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MILITARY STANDARD

INTERFACE STANDARD FOR SHIPBOARD SYSTEMS

SECTION 070 - PART 1

D.C. MAGNETIC FIELD ENVIRONMENT
(METRIC)

FSC 1990

DEPARTMENT OF THE NAVY

WASHINGTON, DC 20362

Interface Standard for Shipboard Systems,
D.c. Magnetic Field Environment

DOD-STD-1399(NAVY)
SECTION 070 - Part 1

1. This Military Standard is approved for use by all interested Commands of the Department of the Navy in the technical development plans, design, and acquisition specifications for new ship acquisitions, ship modernizations or conversions, and equipment for installation therein and into active fleet ships where applicable, and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Ship Engineering Center, SEC 6124, Department of the Navy, Washington, DC 20362, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FOREWORD

Purpose. This section defines the standard interface requirements for, and the constraints on, the design of shipboard equipment whose performance may be degraded when subjected to the shipboard direct current (d.c.) magnetic field environment.

Nature of the interface. Equipment installed on board a Naval ship can expect to encounter a magnetic field environment which would not be expected in other circumstances. This field is generated by the efforts (i.e., degaussing) to counteract the normal magnetic signature of a metallic ship, and may have a degrading effect on the performance of certain susceptible equipment.

Structure. The technical content first delineates the characteristics in terms of the magnetic field strength and distribution. The constraints on equipment design and installation which are necessary to achieve shipboard compatibility with these characteristics are then established.

Numerical quantities. Numerical quantities stated in this section are expressed in metric (SI) units.

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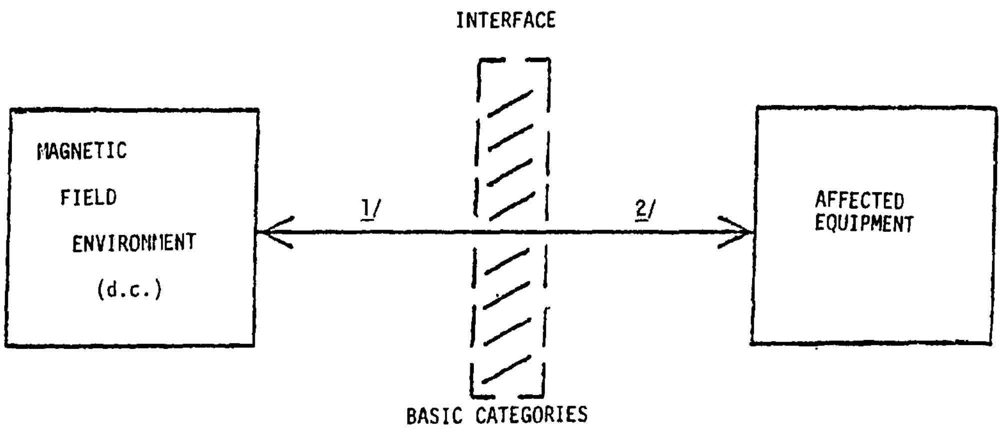
1. GENERAL, SCOPE, INTERFACE AND APPLICABILITY

1.1 General. Policies and procedures established by DOD-STD-1399 are mandatory. This section and the basic standard, i.e., DOD-STD-1399, are to be viewed as an integral single document.

1.2 Scope. This section establishes interface requirements for shipboard equipment whose performance may be degraded when subjected to the ship's d.c. magnetic field to ensure compatibility between such equipment and the magnetic field environment.

1.3 Interface. Basic characteristics and constraint categories concerned with this interface are shown symbolically on figure 1 (see section 3, "Definitions", of DOD-STD-1399):



1/ CHARACTERISTICS
Field strength
Field distribution

2/ CONSTRAINTS
Compatibility
Location
Structural shielding

FIGURE 1. Interface.

The particular interface characteristics and constraints pertinent to this section are described in 5.2 and 5.3.

