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USACE / NAVFAC / AFCEC / NASA **UFGS-13 27 54.00 10 (October 2007)**

Preparing Activity: USACE **Superseding**
UFGS-13 27 54.00 10 (April 2006)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2014
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DIVISION 13 - SPECIAL CONSTRUCTION

SECTION 13 27 54.00 10

ELECTROMAGNETIC (EM) SHIELDING

10/07

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SECTION 13 27 54.00 10

ELECTROMAGNETIC (EM) SHIELDING
10/07

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NOTE: This guide specification covers the requirements for electromagnetic shielded facilities.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).

****

PART 1 GENERAL

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NOTE: The following information must be shown on the project drawings:

1. Assembly details.

2. Typical penetration details.

3. Method of mounting shielded enclosure within building.

4. Shield penetration plan containing wall elevations, floor and ceiling plans showing the locations of all penetrations (to include all mechanical, electrical, fire protection, etc.) to the HEMP shield.

5. Location of mechanical and electrical equipment within shielded enclosure.

6. Detail equipment mounted or suspended from the shielded ceiling.

7. Shield penetration schedule to include:
  a. Location of the waveguide.
  b. Size of waveguide (dimensions).
  c. No. of penetrations in the waveguide.
  d. Penetration designation of each penetration in the waveguide (if more than one).
  e. Size of pipe for each penetration in the waveguide.
  f. Type of pipe for each waveguide penetration.
  g. Type of penetration.
  h. The detail/sheet no. of the waveguide detail.
  i. Any remarks pertaining to the waveguide.

8. Filter schedule to include:
  a. Location of filter.
  b. Type of filter (power or signal).
  c. No. Of filters in the filter enclosure.
  d. Electrical characteristics of the filter (, amperage, no. of poles, frequency).
  e. Purpose of the filter.
  f. The detail/sheet no. Of the typical filter detail.
  g. Any remarks pertaining to the filter.

9. Typical filter details.

10. Hardness critical items (HCI) should be identified using the (HCI) symbol on project drawings.

Refer to MIL-HDBK 419 for special grounding and bonding requirements for EM shielded enclosures. Refer to the U.S. Air Force Handbook for the Design and Construction of HEMP/TEMPEST and Other Shields in Facilities (March 1993). This document can be obtained from HQ AFIC/LEEE, San Antonio, Texas 78243-5001. Also refer to AR 380-19. MIL-HDBK 423 should be used for projects requiring HEMP protection. The designer should consult these documents and other appropriate sources before applying this guide specification to large-scale EM shielded enclosures or to HEMP or TEMPEST projects. The requirement for thermal expansion joints inherent to large-scale enclosures is not addressed in this guide specification. The extent and location of the work to be accomplished and wiring, equipment, and accessories necessary for a complete installation should be indicated on the project drawings. The Air Force contracts with an independent testing laboratory to perform their acceptance testing. The test can consist of a SELDS or equivalent test and H-field and plane wave CW tests per MIL-STD-188-125 and/or IEEE 299. See the

U.S. Air Force Handbook for the Design and Construction of HEMP/TEMPEST and Other Shields in Facilities for more details. Methodology and procedures for setting up equipment are contained in MIL-HDBK-423. Full MIL-STD-188-125 acceptance testing (PCI tests as specified in appendix B) should be avoided. (Also see designer notes K and U). Although not addressed in this specification, fiber optic cable has gained acceptance as an effective method of transmitting data across the boundary of shielded enclosures without filtering. If fiber optic cable is used, describe the waveguide penetration of the shield in detail. Fiber optic cable is specified in Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM.
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1.1 REFERENCES

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NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a RID outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.
****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN HARDBOARD ASSOCIATION (AHA)

AHA A135.4 (1995; R 2004) Basic Hardboard

AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC)

AISC 325 (2011) Steel Construction Manual

AMERICAN WELDING SOCIETY (AWS)

AWS A5.18/A5.18M (2005) Carbon Steel Filler Metals for Gas Shielded Arc Welding

AWS BRH (2007; 5th Ed) Brazing Handbook

AWS D1.1/D1.1M	(2010; Errata 2011) Structural Welding Code - Steel
AWS D1.3/D1.3M	(2008; Errata 2008) Structural Welding Code - Sheet Steel
AWS D9.1M/D9.1	(2012) Sheet Metal Welding Code

APA - THE ENGINEERED WOOD ASSOCIATION (APA)

APA L870	(2010) Voluntary Product Standard, PS 1-09, Structural Plywood

ASTM INTERNATIONAL (ASTM)

ASTM A123/A123M	(2013) Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
ASTM A227/A227M	(2006; R 2011) Standard Specification for Steel Wire, Cold-Drawn for Mechanical Springs
ASTM A36/A36M	(2012) Standard Specification for Carbon Structural Steel
ASTM A568/A568M	(2013a) Standard Specifications for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements for
ASTM A653/A653M	(2011) Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
ASTM B194	(2008) Standard Specification for Copper-Beryllium Alloy Plate, Sheet, Strip, and Rolled Bar
ASTM B545	(2013) Standard Specification for Electrodeposited Coatings of Tin
ASTM B633	(2013) Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel
ASTM E84	(2013a) Standard Test Method for Surface Burning Characteristics of Building Materials
ASTM E90	(2009) Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 142	(2007) Recommended Practice for Grounding of Industrial and Commercial Power Systems

- IEEE Green Book

IEEE 299	(2006) Standard Method for Measuring the Effectiveness of Electromagnetic Shielding Enclosures
IEEE C62.11	(2012) Standard for Metal-Oxide Surge Arresters for Alternating Current Power Circuits (>1kV)
IEEE C62.33	(1982; R 2000) Standard for Test Specifications for Varistor Surge-Protective Devices
IEEE C62.41.1	(2002; R 2008) Guide on the Surges Environment in Low-Voltage (1000 V and Less) AC Power Circuits
IEEE C62.41.2	(2002) Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA ICS 2	(2000; R 2005; Errata 2008) Standard for Controllers, Contactors, and Overload Relays Rated 600 V
NEMA ICS 6	(1993; R 2011) Enclosures
NEMA MG 1	(2011; Errata 2012) Motors and Generators

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 101	(2012; Amendment 1 2012) Life Safety Code
NFPA 70	(2014; AMD 1 2013; Errata 2013; AMD 2 2013) National Electrical Code
NFPA 77	(2014) Recommended Practice on Static Electricity
NFPA 780	(2014) Standard for the Installation of Lightning Protection Systems
NFPA 80	(2013) Standard for Fire Doors and Other Opening Protectives
NFPA 80A	(2012) Recommended Practice for Protection of Buildings from Exterior Fire Exposures

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-HDBK-419	(1987; Rev A) Grounding, Bonding, and Shielding for Electronic Equipments and Facilities Volumes 1 of 2 Basic Theory
MIL-STD-188-124	(1998; Rev B; Notice 2 1998; Notice 3 2000; Notice 4 2013) Grounding, Bonding

	and Shielding for Common Long Haul/Tactical Communications Systems, Including Ground Based Communications - Electronics Facilities and Equipments
MIL-STD-188-125-1	(1998; Basic; Notice 1 2005) High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C41 Facilities Performing Critical, Time-Urgent Missions, Part I Fixed Facilities
MIL-STD-220	(2009; Rev C) Method of Insertion Loss Measurement
UFC 3-310-04	(2012) Seismic Design for Buildings

UNDERWRITERS LABORATORIES (UL)

UL 1283	(2005; Reprint Feb 2013) Electromagnetic Interference Filters
UL 1449	(2006; Reprint Sep 2013) Surge Protective Devices
UL 486A-486B	(2013) Wire Connectors

1.2 SYSTEM DESCRIPTION

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NOTE: Projects involving military communications equipment must be designed to incorporate the applicable requirements of MIL-STD-188-124, which will be provided in the ELECTRICAL WORK, INTERIOR specification.

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1.2.1 Shielding Specialist

Work performed under this section shall be supervised and inspected by the shielding specialist. Materials and equipment shall be approved and verified by the shielding specialist before being submitted to the Contracting Officer for approval. The submittal shall be date stamped and signed by the shielding specialist. The shielding specialist shall be responsible for coordinating the required shielding work with the work of all other trades that will interface or affect the shielding work in any way.

1.2.2 General Requirements

The shielded facility shall meet or exceed minimum attenuation decibel (dB) levels specified. The EM shielding system shall include, but is not limited to, the following:

a. The [welded steel] [bolted] EM shield.

b. EM shielded doors for access into the facility.

c. Electrical and electronic penetrations of the shield.

d. EM filter/surge arrester assemblies, including their EM enclosures.

e. EM shielded pull boxes and junction boxes.

f. EM shielded conduit runs.

g. Special protective measures for mission-essential equipment outside the EM shield.

h. Structural penetrations.

i. Mechanical and utility penetrations (such as air ducts, gas, and water).

j. Instrumentation and control.

k. Equipment door/access panels.

l. Sufficient supervisory and/or quality control personnel onsite to supervise the installation crew and to conduct in-progress quality assurance tests.

1.2.3 Factory Tests

Perform factory tests as specified. The Contracting Officer reserves the right to witness the specified factory tests. Notify the Contracting Officer at least 30 days before factory tests are scheduled to be performed. Test data shall include a detailed description of the test instrumentation and equipment, including calibration dates, a detailed description of the test procedure, and the recorded test data.

1.3 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project.

The Guide Specification technical editors have designated those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item, if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.
****

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for [Contractor Quality Control approval.] [information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Installation[; G][; G, [_____]]
Approved Drawings[; G][; G, [_____]]

SD-03 Product Data

EM Shielding System[; G][; G, [_____]]
Installation[; G][; G, [_____]]
Quality Control Plan[; G][; G, [_____]]
Qualifications[; G][; G, [_____]]
Qualifications of Welders[; G][; G, [_____]]
EM Door[; G][; G, [_____]]
Filter Assemblies[; G][; G, [_____]]
Penetrations[; G][; G, [_____]]

SD-06 Test Reports

Impulse Sparkover Voltage
ESA Extinguishing Test
ESA Extreme Duty Discharge Test
Field Testing

SD-07 Certificates

Qualifications of Welders

SD-10 Operation and Maintenance Data

Operating and Maintenance Manuals
Service Organization[; G][; G, [_____]]

1.4 QUALITY ASSURANCE

1.4.1 Shielding Specialists, Installers and Testing Specialists

Provide the name and background qualifications of individuals who will be responsible for installation, supervision, and testing of the shielding systems on this project. Shielding and testing specialist credentials shall include a bachelor's degree in science or engineering and post-degree training and experience with EM shielding.

1.4.1.1 Testing Experience

The testing specialist shall have experience during the previous 5 years in shielded enclosure leak detection system (SELDS), IEEE 299, and other methods of shielded enclosure testing.

1.4.1.2 Work Experience

The EM shielded system shall be provided by an experienced firm or individual that has been regularly and successfully engaged in the installation, supervision, and/or testing of equivalent EM shielded systems for at least the previous 5 years. The principal work of this firm or individual shall be the satisfactory installation and construction of EM shielded protection systems. Such experience shall include achieving specified requirements for shielded system attenuation and maintainability of attenuation levels on work performed.

1.4.1.3 Project Experience

Furnish a project experience list on projects of similar scope which have been completed during the previous 5 years. Include project completion dates and the name and telephone number of the user and/or owner of each project. Project experience for installers shall indicate the installation responsibilities, performance, materials, and methods used. Project experience for the shielding specialist shall indicate the responsibilities performed. Project experience for the testing specialist shall indicate the test methods performed.

1.4.2 Qualifications of Welders

Welding shall be performed by certified welders. Provide the names of the welders to be employed and certification that each welder has passed qualification tests within the last 2 years in the processes specified in AWS D1.1/D1.1M, AWS D9.1M/D9.1, and as required by the Contracting Officer.

1.4.3 Filter and Electrical Work Requirements

Filter and electrical work shall comply with NFPA 70, UL 486A-486B, and UL 1283. The label and listing of the Underwriters Laboratories or other nationally recognized testing laboratory will be acceptable evidence that the material or equipment conforms to the applicable standards of that agency. In lieu of the label or listing, a certificate may be furnished from an acceptable testing organization adequately equipped and competent to perform such services. The certificate shall state that the items have been tested and that they conform to the specified standard.

1.4.4 Field Samples

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NOTE: Requests for field samples and mock-ups usually add cost to the project. Samples should only be required for special applications and should be limited to scaled-down items. For example, the designer may ask for a welded floor/wall corner section. Do not normally ask for samples of filters and full-size waveguide vents.

****

Provide field samples for the following: [shielding sheet installation,] [shielding fastening,] [doors,] [[30] [100] [_____] ampere power filter,] [communication filter,] [waveguide,] [penetration,] and [_____].

1.4.5 Pre-Installation Meeting

Hold a pre-installation meeting with the subcontractors and installers working in, on, or near the EM shield. Discuss coordination requirements and instructions shall be stated to ensure the integrity of the EM shield.

1.5 DELIVERY, STORAGE, AND HANDLING

Protect equipment delivered and stored from excessive humidity and temperature variation, dirt, and other contaminants.

1.6 PROJECT/SITE CONDITIONS

Perform welding of EM shielding material and sheet steel at an ambient temperature of 10 degrees C 50 degrees F minimum to 32 degrees C 90 degrees F. Shielding shall not be installed until the building has been weather enclosed. Sheet steel welding shall not be performed in direct sunlight.

1.7 MAINTENANCE

1.7.1 Maintenance Supplies and Procedures

Provide maintenance supplies sufficient for a [3] [_____] year period or [50,000] [_____] open-close cycles, whichever is greater, for each EM shielded door. The maintenance instructions required to maintain the door through the cycle count shall be prominently displayed nearby.

