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METRIC

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DEPARTMENT OF DEFENSE
MILITARY HANDBOOK

DEFINITIONS AND SYSTEMS OF UNITS, MAGNETIC SILENCING (METRIC)

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DEPARTMENT OF THE NAVY
NAVAL SEA SYSTEMS COMMAND

Washington, DC 20362

Definitions and Systems of Units, Magnetic Silencing (Metric).

DOD-STD-2141(SH)

1. This Military Standard is approved for use by the Naval Sea Systems Command, Department of the Navy, 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 Sea Systems Command, SEA 5523, 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

1. The application of magnetic silencing requirements for nonmagnetic mine warfare ships and craft requires the establishment of a method of communication to ensure that coordinated thinking is applied. Key words and terms more commonly used are defined in this standard, The standard also states the systems of units which are used.

2. The user of this document may wish to consult commercial standards, such as ASTM A 340 for definitions beyond those included in this standard.

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TABLES

1. SCOPE

1.1 scope. This standard contains definition, abbreviations, acronyms, units and symbols used in magnetic silencing. Definitions of abbreviations and terms are limited to statements of meaning as related to this and referenced standards, rather than encyclopedia or textbook discussions.

2. REFERENCED DOCUMENTS

2.1 Other publications. The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

A 340 - Terms, Symbols, and Conversion Factors Relating to Magnetic Testing.
E 380 - Standard for Metric Practice.

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 268 - Metric Practices.

(Application for copies should be addressed to the Institute of Electrical and Electronics Engineers, 345 East 47th Street, New York, NY 10017.)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

3* DEFINITIONS

3.1 Applicability of definitions. The following definitions and terms apply to the restricted field of magnetic silencing for nonmagnetic mine warfare ships and craft. To the extent possible, these definitions are in agreement with those of ASTM A 340.

3.1.1 Air-gap magnetizing force. Air-gap magnetizing force is the magnetizing force required to produce the induction existing at some point in a nonmagnetic gap in a magnetic circuit (H_g). In the cgs system, H_8 is numerically equal to the induction existing at such a point and exceeds the magnetizing force in the magnetic material.

3.1.2 Ampere-turn. Ampere-turn is a unit of magnetomotive force in SI. One ampere-turn equals 4¶/10 or 1.257 gilberts.

3.1.3 Ampere-turn per meter. Ampere-turn per meter is a unit of magnetizing force (magnetic field strength) in SI. One ampere-turn per meter is 4¶ x 10^{-3} or 0.01257 oersted.

3.1.4 Anisotropic material. Anisotropic material is a material in which the magnetic properties differ in various directions.

3.1.5 Antiferromagnetic material. Antiferromagnetic material is feebly magnetic material in which almost equal magnetic moments are lined up anti-parallel to each other. Its susceptibility increases as the temperature is raised until a critical (Neel) temperature is reached; above this temperature the material becomes paramagnetic.

3.1.6 Area. Area is the geometric region encompassed by a magnetic path, an electric path or a physical boundary. An area may be a limiting area (see 3.1.71), a surface area (A) or a cross-sectional area (a or A).

3.1.7 Calibration. Calibration is the adjustment of the means of magnetic field compensation installed aboard ship to provide an optimum magnetic field compensation.

3.1.8 Calibration limit. Calibration limit is the maximum acceptable limit for a magnetic field or a single component of a magnetic field, from a given source or combination of sources, placed on the peak value of the field or component at the end of calibration, in order that the corresponding field or component maintenance will not be exceeded during the subsequent period of operations.

3.1.9 Cgs-em system of units. Cgs-em system of units is a former system for measuring physical quantities in which the basic units are the centimeter, gram, and second (cgs), and the numerical value of the magnetic constant, I'm, is unity.

3.1.10 Coercive force. Coercive force is the magnetizing force at which the magnetic flux density is zero when the material is in a symmetrically cyclically magnetized condition (H_c).

3.1.11 Coercive force, intrinsic. Intrinsic coercive force is the magnetizing force at which the intrinsic induction is zero when the material is in a symmetrically cyclically magnetized condition (H_{C1}).