1.4 Applicability. The criteria of this section apply to equipment whose performance may be degraded when subjected to the magnetic fields defined herein. Such fields will normally be experienced in surface ships and submarines which have a degaussing installation, and in all ships which are or may be subjected to magnetic treatment (see 3.2.2 and 5.3.3).

2. REFERENCED DOCUMENTS

Not applicable.

3. DEFINITIONS

3.1 Ship's d.c. magnetic fields. A ship's d.c. magnetic field is the quantity of magnetic lines of force existing at a location in or on the ship at a given instant of time.

3.1.1 Magnetic field strength. Magnetic field strength is expressed in amperes per meter (A/m). The unit of field strength in cgs system is the oersted (Oe) which corresponds to one line of force per square centimeter (cm^2) of area perpendicular to that line of force. One Oe is approximately equal to 80 A/m.

3.2 Degaussing. Degaussing is the science dealing with the methods and techniques of reducing a ship's normal d.c. magnetic signature so that the possibility of detection by magnetic mines and other magnetic influence detection devices is minimized.

3.2.1 Degaussing coil system. A degaussing coil system is a system consisting of control equipment and one or more coils of electrical cable installed at specific locations on board ship for the purpose of reducing the ship's d.c. magnetic signature. In operation, these coils are energized with d.c. so that the magnetic field produced is in opposition to, and reduces, the magnetic field of the ship. Provision is made to vary the current through the coils in both magnitude and polarity.

3.2.2 Magnetic treatment. Degaussing by magnetic treatment is a method of altering, reducing, or removing the permanent magnetic field of a ship. This is accomplished by temporarily rigging coils of electrical cable externally around the ship and about the ship, including the superstructure where necessary, and energizing the coils with a sequence of d.c. pulses of predetermined polarities and magnitudes. "Deperming" and "flashing" are types of treatment.

(a) Deperming: The method of reducing the permanent magnetism of a ship by energizing coils placed vertically around the ship.
(b) Flashing: The method of altering the permanent magnetism of a ship by energizing coils placed horizontally around the ship.

3.3 Equipment. Equipment, as referred to in this section, comprises those shipboard components, equipments, and systems whose performance may be degraded when subjected to a magnetic field environment as specified herein.

4. REQUIREMENTS

4.1 Requirements. The specific interface requirements and constraints established herein are mandatory and shall be adhered to by SYSCOMs, Project Managers, contractors, and all others engaged in any aspect of shipboard design to which these requirements and constraints apply including equipment design, production, and installation (see section 4 "Requirements" of DOD-STD-1399).

5. INTERFACE CHARACTERISTICS AND CONSTRAINTS

5.1 General considerations. The shipboard magnetic field environment is the summation of the magnetic lines of force existing in or about the ship. This field is not uniform and will vary both in location and time. If this field is of sufficient magnitude in any given instance, it may have a degrading influence on the performance of equipment installed in or on the ship. Detailed knowledge of the exact installation location, as well as a forecast of future changes, would be involved if a determination of equipment suitability were to be made on other than general environmental expectations. Equipment should be so designed and built that it will not be adversely affected even in the "worst case" situation which can normally be expected. This situation will exist when the ship undergoes magnetic treatment or operates with degaussing coils energized and is of a magnitude of 1600 A/m.

5.2 Interface characteristics. The interface characteristics of the ship's d.c. magnetic field environment are described in 5.2.1 and 5.2.2 and may be expected to be present where the equipment interfaces with the shipboard d.c. magnetic field environment.

5.2.1 Field strength. The maximum expected steady state field strength is 1600 A/m. Its maximum rate of change is 1600 A/m per second. No particular orientation of the direction of the magnetic field may be assumed.

5.2.2 Field distribution. The magnetic field delineated in 5.2.1 is not uniform throughout the ship, but is that which can be expected in those compartments in which degaussing cables are installed. This includes approximately 75 percent of the compartments located between the keel and main deck. However, during magnetic treatment of the ship (see 3.2.2), these field values can be expected over the entire ship. Other factors, such as proximity to degaussing cables or certain motors, generators, or other electrical devices, may also affect the field distribution (see 5.3).