1.7.2 Extra Materials

1.7.2.1 Filters

[One extra EM power filter] [[_____] extra EM power filters] and [one extra communications filter] [[_____] extra communications filters] of each different type furnished on the project shall be furnished as a spare.

1.7.2.2 EM Shielded Doors

Furnish one set of finger stock and EM gaskets (if used) for each hinged EM shielded door provided. In addition, provide one set of manufacturer recommended and Contracting Officer approved spare parts for EM shielded doors of each style installed.

1.7.2.3 Tools

Furnish one full set of tools that are required to maintain the doors and are not typically available from tool vendors. Furnish environmentally safe lubricants, cleaning solvents, or coatings in sufficient quantities to last for [6] [_____] months.

1.7.2.4 Special Tools

Provide one set of special tools, calibration devices, and instruments required for operation, calibration, and maintenance of the equipment as follows: [SELDS Test Set][_____]

1.7.3 Operating and Maintenance Manuals

Submit manufacturer's written instructions for operation and maintenance of EM Shielding system. The manual shall address all components and aspects of the EM shielding and shall include, but not be limited to, the following:

a. A complete set of assembly drawings to include penetration locations and installation details.

b. The construction specification on EM shielding.

c. Shield penetration schedule.

d. Power/signal filter schedule.

e. Test plan.

f. The prepared preventive maintenance instructions for periodic inspection, testing and servicing, lubrication, alignment, calibration, and adjustment events normally encountered. Complex preventive maintenance events shall be extracted from or shall refer to detailed vendor or manufacturer data. This information shall be derived from an evaluation of engineering data considering local environmental conditions, manufacturer's recommendations, estimated operating life for the specific application and use of the equipment, and types of job skills available at the operating site.

g. Spare parts data approved and verified by the shielding specialist prior to submission. The data shall include a complete list of recommended parts and supplies with current unit prices and source of supply.

h. Provide a list of hardness critical items (HCI) requiring periodic inspection to maintain EM shield integrity. Hardness critical items are those components and/or construction features which singularly and collectively provide specific levels of HEMP protection, such as the EM shield, surge arresters, EM shielded doors, shield welding, electrical filters, honeycomb waveguides, and waveguides-below-cutoff.

PART 2 PRODUCTS

2.1 MATERIALS AND EQUIPMENT

2.1.1 Standard Products

Provide materials and equipment which are the standard products of a manufacturer regularly engaged in the manufacture of such products and essentially duplicate items that have been in satisfactory use for at least 2 years prior to bid opening. Support equipment by a service organization that is, in the opinion of the Contracting Officer, reasonably convenient to the site.

2.1.2 Nameplates

Each major item of equipment shall have the manufacturer's name, address, type or style, model or serial number, and catalog number on a plate secured to the item of equipment.

2.1.3 Testability

Equipment and materials of the EM shielding shall be designed and built to facilitate testing and maintenance.

2.2 EM SHIELDING EFFECTIVENESS

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NOTE: The designer will consider the shield as early in the design as possible while the geometry of the shielded enclosure can be located to utilize components inherent in the structure. Failure to consider the shield configuration first in the design will increase design costs, cause problems in its incorporation into the structure, and lose installation simplicity. The EM shielded enclosure design should be coordinated by the structural, mechanical, and electrical engineers and architect. The structural and shielding systems should drive each other on large projects. Multi-story shielded enclosures require continuous connections of shielding steel interconnected to the structural steel. In these cases, the shielding wall layout should coincide with the structural steel beam layout. The shield within an exterior building concept must employ a design which allows for settling, seismic motion, and differential thermal expansion between the steel and concrete of the building and the steel of the EM shielding.

****

The EM shielded enclosure complete with all filters, doors, and/or waveguides shall have the following minimum EM shielding effectiveness attenuation. Minimum magnetic field attenuation shall be [20 dB] [_____] at 14 kHz increasing linearly to [50 dB] [100 dB] at [200 kHz] [1 MHz] [_____]. Minimum electric field and plane wave attenuation shall be [50 dB] [100 dB] [_____] from 14 kHz to [1 GHz] [10 GHz] [_____].

2.3 EM SHIELDING ENCLOSURE REQUIREMENTS (WELDED CONSTRUCTION)

****

NOTE: For the EM shielding enclosure, choose either welded or bolted construction. The unused method should be deleted from the project specification. Welded construction will usually consist of continuous 1.897 mm (14 gauge) thick steel plate and angles to form the enclosure. Thicker material may be used if it is more cost-effective or required for structural reasons. Welded construction is used when a shielded facility requires a long maintainable service life of high-level protection, 100 dB attenuation, or HEMP protection, 100 dB. Bolted construction is associated with a lower level (50 dB) of maintained shielding effectiveness. Bolted construction will usually consist of modular panels bolted together with metal strips or channels. Panels are commonly plywood with steel sheets laminated to one or both sides. Bolted construction is used when a shielded facility's service life is short, 10 years or less, or the system is required to be demountable for change of location. This system requires more maintenance than a welded system and requires access to the panels. The EM shield layout may restrict

attenuation testing of the enclosure. It is desirable for large facilities to place the shield at least 1 meter (3.3 feet) inside the exterior walls, although cost and construction restrict this consideration. The floor shielding can be tested by SELDS test but not by IEEE 299 if it is on grade. The facility layout must be carefully planned to allow for testing and shield maintenance.
****

2.3.1 Welded Shielding Enclosure

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NOTE: Shielding steel thickness should not be based solely on the minimum thickness required for HEMP/TEMPEST attenuation. Thicker steel may be necessary because of structural factors and heat deformation or burn-through from seam welding.
****

The intent of this section and the drawings is to provide a complete metal enclosure including floor, walls, ceiling, doors, penetrations, welds, and the embedded structural members to form a continuous EM shielded enclosure. Shielding sheets and closures shall be [3.416] [_____] mm [10] [_____] gauge thick hot-rolled steel conforming to ASTM A568/A568M. Steel plates, channels, or angles of minimum 6 mm 1/4 inch thick shall be used to reinforce shield sheets for attachments of ducts, waveguides, conduit, pipes, and other penetrating items. Furring channels used to attach shielding sheets to walls or floors shall be the minimum gauge of the shielding steel. The shielding sheet steel gauge may be thicker at the Contractor's option to reduce labor and welding effort only if structurally tolerable with the existing design. Steel shall be free of oil, dents, rust, and defects.

2.3.2 Metal Members

Structural steel shapes, plates, and miscellaneous metal shall conform to ASTM A36/A36M.

2.3.3 Steel and Welding Material

Welding materials shall comply with the applicable requirements of AWS D1.1/D1.1M and AWS D9.1M/D9.1. Steel and welding material shall conform to AISC 325. Welding electrodes shall conform to AWS D1.1/D1.1M for metal inert gas (MIG) welding method. Weld filler metal shall conform to AWS A5.18/A5.18M.

2.3.4 Fasteners

Self-tapping screws shall not be used for attachment of shielding. Power-actuated drive pins shall be zinc-coated steel, Type I, pin size No. 4 to secure steel sheets to concrete surfaces and to light gauge furring channels. The drive pins shall conform to ASTM A227/A227M Class 1 for materials and ASTM B633 for plating.

2.3.5 Miscellaneous Materials and Parts

Miscellaneous bolts and anchors, supports, braces, and connections necessary to complete the miscellaneous metal work shall be provided. The necessary lugs, rebars, and brackets to assemble work shall be provided. Holes for bolts and screws shall be drilled or punched. Poor matching of holes will be cause for rejection. Thickness of metal and details of assembly and supports shall provide ample strength and stiffness. The materials shall be galvanically similar.

2.3.6 Penetrations

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NOTE: Configure the facility to minimize the number of metallic structural elements required to penetrate the barrier.

****

Penetrations of the shield, including bolts or fasteners, shall be sealed with puddle welds or full circumferential EM welds. Structural penetrations including beams, columns, and other metallic structural elements shall be provided with continuously welded or brazed seams and joints between the penetrating element and the shield. Nonmetallic structural elements shall not penetrate the electromagnetic barrier.

2.3.7 Penetration Plates (Welded Construction)

The penetration plate shall be the central location for treatment of penetrations. The panel shall be constructed of 6 mm 1/4 inch thick ASTM A36/A36M steel plate welded to the shield. Waveguide, conduit, and piping penetrations shall be circumferentially welded at the point of penetration to the inner surface of the penetration plate. Penetration plates shall extend at least 150 mm 6 inch beyond all penetrations.

2.3.8 Floor Finish

****

NOTE: Indicate or specify whether other flooring is to be provided or higher floor loads are required. This is most critical when raised floors are specified. Allowances must be made for elevated door thresholds. Specify special requirements for laboratory loads, provide seismic requirements, if a Government designer is the Engineer of Record, and show on the drawings. Delete the inappropriate bracketed phrase. Pertinent portions of UFC 3-310 04 and Sections 13 48 00 and 13 48 00.00 10 must be enclosed in the contract documents.

If concrete floor wearing slabs are specified, they should be thick enough to hold anchor bolts for equipment, supports, and interior partitions. Concrete wearing slabs may be provided in most applications with a minimum thickness of 100 mm (4 inches). The Air Force is opposed to placing concrete wearing slabs over shielding steel because of problems with testing and repair. Placing concrete over floor shielding requires a waiver from HQ AFCEC/ENE.

****

Floor EM shielding shall be covered by a reinforced cast-in-place concrete slab [100] [_____] mm [4] [_____] inch thick. Seismic requirements shall be [in accordance with UFC 3-310-04 and Sections 13 48 00 SEISMIC PROTECTION FOR MISCELLANEOUS EQUIPMENT and 13 48 00.00 10 SEISMIC PROTECTION FOR MECHANICAL EQUIPMENT and [09 69 13 RIGID GRID ACCESS FLOORING][09 69 19 STRINGERLESS ACCESS FLOORING] (if needed)].

2.4 EM SHIELDING ENCLOSURE REQUIREMENTS (BOLTED CONSTRUCTION)

****

NOTE: For the EM shielding enclosure, choose either welded or bolted construction. The unused method should be deleted from the project specification. Welded construction will usually consist of continuous 1.897 mm (14 gauge) thick steel plate and angles to form the enclosure. Thicker material may be used if it is more cost-effective or required for structural reasons. Welded construction is used when a shielded facility requires a long maintainable service life of high-level protection, 100 dB attenuation, or HEMP protection, 100 dB. Bolted construction is associated with a lower level (50 dB) of maintained shielding effectiveness. Bolted construction will usually consist of modular panels bolted together with metal strips or channels. Panels are commonly plywood with steel sheets laminated to one or both sides. Bolted construction is used when a shielded facility's service life is short, 10 years or less, or the system is required to be demountable for change of location. This system requires more maintenance than a welded system and requires access to the panels. The EM shield layout may restrict attenuation testing of the enclosure. It is desirable for large facilities to place the shield at least 1 meter (3.3 feet) inside the exterior walls, although cost and construction restrict this consideration. The floor shielding can be tested by SELDS test but not by IEEE 299 if it is on grade. The facility layout must be carefully planned to allow for testing and shield maintenance.

****

2.4.1 Panel Construction

Flat steel sheets shall be laminated to each side of a 19 mm 3/4 inch thick structural core of either plywood or hardboard. Panels shall have a flame spread rating of less than 25 when tested according to ASTM E84. Flat steel shall conform to ASTM A653/A653M with G-60 coating, minimum 0.5512 mm 26 gauge thick, zinc-coated phosphatized. Plywood shall conform to APA L870 for exterior, sound grade hardwood, Type I. Hardboard shall conform to AHA A135.4, Class 4, SIS, for standard type hardboard. Adhesive for laminating steel sheets to structural core shall be a waterproof type which maintains a permanent bond for the lifetime of the enclosure.

2.4.2 Framing

Panels shall be joined and supported by specially designed framing members that clamp the edges of the panels and provide continuous, uniform, and constant pressure for contact to connect the shielding elements of the panels. The walls shall be self supporting from floor to ceiling with no bracing. Deflection of walls under a static load of 335 N 75 pounds applied normally to the wall surface at any point along the framing members shall not exceed 1/250 of the span between supports. [Ceilings shall be self-supporting from wall to wall.] [Ceilings shall be supported by adjustable, nonconducting, isolated hangers from the structural ceiling above.] Ceilings shall be designed to have a deflection under total weight, including ceiling finish, of not more than 1/270 of the span. A one-piece factory pre-welded corner section or trihedral corner framed with a brass machine cast corner cap assembly consisting of inner and outer parts shall be provided at all corner intersections of walls and floor or ceiling. The modular enclosure shall be designed for ease of erection, disassembly, and reassembly.

2.4.3 Channel

The framing-joining system members shall consist of 3 mm 1/8 inch thick zinc-plated steel channels having a minimum 16 mm 5/8 inch overlap along each side of the contacting surface. Screw fasteners shall be spaced at 75 or 100 mm 3 or 4 inch intervals. Screw fasteners shall be either zinc or cadmium-plated steel, minimum size 6 mm 1/4 inch, with a pan or flat Phillips head. Fasteners shall be heat-treated and hardened with a minimum tensile strength of 931 MPa 135,000 psi.

2.4.4 Sound Transmission Class (STC)

Enclosure panels shall have an STC of [30] [_____] dB minimum when tested according to ASTM E90.

2.4.5 Penetration Plates (Bolted Construction)

Plates shall be a minimum 3 mm 1/8 inch thick ASTM A36/A36M steel plate, sized [450] [_____] by [450] [_____] mm [18] [_____] by [18] [_____] inch and shall have a 6 mm 1/4 inch thick extruded brass frame for mounting to the shielded enclosure wall panel. Penetration plates shall extend at least 150 mm inch beyond all penetrations.

