitude and waveform requirements refer to the signal observed on the external current sensor. The external current sensor shall be within 15 cm (6 in) of the external terminal of the POE protective device, and there shall be no branches in the wiring between the sensor location and the external terminal. The internal current sensor shall be within 15 cm (6 in) of the internal terminal of the POE protective device, and there shall be no branches in the wiring between the sensor location and the internal terminal.

50.1.1 Acceptance test configuration. For PCI performed as acceptance testing, the external load shall be an open-circuit termination and the internal load shall be a dummy resistor (see B 50.2.3).

50.1.2 Verification test configuration. For PCI verification testing, the external load shall be the installed site equipment or an equivalent dummy load impedance,[12] which permits the circuit under test to be energized and performing actual or simulated functions. The internal load for PCI verification testing shall be the installed site equipment, which shall be energized[13] and performing actual or simulated functions. Isolators shall be installed on the wires under test to direct injected current towards the internal load under test (see figure 14). The isolators shall be compatible with site equipment in actual or simulated operating condition.

50.2 Current injection requirements.

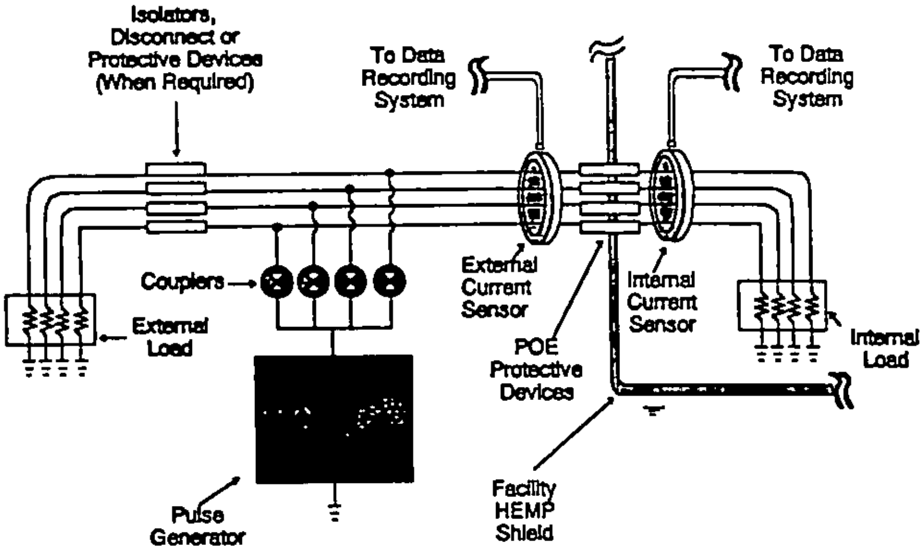
50.2.1 Maximum injection levels. Maximum required short circuit current amplitudes, source impedances, and prescribed waveforms for acceptance and verification PCI testing for all classes of electrical POEs shall be as shown in table IV and figures 12 and 13. Common mode PCI injections are required only during verification testing, and that intermediate and long pulse wire-to-ground tests on intersite audio or data lines are required only for acceptance testing.

50.2.2 Testing sequence. To minimize the possibility of POE protective device or equipment damage, a series of pulses at increasing amplitudes shall be applied as follows:

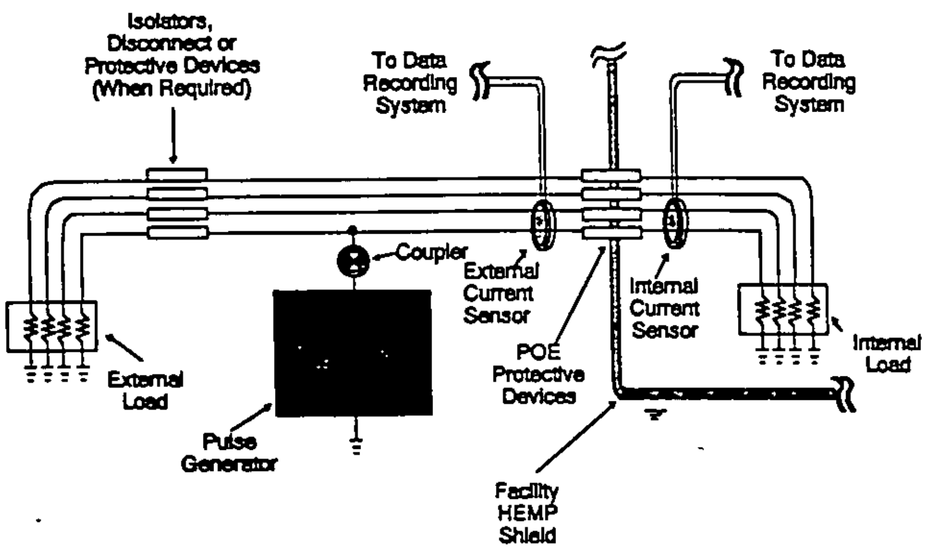
a. Pulse at the lowest available current output from the pulse generator. This level shall be less than 10 percent of the maximum amplitude in table IV, or less than

[12]When the external equipment is not designed to withstand the test transients, temporary protection should be provided or a dummy load should be used in place of the external equipment.