5.3 Interface constraints. Interface characteristics of the ship's d.c. magnetic field environment impose certain constraints on the design and location of shipboard equipment subjected to this environment. These constraints are described in 5.3.1 through 5.3.3.

5.3.1 Compatibility. The design of equipment which will be subjected to the ship's magnetic field environment shall be compatible with the interface characteristics given in 5.2.

5.3.2 Location considerations. Since the magnetic field is not uniform, consideration shall be given to its vagaries in determining the location of shipboard equipment. The situations which shall be considered are discussed in 5.3.2.1 through 5.3.2.4.

5.3.2.1 Proximity to degaussing cables. Field strength in excess of 1600 A/m may be expected within an area closer than 0.3 m from any degaussing cable.

5.3.2.2 Local magnetic fields. Local magnetic fields in excess of 1600 A/m can be generated by various individual sources such as:

(a) Electrical power cables.
(b) Generators.
(c) Motors.
(d) Welding circuits.
(e) Electrical power switchboards and control equipment.

Location of equipment in the proximity of those sources shall be judiciously considered.

5.3.2.3 Structural discontinuities. Bulkheads or other steel structural members (including equipment) may act as a return path for the magnetic flux lines, resulting in a localized concentration of the magnetic field. If there is a discontinuity (gaps, openings, etc.) in this return path, increased field values may be experienced in the vicinity of the discontinuity. When equipment is to be installed in the near vicinity of such a discontinuity, the possible degrading effect of the enhanced magnetic field environment shall be taken into account.

5.3.2.4 Structural shielding. Steel decks and bulkheads between degaussing cables or other sources of magnetic fields and the equipment may provide some degree of shielding, and thereby reduce the magnetic field which would otherwise exist. However, taking advantage of this shielding effect would require precise knowledge of the location of the degaussing cables or other sources in relation to the location of the equipment, and will require rigid control over location changes. This shielding effect shall not be utilized to exempt any equipment from the requirements of this section. However, in cases where it has been established that it is not technically feasible for equipment to meet the requirements of this section, a deviation utilizing structural shielding may be justified (see 7.1).

5.3.3 Special circumstances. Certain surface ships and submarines which do not have degaussing installations are subject to magnetic treatment at periodic intervals. This treatment is accomplished at dockside, and does not necessarily require equipment to be in an operating status during such treatment. The essential requirement is that the equipment operate satisfactorily within equipment specification requirements in the presence of a residual field of 400 A/m after exposure to the magnetic treatment. In certain circumstances, therefore, it may not be practical or cost-effective to design specialized equipment to operate in the maximum expected field. In such cases, the need to deviate from the requirement of 5.3.1 shall be fully justified (see 7.1).

6. PERFORMANCE TESTING

6.1 Requirement. When it is considered necessary to determine if an equipment (see 3.3) will meet the criteria of this section, performance tests shall be conducted. Such shipboard equipment shall be tested by exposing it to both an ambient steady state magnetic field having a maximum magnitude of 1600 A/m and a magnetic field having a maximum rate of change of 1600 A/m per second. The minimum exposure to the steady state field shall be 5 minutes. No particular orientation of the direction of the magnetic field may be assumed. Equipment shall be tested in operating condition and the equipment performance evaluated in the presence of the test field. Requirements for testing individual equipments shall be specified in the individual equipment specification.