2.5 EM SHIELDED DOORS

****
NOTE: Edit these paragraphs depending on type of door used on project.
****

2.5.1 General

Material in shielded doors and frames shall be steel conforming to ASTM A36/A36M or ASTM A568/A568M and shall be stretcher-leveled and installed free of mill scale. Metal shall be thicker where indicated or required for its use and purpose. Metal thresholds of the type for proper shielding at the floor shall be provided. Fire rated shielded doors and assemblies shall meet NFPA 80 and NFPA 80A requirements and shall bear the identifying label of a nationally recognized testing agency qualified to perform certification programs. The EM shielded doors shall be provided by a single supplier who has been regularly engaged in the manufacture of these items for at least the previous 5 years. The assemblies shall be supplied complete with a rigid structural frame, hinges, latches, and parts necessary for operation. The products supplied shall duplicate assemblies that have been in satisfactory use for at least 2 years. The door frame shall be steel suitable for [welding] [bolting] to the surrounding structure and shield. The EM filters, EM waveguide penetrations for door systems, and miscellaneous material shall be provided for a complete system. The enclosure door shall be nonsagging and nonwarping. The EM shielded door shall provide a shielding effectiveness of [10 dB] [20 dB] greater than the minimum EM shielding effectiveness requirements. The door shall have a clear opening [as shown on the drawings] [of [915] [_____] mm [36] [_____] inch wide and [2135] [_____] mm [84] [_____] inch] high. The door and frame assembly shall have a sound rating of STC [30] [_____] minimum. Testing shall be performed in accordance with ASTM E90.

2.5.1.1 Door Latch

The door latch shall be lever controlled with roller cam action requiring not more than 67 N 15 pounds of operating force on the lever handle for both opening and closing. The door shall be equipped with a latching mechanism having a minimum of three latching points that provides proper compressive force for the EM seal. The mechanism shall be operable from both sides of the door and shall have permanently lubricated ball or thrust bearings as required at points of pivot and rotation.

2.5.1.2 Hinges

Doors shall be equipped with a minimum of three well-balanced adjustable ball-bearing or adjustable radial thrust bearing hinges suitable for equal weight distribution of the shielded doors. Hinges shall allow adjustment in two directions. Force necessary to move the doors shall not exceed 22 N 5 pounds.

2.5.1.3 Threshold Protectors

Threshold protectors shall be furnished for each EM shielded door. Protectors shall consist of portable ramps that protect the threshold when equipment carts or other wheeled vehicles are used to move heavy items across the threshold. The ramps may be asymmetrical to account for different floor elevations on each side, but the slope of the ramp shall not exceed 4:1 on either side. Ramps shall be designed to support a [227] [_____] kg [500] [_____] pound vertical force applied to a 75 by 13 mm 3 by 1/2 inch area for a personnel door, and a [907] [_____] kg [2,000] [_____] pound vertical force applied to a 75 by 13 mm 3 by 1/2 inch area for an equipment double leaf door. The force shall be applied to the contact area between the threshold and the door. Mounting brackets, convenient to the entry, shall be provided to store the ramp when not in use.

2.5.1.4 Frequency of Operation

With proper maintenance, door assemblies shall function properly through 100,000 cycles and 15-year service life minimum without the shielding effectiveness decreasing below the overall shield required attenuation.

2.5.1.5 Electric Interlocking Devices

Electric interlocking devices shall be provided for vestibules equipped with shielded doors at each end. Electric interlocking devices shall be provided so that shielded doors at the ends of the vestibule cannot be opened at the same time during normal operation. A manual override shall be provided to allow emergency egress, and an audible alarm shall be provided to indicate that doors at each end of the vestibule are open. The alarm will continue to sound while both doors are open. Provide a low-piezoelectric-type alarm, in a tamperproof enclosure, at a location shown on the project drawings or as directed by the Contracting Officer's representative. The sound intensity shall be 45 dBA minimum at 3.05 m 10 feet. Lights shall be provided on the side of each door outside the vestibule to indicate that the other door is open. Interlock systems may be integrated into a cypher lock system. The interlock system shall be powered by an uninterruptible power source and shall be fail-safe in an unlocked condition in the event of a power failure.

2.5.1.6 Electric Connectivity

Electric connectivity for sensors, alarms, and electric interlocking devices shall be installed in accordance with the door manufacturer's instructions, the approved drawings, and Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Submit detail drawings showing location, number, and method of penetrating the shielding material. Fabrication details for penetrations of the shielding material and the complete EM shielded enclosure to include doors and filters. Drawings shall show erection details and sequence of erection and shall clearly indicate the methods necessary to ensure shield integrity under all columns and other structural members.

2.5.1.7 Threshold Alarm

A press-at-any-point ribbon switch shall be applied to the threshold. The switch shall enunciate an alarm whenever pressure is applied to the threshold of the EM shielded door.

2.5.1.8 Hold Open and Stop Device

Each EM shielded door leaf shall be provided with a hold open and stop device permanently attached to the door leaf. Shielded doors shall have a fastener plate welded onto the door. The device shall not interfere with the finger stock. Drilling or tapping of the shielded door will not be allowed.

2.5.1.9 Emergency Exit Hardware

Emergency exit EM shielded doors shall be equipped with single motion egress hardware. The force required to latch and unlatch emergency exit hardware on EM shielded doors shall meet life safety code NFPA 101. Field alterations or modifications to panic hardware will not be allowed.

2.5.1.10 Finish

EM shielded doors shall be factory prime painted with zinc chromate primer. Doors may be factory finish painted or galvanized. Touch up any damaged finish.

2.5.1.11 Door Counter

A door operation counter shall be provided on the enclosure interior.

2.5.1.12 Additional Hardware

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NOTE: Alarms would normally be specified in Section 28 20 01.00 10 ELECTRONIC SECURITY SYSTEM or 28 16 01.00 10 SMALL INTRUSION DETECTION SYSTEM. Hardware will be specified in the hardware section.

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See door schedule on drawings and Section 08 71 00 DOOR HARDWARE, for additional hardware requirements. Fire rating and STC sound ratings shall be as required by the door finish schedule on the drawings or in the specifications.

2.5.2 Latching Type Doors

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NOTE: The knife edge shall be made of stainless steel 430 series if it will be exposed to moist air containing salt (near the sea coast) or in an uncontrolled or corrosive environment.

****

Doors shall be [steel] [laminated] type. [Steel doors shall be a minimum of 3.416 mm 10 gauge thick steel sheet electrically and mechanically joined by welded steel frames overlapping joints with continuous EM welds.] [Laminated type shall be the same construction as enclosure panels, except the steel faces shall be electrically and mechanically joined by channels or overlapping seams, both of which shall be continuously seam welded or soldered along all joined surfaces.] The closure seal shall utilize an extruded brass channel containing a recess into which [two] [_____] sets of [beryllium copper condition HT in accordance with ASTM B194] [stainless steel 430 (magnetic type) series] contact fingers and a closed cell foam rubber air seal are fitted and can be easily removed and replaced without the use of special tools and without the application of solders. The door shall mate to the frame in a manner that allows the insertion of a brass knife edge between the two rows of the radio frequency finger stock, to obtain optimum conductivity and electromagnetic shielding. High-temperature silver solder shall be used to attach the brass knife edge components to the door panels and the frame. The fingers that form a contact between the door and its frame shall be protected from damage due to physical contact and shall be concealed within the door and frame assembly.

2.5.3 Pneumatic Sealing Doors

Pneumatic sealing mechanisms shall achieve EM shielding by using pressure to force the door panel against the frame surface. Contact areas of door and frame shall be a peripheral strip not less than 75 mm 3 inch wide completely around the door with a tinned or highly conductive noncorrosive surface. After the door is in a closed position, the pneumatic sealing mechanism shall exert pressure in not more than 10 seconds. The sealing mechanism release shall be actuated in not more than 5 seconds. Manual [override] [operation] shall not exceed a maximum of [155] [_____] N [35] [_____] pounds. When the door is sealed, the attenuation around the edges shall meet the EM shielding effectiveness requirements of this specification. Swinging doors shall have a threshold of zinc-plated steel, not less than 9.5 mm 3/8 inch thick. The door shall be provided with a pneumatic system that maintains a nominal sealing pressure of [240] [_____] kPa [35] [_____] psi. A label shall be attached to pneumatic doors warning against painting of the mating surfaces.

2.5.3.1 Door and Enclosure Design

Doors shall be designed for long life and reliability without the use of EM gaskets, EM finger stock, or other sealing devices other than the direct metal-to-metal contact specified. The EM sealing device shall be fail-safe upon loss of air pressure and shall readily allow manual opening of the door. For either normal or fail-safe operation, the maximum time to reach the open position shall be no more than 7 seconds. The enclosure design shall include provision for removing the door for routine maintenance without disturbing its alignment and EM sealing properties.

2.5.3.2 Control Panel

The inside and outside of the shielded enclosure shall contain a control panel including the necessary opening and closing pneumatic valves. The outside control panel shall also have a pressure regulator and filter. The door air supply shall be capable of quick opening from inside the enclosure to allow escape when opening pneumatic valves fail or malfunction.

2.5.3.3 Air System for Pneumatic Sealing

A complete air system including compressor, filter alarm, tank, lines, air filter, dryer, air control valves, and controls shall be provided. Air tank capacity shall be sized so that the air volume and pressure are sufficient to operate the door through ten complete cycles after the loss of normal power.

2.5.4 Magnetic Sealed Door Type

An EM seal shall be formed by a solid metal-to-metal contact around the periphery of the door frame. The materials at the contact area shall be compatible and corrosion resistant. The contact force for the door EM seal shall be provided by electromagnets. When the electromagnet is energized, the door leaf shall be pulled in to ensure a solid and continuous contact with the door frame. When the electromagnet is de-energized, the door leaf shall be free to swing. The EM shielded doors may use electromagnets or a combination of permanent magnets and electromagnets.

2.5.5 Sliding Type Door

A sliding shielded door shall be of the size and operating direction indicated. Clear openings indicated on the drawings shall not require dismantling of any part of the door. The door shall be manually operable from either side, inside or outside, with a maximum pull (force) of 155 N 35 pounds to set the shielded door in motion. Shielded door face panels and frames shall be constructed of reinforced steel suitable for achieving the specified attenuation. Frames shall be constructed of steel shapes welded together to form a true rectangular opening. In the sealed position, the shielded doors shall provide the minimum shielding effectiveness specified without any derating. The doors shall be designed for long life and reliability and shall not use EM gaskets, EM finger stocks, or other sealing devices other than the specified direct metal-to-metal contact. A label shall be attached to sliding doors warning against painting of the mating surfaces.

2.5.6 Power Operators

Power operators shall be [pneumatic] [electric] type conforming to NFPA 80 and the requirements specified. Readily adjustable limit switches shall be provided to automatically stop the door in its full open or closed position. All operating devices shall be suitable for the hazardous class, division, and group defined in NFPA 70.

2.5.6.1 Pneumatic Operators

****
NOTE: Designer will coordinate with the drawings to ensure compressed air is available at door locations.
****

Pneumatic operators shall be heavy-duty industrial type designed to operate the door at not less than 0.2 m/s 2/3 fps or more than 0.3 m/s 1 fps with air pressure of [_____] kPa psi. A pressure regulator shall be provided if the operator is not compatible with available air pressure. Dryer, filter, and filter alarm shall be provided. Pneumatic piping shall be provided up to the connection with building compressed air, but not more than 6 m 20 feet from door jambs. Operators shall have provisions for immediate emergency manual operation of the door in case of failure. The operator shall open, close, start, and stop the door smoothly. Control shall be [electrical, conforming to NEMA ICS 2 and NEMA ICS 6; enclosures shall be Type 12 (industrial use), Type 7 or 9 in hazardous locations, or as otherwise indicated] [pneumatic] [with] [pushbutton wall switches] [ceiling pull switches] [rollover floor treadle] [as indicated].

2.5.6.2 Electric Operators

Electric operators shall be heavy-duty industrial type designed to operate the door at not less than 0.2 m/s 2/3 fps or more than 0.3 m/s 1 fps. Electrical controls shall be [pushbutton wall switches] [ceiling pull switches] [rollover floor treadle] [as indicated]. Electric power operators shall be complete with an electric motor, brackets, controls, limit switches, magnetic reversing starter, and other accessories necessary. The operator shall be designed so that the motor may be removed without disturbing the limit switch timing and without affecting the emergency operator. The power operator shall be provided with a slipping clutch coupling to prevent stalling of the motor. Operators shall have provisions for immediate emergency manual operation of the door in case of electrical failure. Where control s differ from motor voltage, a control voltage transformer shall be provided inside as part of the starter. Control voltage shall be 120 volts or less.

2.5.6.2.1 Motors

Drive motors shall conform to NEMA MG 1, shall be high-starting torque reversible type, and shall be of sufficient output to move the door in either direction from any position at the required speed without exceeding the rated capacity. Motors shall be suitable for operation on [[120] [208] [277] [480] volts, 60 Hz] [[220] [240] [380] volts, 50 Hz], [single] [three] phase, and shall be suitable for across-the-line starting. Motors shall be designed to operate at full capacity over a supply variation of plus or minus 10 percent of the motor voltage rating.

2.5.6.2.2 Controls

Each door motor shall have an enclosed reversing across-the-line type magnetic starter with thermal overload protection, limit switches, and remote control switches. The control equipment shall conform to NEMA ICS 2; enclosures shall conform to NEMA ICS 6, and shall be Type 12 (industrial use), Type 7 or 9 in hazardous locations, or as otherwise indicated. Each wall control station shall be of the three-button type, with the controls marked and color coded: OPEN - white; CLOSE - green; and STOP - red. When the door is in motion and the stop control is pressed, the door shall stop instantly and remain in the stop position. From the stop position, the door shall be operable in either direction by the open or close controls. Controls shall be of the full-guarded type to prevent accidental operation.