[13]When the circuit under test operates at voltages greater than 600 V a.c. or 600 V d.c. and cannot safely be tested with power on, PCI verification testing may be performed in a deenergized condition. Switches, relay contacts, and other circuit interrupters shall be placed in the operating state to simulate the power on condition.



a. Common mode test configuration.



b. Wire-to-ground test configuration.

FIGURE 14. Typical wire-to-ground test configuration

that amplitude which activates any nonlinear components in the POE protective device, whichever is greater.

b. Perform a series of pulses, increasing the amplitude by a factor of approximately two at each step. When testing several circuits with identical POE protective devices, this series of intermediate pulses may be abbreviated after the first two samples.

c. Pulse at the maximum required amplitude for the circuit under test. Peak current should not exceed 110 percent of the levels listed in table IV.

CAUTION: Surge arresters in electrical POE protective devices have limited pulse lives (2000 pulses). The number of test pulses delivered to each device should be recorded for inclusion in maintenance records. If the total number of previous pulses on the device exceeds 90 percent of the rated life, surge arresters should be replaced before starting the test. This sequence shall be used for both acceptance and verification testing.

50.2.3 Acceptance test load resistance. Ohmic values of the PCI acceptance test internal load resistors for all classes of electrical POEs shall be as listed in table IV. For wire-to-ground tests, only the penetrating conductor under test requires the specified termination. For conduit shield tests, internal wiring shall be terminated on normal equipment, if present, and other conductors shall be bundled together and terminated with a common 2 Ω resistor at each end. Wiring which connects the load resistor between the internal terminal of the POE protective device and its enclosure shall be less than 30 cm (12 in) in length.

50.3 Measurements and functional observations.

50.3.1 Data requirements. At each step in the testing sequence, for both acceptance and verification testing, the external pulse amplitude and waveform and the internal pulse amplitude and waveform shall be recorded.[14] The internal pulse waveform shall be recorded for 5 ms after the start of the PCI short drive pulse, with recording instrument sweep speeds which allow resolution of the early, intermediate, and late time response.

[14]When the POE protective device leads into a special protective volume inside the electromagnetic barrier, amplitudes and waveforms shall also be recorded on all electrical POEs through the special protective barrier into the protected volume. The measurements shall be made in the protected volume. Pass/fail criteria for these data are the same as the pass/fail criteria for other internal response measurements.

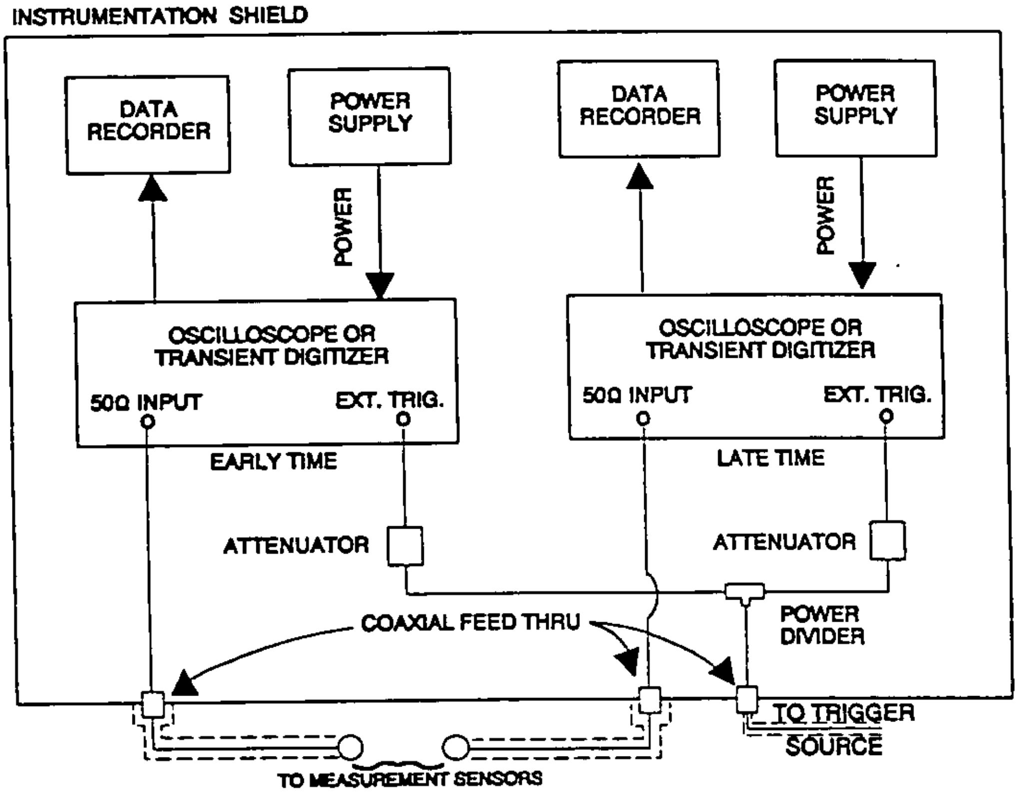


FIGURE 15. Typical PCI data recording system

50.3.2 Verification test functional observations. Operation of facility MCS shall be monitored during and immediately after the pulse for indications of damage or upset. A detailed description of any abnormal occurrences shall be prepared for inclusion in the test chronology.