3.1.12 Coercivity. Coercivity is the maximum value of coercive force (H_{C8})C

3.1.13 Combined magnetic field. Combined magnetic field is the magnetic field which is the sum of the magnetic fields due to two or more sources, such as the normal and roll fields. When applied to ship fields, combined field is assumed to mean the field due to all sources on board or towed by the ship, unless the field is explicitly otherwise defined (except that the magnetic sweep field and the fields due to minesweep winch circuits and circuits used only momentarily are not included).

3.1.14 Craft. A craft is a water surface vehicle with a hull, which has a beam equal to or less than 4.5 meters.

3.1.15 Curie temperature. Curie temperature is the temperature above which a ferromagnetic material becomes paramagnetic (T_c).

3.1.16 Cyclically magnetized condition. Cyclically magnetized condition is a magnetic material in a cyclically magnetized condition (CM) when, after having been subjected to a sufficient number of identical cycles of magnetizing force, it follows identical hysteresis or flux-current loops on successive cycles which are not symmetrical with respect to the origin of the axes.

3.1.17 Degaussing coil. Degaussing coil is a system of electric current loops used to neutralize a component of magnetization. The principal types of degaussing coils are as follows:

(a) M-coil: M-coil is a horizontal coil used to neutralize vertical magnetization.
(b) A-coil: A-coil is a coil with loops in vertical fore and aft planes used to neutralize athwartship magnetization.
(c) L-coil: L-coil is a series of loops generally extending from bow to stern, each loop being in a vertical athwartship plane, used to neutralize longitudinal magnetization.

3.1.18 Degaussing coordinate system. The degaussing coordinate system relative to a ship is defined as follows:

(a) Longitudinal (fore-and-aft), athwartship, and vertical directions and distances are used. When these are described by letters, the letters are respectively: x, positive forward; y, positive to port; and z, positive downward. This is a left-handed system.
(b) The fore-and-aft, athwartship, and vertical distances are measured from the extreme bow, centerline, and full-load waterline of the ship, respectively. The vertical distance is often called the depth.

3.1.19 Demagnetization curve. Demagnetization curve is that portion of a normal hysteresis loop which lies in the second or fourth quadrant; that is, between the residual induction point, B_r, and the coercive force point, H_c. Points on this curve are designated by the coordinates, B_d and H_d.

3.1.20 Demagnetizing coefficient. The demagnetizing coefficient (D_B) is defined by the equation:

$$D_B = [\Gamma_m(H_a - H)]/B_i$$

where:

Ha = applied magnetizing force,

H = magnetizing force actually existing in the magnetic material, and

B_i = intrinsic induction.

r_m = 1 in the cgs system and $4\pi \times 10^{-7}$ henry/meter in SI (rationalized).

For a closed, uniform magnetic circuit the demagnetizing coefficient is zero.

3.1.21 Demagnetizing factor. The demagnetizing factor (ND) is defined as 4¶ times the demagnetizing coefficient, D_B.

3.1.22 Demagnetizing force. Demagnetizing force is a magnetizing force (on the demagnetization curve) applied in such a direction as to reduce the induction in a magnetized body (Hal). See demagnetization curve (3.1.19).

3.1.23 Density. Density is the ratio of the mass to the volume of a material, kg/m^3 or g/cm^3 (6).

3.1.24 Diamagnetic material. Diamagnetic material is material whose relative permeability is less than unity. The intrinsic induction, B_i, is oppositely directed to the applied magnetizing force H.

3.1.25 Domains, ferromagnetic. Domains, ferromagnetic are magnetized regions, either macroscopic or microscopic in size, within ferromagnetic materials. Each domain, per se, is magnetized to intrinsic saturation at all times, and this saturation induction is unidirectional within the domain.

3.1.26 Eddy current field. Eddy current field is the magnetic field due to the eddy currents induced in the conducting material of or on the ship by the rolling motion of the ship in the earth's magnetic field.

3.1.27 Eddy current source. Eddy current source is any item which contains electrically continuous loops of electrically conductive material.

3.1.28 Eddy currents. Eddy currents are the electrical currents induced in a shipboard material as the result of the ship rolling and pitching in the earth's magnetic field.