2.5.6.3 Leading Edge Safety Shutdown

Leading edges of the door with operators shall have a safety shutdown switch strip the entire length of the leading edge. The safety strip shall be press-at-any-point ribbon switches. Activation of the strip shall shut down the operator and release the door with reset required to continue door operation.

2.5.7 EM Shielded Door Factory Test

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NOTE: When specifying nonlatching doors, delete door static load and sag tests and cycle test for door latches. Retain cycle test for door hinges.
****

Test data shall be provided on at least one shielded door of each type provided for the facility to verify that the EM shielded doors of the design supplied have been factory tested for compliance with this specification. Test doors shall not be furnished on the project. Test data reports shall be submitted in accordance with paragraph SUBMITTALS.

2.5.7.1 Swinging Door Static Load Test

The door shall be mounted and latched to its frame, then set down in a horizontal position such that it will open downward with only the frame rigidly and continuously supported from the bottom. A load of 195 kg/psm 40 lb/psf shall be applied uniformly over the entire surface of the door for at least 10 minutes. The door will not be acceptable if this load causes breakage, failure, or permanent deformation which causes the clearance between door leaf and stops to vary more than 1.6 mm 1/16 inch from the original dimension.

2.5.7.2 Swinging Door Sag Test

The door and its frame shall be installed normally and opened 90 degrees. Two 45 kg 100 pound weights, one on each side of the door, shall be suspended from the door within 130 mm 5 inch of the outer edge for at least 10 minutes. The door will not be acceptable if this test causes breakage, failure, or permanent deformation which causes the clearance between the door leaf and door frame to vary more than 1.6 mm 1/16 inch from the original dimension.

2.5.7.3 Door Closure Test

Each door design shall be operated 100,000 complete open-close cycles. The door will not be acceptable if the closure test causes any breakage, failure, or permanent deformation which causes the clearance between the door and door frame to vary more than 1.6 mm 1/16 inch from the original dimension.

2.5.7.4 Handle-Pull Test

The door shall be mounted and latched to its frame. The handle shall have a force of 1100 N 250 pounds applied outward (normal to the surface of the door) at a point within 50 mm 2 inch of the end of the handle. The door will not be acceptable if this test causes any breakage, failure, or permanent deformation exceeding 3 mm 1/8 inch.

2.5.7.5 Door Electromagnetic Shielding Test

The EM shielded door shall be factory tested in accordance with the requirements of this specification both before and after the mechanical tests described above.

2.6 ELECTROMAGNETIC FILTERS

****

NOTE: All EM filters for power and signal lines should be scheduled on the drawings.

This guide specification covers electromagnetic filters for 50, 60, and 400 Hz power lines and signal lines for General Use Only. This specification is NOT applicable for filters to be used with a specific individual item of electronic equipment. Filters for use with specific individual items of equipment must be scheduled on the drawings showing voltage, current, insertion loss, passband, frequency, baud rate, and cutoff frequency.

****

A filter shall be provided for each power, data, and signal line penetrating the enclosure. These lines shall include, but are not limited to, power lines, lines to dummy loads, alarm circuits, lighting circuits, and signal lines such as telephone lines, antenna lines, HVAC control, and fire alarm. Filters [and ESAs] shall be enclosed in metallic cases which shall protect the filter elements from moisture and mechanical damage. All external bonding or grounding surfaces shall be free from insulating protective finishes. All exposed metallic surfaces shall be suitably protected against corrosion by plating, lead-alloy coating, or other means. The finish shall provide good electrical contact when used on a terminal or as a conductor, shall have uniform texture and appearance, shall be adherent, and shall be free from blisters, pinholes and other defects. The filter [and ESA] assemblies shall also meet the requirements of UL 1283. Insertion loss in the stop band between the load side of the filter and the power supply side shall be not less than the EM shielding attenuation specified. The filter used for 400 Hz shall be provided with power factor correcting coil to limit the reactive current to 10 percent maximum of the full load current rating. Each filter unit shall be capable of being mounted individually and shall include one filter for each phase conductor of the power line and the neutral conductor. The signal filters shall include one filter for each conductor.

2.6.1 Enclosure

****

NOTE: The intent of this paragraph is to preserve the integrity of the filter and to shield the input and output circuits from each other. Usually, this is accomplished by mounting the filters in an EM-modified NEMA Type 1 enclosure with separate compartments for the input and the output terminals. If a weatherproof or hazardous area type

enclosure is needed, it must be specified.
****

Filter units shall be mounted in an EM modified NEMA Type [1] [_____] enclosure in accordance with NEMA ICS 6 and meet the requirements of UL 1283. Enclosures shall be made of corrosion resistant steel of 1.9837 mm 14 gauge minimum thickness with welded seams and galvanized bulkhead cover plates. The enclosure nonconductive surfaces shall be finished with a corrosion-inhibiting primer and two coats of baked or finish enamel. The input compartment shall house the individual line filters and the input terminals of the filters and mounting for the surge arrestor. Live parts shall be spaced in accordance with NFPA 70. Filter leads shall be copper. Filter enclosures shall be shielding effectiveness tested in accordance with IEEE 299 and Table I of this specification. [Test leads and coaxial connectors through the enclosure shall be provided for HEMP testing.] [The imbedded configuration shall be used for filter enclosures as required by MIL-STD-188-125-1.]

2.6.1.1 Filter Unit Mounting

Each filter unit shall be mounted individually in an enclosure containing one filter for each penetrating conductor. One end of the individual filter case shall be attached to the rf barrier plate between the two compartments to provide a rf tight seal between the rf barrier plate and the filter case. The terminals of the filters shall project through openings in the rf barrier plate into the inner terminal compartment. The case of each filter shall be attached to both the enclosure and to the barrier plate to prevent undue stress being applied to the rf seal between the filter case and the rf barrier plate. Individual filters shall be removable from the enclosure. Like filters shall be interchangeable.

2.6.1.2 Conduit Connections to Enclosures

The load terminal and input compartments shall have no knockouts, and each compartment shall have weldable threaded conduit hubs. The hubs shall be circumferentially EM welded in place and shall be sized and located as required for the conduits indicated.

2.6.1.3 Access Openings and Cover Plates

Enclosures shall have separate clear front access cover plates on terminal and power input compartments. Access cover plates shall be hinged with EM gaskets and 75 mm 3 inch maximum bolt spacing. The design shall include thick cover plates and folded enclosure edges to prevent enclosure deformation, bolt spacers to prevent uneven gasket compression, and gasket mounting to facilitate replacement. All gasket contact areas shall be tin-plated using the electrodeposited type I method in accordance with ASTM B545. Nuts and bolts shall be permanently fastened to the enclosure by welding or captive attachments.

2.6.1.4 Operating Temperature

The filter and ESA assembly shall be rated for continuous operation, with filters at rated voltage and full-load currents, in ambient temperatures from minus 55 to plus 65 degrees C (measured outside the EM filter enclosure). Filter components shall be suitable for continuous full load operation at a temperature from minus 55 to plus 85 degrees C.

2.6.1.5 Short Circuit Withstand

Filters shall be labeled and built to have standard short circuit withstand ratings in accordance with UL 1283. The minimum ratings shall be as follows:

FILTER RATED CURRENT, RMS AMPERE	SHORT CIRCUIT FULL LOAD AMPERES SYMMETRICAL
0-100	10,000
101-400	14,000

2.6.1.6 Filter Connections

Individual filters shall have prewired standoffs and solderless lugs. The lugs shall be of the hexagonal head bolt or screw type and shall conform to UL 486A-486B. Live parts shall be spaced in accordance with NFPA 70.

2.6.2 Internal Encapsulated Filters (Filter Units)

****

NOTE: There are two kinds of power filters, commonly known as "W" and "X" series. The "W" series filters are designed to achieve rated insertion loss under load when tested in accordance with MIL-STD-220, which only requires testing under load conditions from 100 kHz to 20 MHz. The "X" series device data sheets will contain the phrase "tested using extended range buffer networks" and will satisfy the stated performance under full load at frequencies below 100 kHz. The "X" series filters will also be tested in accordance with MIL-STD-220. The "X" series filters can also be differentiated from "W" devices by the fact that they are usually two to three times greater in weight.

Fire alarm, signal, energy monitoring and control system, telephone, and control lines require filters that pass a specific frequency, voltage, and number of conductors. Fire alarm circuits with ground fault indicators will show a ground fault when connected through a filter and should be avoided. A fiber optic connection through the shield is recommended. Conductors penetrating the shield perimeter shall be kept to a minimum. Systems penetrating the shield will have special requirements in their specifications for compatibility between system signal and control circuits and the EM filters.

****

2.6.2.1 Filter Construction

Individual filters shall be heavy-duty type sealed in a steel case. After the filter is filled with an impregnating or encapsulating compound, the seams shall be welded. When a solid potting compound is used to fill the filter, the filters may be mechanically secured and sealed with solder. Hermetically sealed impregnated capacitors shall be used, or the complete filter assembly shall be vacuum impregnated. Individual filter cases shall be fabricated of not less than 2 mm 14 gauge thick steel and finished with a corrosion-resistant plating,or one coat of corrosion-resistant primer and two coats of finish enamel. The filter shall be filled with an impregnating or potting compound that is chemically inactive with respect to the filter unit and case. The compound, either in the state of original application or as a result of having aged, shall have no adverse effect on the performance of the filter. The same material shall be used for impregnating as is used for filling. Filter terminals shall be copper that can withstand the pull requirements specified and measured in accordance with paragraph ELECTROMAGNETIC FILTERS.

2.6.2.2 Ratings

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NOTE: Indicate maximum current, voltage, and pass band frequency ratings on the drawings. If no drawings are furnished with the specifications, specify the ratings here.
****

[Filters shall be provided in the current, voltage, and frequency ratings indicated on the drawings.] [Filter current shall be [_____].] [Filter voltage shall be [[120] [208] [277] [480] volts, 60 Hz] [[230] [250] [400] volts, 50 Hz].] [The pass band frequencies [_____] Hz to [_____] Hz shall be suitable for use with the [50] [60] [_____] [and] [400] [_____] Hz power source and signal line filters as indicated.]

2.6.2.3 Voltage Drop

Voltage drop through the filter at operation frequency shall not exceed 2 percent of the rated line voltage when the filter is fully loaded with a resistive load (unity power factor). Voltage drop measurements shall be in accordance with paragraph Voltage Drop Measurements.

2.6.2.4 Input Elements

Filters shall be provided with inductive inputs. If inductive input is used an ESA is required to protect the filter. The inductor shall ensure firing potential for the preceding ESA and shall limit the current through the filter capacitor. The input inductor shall be designed to withstand at least a 10,000-volt transient.

2.6.2.5 Drainage of Stored Charge

Filters shall be provided with bleeder resistors to drain the stored charge from the capacitors when power is shut off. Drainage of stored charge shall be in accordance with NFPA 70.

2.6.2.6 Insertion Loss

****
NOTE: Use 100 dB insertion loss at 14 kHz to 10 GHz for applications such as secure communications installations. For other applications, insert appropriate insertion loss and frequency range for

the specific product. Consult filter manufacturer for detailed requirements. Also consult the manufacturer when leakage current is important, such as in life safety areas. There is a tradeoff between leakage current and insertion loss when insertion loss is measured according to MIL-STD-220 because of the test connection and the line-to-ground capacitance. Harmonic loading of EM filters will require alterations to the electrical system design to protect the filters from damage. Large individual loads, such as adjustable speed drive and uninterruptible power supplies, should have shielded isolation transformers on their input line side. Multiple small individual loads, such as computers, should have EM filters derated or shielded isolation transformers between filter output and the harmonic generating loads. EM filters should be derated by 50 percent when serving loads with substantial harmonic components. If a facility is formally required to fully comply with MIL-STD-188-125, filter and ESA characteristics should meet the standard's requirements as applied to the facility. The facility's electrical system should be designed to meet the requirements of MIL-STD-188-125 with commercially available filters and ESA. The commercial electrical power feeder should be arranged in a manner that will meet MIL-STD-188-125 requirements. Voice and data lines should be converted to fiber optics prior to penetration of the EM shield. The requirements of MIL-STD-188-125 should be applied by a shielding specialist experienced in the standard's requirements and applications.

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Insertion loss shall meet or exceed the levels complying with EM shielding effectiveness attenuation requirements herein when measured in accordance with MIL-STD-220. Insertion loss measurements shall be performed in accordance with MIL-STD-220 and the paragraph ELECTROMAGNETIC FILTERS.

2.6.2.7 Operating Temperature Range

Individual filters mounted in the filter enclosure operating at full load amperage and rated voltage shall not exceed plus 85 degrees C 185 degrees F based on an ambient temperature of 65 degrees C 150 degrees F outside the filter enclosure. Continuous operation from minus 55 to plus 85 degrees C minus 67 to plus 185 degrees F shall be demonstrated according to paragraph "Filter Life Test (at Elevated Ambient Temperature)". Filters shall also withstand temperature cycling as specified in paragraph ELECTROMAGNETIC FILTERS. The filter shall remain at rated voltage and full-load current until temperature equilibrium is reached or 24 hours, whichever is greater.

2.6.2.8 Current Overload Capability

Filters shall be capable of operating at 140 percent of rated current for 15 minutes, 200 percent of rated current for 1 minute, and 500 percent of rated current for 1 second when tested in accordance with paragraph Overload Test.

2.6.2.9 Reactive Shunt Current

The reactive shunt current drawn by the filter operating at rated voltage shall not exceed 30 percent of the rated full-load current when measured in accordance with paragraph Reactive Shunt Current Measurements.