50.4 Measurement procedures. PCI test procedures for acceptance and verification testing shall be as follows:

a. Set up the pulse generator source and data acquisition equipment in the desired configuration and perform calibrations.

b. De-energize the circuit to be tested, for acceptance testing or when required by safety considerations, and install sensors. Re-energize the circuit after sensor installation is complete (verification test only).

c. Perform a noise check of the data recording system to ensure a satisfactory signal-to-noise ratio.

d. Establish the required facility, equipment state, and test configurations.

e. Inject a pulse into the circuit under test (see appendix B 50.2.2).

f. Record measurement point responses.

g. Record results from the functional monitoring of the MCS (verification test only).

h. Compare measured and observed results to the pass/fail criteria (see appendix B 50.5). If the results are not satisfactory, halt the test and effect repairs or replacement of the POE protective device. Repeat the PCI test procedure after the corrective action has been completed.

i. Repeat steps e through h at increasing injection levels until the maximum required transient has been injected.

j. Continue to the next state to be tested and repeat steps d through i (verification test only).

k. De-energize the circuit under test, when required, and remove the sensors and pulse generator output connection.

l. Disconnect the electrical surge arrester from the circuit. Measure the voltage at 1 mA d.c. of a metal oxide varistor or the d.c. breakdown voltage of a spark gap. Compare the measured results to the device specifications. If the results are not satisfactory, effect repairs or replacement of the POE protective device. Repeat the PCI test procedure after the corrective action has been completed.

m. Reconnect the electrical surge arrester, and restore the circuit to its operational configuration.

n. Continue to the next circuit to be tested and repeat steps b through m.

50.5 Pass/fail criteria.

50.5.1 Internal response pass/fail criteria. The POE protective device shall be considered satisfactory when both of the following criteria are met:

a. Norms of the measured internal response waveforms, at all short pulse injection levels, do not exceed the maximum allowable norm values of table V for the applicable class of electrical POE.[15]

If internal responses measured in the PCI verification test cannot be discriminated from circuit operating and noise signals, the test shall be repeated in a power-off (acceptance) configuration. The pass/fail determination for internal response norms shall then be made using the resulting power-off data.

b. Post-test physical inspection of the POE protective device, surge arrester measurement of voltage at 1 mA d.c. current (for a metal oxide varistor) or d.c. breakdown voltage (for a spark gap), and response data analysis indicate that the device has not been damaged or degraded by the test pulses.

The internal response pass/fail criteria apply for both acceptance and verification testing.

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[15]When the protected side of the POE protective device is contained within a special protective volume, norms of the measured internal responses must not exceed design values for that special protective volume.

50.5.2 Verification test functional pass/fail criteria. Hardening of equipment within the electromagnetic barrier shall be considered satisfactory when both of the following criteria are met:

a. No damage to MCS occurred during the PCI verification testing.

b. No mission-impacting interruption of mission-essential functions or upsets of MCS occurred during the PCI verification testing.[16]

50.5.3 Test failures. Any failure to satisfy the internal response or functional success criteria shall be considered a HEMP vulnerability. An investigation into the cause of the possible vulnerability shall be conducted. The condition shall be corrected, if possible, and the PCI verification test sequence shall be repeated.

[16]The determination of whether an observed interruption or upset impacts the mission is the responsibility of the operational authority for the facility.

CW IMMERSION TEST PROCEDURES[17]

10. GENERAL

10.1 Scope. This appendix is a mandatory part of the standard. The information contained herein is intended for compliance. This appendix establishes procedures for CW immersion testing of the electromagnetic barrier required for low-risk HEMP protection of critical ground-based facilities with time-urgent missions. The procedures are applicable for testing other HEMP-hardened facilities, when specified by the procurement documentation.

10.2 Applications. These procedures shall be used for verification testing of the facility HEMP shield and aperture POE protective treatments, as required by DETAILED REQUIREMENTS of MIL-STD-188-125A.

20. REFERENCED DOCUMENTS

20.1 Government documents. The following documents form a part of this appendix to the extent specified:

DI-NUOR-80928 -	Nuclear Survivability Test Plan
DI-NUOR-80929A -	Nuclear Survivability Test Report
DOD-STD-2169 -	High-Altitude Electromagnetic Pulse (HEMP) Environment (U) (document is classified Secret).
DNA-EMP-1 -	Electromagnetic Pulse (EMP) Security Classification Guide (U) (document is classified S-RD).

(Copies of specifications, standards, handbooks, drawings, and publications required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

30. DEFINITIONS

30.1 Illuminating field. At a location with respect to the transmitting antenna is

[17] HEMP-unique test procedures are temporarily included as appendices to MIL-STD-188-125; it is intended that these procedures will ultimately be promulgated as separate standards outside of the MIL-STD-188-series.

the total electromagnetic field, including ground effects, which would be measured at that point if the facility or system under test was not present. Thus, the illuminating field does not include reflections from the facility under test.

30.2 Principal component of the illuminating field. A magnetic or electric field component which is maximized by the antenna geometry and ground effects. For example, azimuthal magnetic field and vertical electric field are principal components of the illuminating field of a vertical monopole antenna over a ground plane.

30.3 Reference field. The reference field in a CW immersion test is a measured field for monitoring the output from the transmitting antenna. This field is recorded in the reference channel of the network analyzer used for data acquisition. The reference sensor must be placed at a location with respect to the transmit antenna and subsystem shelter under test are negligible at all frequencies of interest. To minimize errors in the subsequent data analysis, the reference sensor should measure a field component which is relatively smooth and flat over the entire frequency range being measured. Examples of such components are:

a. Horizontal polarization. Radially outward horizontal component of the magnetic field parallel and near to ground[18]

b. Vertical polarization. Azimuthal magnetic field parallel and near to ground or vertical electric field near ground.