3.1.29 Electrical circuit (circuitry). Electrical circuit or circuitry refers to all electrical equipment and interconnecting wires and cables.

3.1.30 Electrical conductivity, percent. Percent electrical conductivity refers to the percent of electrical conductivity of a material relative to the electrical conductivity of copper at the same temperature (c).

3.1.31 Electrical conductivity of copper. The electrical conductivity of copper at 20 degrees Celsius (°C) is 5.8×10^5 siemens per meter (S/m). Copper resistivity (inverse of conductivity) at the same temperature is 1.7241×10^{-6} ohm · m.

3.1.32 Electrical conductor. Electrical conductor is a wire, cable or busbar used to allow electricity to flow from one point to another point.

3.1.33 Electrical steel. Electrical steel is a term used commercially t0 designate a flatrolled iron-silicon alloy used for its magnetic properties.

3.1.34 Electrically conductive material. Electrically conductive material refers to material whose electrical conductivity is greater than *or* equal to 0.5 percent of the electrical conductivity of copper.

3.1.35 Electrically continuous path. Electrically continuous path is a path of electrically conductive material not containing a resistive element.

3.1.36 Electrically continuous surface. Electrically continuous surface is a surface of electrically conductive material not containing a resistive element.

3.1.37 Equipment. Equipment comprises materials, fittings, devices, appliances, fixtures, apparatus, machines, components, systems, and so forth used as part of or in connection with Navy ships.

3.1.38 Fabrication. Fabrication is any type of manipulation of a material to shape it into a required configuration.

3.1.39 Feebly magnetic material. Feebly magnetic material is a material generally classified as nonmagnetic and whose maximum normal permeability is 2.0 or less.

3.1.40 Ferromagnetic material. Ferromagnetic material is material in which unequal magnetic moments are lined up antiparallel to each other, Permeabilities are of the same order of magnitude as those of ferromagnetic materials, but are lower than they would be if all atomic moments were parallel and in the same direction. Under ordinary conditions the magnetic characteristics of ferromagnetic materials are quite similar to those of ferromagnetic materials,

3.1.41 Ferromagnetic field. Ferromagnetic field refers to the magnetic field due to all ferromagnetic materials of and in the ship, including any stores aboard and any sweep gear aboard or streamed, while the ship is not rolling or pitching. It does not include the field of ferromagnetic materials while magnetized specifically for producing a ferromagnetic sweep field.

3.1.42 Ferromagnetic material. Ferromagnetic material refers to a material that, in general, exhibits the phenomena of hysteresis and saturation, and Its permeability is dependent on the magnetizing force.

3.1.43 Ferrous magnetic field. Ferrous magnetic field is the magnetic field of a material which consists of the permanent magnetic field plus the induced magnetic field.

3.1.44 Ferrous source. Ferrous source is any material that generates a ferrous magnetic field.

3.1.45 Flux path length. Flux path length refers to the distance along a flux loop (ℓ).

3.1.46 Gauss. Gauss is the unit of magnetic flux density in the cgs electromagnetic system. The gauss is equal to 1 maxwell per square centimeter or 10^{-4} tesla. See magnetic flux density.

3.1.47 Gilbert. Gilbert is the unit of magnetomotive force in the cgs electromagnetic system. The gilbert is a magnetomotive force of $10/4\pi$ ampere turns.

3.1.48 Go-no-go permeability indicator. Go-no-go permeability indicator is a comparative type indicator which compares the permeability of an unknown sample material with a known standard material.

3.1.49 Helmholtz coil. Helmholtz coil is a special arrangement of a pair of coils which allows the production of a homogeneous magnetic field within a central portion of the volume between the coils for magnetic field testing.

3.1.50 Henry. Henry is the unit of self or mutual inductance. The henry is the inductance of a circuit in which an electromotive force of 1 volt is induced by a uniform rate of a change of 1 ampere per second in the circuit. Alternatively, it is the inductance of a circuit in which 1 ampere produces a flux linkage of 1 Wb · turn or 10^8 maxwell-turns.

3.1.51 Hysteresis loop, biased. Biased hysteresis loop is an Incremental hysteresis loop that lies entirely in any one quadrant. In this case, both of the limiting values of H and B are in the same direction.