2.6.2.10 Dielectric Withstand Voltage

Filters shall be provided which conform to the minimum values of dielectric withstanding voltage. Filter dielectric withstand voltage test shall be in accordance with paragraph "Dielectric Withstand Voltage Test". HEMP filters shall be capable of operating continuously at full-rated voltage and of withstanding an overvoltage test of 2.8 times the rated voltage for 1 minute. In addition, each filter shall be capable of withstanding a 20-kV or 4-kA peak transient pulse of approximately 20 ns pulse width at full operating voltage, without damage.

2.6.2.11 Insulation Resistance

The insulation resistance between each filter terminal and ground shall be greater than 1 megohm when tested in accordance with paragraph Insulation Resistance Test.

2.6.2.12 Parallel Filters (Current Sharing)

Where two or more individual filters are electrically tied in parallel to form a larger filter, they shall equally share the current. Equally sharing is defined to be within 5 percent of the average current. The tests shall be in accordance with paragraph ELECTROMAGNETIC FILTERS.

2.6.2.13 Harmonic Distortion

Harmonics generated by the insertion of a filter shall not increase line voltage distortion more than 2.5 percent when measured with a unity power factor in accordance with the paragraph ELECTROMAGNETIC FILTERS.

2.6.3 Marking of Filter Units

Each filter case shall be marked with HCI tags and with the rated current, rated voltage, manufacturer s name, type of impregnating or potting compound, operating frequency, and model number. In addition, individual filter cases, the filter enclosures, and supply and load panelboards of filtered circuits shall be marked by the manufacturer with the following: "WARNING: Before working on filters, terminals shall be temporarily grounded to ensure discharge of capacitors. Nameplates and warning labels shall be securely attached.

2.6.4 Minimum Life

Filter assemblies shall be designed for a minimum service life of 15 years. Submit filter schedule including voltage, amperage, enclosure type (low, high, band pass), location, cut-off frequency, band pass frequencies, and electrical surge arresters (ESA). Submit data and/or calculations for design of EM door including schedule of EM penetrations.

2.6.5 Power and Signal Line Factory Testing

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NOTE: In most cases, test results for equal filters

are sufficient to determine compliance with specification requirements. Factory tests on individual filters may be required for higher than average temperature applications, special filter configurations, and other special project requirements.

Filters with nonstandard configuration or ratings may require testing by an independent testing organization. These ratings would be for filters above 1,000 amperes.

****

Factory test report data shall be submitted for each filter configuration, voltage, and amperage which shall show the ability of filters to meet the specified requirements. Filter test reports shall be based on prior tests of the same filter assembly design and components. Test data reports shall be submitted in accordance with paragraph SUBMITTALS. Test data shall include the following:

a. Voltage Drop Measurements.

b. Insertion Loss Measurements.

c. Filter Life Test.

d. Thermal Shock Test.

e. Overload Test.

f. Reactive Shunt Current Measurements.

g. Dielectric Withstand Voltage.

h. Insulation Resistance Test.

i. Current Sharing.

j. Harmonic Distortion.

k. Terminals.

2.6.5.1   Voltage Drop Measurements

The voltage drop measurements on both ac and dc filters shall be performed with the components mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method that will be used for mounting in the enclosure. For ac rated filters, measurements shall be made by using expanded scale-type meters. For dc rated filters, measurements shall be made by using a dc meter when the filter is carrying rated current and rated voltage.

2.6.5.2   Insertion Loss Measurements

Insertion loss measurements for power filters shall have the following modifications. The filters shall be installed in the filter/ESA assembly enclosure. The load current power supply shall operate at the rated voltage of the filters and shall be capable of providing any current from no-load through rated full-load current. The rf signal generator shall be a swept continuous wave (cw) source. The buffer networks shall be modified to permit valid measurements over the entire frequency band on which insertion loss requirements are specified (14 kHz-1 Ghz). The receiver or network analyzer shall be capable of operating over the entire frequency band on which insertion loss requirements are specified (14 kHz-1 Ghz). Sensitivity shall be adequate to provide a measurement dynamic range at least 10 dB greater than the insertion loss requirement. The load impedance shall be resistive and shall be capable of dissipating the rated full-load filter current. Insertion loss measurements shall be made at 20 percent, 50 percent, and 100 percent of the filter full-load operating current. Insertion loss measurements for communication/signal line filters shall be performed the same as for power filters except that the insertion loss measurements are required at a load impedance equal to the image impedance of the filter. No load insertion loss measurements shall be performed over the frequencies defined in the EM shielding effectiveness attenuation requirements for both power and communication filters. [Testing shall be load to source for TEMPEST.] [Testing shall be source to load for HEMP.]

2.6.5.3 Filter Life at High Ambient Temperature

This test is conducted for the purpose of determining the effects on electrical and mechanical characteristics of a filter, resulting from exposure of the filter to a high ambient temperature for a specified length of time, while the filter is performing its operational function. Surge current, total resistance, dielectric strength, insulation resistance, and capacitance are types of measurements that would show the deleterious effects due to exposure to elevated ambient temperatures. A suitable test chamber shall be used which will maintain the temperature at the required test temperature and tolerance. Temperature measurements shall be made within a specified number of unobstructed mm inches from any one filter or group of like filters under test. This test shall be made in still air. Specimens shall be mounted by their normal mounting means. When groups of filters are to be tested simultaneously, the mounting distance between filters shall be as specified for the individual groups otherwise the mounting distance shall be sufficient to minimize the temperature on one filter affecting the temperature of another. Filters fabricated of different materials shall not be tested simultaneously. The test temperature shall be 85 + 2 degrees C 184 + 34 degrees F. The length of the test shall be for 5,000 hours. Specified measurements shall be made prior to, during, or after exposure.

2.6.5.4 Thermal Shock Test

This test is conducted for the purpose of determining the resistance of a filter to exposures at extremes of high and low temperatures, and to the shock of alternate exposures to these extremes. Suitable temperature controlled systems shall be used to meet the temperature requirements and test conditions. Environmental chambers shall be used to meet test requirements and to reach specified temperature conditions. Filters shall be placed so that there is no obstruction to the flow of air across and around the filter. The filter shall be subjected to the specified test condition. The first five cycles shall be run continuously. After five cycles, the test may be interrupted after the completion of any full cycle, and the filter allowed to return to room ambient temperature before testing is resumed. One cycle consists of steps 1 through 4 of the applicable test condition for dual environmental test chambers (one low temperature and one high temperature test chamber) and steps 1 and 3 for single compartment test chambers where both high and low temperatures are achieved without moving the filter. The test conditions are as follows:

1. -55 deg C. 0 deg and -3 deg
2. 25 deg C. +10 deg and -5 deg
3. 85 deg C. + 3 deg and -0 deg
4. 25 deg C. +10 deg and -5 deg

The effective total transfer time from the specified low temperature to the specified high temperature shall not exceed 5 minutes. The exposure time in air at the extreme temperatures is a function of the weight of the filter. The minimum exposure time per the weight of the filter shall be as follows:

1 oz. and below	15 minutes
Above 1 oz. to 4.8 oz.	30 minutes
Above 4.8 oz. to 3 lb.	1 hour
Above 3 lb. to 30 lb.	2 hours
Above 30 lb. to 300 lb.	4 hours
Above 300 lb.	8 hours

Specified measurements shall be made prior to the first cycle and upon completion of the final cycle, except that failures shall be based on measurements made after the specimen has stabilized at room temperature following the final cycle.

2.6.5.5 Overload Test

Filters shall be mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method that will be used for mounting in the enclosure. A specified current shall then be applied for a specified period of time. After the filter has returned to room temperature, the insulation resistance and voltage drop shall be measured. The insulation resistance shall be measured using the method in paragraph ELECTROMAGNETIC FILTERS. AC voltage drop measurements shall be made by using expanded scale-type meters which will enable voltage differences of less than 1 volt to be read. DC voltage drop measurements shall be made by using a dc reading meter when the filter is carrying rated current and rated voltage. The insulation resistance and the voltage drop will be measured after each separate overload test. Filters will also be visually examined for evidence of physical damage after each test.

2.6.5.6 Reactive Shunt Current Measurements

The reactive shunt current measurements shall be performed with the filters mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method that will be used for mounting in the enclosure. The filter shall be terminated in the inner compartment in an open circuit. Rated ac voltage shall be applied between the filter outer compartment terminal and the enclosure or metal plate. The ac current into the outer compartment terminal shall be monitored. The measured current is equal to the filter reactive shunt current.

2.6.5.7 Dielectric Withstand Voltage Test

The dielectric withstanding voltage test (also called high-potential, over potential, .voltage breakdown, or dielectric-strength test) consists of the application of a voltage higher than rated voltage for a specific time between mutually insulated portions of a filter or between insulated portions and ground. Repeated application of the test voltage on the same filter is not recommended as even an overpotential less than the breakdown voltage may injure the insulation. When subsequent application of the test potential is specified in the test routine, succeeding tests shall be made at reduced potential. When an alternating potential (ac) is used, the test voltage shall be 60 Hz. and shall approximate a true sine wave in form. All ac potentials shall be expressed as root-mean-square values. The KVA rating and impedance of the source shall permit operation at all testing loads without serious distortion of the waveform and without serious change in voltage for any setting. When a direct potential (dc) is used, the ripple content shall not exceed 5 percent rms of the test potential. A voltmeter shall be used to measure the applied voltage to an accuracy of 5 percent. When a transformer is used as a high-voltage source of ac, a voltmeter shall be connected across the primary side or across a tertiary winding provided that the actual voltage across the filter will be within the allowable tolerance under any normal load condition. Unless otherwise specified, the test voltage shall be dc and shall be as follows:

DC rated only	2.5 times rated voltage
For filters with ac and dc ratings	2.5 times rated dc voltage
AC rated only	4.2 times rated rms voltage

The duration of the dc test voltages shall be 5 seconds minimum, 1 minute maximum, after the filter has reached thermal stability at maximum operating temperature produced by passage of rated current. The test voltage shall be applied between the case (ground) and all live (not grounded) terminals of the same circuit connected together. The test voltage shall be raised from zero to the specified value as uniformly as possible, at a rate of approximately 500 volts (rms or dc) per second. Upon completion of the test, the test voltage shall be gradually reduced to avoid voltage surges. The changing current shall be 50 mA maximum. During the dielectric withstanding voltage test, the fault indicator shall be monitored for evidence of disruptive discharge and leakage current. The sensitivity of the breakdown test equipment shall be sufficient to indicate breakdown when at least 0.5 mA of leakage current flows through the filter under test. The test shall be performed with the components mounted in the filter/ESA assembly enclosure. Filters for ac circuits shall be tested with an ac source while filters for dc circuits shall be tested with a dc source. After the test the filter shall be examined and measurements shall be performed to include insulation resistance measurements to determine the effect of the dielectric withstanding voltage test on specific operating characteristics.

2.6.5.8 Insulation Resistance Test

This is a test to measure the resistance offered by the insulating members of a filter to an impressed direct voltage tending to produce a leakage current through or on the surface of these filters. Insulation-resistance measurements shall be made on an apparatus suitable for the characteristics of the filter to be measured such as a megohm bridge, megohm-meter, insulation-resistance test set, or other suitable apparatus. The test shall be performed with the components mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method that will be used for mounting in the enclosure. The bleeder resistor shall be disconnected. The direct potential applied to the specimen shall be the largest test condition voltage (100, 500, or 1,000 volts +10 percent) that does not exceed the rated peak ac voltage or the rated dc voltage. A separate dc power supply may be used to charge the filters to the test voltage. The measurement error at the insulation-resistance value required shall not exceed 10 percent. Proper guarding techniques shall be used to prevent erroneous readings due to leakage along undesired paths. Insulation-resistance measurements shall be made between the mutually insulated points or between insulated points and ground. The insulation resistance value shall be read with a megohmmeter and recorded after the reading has stabilized. When more than one measurement is specified, subsequent measurements of insulation resistance shall be made using the same polarity as the initial measurements.

2.6.5.9 Current Sharing

Testing shall be performed with the filters mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method that will be used for mounting in the enclosure. The filter inner compartment terminals shall be loaded with a resistor equal in value to the rated operating voltage divided by the sum of the current ratings of the devices in parallel. The resistor shall be capable of dissipating the total current. Rated operating voltage shall be applied at the filter outer compartment terminals. The current into each filter outer compartment terminal shall be monitored.

2.6.5.10 Harmonic Distortion Test

Harmonic distortion measurements shall be made using a spectrum analyzer having a dynamic range of [70 dB] [_____] and a frequency range from [10 kHz to 1.7 GHz] [_____]. Total harmonic distortion shall be measured at the input and output terminals of the filter when operating at 25, 50, and 100 percent of rated full-load current.

2.6.5.11 Terminals Pull Test

The purpose of this test is to determine whether the design of the filter terminals can withstand the mechanical stresses to which they will be subjected during installation or disassembly in equipment. Testing shall be performed with the components mounted in the filter/ESA assembly enclosure or mounted on a plate by the same holding method that will be used for mounting in the enclosure. The force applied to the terminal shall be 89 N 20 pounds. The point of application of the force and the force applied shall be in the direction of the axes of the terminations. The force shall be applied gradually to the terminal and then maintained for a period of 5 to 10 seconds. The terminals shall be checked before and after the pull test for poor workmanship, faulty designs, inadequate methods of attaching of the terminals to the body of the part, broken seals, cracking of the materials surrounding the terminals, and the changes in electrical characteristics such as shorted or interrupted circuits. Measurements are to be made before and after the test.