The reference field must be recorded for two types of measurements:

a. Field at the test object - Measurement of the illuminating field at the location of the test object relative to the reference sensor when the test object is not present. This is needed for subsequent data analysis (extrapolation to threat and establishment of pass/fail criteria - see C 50.6).

b. Subsystem response - Measurement of the residual response current inside the subsystem relative to the reference sensor when the facility is illuminated by the CW field.

[18] The horizontal component of the electric field or the vertical component of the magnetic field should not be used because of the low magnitude of these field components close to above ground. At a height above ground where the magnitude of these components becomes large, this magnitude contains man nulls in the range of 5 MHz to 1 GHz.

50.6 describes the analysis of the data from the above two measurements to establish pass/fail criteria.

40. GENERAL REQUIREMENTS

40.1 General. The CW immersion test procedure is an element of verification testing, performed as soon as practical after the HEMP-protected facility is completed and operational. The test method illuminates the exterior surface of the electromagnetic barrier with radiated CW fields and surveys the interior protected volume to identify shield defects and inadequately protected aperture POEs and to provide data for hardness assessment. Because coupling to exposed external portions of penetrating conductors may not be efficient, CW immersion has limited effectiveness for evaluating conductive POE protection. Therefore, protection provided for penetrating conductors is also evaluated with PCI testing (see appendix B). Both horizontal and vertical polarization must be used for the incident field.

40.2 Purpose. The purposes of CW immersion testing are as follows:

a. To measure attenuation of electromagnetic fields in the HEMP portion of the spectrum by linear elements of the as-built electromagnetic barrier.

b. To identify HEMP shield and aperture POE protective device defects, faulty installation practices, and inadvertent POEs, so that repairs can be made.

c. To characterize residual internal field and conducted electromagnetic stresses, within limitations of the linearity and planarity assumptions, through post-test analysis.

d. To observe operation of the facility for interference or upset (interference which occurs as the result of the low-level CW excitation may indicate a circuit which is particularly vulnerable to HEMP effects)

e. To provide data for HEMP hardness assessment of the facility and baseline data for the HM/HS program.

40.3 HEMP protection subsystem test configuration. During conduct of the CW immersion test, the facility shall be in a normal operating configuration and should be performing actual or simulated mission functions. The HEMP protection subsystem shall be intact.

40.4 Pretest analysis requirements. Pretest analysis shall be performed to select transmitting antenna locations, reference sensor locations, and measurement points. Transmitting antenna locations shall be chosen to obtain the required illuminating field strength and efficient coupling to all areas on the electromagnetic barrier surface. Reference sensor locations shall be chosen to monitor the transmitting antenna output and determine the illuminating field. Measurement points shall be chosen to provide representative mappings of field responses within the protected volume and special protective volumes and current responses within the internal cable plant.

40.5 Test equipment requirements. Test equipment required for CW immersion testing is identified in table VII.

TABLE VII. CW immersion test equipment requirements

Equipment	Characteristics
Network Analyzer(s)[1]	5 MHz-1 GHz, minimum sensitivity as required for measurement sensitivity
Power Amplifier(s)[2]	5 MHz-1 GHz, amplification as required for measurement sensitivity
Antenna(s)[3]	5 MHz-1 GHz
Sensors	Free-field, current, 1 MHz-1 GHz
Preamplifiers[4]	5 MHz-1 GHz, amplification and noise figure as required for measurement sensitivity
Data Recorder[1]	Dual channel
Fiber Optic Links[5]	5 MHz-1 GHz, up to 100 meters in length
Miscellaneous Cables and Attenuators	As required

[1]Use of a personal computer with an IEEE-488 general purpose interface bus (GPIB) to control the network analyzer, the fiber optic links, preamplifiers, and data acquisition (including storage of test data on magnetic disk or tape) is strongly recommended.
[2]Typically, several linear power amplifiers are required. For example, 150 watts for 1MHz – 220 MHz, and 10 watts for 200MHz- 1GHz.
[3]In order to cover a broad frequency range, several transmit antennas may be required. Examples are: Horizontal dipoles and vertical monopoles for frequencies up to 50 MHz and various log periodic antennas for both polarizations for frequency ranges such as 30MHz-100MHz and 90MHz to 1GHz.
[4]Typically, low-watt linear amplifiers having a gain of more than 30dB.
[5]Must have at least 30dB dynamic range. Must be able to extend the measurement range by use of attenuators and preamplifiers.

40.6 Operational impact analysis and risk. Since the electromagnetic barrier must remain intact during conduct of the CW immersion test and use of electrically noisy equipment which is not part of the normal site equipment complement must be restricted, unusual operations (facility modification, maintenance) may be affected. Mission operations can continue normally, except that a special sequence of activities may be required so that the facility can be tested in its various operating states (transmitting, receive-only, etc.). Radiated signal levels are low and present no hazard to equipment, but frequency clearance and bands in which transmissions must be suppressed may be required to avoid self-interference or interference with nearby facilities. Normal electrical safety precautions apply.