6.2 Test procedure. A square or circular coil of electrical conductors large enough to encircle the equipment shall be provided (see appendix). In lieu of a single coil, Helmholtz coils may be used to satisfy the coil requirements. (Note: The criteria contained in the appendix are not applicable to the Helmholtz coils.) The coil shall contain enough ampere-turns to develop a magnetic field of 1600 A/m at the center of the coil when the coil is energized by a source of power. The coil shall be calibrated for a 1600 A/m field in air, that is, without the equipment in the field. The source of power shall be capable of providing a variable (single polarity) d.c. The equipment under test shall be positioned at the center of the coil and the test performed as follows:

(a) Increase the current in the coil such that the equipment is subjected to a magnetic field that increases from 0 to 1600 A/m at a relatively constant rate. The maximum applied field shall be no less than 1600 A/m and the field shall be increased at a rate between 1600 and 16,000 A/m per second. Maintain the field at 1600 A/m for 5 minutes, or longer if necessary, to obtain sufficient operational data from the equipment to verify correct operation. Decrease the magnetic field from 1600 to 0 A/m at a rate between 1600 and 16,000 A/m per second.

(b) Reverse the connections of the coil to the power source, and repeat the test procedure stated in (a).

(c) Rotate the coil 90 degrees such that the plane of the coil is perpendicular to the plane of the coil as described in (a), and repeat the test procedure as stated in (a) and (b). If more convenient, the equipment rather than the coil may be rotated.

(d) Rotate the coil 90 degrees such that the plane of the coil is perpendicular to the plane of the coil as described in both (a) and (c), and repeat the test procedure as stated in (a) and (b). If more convenient, the equipment rather than the coil may be rotated.

7. DEVIATIONS

7.1 Conditions. In achieving the purpose of this section, it is recognized that there must be some flexibility of application. During the early design stage of shipboard equipment which will be subjected to the magnetic field environment and whose performance may be degraded by this environment, it may become apparent that significant advantages in the overall design/operation of such equipment can be achieved by deviating from the standard characterisitics specified herein. In such instance, the provisions of section 6, "Deviations", of DOD-STD-1399 shall be complied with.

7.1.1 Deviation procedure. Requests for deviations shall be submitted to the Naval Sea Systems Command with copies to:

(a) Program/Project Manager.
(b) NAVSEC 6157.

Review activities:
OS, EC
User activity:
AS

Preparing activity:
Navy - SH
(Project 1990-N032)

APPENDIX

COIL DESIGN PROCEDURE AND CRITERIA

10. Application. The material in this appendix is provided for information and guidance to assist the designer in complying with the test requirements of this standard. It delineates the mathematical approach for determining the minimum diameter of a coil to generate a magnetic field of 1600 A/m at the center of the coil in air (i.e., without the equipment in the field) and a field of some larger predetermined value at the surface of the equipment nearest the coil.

20. Ampere's formula. In a nonmagnetic medium, the magnetic field intensity dH produced at a point by an element of a conductor $d\ell$ in meters (m) through which there is a current of I amperes is:

$$dH = \frac{I \sin \theta \, d\ell}{4\pi r^2} \text{ A/m} \quad \text{(Equation 1)}$$

where r is the distance, in m, between the element $d\ell$ and the point, and θ is the angle between the directions of $d\ell$ and r (see figure 2).

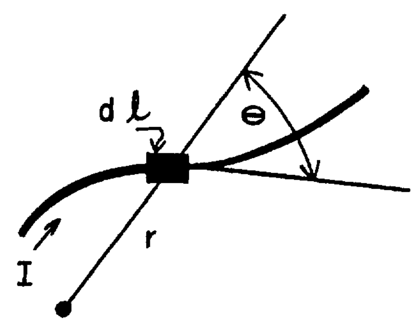


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FIGURE 2. Ampere's formula.

30. Coil design. The magnetic field intensity, in air, produced at a point by a closed circular coil can be derived using ampere's formula. The derivation for a point inside the coil and in the plane of the coil is as follows (see figure 3):

A - point at center of coil.
B - tangent point on circumference.
C - point in plane of coil and inside coil.
R - mean radius of coil.