2.7 ELECTRICAL SURGE ARRESTERS (ESA)

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NOTE: ESA application guidance is found in MIL-HDBK 423.
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2.7.1 Power and Signal Line ESA

2.7.1.1 ESA General

ESAs shall be metal oxide varistors (MOVs) or spark gaps. When a spark gap is specified, the ESA shall be enclosed within a metal case. Discharges shall be contained within the case; no external corona or arcing will be permitted. ESAs shall be factory installed with minimum lead lengths within the outer compartment. For all power filter/ESA assemblies, the ESAs shall be installed a minimum of 75 mm 3 inch apart, with terminals at least 75 mm3 inch from a grounded surface. For telephone filter/ESA assemblies, the ESAs shall have a minimum clearance spacing of 25 mm 1 inch, and terminals shall be at least 75 mm 3 inch from a grounded surface. Each phase, neutral and telephone circuit conductor shall be connected through an ESA to the ground bus. The ESA shall be installed [in the power input compartment of the filter] [in a separate EM shielded enclosure]. ESA units within the filter/ESA assembly shall be individually replaceable. Like ESAs shall be interchangeable. ESA terminals shall withstand the 89 N 20 lb pull test. Live parts shall be spaced in accordance with NFPA 70. ESA leads shall be copper. Individual ESAs shall be marked with HCI tags and shall be marked with the manufacturer's name or trademark and part number. The ESA shall meet the requirements of IEEE C62.11, IEEE C62.41.1, IEEE C62.41.2, and UL 1449.

2.7.1.2 Wiring

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NOTE: Some designers prefer coiling the wire between the ESA and the filter, because it creates enough inductance to develop the ESA firing potential during transients for HEMP applications. Short leads, as recommended herein, improve the voltage-limiting effectiveness of the ESA. Fusing of the ESA is not recommended because protection may be lost without the operator's knowledge. If fusing is necessary, a light to indicate a blown fuse will be provided on the ESA enclosures.
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The ESAs shall be located so that leads of minimum length connect the ESA ground terminal to the enclosure. The total lead length connecting the ESA to the filter and the ESA ground terminal to the enclosure shall be less than 300 mm 12 inch. Power line ESA wiring shall be No. 4 AWG minimum. Communication/signal line ESA wiring shall be of the same or heavier gauge than the communication/signal line conductor.

2.7.1.3 Voltage Characteristics

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NOTE: Clamping voltage requirement is intended to ensure that the ESA does not have excessive series resistance. The specific value should be chosen

after reviewing manufacturer's data.

Specified dc breakdown voltage (or MOV voltage at 1 milliampere dc current) for dc and single phase ac power should be in the range of 150 to 200 percent of the peak (not rms) operating voltage. Use 200 to 250 percent on three-phase circuits, so that a short-circuit fault in one phase will not fire ESA on the other two phases.

The spark gap dc breakdown voltage requirement is intended to ensure that the spark gap is a low-inductance, fast device. The precise values are not critical and should be chosen after reviewing ESA catalog information.

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Measurements of (MOV) voltage at 1 mA dc current and spark gap dc breakdown voltage shall be made in accordance with the following procedure. Testing shall be performed with the ESAs mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method which will be used for mounting in the enclosure. A variable dc power supply shall be connected between the ESA terminal and the enclosure (or plate). The applied dc voltage shall be increased at a rate not to exceed 10 percent of the rated firing voltage per second. The (MOV) voltage at 1 mA dc current is the power supply output voltage, when the output current is 1 milliampere. The spark gap dc breakdown voltage is the applied voltage just prior to breakdown (indicated by a rapid decrease in the voltage across the device). The power supply shall be de-energize immediately after the value has been recorded. MOV direct current breakdown voltage at 1 milliampere dc current shall be at least [340] [500] [1,000] [_____] volts and less than [425] [1,500] [_____] volts. MOV testing shall be in accordance with IEEE C62.33. Spark gap direct current breakdown (sparkover) voltage shall be at least [500] [1,000] [_____] volts and less than [1,500] [3,000] [_____] volts. Spark gap impulse sparkover voltage of the ESA shall be less than 4,000 volts. This voltage shall be on surges of either polarity having a rate of rise of 1,000 volts/nanosecond. Testing of the ESA impulse sparkover voltage shall be performed with the spark gaps mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method which will be used for mounting in the enclosure. The pulse generator shall be connected between the spark gap terminal and the enclosure (or plate) with a minimum inductance connection. The pulse generator shall be capable of providing a ramp voltage of 1 kV/ns to a peak voltage which is at least twice the open circuit impulse sparkover voltage. Voltage across the spark gap shall be monitored on an oscilloscope or transient digitizing recorder, capable of at least 1 ns resolution. The peak transient voltage during the pulse is the impulse sparkover voltage. Response time shall be less than 4 nanoseconds. Clamping voltage of the ESA shall be less than [900] [_____] volts at a current pulse of 10 kA. ESA clamping voltage measurements shall be performed with the ESAs mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method which will be used for mounting in the enclosure. The pulse generator shall be connected between the ESA terminal and the enclosure (or plate) with a minimum inductance connection. The pulse generator shall be capable of providing a 10 kA current pulse, on an 8- by 20-microsecond waveshape into the ESA. Current through the ESA and voltage across the ESA shall be monitored on oscilloscopes or transient digitizing recorders. The asymptotic voltage during the 10 kA portion of the pulse is the clamping voltage.

2.7.1.4 ESA Extinguishing Characteristics

The ESA shall extinguish and be self-restoring to the normal nonconductive state within one-half cycle at the operating frequency. The ESA extinguishing test shall be performed with the ESA mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method which will be used for mounting in the enclosure. The extinguishing test shall use an ac power source connected between the ESA terminal and ground which shall be at the rated voltage and frequency capable of providing at least 25 amperes into a short-circuit load. A pulse generator capable of providing a short pulse which will fire the ESA shall also be connected across the ESA. Voltage across the ESA shall be monitored on an oscilloscope or transient digitizing recorder. A series of ten pulses shall be injected. Performance of the ESA is satisfactory if the arc extinguishes (indicated by re-occurrence of the sinusoidal waveform) within 8.5 milliseconds after the start of each pulse.

2.7.1.5 ESA Extreme Duty Discharge Current

The ESA shall be rated to survive the extreme duty discharge current of a single 8- x 20-microsecond pulse with a 10 to 90 percent rise time of 8 microseconds and fall time to a value of 36.8 percent of peak in 20 microseconds. The ESA for high voltage power lines (above 600 volts) shall have an extreme duty discharge capability equal to or greater than 70 kA. The ESA for low voltage power lines (below 600 volts) to such things as building interiors, area lighting, and external HVAC equipment shall have an extreme duty discharge capability equal to or greater than 50 kA. The ESAs for control circuits such as interior alarms, indicator lights, door access controllers, HVAC controls, and telephones, shall have an extreme duty discharge capability equal to or greater than 10 kA. The ESA extreme duty discharge test shall be performed with the ESA mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method which will be used for mounting in the enclosure. A pulse generator shall be connected between the ESA terminal and the enclosure (or plate) with a minimum inductance connection. The pulse generator shall be capable of supplying an 8- x 20-microsecond waveshape and a only single pulse is required. Current through the ESA and voltage across the ESA shall be monitored on oscilloscopes or transient digitizing recorders. The ESA shall be visually monitored during the test and after the pulse inspected for charring, cracks, or other signs of degradation or damage. Test shall be on a prototype only. The dc breakdown voltage test shall be repeated.

2.7.1.6 Minimum Operating Life

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NOTE: Surge life test will be performed only when required by the user. Coordinate current amplitude with manufacturer.

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The ESA operating life tests shall be performed with the ESA mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method which will be used for mounting in the enclosure. A pulse generator shall be connected between the ESA terminal and the enclosure (or plate) with a minimum inductance connection. The pulse generator shall be capable of supplying repetitive 4 kA current pulses, with a 50 ns x 500 ns waveshape, to the ESA. A series of ten pulses is required. Current through the ESA and voltage across the ESA shall be monitored on oscilloscopes or transient digitizing recorders. The ESA shall be visually monitored during the series of pulses for indications of external breakdown. The ESA shall be able to conduct 2,000 pulses at a peak current of 4 kA and 50 nanoseconds x 500 nanoseconds waveform. Post-test shall include inspection for charring, cracks, or signs of degradation. The dc breakdown voltage test shall be repeated.

2.7.1.7 Operating Temperature

The ESA shall be rated for continuous operation in ambient temperatures from minus 25 to plus 125 degrees C minus 12 to plus 255 degrees F.

2.7.2 ESA Testing

ESA factory test data shall be submitted which shall show the ability to meet the requirements herein, based on prior tests of the same ESA assembly components and design. Testing shall be performed with the ESA mounted in the filter/ESA assembly enclosure or mounted on a metal plate by the same holding method which will be used for mounting in the enclosure. The pulse generator shall be connected between the ESA terminal and the enclosure (or plate) with a minimum inductance connection. Current through the ESA and voltage across the ESA shall be monitored on oscilloscopes or transient digitizing recorders. Test data shall include the following:

a. Breakdown Voltage.

b. Impulse Sparkover Voltage.

c. Clamping Voltage.

d. Extinguishing.

e. Extreme Duty Discharge.

f. Surge Life.

2.8 WAVEGUIDE ASSEMBLIES

Waveguide-below-cutoff (WBC) protection shall be provided for all piping, ventilation, fiber optic cable penetrations and microwave communications barrier penetrations of the HEMP electromagnetic barrier. These WBC penetrations shall be protected with cutoff frequencies and attenuation no less than the EM shielding effectiveness values listed herein. The cutoff frequencies shall be no less than 1.5 times the highest frequency of the shielding effectiveness. For 1 GHz, the maximum rectangular linear diagonal dimension shall be 100 mm 4 inch and the maximum circular diameter shall be 100 mm 4 inch. The length-to-cell cross-section dimension ratio of the waveguide shall be a minimum of [5:1 to attain 100 dB] [3:1 to attain 50 dB]. Penetration locations shall be arranged to facilitate installation and testing by minimizing the number of locations. Waveguides of each assembly type shall be factory tested in accordance with IEEE 299 and Table I of this specification.

2.8.1 Waveguide-Type Air Vents

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NOTE: Occurrence of dissimilar metals will use corrosion resistant design.

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Each ventilation WBC array shall be a honeycomb-type air vent with a core fabricated of corrosion resistant steel as shown on the drawings. Waveguide construction shall include heavy frames to dissipate the heat of welding to the shield. A welded WBC array shall be constructed from sheet metal or square tubes. Array cells shall be formed by welding the sheets at intersections or welding adjacent tubes along the entire length of the WBC section. The maximum cell size shall be 100 mm 4 inch on a diagonal. The length of the WBC section shall be at least five times the diagonal dimension of the cells. Air vents shall be a permanent part of the shielded enclosure and shall have a shielding effectiveness equal to that of the total enclosure. Static pressure drop through the vents shall not exceed 3.4 gpscm 0.01 inch of water at an air velocity of 305 m/s 1000 fpm. Waveguides for air vents (honeycomb) shall have access doors in duct work for maintenance. The frame of the honeycomb panel shall be [welded] [bolted] into the penetration plate [with continuous circumferential EM welds.] [with bolts 75 mm 3 inch on center.] Welds for fabrication and installation of honeycomb waveguide panels are primary shield welds and shall be inspected as indicated. Acceptance testing of all honeycomb panels shall be included with the final acceptance test. Conductors, such as wires and louver operating rods, shall not pass through the waveguide openings.

2.8.2 Piping Penetrations

All piping penetrations of the HEMP barrier to include utility piping, fire mains, vent pipes, and generator and boiler exhausts shall be made with piping WBC sections. The WBC material shall be steel with a composition suitable for welding to the HEMP shield. The minimum wall thickness shall be 3.2 mm 0.125 inch. The maximum inside diameter shall be 100 mm 4 inch or a metallic honeycomb insert with a maximum cell dimension of 100 mm 4 inch shall be installed. The WBC section shall have an unbroken length of at least five diameters to form a minimum cutoff frequency of 1.5 times the highest frequency of the shield effectiveness. The piping WBC section shall be circumferentially welded or brazed to the HEMP shield, pipe sleeve or a penetration plate as shown on the drawings. Generator and boiler exhausts shall be constructed as shown in the drawings and shall be configured as a WBC or WBC array. The circumferential penetration welds are primary shield welds and shall be inspected and tested as indicated.

2.8.3 Waveguide Penetrations

Waveguide penetrations for dielectric fibers or hoses shall be implemented in the same manner as piping penetrations. Dielectric hoses or pipes shall be converted to metal waveguide piping before penetrating the shield. Conductors, such as wires and fiber cable strength members, shall not pass through the waveguide opening.

2.8.4 GROUNDING STUD

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NOTE: Grounding stud will be provided only for small (under 100 square meters (1,000 square feet) of floor area) bolted and welded enclosures.

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Enclosure shall have 13 mm 1/2 inch diameter stud circumferentially welded to each side of the shielding penetration plate.

2.9 PENETRATION PLATES

Penetration plates shall be minimum 6 mm 1/4 inch thick and sized as shown on the drawings. The penetration plate shall overlap the shield penetration cutout dimension by a minimum of 150 mm 6 inch on each side. The penetration plate shall be [welded] [bolted] to the HEMP shield [with continuous circumferential EM welds.] [with bolts 75 mm 3 inch on center.]

2.10 GALVANIZING

Galvanizing, when practical and not otherwise indicated, shall be hot-dipped processed after fabrication. Galvanizing shall be in accordance with ASTM A123/A123M, or ASTM A653/A653M, as applicable. Exposed fastenings shall be galvanically compatible material. Electrolytic couples and dissimilar metals that tend to seize or gall shall be avoided.