40.7 Test plan and procedures. A comprehensive, site-specific test plan and detailed test procedures for CW immersion testing shall be prepared. These may be combined into a single document or two separate documents may be used. As a minimum, the test documentation shall contain the following information:

a. A statement of the test objectives.

b. Facility identification and description (including a site plan, floor plan of the protected volume, list of shield POEs, list of mission-essential equipment inside and outside the electromagnetic barrier, and a description of the HEMP protective subsystem).

c. Transmitting antenna locations, reference sensor locations, and expected measurement sensitivity of the illumination and instrumentation system.

d. CW illumination and data acquisition equipment identification (including manufacturer, model and serial numbers, characteristics, and detailed calibration procedures).

e. Detailed test procedures (including facility configuration requirements, equipment operating states, diagrams of the test configuration, step-by-step procedures, and measurement point locations).

f. Data management (including data quality control procedures, data acceptability criteria, data processing requirements, annotation and preservation of data records, and pass/fail criteria).

g. Safety.

h. Security (see C 40.10).

i. Test schedule (including priority of measurements).

Data item description DI-NUOR-80928, "Nuclear Survivability Test Plan", shall be used

40.8 Test report requirements. A CW immersion test report shall be prepared. As a minimum, the test report shall contain the following information:

a. Facility identification and test plan reference.

b. A discussion of any deviations from the test plan and requirements of this appendix.

c. Copies of the measured results, along with sensor calibrations and instrumentation settings required to convert the data to engineering units. Ideally, the data are acquired with an automated (and calibrated) data acquisition system which automatically folds in any calibration factors, gain or attenuation settings. In this case, processed data can be shown in place of the directly measured results.

d. Test conclusions based on CW immersion and PCI test results and supporting analysis. A definitive statement of HEMP hardness of mission functions will be made based on the conclusions of the complete battery of verification tests (including PCI and CW immersion).

e. Test chronology - including a sequence of events and identification of failures observed and the conditions under which they occurred.

Data item description DI-NUOR-80929A, "Nuclear Survivability Test Report", shall be used.

40.9 Post-test analysis requirements. A post-test analysis of the measured data shall be performed to assist in developing a definitive statement of facility HEMP hardness. Detailed requirements for post-test analyses of verification test results shall be established by the sponsoring agency for the test. They will generally include calculations of threat responses from CW immersion and PCI test data, analysis of verification test adequacy, development of hardness conclusions, and recommendations for corrective action, if required.

40.10 Data classification. Test data may be classified. DNA-EMP-1 and the classification guide for the specific facility or system should be consulted for guidance.

40.11 Alternative test methods. When CW illumination of a facility is not practical because of physical interference with other facilities in the vicinity, the CW immersion test may be performed using CW current injection on the outer surface of the electromagnetic barrier. A site-specific CW shield current injection test plan and detailed procedures shall define the shield excitation technique, source strength, injection point, and predicted shield current density distributions. Minimum data acquisition system sensitivity required for verifying the HEMP protection subsystem effectiveness and pass/fail criteria shall be determined.

When approved by the sponsoring agency, a thorough program of shielding effectiveness measurements (appendix A) and a thorough SELDS survey IAW MIL-HDBK-423 guidance may be used for verification testing in lieu of the CW immersion test.

50. DETAILED REQUIREMENTS

50.1 Test configuration. The CW immersion test configuration is illustrated on figure 16. Swept or stepped CW excitation, generated by the network analyzer source, is propagated to the transmitting antenna location via a hardwired or fiber optic link.

The signal is amplified and radiated from the antenna (a vertical monopole, horizontal dipole, log periodic, rhombic or other antenna) to illuminate the facility. The reference sensor, located in a clear area where the measured field has a known relationship to the total field illuminating the facility, monitors the source output. Free-field, surface current or charge density, current and voltage sensors monitor the response at measurement points inside (and outside, if desired) the electromagnetic barrier. Preamplifiers and fiber optic links are used, as required, in the measurement channels. Reference and measurement point data are monitored on the network analyzer and recorded. Figure 17 illustrates a sample 1 MHz to 100 MHz data record, where identical B sensors (time rate of change of the magnetic induction field) are employed in both channels and the reference channel is a direct measurement of the illuminating field.

50.2 Transmitting antenna locations. Transmitting antenna locations shall be chosen to illuminate all areas on the barrier surface with the radiated field excitation. Three or four locations around the periphery of the facility will normally