3.1.52 Hysteresis loop, incremental. The incremental hysteresis loop is nonsymmetrical with respect to the B and H axes, exhibited by a ferromagnetic material in a CM condition. In this case both of the limiting values H may have opposite polarity, but definitely have different absolute values of H_m. An incremental loop may be initiated at either some point on a normal hysteresis loop or at some point on the normal induction curve of the specimen.

3.1.53 Hysteresis loop, intrinsic. An intrinsic hysteresis loop is obtained with a ferromagnetic material by plotting (usually to rectangular coordinates) corresponding direct current (d.c.) values of intrinsic induction, B_i, for ordinates and magnetizing force, H, for abscissae.

3.1.54 Hysteresis loop, normal. A normal hysteresis loop is a closed curve obtained with a ferromagnetic material by plotting (usually to rectangular coordinates) corresponding d.c. values of magnetic flux density, B, for ordinates and magnetizing force, H, for abscissae when the material is passing through a complete cycle between equal definite limits of either magnetizing force, $\pm H_m$, or magnetic flux density, $\pm B_m$. In general the normal hysteresis loop has–mirror symmetry with respect to the origin of the B and H axes but this may not be true for special materials.

3.1.55 Hysteresis, magnetic. Magnetic hysteresis is the property of a ferromagnetic material exhibited by the lack of correspondence between the changes in induction resulting from increasing magnetizing force and from decreasing magnetizing force.

3.1.56 Induced magnetic field. Induced magnetic field is the magnetic field that is created in the neighborhood of a material by the material because of the presence of an external magnetic field.

3.1.57 Induction, intrinsic. Intrinsic induction refers to the vector difference between the magnetic flux density in a magnetic material and the magnetic flux density that would exist in a vacuum under the influence of the same magnetizing force (B_i). This is expressed by the equation:

$$B_i = B - \Gamma_m H$$

In the cgs-em system $B_i/4$ is often called magnetic polarization.

3.1.58 Induction, maximum. Maximum induction is the maximum value of B in a hysteresis loop (B_m). The tip of this loop has the magnetostatic coordinates H_m, B_m, which exist simultaneously.

3.1.59 Induction, normal. Normal induction is the maximum induction, in a magnetic material that is in a symmetrically magnetized condition (B). Normal induction is a magnetostatic parameter usually measured by ballistic methods.

3.1.60 Induction, remanent. Remanent induction is the magnetic flux density that remains in a magnetic circuit after the removal of an applied magnetomotive force (B_d). If there are no air gaps or other inhomogeneities in the magnetic circuit, the remanent induction, B_d, will equal the residual induction, B_r; if air gaps or other inhomogeneities are present, B_d will be less than than B_r.

3.1.61 Induction, residual. Residual induction is the magnetic flux density corresponding to zero magnetizing force in a magnetic material that is in a symmetrically cyclically magnetized condition (B_r).

3.1.62 Induction, saturation. Saturation induction is the maximum intrinsic induction possible In a material (B_8).

3.1.63 Induction curve, intrinsic (ferric). Intrinsic (ferric) induction curve refers to a curve of a previously demagnetized specimen depicting the relation between intrinsic induction and corresponding ascending values of magnetizing force. This curve starts at the origin of the B_i and H axes.

3.1.64 Induction curve, normal. Normal induction curve is a curve of a previously demagnetized specimen depicting the relation between normal induction and corresponding ascending values of magnetizing force. This curve starts at the origin of the B and H axes.

3.1.65 Insulation resistance. Insulation resistance is the apparent resistance between adjacent contacting laminations, calculated as a ratio of the applied voltage to conduction current (R_s). This parameter is normally a function of the applied force and voltage.

3.1.66 International annealed copper standards (IACS). IACS is a standard according to which the specific resistance of pure annealed copper at 20°C is 1.7241 microohms/cm^2/cm. The electrical conductivity is therefore 0.58001 reciprocal microohm/cm^2/cm. The conductivity of other metals is defined as a percentage of this value.