2.11 EM SHIELDED CABINETS AND PULL BOXES

Cabinets and pull boxes shall be modified NEMA [1] [_____] in accordance with NEMA ICS 6 made of corrosion resistant steel of not less than 2 mm 14 gauge thick with welded seams and galvanized bulkhead cover plates. Access cover plates shall be hinged with EM gaskets and 75 mm 3 inch maximum bolt spacing. Design shall include thick cover plates, folded enclosure edges, and bolt spacers to prevent uneven gasket compression and enclosure deformation. Gasket shall be easy to replace. Gasket contact areas shall be tin-plated using the electrodeposited type I method in accordance with ASTM B545. Conduit hub shall be circumferentially EM welded to the enclosure. The cabinets shall be finished with a corrosion-inhibiting primer and two coats of baked or finish enamel. Cabinets shall be provided with mounting brackets for wall mounting or legs for floor mounting. Cabinets and boxes of each type shall be factory tested in accordance with IEEE 299 and Table I of this specification.

2.12 QUALITATIVE MONITORING SYSTEM

A built-in shield monitoring system for SELDS testing shall be provided. The system shall consist of either multiple injection points or a surface loop system. Driving conductors shall be brought to a single lockable EM shielded connection box, located outside the shield in a controlled space.

PART 3 EXECUTION

3.1 EXAMINATION

After becoming familiar with all details of the work, verify dimensions in the field, and advise the Contracting Officer of any discrepancy before performing the work.

3.2 INSTALLATION

3.2.1 Coordination

The EM shielding installer shall instruct other trades in the presence and with the direction of the Government representative, in advance of the EM shielding system installation, to ensure that all individuals are aware of the critical installation requirements. Submit manufacturer's data, catalog cuts, and printed documentation regarding the work. Cleaners, solvents, coatings, finishes, physical barriers, and door threshold protectors shall be provided as required to protect the shielding system from corrosion, damage, and degradation. The shielding installation plan shall be approved before construction begins.

3.2.2   Verification

Before, during, and after the EM shielding and penetration protection subsystem installation, the shielding specialist shall verify and approve the installation for compliance with the specifications. Materials and methods, shop drawings, and other items for the shielding subsystem shall bear an approval stamp of the shielding specialist. Compliance notification shall be provided to the Contracting Officer before materials are installed or methods performed.

3.2.3   Inspection

During and after EM shielding and penetration protection subsystem installation, including EM filters and waveguides, a qualified shielding specialist shall inspect the installation for compliance with the specifications. Complete the inspection before a finish or concrete topping coat is installed.

3.2.4   Manufacturer's Services

Provide the services of a manufacturer's representative who is experienced in the installation, adjustment, and operation of the equipment specified. The representative shall supervise the installation, adjustment, and testing of the equipment.

3.2.5   Posting Framed Instructions

Post framed instructions containing wiring and control diagrams under glass or in laminated plastic. Condensed operating instructions, prepared in typed form, shall be framed as specified above and posted beside the diagrams before acceptance testing of the system.

3.3   ENCLOSURE INSTALLATION - WELDED STEEL CONSTRUCTION

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NOTE: Either the welded or bolted construction will be used for the EM shielding enclosure. Choose the appropriate construction and delete the non-applicable paragraphs.

Welded construction will usually consist of continuous 1.897 mm (14 gauge) thick steel plate and angles to form the enclosure. Thicker material may be used if it is more cost-effective or required for structural reasons. Welded construction is used when a shielded facility requires a long maintainable service life of high-level protection, 100 dB attenuation, or HEMP protection, 100 dB. For bolted construction see the NOTE and paragraphs below under the title ENCLOSURE INSTALLATION - BOLTED CONSTRUCTION

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Install the EM shielded enclosure in accordance with this specification, the drawings, and the recommendations of the manufacturer and EM shielding specialist. Handle and install shielding steel without damage. Penetrations of the shield, other than those indicated on the drawings, will not be permitted, including fasteners and mounting bolts, without prior written authorization from the Contracting Officer.

3.3.1 Surface Preparation

Clean and buff contacting surfaces to ensure firm contact with shielding steel.

3.3.2 Control of Warping

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NOTE: Steel plates exposed to sunlight and changing environmental conditions increase warpage and buckling.
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Keep warping of steel shielding plates during installation and welding within 1 mm in 1 meter 1/8 inch in 10 feet. use embeds, drive pins, and/or anchor bolts or ties to hold plates in place during welding. Other techniques such as skip welding shall also be used to reduce warpage. The system chosen shall be fully coordinated and approved by the Contracting Officer. Fasteners, drive pins, and other shield penetrations shall be sealed with full penetration circumferential EM welds.

3.3.3 Placement of Floor Shield

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NOTE: The shingle overlap method is one successful method of floor shield placement. Designers have the option to select other methods.
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Placement of the floor shield shall not begin until at least 14 days after the pouring of the floor slab and Contracting Officer approval of all required submittals. [The placement of the floor shield shall utilize [the shingle overlap method] [_____].] [Individual floor sheet shall be attached on the top and one side only with air-pressure drive tools to the floor. Floor shielding sheets shall be overlapped 50 mm 2 inch at joints, bent and laid flat on the concrete floor without voids or gaps, and sealed with continuous EM welds at all seams and joints.] The floor shield installation shall start at the center of the space.

3.3.4 Placement of Overslab

Before placement of the overslab over any portion of the floor shield, the Contracting Officer's approval is required. Both visual and SELDS testing of the shielding within the area to be covered shall be successfully completed, any defects repaired and retested, and full test results supplied to the Contracting Officer prior to placement of the overslab. A vapor barrier shall be placed over the floor shield.

3.3.5 Welding

The shielding work shall be provided in accordance with the performance criteria specified. Shielding steel structurally welded to the steel frame shall be welded in accordance with AWS D1.1/D1.1M and AWS D1.3/D1.3M. EM shielding seams shall be sealed EM-tight by the MIG method, using electrodes structurally and electrically compatible with the adjacent steel sheets. [Sheet steel shall be welded to support steel by plug or tack welding at 300 mm 12 inch on center, and then sheet seams shall be continuously EM welded to seal the enclosure] [_____]. Slag inclusions, gas pockets, voids, or incomplete fusion will not be allowed anywhere along welded seams. Weld failures shall be corrected by grinding out such welds and replacing with new welds. A qualified welder shall perform welding, both structural and EM sealing. Weldments critical to shielding effectiveness are shown on the drawings and shall be performed in the manner shown on the drawings. Where both structural integrity and shielding quality are required for a given weldment, both criteria shall be met simultaneously. Brazing shall conform to the documents discussed above, where practical, and shall also conform to requirement of AWS BRH. Structural, mechanical, or electrical systems penetrations shall be sealed by providing a continuous solid perimeter weld, or braze to the shield as specified. All shield joints and seams shall have a minimum 50 mm 2 inch overlap and shall be sealed with a continuous solid weld. After testing, the Contracting Officer will inspect and approve the installation prior to covering by other trades.

3.3.6 Wall Shielding Attachment

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NOTE: The wall attachment method outlined in this paragraph is one successful example. Site-specific methods must be edited at this point in this specification. Note that all attachment penetrations must be welded closed. Metal wall studs or furring strips should be of equal or greater thickness (gauge) than the shield steel when shield steel is welded to supporting metal.

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Continuous [1.613] [_____] mm [16] [_____] gauge thick furring channels spaced not more than 600 mm 24 inch on center shall be secured to steel wall studs by using self-tapping sheet metal screws. The steel sheets shall be tack welded to the furring strips every 400 mm 16 inch on center horizontally and 600 mm 24 inch on center vertically. A continuous full penetration EM weld shall be made to join the sheets and form the shield. Welds shall not form dimples or depressions causing fish mouths at the edge of the sheet.

3.3.7 Formed Closures

Install formed closures where indicated and/or necessary to completely close all joints, openings, enclosures of pipe chases, and structural penetrations, columns, and beams.

3.3.8 Sequence of Installation

Erection of the steel shall be sequenced to prevent steel sheet warpage. Install shielding components that have passed initial testing (part 1) before construction of any features that would limit access for repairs to the shield.

3.3.9 Door Assemblies

Mount doors to perform as specified. Door framing shall be continuously welded to the EM shield. The structural system supporting the door frame shall provide proper support for doors and frame.

3.4 ENCLOSURE INSTALLATION - BOLTED CONSTRUCTION

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NOTE: Either welded or bolted construction will be used for the EM shielding enclosure. For welded construction see the NOTE and paragraphs above.

Bolted construction is associated with a lower level (50 dB) of maintained shielding effectiveness. Bolted construction will usually consist of modular panels bolted together with metal strips or channels. Panels are commonly plywood with steel sheets laminated to one or both sides. Bolted construction is used when a shielded facility's service life is short, 10 years or less, or the system is required to be demountable for change of location. This system requires more maintenance than a welded system and requires access to the panels. The EM shield layout may restrict attenuation testing of the enclosure. It is desirable for large facilities to place the shield at least 1 meter (3.3 feet) inside the exterior walls, although cost and construction restrict this consideration. The floor shielding can be tested by SELDS test but not by IEEE 299 if it is on grade. The facility layout must be carefully planned to allow for testing and shield maintenance.

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3.4.1 Enclosure Panel Installation

Install panels, without damage to the shielding steel, in accordance with the shielding manufacturer's recommendations. Exposed surfaces shall be cleaned of dirt, finger marks, and foreign matter resulting from manufacturing processes, handling, and installation. Install electrical conduits as close to the EM shield as possible. Framing-joining system bolts shall not be used to mount material and equipment. Material and equipment which penetrate the shielded enclosure shall be seam welded or soldered to both shielding surfaces.

3.4.2 Surface Preparation

Clean and buff surfaces to ensure good electrical contact with shielding surface. Paint or other coverings on mating surfaces of special boxes such as for fire alarm systems, buzzers, and signal lights, including areas between box and cover, box and wall, and box and conduit, shall be removed. Remove insulating material to maintain a low-resistance ground system and to ensure firm mating of metal surfaces.

3.4.3 Floor Panel Setting

Place a polyethylene film 0.15 mm 6 mil thick vapor barrier over the structural floor of the parent room before any other work is set thereon. Provide a 3 mm 1/8 inch thick layer of hardboard over this film with joints loosely butted. Over this layer an additional layer of similar filler material of equal thickness as the projection of the framing-joining member from the bottom surface of the floor panel shall be provided leaving no more than 6 mm 1/4 inch of space between the hardboard and the framing-joining member.

3.4.4 Framing-Joining System

Tighten screws with a calibrated adjustable torque wrench with equal torque set for each screw. Proper torque values shall be in accordance with the manufacturer's requirements.

3.4.5 Door Assemblies

Mount the door to perform as specified. The door shall be through-bolted to the EM shield.

3.4.6 Filter Installation

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NOTE: When the filter unit must be installed inside the shielded enclosure, the input terminal compartment will be EM-tight instead of the load terminal compartment, and the filters will be located in the load terminal compartment. This arrangement is necessary to prevent radiated EM energy within the shielded enclosure from inducing EM energy in the power conductors between the filters and the point where the conductors pass through the shielded enclosure wall. To provide for this arrangement, change the wording as necessary; i.e., change the word "load" to read "input" and change the words "input" to read "output" or "load," as appropriate.

****

Support filters independently of the wall shielding. Conduct inspections on filters provided under this specification, to verify compliance with the specified requirements. Filters shall be shipped after successful testing and shall be examined prior to installation to determine if damage occurred during shipment. Damage, no matter how slight, will be reason for rejection of the filter.

3.5 WAVEGUIDE INSTALLATION

Penetrations of the EM shield shall be treated with the appropriate waveguide method. Waveguides shall be suitable for piping and for fluids or gases contained within, in accordance with specified requirements.

3.6 SHIELDING PENETRATION INSTALLATION

Penetrations shall be installed in accordance with requirements of the penetration schedule and coordinated with system installation.

3.7 FIELD QUALITY CONTROL

Develop a quality control plan to ensure compliance with contract requirements; maintain quality control records for construction operations required under this section; and submit the quality control plan to the Contracting Officer. Furnish a copy of testing records, as well as the records of corrective actions taken. The in-progress and final acceptance testing of EM shielding and penetration protection system work shall be performed as specified. Correct deficiencies at no additional cost to the Government. Legible copies of the daily inspection reports shall be maintained by the shielding specialist at the project site, and the copies of the Construction Quality Control Report shall be delivered to the Contracting Officer on the third workday following the date of the report. The daily inspections shall include the type of work being performed during the report period and locations, type of testing, deficiencies, corrective actions, unsolved problems, and recommendations to assure adequate quality control. Results of inspections and tests performed in accordance with this specification shall be attached to the daily Construction Quality Control Report.

3.8 FIELD TRAINING

Provide a field training course for designated operating and maintenance staff members. Training shall be provided for a total period of [8] [_____] hours of normal working time and shall start after the system is functionally complete but prior to the final acceptance test. Field training shall cover all the items contained in the Operating and Maintenance Manuals.

3.9 SHIELDING QUALITY CONTROL

The Contractor's organizational structure for shielding quality control shall be integrated into the jobsite management. Testing shall be performed by [an independent testing firm] [the shielding installer].

3.9.1 HEMP Hardness Critical Item Schedule

Hardness critical items shall be identified during the detail drawing submittal period. These items are those components and/or construction features which singularly and collectively provide specified levels of HEMP protection, such as the EM shield, surge arresters, EM shielded doors, shield welding, electrical filters, honeycomb waveguides, and waveguides-below-cutoff.

3.9.1.1 Performance Test Plan

Submit a performance test plan for Contracting Officer approval. Testing shall be accomplished in three parts: (1) in-progress; (2) initial shielded enclosure effectiveness; and (3) final acceptance, shield enclosure effectiveness. Include in the test plan equipment listings (including calibration dates and antenna factors) and the proposed test report format. The plan shall also include specific test dates and durations during the overall construction period so that the Contracting Officer may be scheduled to observe the testing and so that repairs may be made to the shield and retests conducted. This separate testing schedule for the EM enclosure shall show the points, during construction, when it begins and ends as well as a day-by-day test schedule. The test plan shall indicate proposed dates and duration of lowest and highest frequency tests so that the Contracting Officer may be available for these final acceptance tests. A test grid shall be identified and the plan for correlation of that grid to the structure shall be provided.