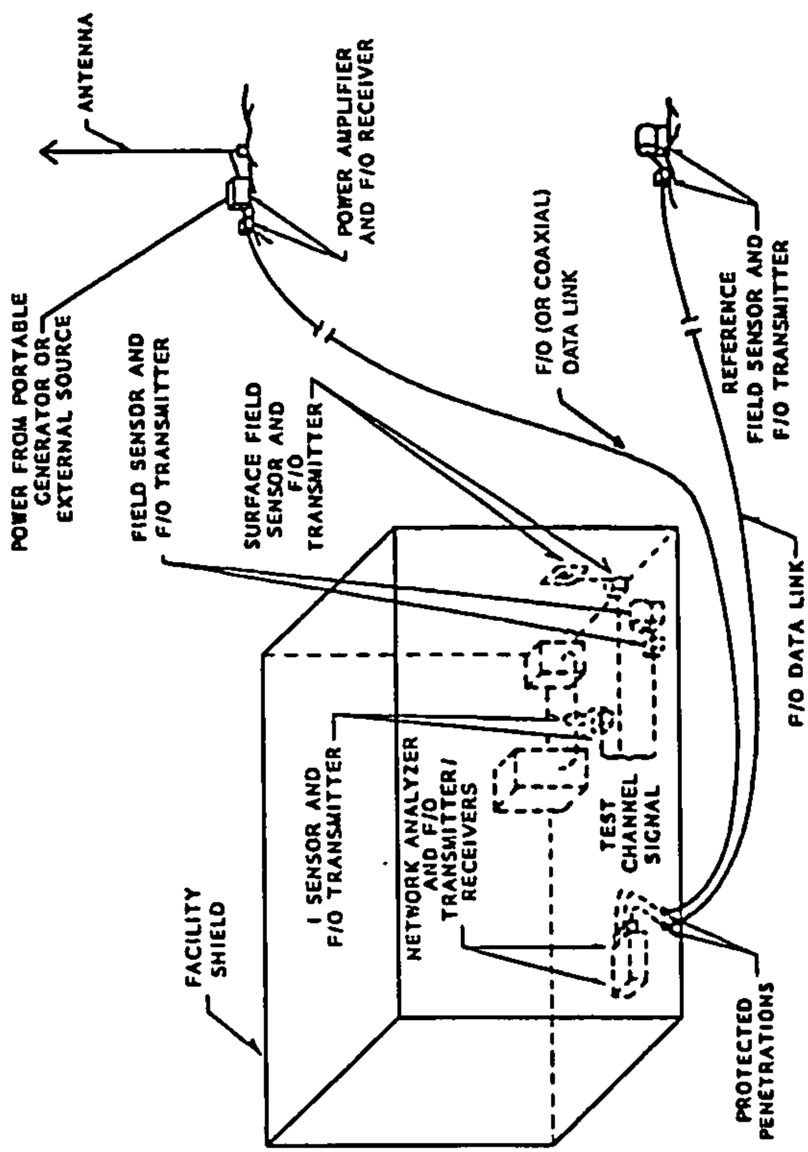

FIGURE 16. CW immersion testing

be required. The antenna shall be placed as far from transmit antenna as possible, within physical and measurement sensitivity constraints.[19]

50.3 Measurement locations. For facilities less than 900 m^2 (10,000 ft^2) in shielded floor area, a minimum of 5 (x3 components) electric or magnetic free-field measurement locations, 3 (x2 components) surface current or charge density measurement locations, and 20 current measurement locations throughout the shielded volume shall be chosen for each transmitting antenna location. For larger facilities, the number of measurement locations shall be increased in proportion to the total shielded floor area.

Measurement points for each transmitting antenna location should be concentrated in the 40 to 50 percent of the protected volume and in special protective volumes physically closest to electromagnetic barrier surfaces which are directly illuminated.

Internal free-field measurement points shall be chosen to provide a representative mapping of field responses within the electromagnetic barrier. The free-field measurements shall be made in areas which are relatively clear of equipment. The three orthogonal components of the field response shall be recorded. Internal magnetic free-field measurements should normally be emphasized.

Internal surface current or charge density measurements shall principally be made at penetration areas on the electromagnetic barrier. Internal surface current density measurements should normally be emphasized. When measuring surface current density, the two orthogonal components of the response shall be recorded.

Internal current measurement points shall be chosen to provide a representative mapping of current responses in the internal cable plant. Current measurements shall be made on selected penetrating cables near their POE protective devices, on selected cables with long interior runs or layouts producing efficient coupling geometries, and on input cables to selected mission-essential equipment.