3.1.67 Isotropic material. Isotropic material is material in which the magnetic properties are the same for all directional

3.1.68 Item. Item refers to any part or equipment.

3.1.69 Joule. Joule is the unit or energy in SI. One joule is one newton-meter.

3.1.70 Leakage flux. Leakage flux is the flux outside the boundary of the practical magnetic circuit.

3.1.71 Limiting area. Limiting area is the maximum area allowed to be enclosed by an electrically continuous path (A).

3.1.72 Lines/in^2. Lines/in^2 refers to the unit of induction frequently used in commercial practice. One line/in^2 equals 0.1550 gauss and 1.550 x 10^{-5} tesla.

3.1.73 Magnet. A magnet is a body that produces a magnetic field external to itself. By convention, the north-seeking pole of a magnet is marked with an N, +, or is colored red. Natural magnets consist of certain ores such as magnetite (loadstone); artificial (permanent) magnets are made of magnetically hard materials; electromagnets have cores made of magnetically soft materials which are energized by a current carrying winding.

3.1.74 Magnetic. Magnetic is a relative term describing a material that has a relative magnetic permeability greater than 2.0 after fabrication.

3.1.75 Magnetic circuit. A magnetic circuit is a region where the surface of the magnetic flux density is tangential. A practical magnetic circuit is the region containing the flux of practical interest, such as the core of a transformer. It may consist of ferromagnetic material with or without air gaps or other feebly magnetic materials such as porcelain and brass.

3.1.76 Magnetic constant (permeability of space). Magnetic constant (permeability of space) refers to the dimensional scalar factor that relates the mechanical force between two currents to their intensities and geometrical configurations (P_m). The numerical values of r_m depend upon the system of units employed. In the cgs-em system P_m - 1; in SI P_m - 4¶ x 10^{-7} H/m. The magnetic constant expresses the ratio of magnetic flux density to the corresponding magnetizing force at any point in a vacuum and therefore is sometimes called the permeability of space, μ_0. The magnetic constant times the relative permeability is equal to the absolute permeability ($\mu_{abs} = P_m \mu_r$).

3.1.77 Magnetic excursion range. Magnetic excursion range is for any hysteresis loop or any fluxcurrent loop, the excursion ranges equal the algebraic differences between the upper and lower values of B (ΔB) and between the upper and lower values of H (ΔH), obtained in the loop.

3.1.78 Magnetic field of a ship or craft. The magnetic field of a ship or craft consists of the superposition of the magnetic field from four basic sources: (a) ferrous field, (b) eddy current field, (c) ship service stray field, and (d) minesweep generator stray field.

3.1.79 Magnetic field of induction, Magnetic field of induction is's state of a "region such that a conductor carrying a current in the region would be subjected to a mechanical force, and an electromotive force would be induced in an elementary loop rotated with respect to the field in such a manner as to change the flux linkage.

3.1.80 Magnetic field strength. (See 3.1.97).

3.1.81 Magnetic fields, static and alternating. The following definitions of static and alternating fields assume the field source to be stationary with respect to the field sensor.

(a) Alternating electric (AE) field is the electric field component of an electromagnetic field whose magnitude varies with time, whether periodically or aperiodically.
(b) Alternating magnetic (AM) field is the magnetic field component of an electromagnetic field whose magnitude varies with time, whether periodically or aperiodically.
(c) Static electric (SE) field is an electric field whose magnitude remains constant with time.
(d) Static magnetic (SM) field is a magnetic field whose magnitude remains constant with time.

3.1.82 Magnetic flux. Magnetic flux is the product of the magnetic flux density, B, and the area of a surface (or cross-section), A, when the magnetic flux density B is uniformly distributed and normal to the plane of the surface (ϕ).

$$\phi = BA$$

where:

ϕ = magnetic flux,
B = magnetic flux density, and
A = area of the surface.

3.1.83 Magnetic flux density. Magnetic flux density refers to that magnetic vector quantity (B) which at any point in a magnetic field is measured either by the mechanical force experienced by an element of electric current at the point, or by the electromotive force induced in an elementary loop during any change in flux linkages with the loop at the point. If the magnetic flux density, B, is uniformly distributed and normal to a surface or cross-section, then the magnetic flux density is:

$$B = \phi/A$$

where:

B = magnetic flux density,
ϕ = total flux, and
A = area of surface or cross-section.
B_{in} is the instantaneous value of the magnetic flux density and B_m is the maximum value of the magnetic flux density.