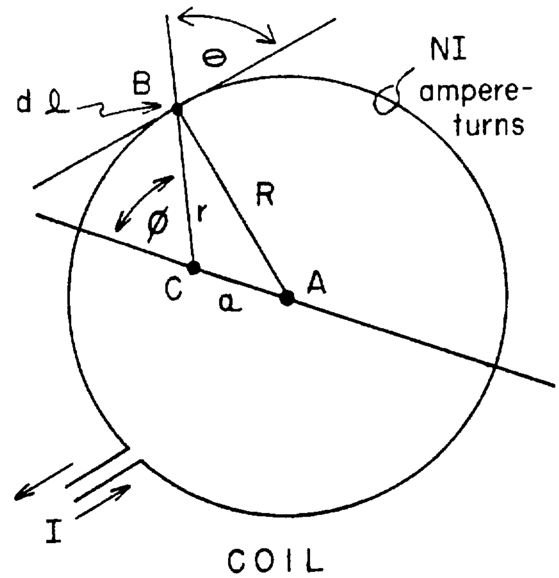

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FIGURE 3. Coil design.

Solving for r as a function of ø (from the law of cosines for triangle ABC):

$$R^2 = r^2 + a^2 - 2ar\cos(180 - \emptyset)$$

$$R^2 = r^2 + a^2 + 2ar\cos\emptyset$$

$$0 = r^2 + (2a\cos\emptyset)r + (a^2 - R^2)$$

$$r = \frac{-2a\cos\emptyset \pm \sqrt{4a^2\cos^2\emptyset - 4(a^2 - R^2)}}{2}$$

$$\therefore r = -a\cos\emptyset + \sqrt{R^2 - a^2\sin^2\emptyset} \quad \text{(Equation 2)}$$

Solving for θ as a function of ø (from the law of sines for triangle ABC):

$$\frac{\sin(180 - \emptyset)}{R} = \frac{\sin(90 - \theta)}{a}$$

$$\frac{\sin\emptyset}{R} = \frac{\cos\theta}{a}$$

$$\cos\theta = \frac{a}{R}\sin\emptyset$$

$$\sqrt{1 - \sin^2\theta} = \frac{a}{R}\sin\emptyset$$

$$\sin^2\theta = 1 - \frac{a^2}{R^2}\sin^2\emptyset$$

$$\sin\theta = \frac{1}{R}\sqrt{R^2 - a^2\sin^2\emptyset} \quad \text{(Equation 3)}$$

And $d\ell \approx r\, d\phi$, (see figure for validity of approximation). (Equation 4)

Substituting equations 3 and 4 into equation 1:

$$dH = \frac{I}{4\pi r^2}\frac{1}{R}\sqrt{R^2 - a^2 \sin^2 \phi}\; r\, d\phi$$

$$dH = \frac{I}{4\pi R}\frac{\sqrt{R^2 - a^2 \sin^2 \phi}}{r}\, d\phi$$

Now substituting r from equation 2 gives:

$$dH = \frac{I}{4\pi R}\frac{\sqrt{R^2 - a^2 \sin^2 \phi}}{\sqrt{R^2 - a^2 \sin^2 \phi} - a\cos\phi}\, d\phi$$

$$H = 2\int_0^{\pi}\frac{I}{4\pi R}\left(1 + \frac{a\cos\phi}{\sqrt{R^2 - a^2 \sin^2 \phi} - a\cos\phi}\right)d\phi$$

Rationalizing the denominator gives:

$$H = \frac{2I}{4\pi R}\int_0^{\pi}\left[1 + \frac{a\cos\phi\sqrt{R^2 - a^2 \sin^2 \phi} + a^2\cos^2\phi}{R^2 - a^2\sin^2\phi - a^2\cos^2\phi}\right]d\phi$$

$$H = \frac{2I}{4\pi R}\left[\int_0^{\pi} d\phi + \frac{1}{R^2 - a^2}\left(\int_0^{\pi}\sqrt{R^2 - a^2\sin^2\phi}\; a\cos\phi\; d\phi + a^2\int_0^{\pi}\cos^2\phi\, d\phi\right)\right]$$

Integrating the second term using the substitution: $a \sin \phi = u$, $a \cos \phi\, d\phi = du$, with the limits from 0 to 0; the term goes to 0.