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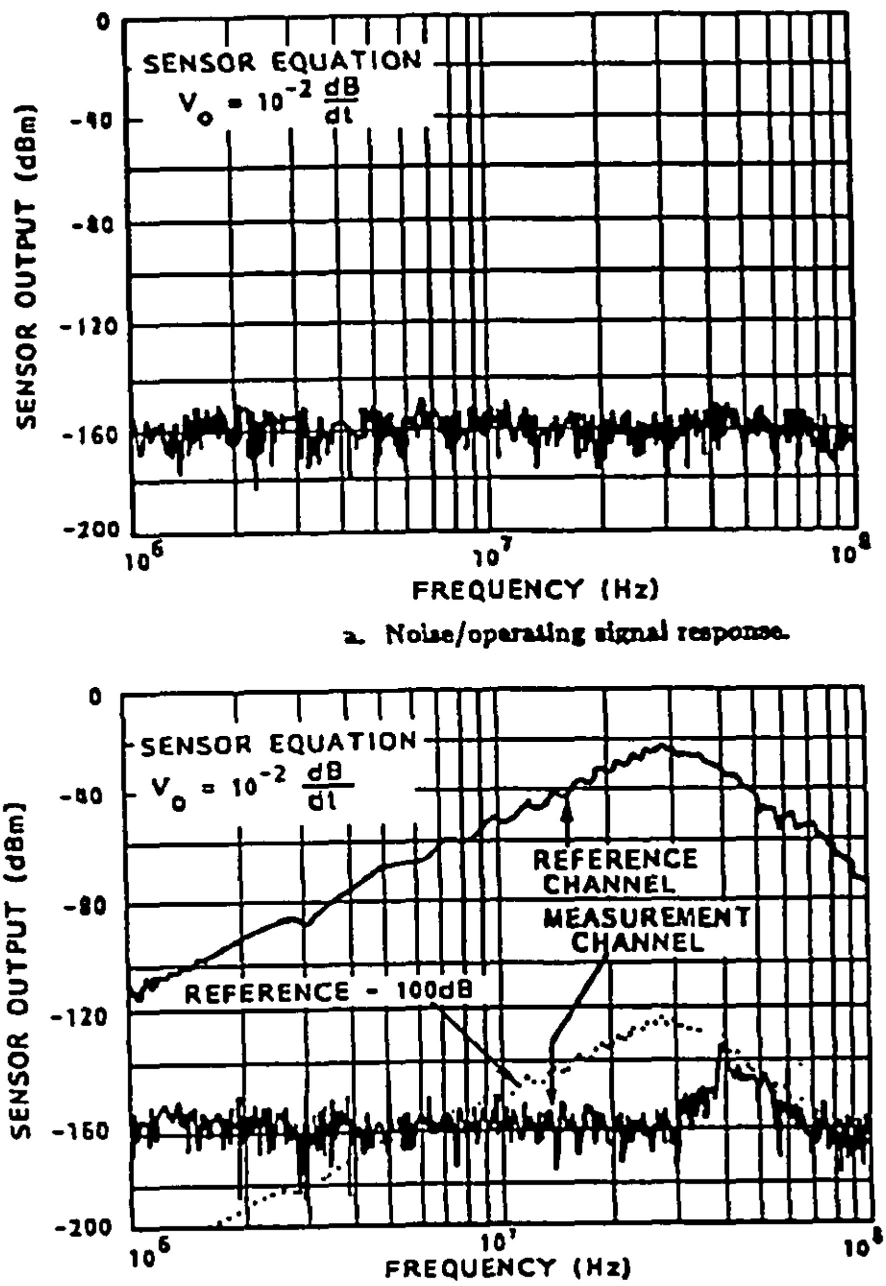
[19] Results can be interpreted as plane wave responses when: $R > \lambda_{MAX}$ and $R > 2\, D^2/\lambda_{MIN}$ - where R is the distance from the antenna to the barrier, λ_{MAX} is the wavelength of the lowest radiated frequency, λ_{MIN} is the wavelength of the highest radiated frequency, and D is the antenna characteristic length or largest barrier dimension transverse to the propagation direction of the illuminating field. When these inequalities are not satisfied, near-field and wave curvature effects may be significant.



a. Noise/operating signal response.

FIGURE 17. CW immersion test record.

An interior electromagnetic survey, with CW excitation applied from each transmitting antenna location, shall be performed to locate areas of maximum response. Particular attention should be given to barrier penetration areas. Additional free-field and current measurement points shall be chosen where the largest signals are detected during the survey.

50.4 Test frequencies. Test data are desired at frequencies from 100 kHz to 1 GHz. It is usually necessary to divide the frequencies into several bands, selecting different antennas to maximize the radiation efficiency in the different bands.

50.5 Measurement procedures. CW immersion test procedures shall be as follows:

a. Set up the data acquisition equipment in the desired configuration and perform calibrations. Minimum sensitivity of the data acquisition system should be 147 dBm or lower.

b. Set up the transmitting antenna and map its fields. The principal component of the illuminating field[20] should be at least 1 V/m from 1 MHz to 50 MHz and at least 0.1 V/m from 50 MHz to 100 MHz at the point on the electromagnetic barrier closest to the transmitting antenna. As a design objective, the principal component of the illuminating field should be at least 0.1 V/m from 100 kHz V/m from 100 kHz to 1 MHz and 0.01 V/m from 100 MHz to 1 GHz. Choose a reference sensor location.

c. Perform a check of each data acquisition channel to verify link noise immunity. Disconnect the sensor and terminate the sensor cable in its characteristic impedance. Energize the radiating source, and record the received signal strength as a function of frequency.

d. With the radiating source energized, perform a survey of the area to be monitored and select the additional measurement locations.

e. Place the sensor and use preamplifiers as required to obtain the desired measurement sensitivity.

[20]The illuminating field is expressed as: $c \times B_{illuminating}$ or $c \times E_{illuminating}$ where c equals the speed of light, $B_{illuminating}$ equals the magnetic induction field, and $E_{illuminating}$ equals the electric field.

f. With the source and data acquisition equipment in a normal configuration, except that the power amplifier is turned off, record the noise and operating signal response at the measurement point as a function of frequency. Narrow band filter and long sweep time settings of the network analyzer are necessary.

g. Turn the power amplifier on and record the reference and measurement point responses as a function of frequency, using the same filter and sweep time settings employed for the noise and operating signal measurement.

h. Perform data quality control. Annotate and preserve the data records.

i. Record any interference with the operation of facility equipment observed during the CW immersion test. Also record test and operational conditions which existed at the time the interference was noted.

j. Continue to the next measurement location and repeat steps e through i.

k. When measurements for one transmitting antenna location are completed, continue to the next transmitting antenna location and repeat steps b through j.

50.6 Pass/fail criteria.[21]

50.6.1 Internal field measurements. In frequency bands where the measurement dynamic range is less than the required attenuation, internal CW immersion free-field and surface current or charge density measurements shall be considered satisfactory when there is no observable test point response above the noise and operating signal level.

In the frequency band where the measurement dynamic range is greater than the required attenuation (expected to be at least 5 MHz to 100 MHz) internal CW immersion field measurements shall be considered satisfactory when the test point responses are below the principal component of the illuminating field by at least the required attenuation. This success criterion is expressed by the following equations:

[21] These pass/fail criteria apply to all measurements made in the protected volume. Responses measured in a special protective volume must not exceed design values for that special protective volume.