3.1.84 Magnetic line of force. A magnetic line of force is an imaginary line in a magnetic field which at every point has the direction of magnetic flux density at the point. Extended lines of force must always form noninter-secting closed loops.

3.1.85 Magnetic material. Magnetic material is a material that has a relative magnetic permeability greater than 2.0 after fabrication.

3.1.86 Magnetic minesweep terminal box. The magnetic minesweep terminal box is the device which connects the magnetic minesweep cable to the sweep tail cable.

3.1.87 Magnetic moment. Magnetic moment is a measure of the magnetizing force, H, produced at points in space by a plane current loop or a magnetized body (m). The magnetic moment of a plane current loop is a vector, the magnitude of which is the product of the area of the loop and the current. The direction of the vector is normal to the plane of the loop In that direction around which the current has a clockwise rotation when viewed along the vector. The magnetic moment of a magnetized body is the volume integral of the magnetization, M. In the cgs-em system, magnetic moment is usually defined as the pole strength multiplied by the distance between poles. This is sometimes called the magnetic dipole moment.

3.1.88 Magnetic ohm. Magnetic ohm is the unit of reluctance sometimes used in the cgs-em system. One magnetic ohm equals one gilbert/maxwell or $4\pi/10^9$ ampere-turns/weber.

3.1.89 Magnetic permeability. (See 3.1.116.)

3.1.90 Magnetic polarization. In the cgs-em system, the intrinsic induction divided by 4π is sometimes called magnetic polarization or magnetic dipole moment per unit volume (J).

3.1.91 Magnetic pole. The magnetic poles of a magnet are those portions of the magnet toward which or from which the external magnetic flux density appears to converge or diverge respectively. In the hypothetical case of a uniformly magnetized body of constant cross-sectional area, the poles would be located at its ends. By convention, the north-seeking pole is marked with an N, or +, or is colored red.

3.1.92 Magnetic pole strength. Magnetic pole strength is the magnetic moment divided by the distance between the poles (p).

$$p = m/\ell$$

where:

p = pole strength,
m - magnetic moment, and
ℓ - distance between the poles.

3.1.93 Magnetic signature of a ship or craft. Magnetic signature of a ship or craft is a graph of the magnetic field or magnetic field component as a function of x, y, or z with the other two variables kept constant. Signatures are called longitudinal or x, athwartships or y, or vertical or z, according to whether they are functions of x, y or z, respectively. Unless it is stated or clearly apparent from the context that another meaning is intended, magnetic signature is assumed to mean that particular longitudinal signature of the ship's vertical field which contains the peak value of that field.

3.1.94 Magnetic sweep field. A magnetic sweep field is the magnetic field at a given point, under specified circumstances, due to the existence of all magnetic sweep electrical current beyond the sweep terminal box and the field of any magnetized ferromagnetic material of the sweep or sweeper which is magnetized specifically to produce ferromagnetic sweep field.

3.1.95 Magnetics (magnetism). Magnetics (magnetism) refers to that branch of science which deals with the laws of magnetic phenomena and their application.

3.1.96 Magnetization.

(a) The component of the total magnetizing force that produces the intrinsic induction in a magnetic material (M).

$$M = (B - \Gamma_m H)/\Gamma_m \mu_r = B_i/\mu_{abs}$$

where:

M - magnetization,
H = applied magnetizing force,
Γ_m = magnetic constant,
B = total magnetic flux density,
μ_r = relative permeability,
μ_{abs} = absolute permeability, and
B_i = intrinsic induction.

The magnetization can be interpreted as the volume density of magnetic moment.