$$H = \frac{2I}{4\pi R}\left[\phi + \frac{a^2}{R^2 - a^2}\left(\frac{1}{2}\phi + \frac{1}{4}\sin 2\phi\right)\right]_0^{\pi}$$

$$= \frac{2I}{4\pi R}\left[\phi + \frac{a^2}{2(R^2 - a^2)}\left(\phi + \frac{1}{2}\sin 2\phi\right)\right]_0^{\pi}$$

$$= \frac{2I}{4\pi R}\left[\pi + \frac{a^2}{2(R^2 - a^2)}\pi\right]$$

$$= \frac{2\pi I}{4\pi R}\left[\frac{2R^2 - 2a^2 + a^2}{2(R^2 - a^2)}\right]$$

$$H = \frac{\pi I}{4\pi R}\left[\frac{2R^2 - a^2}{R^2 - a^2}\right]$$

For a coil with N turns:

$$H = \frac{\pi NI}{4\pi R}\left(\frac{2R^2 - a^2}{R^2 - a^2}\right) = \frac{NI}{4R}\left(\frac{2R^2 - a^2}{R^2 - a^2}\right) \quad \text{(Equation 5)}$$

The magnetic field intensity at the center of the coil (a = 0) is:

$$H = \frac{2\pi NI}{4\pi R} = \frac{NI}{2R}\ \text{A/m} \quad \text{(Equation 6)}$$

40. Maximum field. Determine the point on the surface of the equipment nearest the coil (point of maximum field). Equipment dimensions are ℓ, w, and h, where ℓ > w > h (see figure 4). Let "a" equal the longest distance from the center of the equipment to a point on the surface of the equipment in the plane of the coil:

$$a = \sqrt{(\ell/2)^2 + (w/2)^2} \quad \text{(Equation 7)}$$

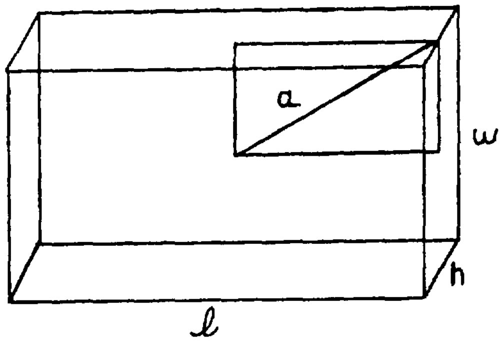

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FIGURE 4. Equipment dimensions.

Equations 5, 6, and 7 can be used to determine the minimum diameter of a coil for performance testing. The procedure is illustrated by the following example:

Given: Equipment dimensions are 1.4 x 0.9 x 0.7 m and the coil is to produce a field of 1600 A/m at the center and less than some larger. predetermined value (4000 A/m in this example) at the surface of the equipment nearest the coil.

Step 1 - Calculate "a" using equation 7:

$$a = \sqrt{\left(\frac{1.4}{2}\right)^2 + \left(\frac{0.9}{2}\right)^2}$$

$$= 0.83 \text{ m}$$

Step 2 - Determine NI from equation 6 when H = 1600 A/m at the coil center:

$$NI = 2\ RH = 3200\ R$$

Step 3 - Determine minimum R for coil by substituting NI and "a" into equation 5:

$$4000 = \frac{3200R}{4R}\left[\frac{2R^2 - (0.83)^2}{R^2 - (0.83)^2}\right]$$

$$4000 = \left[\frac{2R^2 - 0.6925}{R^2 - 0.6925}\right]$$

Solving for R gives:

$$R = 0.94 \text{ m}$$

$$D = 2R = 1.88 \text{ m}$$

The coil diameter must be greater than 1.88 m to produce a field of 1600 A/m at the center and less than 4000 A/m at the distance of 0.83 m from the center. Maximum coil diameter is limited by available power or materials (cost).

50. Detail design of a coil is beyond the scope of this appendix since actual coil esign parameters are dependent on equipment size and available power, voltage, current, aterials, space, etc.

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