3.9.1.2 Test Reports

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NOTE: Specifications and/or quality assurance test results of this paragraph may be classified for some

projects. Provide appropriate instructions when this occurs.

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Test reports shall include the method of testing, equipment used, personnel, location of tests, and test results. Daily reports of results of each test performed on each portion of the shielding system shall be submitted to the Contracting Officer within 3 working days of the test. Location of the area tested shall be clearly identified. Leaks detected during testing shall be identified with sufficient accuracy to permit relocation for testing in accordance with test procedures. Reports of testing shall be submitted to the Contracting Officer with required certification by the testing agency representative or consultant. Three reports (in-progress test report, initial test report, and final acceptance test report) shall be submitted in accordance with the format described below.

Cover Page:
A cover page is required.

Administrative Data:
Test personnel.
Contract number.
Date of test.

Authentication. Contractor personnel responsible for performance of the tests and witnessing organization or representatives.

Contents:
Shielded facility description.
Nomenclature of measurement equipment.

Serial numbers of measurement equipment. Date of last calibration of measurement equipment. Type of test performed. Measured level of reference measurements and ambient level at each frequency and test point. Measured level of attenuation in decibels at each frequency and test point. Dynamic range at each test frequency and test point. Test frequencies. Location on the shielded enclosure of each test point. Actual attenuation level at each test point.

Conclusions: This section shall include results of the tests in brief narrative form.

Number of Copies of the Report:
[Three] [_____] copies.

3.9.2 Field Testing

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NOTE: If a facility is required to fully comply with MIL-STD-188-125 by the Joint Chiefs of Staff, a military department headquarters, or a major command, coordinate with the using organization to establish test requirements. Quality assurance and the testing required by appendix A of that standard should be performed. However, the using organization may insist on full testing in accordance with appendix B as well. In that case, advise the user that, based on limited testing to

date, no existing EM filter/ESA devices have survived the E-2 and E-3 waveforms. Include appropriate cost and scheduling considerations if appendix B testing is required. If MIL-STD-188-125 is not a requirement, avoid its reference.
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Submit reports of certified test results and results of all field and factory tests as specified and as required by the Contracting Officer. Testing shall be accomplished in the three parts described below.

3.9.2.1 Testing - Part 1

Perform Part 1 as in-progress testing including inspection, visual seam inspection, and seam testing of all EM shielding materials and installation. [In-progress testing of welded shielding shall include testing the structural welds to be embedded prior to concrete placement by dye penetrant and magnetic particle testing and 100 percent testing of wall, ceiling, and floor shielding welds by the SELDS tests.] [In-progress testing of bolted construction shall include 100 percent testing of floor, wall, and ceiling shielding seams by the SELDS testing.] After successful completion of in-progress testing, including defect repairs and retest, and with prior approval of the Contracting Officer, placement of embedments covering may be made to complete the structural systems. Submit an in-progress test report.

3.9.2.2 Testing - Part 2

Part 2 initial testing shall consist of inspection, visual seam inspection, seam testing, and shielded enclosure effectiveness testing after shielding and shielding penetrations are completed, but before the installation of finish materials over the shielding. Access to penetrations is required. All [seams] [welds], including shielding and penetrations not tested in part 1, shall be SELDS tested. The initial shielded enclosure effectiveness acceptance test shall consist of a MIL-STD-188-125-1 test utilizing specified test frequencies for magnetic and plane wave. Testing shall be conducted in accordance with the paragraph EM Shielding Effectiveness Testing. These tests shall be performed with the number of shield penetrations limited to those required to support the test. After successful completion of Part 2 initial testing, including defect repairs and retest, and with prior approval of the Contracting Officer, placement of any covering may be made except in areas where penetrations are located. Submit an initial test report.

3.9.2.3 Testing - Part 3

Perform Part 3 final acceptance testing consisting of a visual inspection and a shielded enclosure effectiveness test of the EM shielding materials and installation. All [seams] [welds], including shielding and penetrations not tested in parts 1 and 2, shall be SELDS tested. Part 3 testing shall be performed upon completion of construction and when the building is ready for occupancy. Facilities requiring HEMP protection shall be tested for shielding effectiveness in accordance with acceptance test procedures in MIL-STD-188-125-1. Notify the Contracting Officer in writing 14 days prior to tests to permit adequate monitoring by authorized representatives. Corrective work shall be accomplished immediately upon detection that any area has failed to meet the requirements specified. Retesting shall be performed to verify that remedial work done to meet the required attenuation has been properly installed. Submit a final acceptance test report.

3.9.3 Weld Inspection

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NOTE: Additional welding tests may be specified, such as ultrasonic or radiographic tests, but these tests are costly.
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The weld seams shall be visually inspected by a qualified welder during the welding operation and after welding is completed. Completed welds shall be inspected after the welds have been thoroughly cleaned by hand or power wire-brush. Welds shall be inspected with magnifiers under bright light for surface cracking, porosity, slag inclusion, excessive roughness, unfilled craters, gas pockets, undercuts, overlaps, size, and insufficient throat and concavity. Defective welds shall be ground out and replaced with sound welds.

3.9.4 Shielded Enclosure Leak Detection System (SELDS) Testing

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NOTE: SELDS testing the welds in the floor shielding is usually performed on the interior only because it is not possible to "sniff" on both sides (assuming the shield is on the ground level). Dye penetrant may also be used to test the welds where SELDS testing is not possible. The SELDS can be obtained commercially from the following: 1. Carnel Labs Corporation 21434 Osborne Street Canoga Park, CA 91304 Telephone: (818) 882-3977 2. Rayproof Shielding Systems Corporation 50 Keeler Avenue Norwalk, CT 06854 Telephone: (203) 838-4555 3. Retlif Corporation 795 Marconi Avenue Ronkonkoma, NY 11779 Telephone: (516) 737-1500
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The leak detection system shall use a 95- to 105-kHz oscillator and a battery operated hand-held receiver. The receiver or "sniffer" shall have a ferrite loop probe capable of sensing leaks within 6 mm 1/4 inch of the probe location with a dynamic range of 140 dB. Testing shall be conducted in accordance with test equipment manufacturer's instructions. Test loops or leads shall be placed under the shield floor or into inaccessible locations prior to installation to assist in the detection of seam leaks in the floor, ceiling and walls. The loop or lead wires shall be placed between the vapor barrier and the structural slab for the floor shield with the leads brought to an accessible location. The test leads shall be insulated stranded copper conductors 2 to 2.5 mm 5/64 to 3/32 inch diameter and bonded to the shield only at the end. Test leads shall be placed in plastic conduit for protection and shall not exceed 45 m 150 ft in length. The surface area of the shield will determine the number of test leads (drive points) that are required. Drive points shall be installed on the shielding exterior and attached to two sets of diagonally opposing corners during construction. The distance between test lead connections on a shield surface shall not be more than 20 m 66 ft. The maximum testing area shall be 400 sm 4300 sf. If the shield area exceeds this requirement, additional drive points shall be provided. Bonding of the test leads to the shield is accomplished by brazing or high-temperature soldering. Test leads from the drive points shall be run to a lockable test cabinet for connection to the SELDS oscillator. If more than one test cabinet is required for a given area or building, test leads that would be common to different surface areas shall be duplicated at each test cabinet to ensure that test point parings are maintained. Record the location of the permanent test leads and shall provide this information to the Contracting Officer for permanent reference. Welds and seams shall be 100 percent tested. Seams shall be continuously probed with the test receiver set to detect abrupt changes of shielding level greater than 10 dB on the shielding unit scale. Points having a change greater than 10 dB shall be clearly marked and shall have the weld repaired to meet the specified requirement. Each repaired point shall be retested until there are no points on seams which fail the test.

3.9.5 EM Shielding Effectiveness Testing

Services of an EM shielding testing specialist, approved by the Contracting Officer, shall be furnished to test the shielded enclosure. The laboratory shall be equipped and staffed to perform field tests of EM shielded enclosures and shall perform these tests as a normal service. Test equipment used shall have been calibrated within the last 12 months.

3.9.5.1 Test Procedure

Test procedure and equipment shall be similar to that specified in MIL-STD-188-125-1. Test frequencies are specified herein. Test points shall be as indicated in Table I. Corner points of the grid shall occur at the intersection of three planes (two-wall surfaces and ceiling or two wall surfaces and floor). Measurement data at all test points shall be recorded, and a grid map for each surface tested shall be provided. For any test point where required attenuation is not provided, correct the discrepancy and retest. Both the results of the test failure and the successful results shall be provided. Enclosure effectiveness test for magnetic attenuation shall be performed with the antennas located directly opposite each other and separated by a distance of 600 mm 2 ft plus the wall thickness. Plane wave attenuation tests shall be performed with the antennas located directly opposite each other and with the transmitting antenna placed 300 mm 1 ft away from the enclosure wall and with the receiving antenna set 300 mm 1 ft from the wall for stationary measurements and 50 to 600 mm 2 inch to 2 ft from the wall for swept measurements. The magnetic field test and the plane wave test shall be performed using the following sequence. The calibrations shall be performed at the beginning of each test day. Then the test area shall be set up for the 100 to 400 MHz stationary measurement in on to the two required polarizations. With the transmitter off check the receiver sensitivity. Energize the transmitter, and record the fixed measurement data. Remove the receiving antenna from the test stand and perform the swept measurement at the same frequency and transmitting antenna polarization. Rotate the transmitting antenna, and perform the second 100 to 400 MHz stationary measurement. Perform the swept measurement for the second transmitting antenna polarization. Reconfigure the equipment for the 900 to 1000 MHz test frequency, and repeat the series of four measurements. To perform the swept measurement, remove the receiving antenna from the test stand and hold with a dielectric rod at least 300 mm 12 inch in length. A dielectric spacer shall be attached to the sweeping antenna to assist in maintaining the 50 mm 2 inch distance from the shield. A rapid sweep to locate hot spots shall be made by rotating the polarization and waving the antenna through the specified volume. The final activity of each test day shall be to repeat the calibrations and verify the consistency with the previous calibration results. Test procedures shall include a definition of all test points including but not limited to walls, door frames, accessible joints, and around filters and penetrations. Each EM door shall be tested at the locations indicated in Table I.

TABLE I - SHIELDING EFFECTIVENESS TEST POINTS	
Testing Location	Test Points Spacing
Joints between steel panels for roof, walls, and floors	Test every 3 m 10 feet (Note 1; minimum of one test point per side)
Corner seams for walls to floor, walls to roof, and wall to wall	Test every 3 m 10 feet (Note 1; minimum of one test point per corner seam)
Corners (intersection of three surfaces)	Test at all corners in Shield
Single doors	Test at each corner; at midpoint of each side longer than 1.5 m 5 feet; and at center
Double doors	Test each separately at same test point as single doors
WBC vents and panels	Test in center (on axis) for all sizes (including single); at all four corners if 300 by 300 mm 12 by 12 inches or larger; and at the midpoint of each side longer than 1.5 m 5 feet
At treated penetrations of shield (and entry panel and backshield)	Test as close to "an-axis" as possible, or orient for maximum signal
All other shield joints, seams, or corners	Sweep all surfaces at one frequency in the range of 400 MHz to 1 GHz. Test every 3 m 10 feet max. plane wave
Doors	Door handles
EM filter enclosures	Test at each seam corner and midpoint of each side longer than 1.5 m 5 feet at center
EM cabinets and enclosures	Test at each seam corner and each side 1.5 m 5 feet on center
NOTE 1. Each point shall be swept in space 600 mm 2 feet around the point.	

3.9.5.2 Test Points

Additional test points shall be measured in accordance with MIL-STD-188-125-1 for facilities requiring HEMP protection. Test points include the periphery of doors and covers, handles, latches, power filter penetrations, air vent filters, communications line filter penetrations, and points of penetration by pipes, tubes, and bolts.

3.9.5.3 Test Methodology

Antennas shall be oriented for maximum signal pickup. Each test point shall be probed for area of maximum leakage, such as around door frames, accessible joints, filters, pipes, and air ducts. Magnitude and location of maximum signal levels emanating from the enclosure shall be determined for each accessible wall at a minimum of two locations on each wall, around doors, and at penetrations and seams of the enclosure. Measurement of attenuation shall be accomplished in accordance with Table I.

3.9.5.4 Test Frequencies

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NOTE: Test frequencies will be in accordance with MIL-STD-188-125 when applicable.

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Testing frequencies for shielded enclosures shall be as follows:

Magnetic field	[14 kHz,] [400 kHz,] and [10.1 MHz] [_____]
Electric field	[200 kHz] and [16 MHz] [_____]
Plane wave	[100 MHz], [415 MHz], and [1.29] [18] [_____] [GHz]
MIL-STD-188-125-1 frequencies are as follows:	
Magnetic	[_____]
Plane wave	[_____]

3.9.6 Weld Testing

Structural welds to be embedded shall be tested in accordance with AWS D1.1/D1.1M using magnetic particle inspection or dye penetrant inspection and 100 percent of the shielding seams by the SELDS testing prior to embedment.

3.10 GROUNDING

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NOTE: Grounding method will be in accordance with MIL-STD-188-124. An equipotential ground plane is recommended for shielded facilities.

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The contract drawings indicate the extent and general arrangement of the shielded enclosure grounding system. The grounding methods shall be an equipotential grounding plane method in accordance with UL 1283, NFPA 70, NFPA 77, NFPA 780, IEEE 142, MIL-STD-188-124, and MIL-HDBK-419. For additional facility grounding requirements, see Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

-- End of Section --