(b) The characteristic of the ferromagnetic material of the ship which causes the ferromagnetic field. This characteristic may be defined as a combination of permanent, induced, and equilibrium magnetization. Permanent magnetization is changed only by magnetic treatment or, over a period of time, by mechanical stress set up in the material by operation or repair. The induced magnetization changes immediately with a change in the magnetic field producing it. The equilibrium magnetization is the maximum magnetization obtained when a ship is magnetically shaken by an alternating or cycling magnetic field or stress in the presence of a steady component of the earth's field. Equilibrium magnetization is equal to the sum of the induced magnetization and the equilibrium permanent magnetization for a given magnetic location. The components of magnetization and their abbreviations are as follows:

(1) vertical magnetization (VM)

a. equilibrium vertical magnetization (EVM)
b. permanent vertical magnetization (PVM)
c. induced vertical magnetization (IVM)

(2) longitudinal magnetization (LM)

a. equilibrium longitudinal magnetization (ELM)
b. permanent longitudinal magnetization (PLM)
c. induced longitudinal magnetization (ILM)

(3) athwartship magnetization (AM)

a. equilibrium athwartship magnetization (EM)
b. permanent athwartship magnetization (PAM)
c. induced athwartship magnetization (IAM)

3.1.97 Magnetizing force (magnetic field strength). Magnetizing force (magnetic field strength) refers to the magnetic vector quantity at a point in a magnetic field which measures the ability of electric currents or magnetized bodies to produce magnetic flux density at the given point. The magnetizing force, H, may be calculated from the current and the geometry of certain magnetizing circuits. For example, in the center of a uniformly-wound long solenoid,

$$H = C(NI/\ell)$$

where:

H = magnetizing force,
C = constant whose value depends on the system of units,
N = number of turns,
I = current, and
ℓ = axial length of the coil.

If I is expressed in amperes and ℓ is expressed in centimeters, then C = 4¶/10 in order to obtain H in the cgs-em unit, the oersted. If I is expressed in amperes and ℓ is expressed in meters, then C - 1 in order to obtain H in SI, ampere-turn per meter. The magnetizing force, H, at a point in air may be calculated from the measured value of induction at point by dividing this value by the magnetic constant P_m.

3.1.98 Magnetizing force, maximum. Maximum magnetizing force is for magnetostatics, the maximum value of H in a hysteresis loop (H_m). For magnetodynamics, the maximum value of H is a flux-current loop (H_{max}).

3.1.99 Magnetometer. Magnetometer is an instrument for q easuring a magnetic field.

3.1.100 Magnetostatic. Magnetostatic refers to the magnetic condition when the values of magnetizing force and induction are considered to remain invariant with time during the period of measurement. This is often referred to as a d.c. condition,

3.1.101 Magnetostriction. Magnetostriction refers to changes in dimensions of a body resulting from magnetization.

3.1.102 Maintenance allowance. Maintenance allowance is the difference between a given maintenance limit and the corresponding calibration limit.

3.1.103 Maintenance limit. Maintenance limit is the limit for a magnetic field or a single component of a magnetic field, from a given source or combination of sources, such that if it is exceeded by the corresponding field or component for a particular ship when measured, action shall be taken to recalibrate at least the corresponding part of the ship's degaussing. Standard magnetic conditions and code depth are understood unless other conditions are stated.

3.1.104 Maxwell. Maxwell is the unit of magnetic flux in the cgs electromagnetic system. One maxwell equals 10^{-8} weber (see 3.1.82.)

3.1.105 Minesweep generator stray magnetic field. Minesweep generator stray magnetic field is the magnetic field, due to all of the electrical circuits which are energized and de-energized in unison during the magnetic sweep. It includes the field of the magnetic sweep circuit up to and including the sweep terminal box.

3.1.106 Mksa rationalized system of units. The mksa (Giorgi) rationalized system of units is an obsolete system for measuring physical quantities in which the basic units are the meter, kilogram, and second, and the ampere is a derived unit as defined by assigning the magnitude 4¶ x 10^{-7} to the rationalized magnetic constant (sometimes called the permeability of space). The electrical units of this system were formerly called the "practical" electrical units. In this system dimensional analysis is customarily used with the four independent (basic) dimensions; length, mass, time, and current.

3.1.107 Nonmagnetic. Nonmagnetic is a relative term describing a material that has a relative magnetic permeability of 2.0 or less after fabrication. Certain materials may be nonmagnetic only under limited conditions.