50.6.1.1 For internal magnetic induction field measurements.

$$B_{internal} \leq \frac{8000}{\omega} \times B_{illuminating} \qquad \omega < 8 \times 10^8$$

$$\leq 10^{-5} \times B_{illuminating} \qquad \omega \geq 8 \times 10^8$$

where

$B_{internal}$ = measured component of the magnetic induction field at a test point inside the electromagnetic barrier (Wb/m^2)

$B_{illuminating}$ = principal component of the illuminating magnetic induction field at the point on the electromagnetic barrier closest to the transmitting antenna (Wb/m^2)

ω = angular velocity (s^{-1})

50.6.1.2 For internal electric field measurements.

$$E_{internal} \leq 10^{-5} \times E_{illuminating}$$

where

$E_{internal}$ = measured component of the electric field at a test point inside the electromagnetic barrier (V/m)

$E_{illuminating}$ = principal component of the illuminating electric field at the point on the electromagnetic barrier closest to the transmitting antenna (V/m)

50.6.1.3 For internal surface current density measurements.

$$J_{s_{internal}} \leq \frac{6.4 \times 10^9}{\omega} \times B_{illuminating} \qquad \omega < 8 \times 10^8$$

$$\leq 8 \times B_{illuminating} \qquad \omega \geq 8 \times 10^8$$

$J_{S_{internal}}$ = measured surface charge density at a test point inside the electromagnetic barrier (A/m^2)

50.6.1.4 For internal charge density measurements.

$$Q_{S_{internal}} \leq 8.9 \times 10^{-17} \times E_{illuminating}$$

where

$Q_{S_{internal}}$ = measured surface charge density at a test point inside the electromagnetic barrier (C/m^2)

50.6.2 Internal current measurements. Internal CW immersion current measurements shall be considered satisfactory when the peak value of the threat-extrapolated response, transformed into the time domain, does not exceed 0.1 amperes and the peak derivative does not exceed 10^7 A/s. This success criteria is expressed by the following equations:

$$\left| \frac{1}{2\pi} \int_{2\pi f_e}^{2\pi f_u} \left[I_{threat}(\omega)\, e^{-i\omega t} + I^{*}_{threat}(\omega)\, e^{i\omega t} \right] d\omega \right| \leq 0.1$$

$$\left| -\frac{i}{2\pi} \int_{2\pi f^{t}}^{2\pi f^{u}} \left[I_{threat}(\omega)\, e^{-i\omega t} - I^{*}_{threat}(\omega)\, e^{i\omega t} \right] \omega\, d\omega \right| \leq 10^{7}$$

for all time t, where

f_e = the lowest CW immersion test frequency (Hz)

f_u = the highest CW immersion test frequency (Hz)

$I_{threat}(\omega)$ = threat-extrapolated current in the frequency domain (A/Hz)

$$= \frac{I_{internal}(\omega)}{[c \times B_{illuminating}(\omega)] or E_{illuminating}} \times E_{threat}(\omega)$$

$I_{internal}(\omega)$ = measured current at a test point inside the electromagnetic barrier (A)

$E_{threat}(\omega)$ = early-time threat HEMP field in the frequency domain (V/m-Hz) (see DOD-STD 2169)

$I^*_{threat}(\omega)$ = complex conjugate of $I_{threat}(\omega)$

50.6.3 Interference. Functional monitoring of facility operation shall be considered satisfactory when no interference with mission-essential communication-electronics or support equipment is observed.

50.6.4 Test failures. Any failure to satisfy the internal field measurement, internal current measurement, or interference success criteria shall be considered a HEMP vulnerability. An investigation into the cause of the possible vulnerability shall be conducted. The condition shall be corrected, if possible, and the CW immersion test sequence shall be repeated.

Custodians:
Army-SC
Navy-EC
Air Force-90

Preparing activity:
Air Force-90

(Project SLHC 1252)

Review Activities:
OASD-WS
ADASD-IR
Army-AC,AM,CE,CR,TE
Navy-MC,NC,NM,OM,TD
Air Force-01,02,13,14,15,17,19,89,91,92,93
DLA-DH
DNA-DS
DISA-DC
NSA-NS
DOD/ECAC-EM
DMA-MP

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I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER MIL-STD-188-125A, Vol I	2. DOCUMENT DATE (YYMMDD)

3. DOCUMENT TITLE High-altitude Electromagnetic Pulse (HEMP) Protection for Ground-based C4 Facilities Performing Critical, Time-urgent Missions, Volume I Fixed Facilities

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*	b. ORGANIZATION	
c. ADDRESS *(Include Zip Code)*	d. TELEPHONE *(Include Area Code)* (1) Commercial (2) AUTOVON *(If applicable)*	7. DATE SUBMITTED *(YYMMDD)*

8. PREPARING ACTIVITY

a. NAME HQ Air Force C4 Agency (HQAFC4A/TNAB)	b. TELEPHONE *(Include Area Code)* (1) Commercial (618) 256-2975 (2) AUTOVON 576-2975
c. ADDRESS *(Include Zip Code)* 607 Pierce Street, Room 303 Attn: Rex McKinnon Scott AFB, IL 62225-5421	IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403, Falls Church, VA 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340