3.1.108 Nonmagnetic equipment. Nonmagnetic equipment is equipment of which each part is constructed of nonmagnetic material, where parts required to be magnetic for reasons of function or mechanical strength are excepted.

3.1.109 Nonoriented electrical steel. Nonoriented electrical steel is a flat-rolled electrical steel which has approximately the same magnetic properties in all directions.

3.1.110 Normal field. Normal field is the magnetic field which is the vector sum of the degaussed ferromagnetic and normal service stray fields.

3.1.111 Oersted. Oersted is the unit of magnetic field strength (magnetizing force) in the cgs electromagnetic system. One oersted equals a magnetomotive force of 1 gilbert/cm of flux path. One oersted equals 1000/4¶ or 79.58 ampere-turns per meter. See also, magnetizing force (magnetic field strength) (3.1.97).

3.1.112 operational service field. Operational service field is the magnetic field due to any electrical currents normally existing more than momentarily while the ship is operating, except that the minegweep generator stray field and the magnetic sweep field are not included. Momentarily means for not more than 15 seconds at a time and for not more than an average of 15 percent of the time while the ship is in a minefield. The operational service field is the vector sum of the normal service field and the added service field. The normal service field is the field due to the minimum number of electrical circuits which must be operating in order for the ship to proceed across a range. The added service field is the vector difference between the operational service field and the normal service field.

3.1.113 Paramagnetic material. Paramagnetic material is a material having a relative permeability which is slightly greater than unity, and which is practically independent of the magnetizing force.

3.1.114 Peak field. For a particular component of a magnetic field, the peak field is the largest absolute value (that is, the largest numerical value whether positive or negative) of that field or component found on a given surface or in a given volume. Unless otherwise stated, it refers to the maximum absolute value found on a horizontal plane at a given depth.

3.1.115 Permanent magnetic field. Permanent magnetic field is the magnetic field that exists in the neighborhood of a material after the external magnetic field has been removed.

3.1.116 Permeability. Permeability is a general term used to express relationships between magnetic flux density, B, and magnetizing force, H, under various conditions of magnetic excitation. These relationships are either (a) absolute permeability, which in general is the quotient of a change in magnetic flux density divided by the corresponding change in magnetizing force, or (b) relative permeability to the magnetic constant (P_m). The magnetic constant P_m is a scalar quantity differing in value and uniquely determined by each electromagnetic system of units. In the unrationalized cgs system P_m is 1 gauss/oersted and in SI, P_m = 4¶ x 10^{-7} H/m. Relative permeability is a pure number which is the same in all unit systems. The value and dimension of absolute permeability depends on the system of units employed. For any ferromagnetic material, permeability is a function of the degree of magnetization. However, initial permeability, μ_0 and maximum permeability, μ_m, are unique values for a given specimen under specified conditions. Except for initial pemeability, μ_o, a numerical value for any of the permeabilities is meaningless unless the corresponding B or E excitation level is specified. For the incremental permeabilities, μ_Δ and μ_Δ a numerical value is meaningless unless both the corresponding values of mean excitation level (B or H) and the excursion range (ΔB or ΔH) are specified.

3.1.117 Permeability, absolute. Absolute permeability refers to the sum of the magnetic constant and intrinsic permeability (μ_{abs}). It is also equal to the product of the magnet constant and the relative permeability:

$$\mu_{abs} = \Gamma_m + \mu_i = \Gamma_m \mu_r$$

3.1.118 Permeability, differential. Differential permeability refers to the absolute value of the slope of the hysteresis loop at any point, or the slope of the normal magnetizing curve at any point (μ_d).

3.1.119 Permeability, effective circuit. When a magnetic circuit consists of two or more components, each individually homogeneous throughout but having different permeability values, the effective (overall) permeability of the circuit (μ_{eff}) is that value computed in terms of the total magnetomotive force, the total resulting flux, and the geometry of the circuit. For a symmetrical series circuit in which each component has the same cross-sectional area, reluctance values add directly giving:

$$\text{eff} = \frac{\ell_1 + \ell_2 + \ell_3 + \cdots}{\frac{\ell_1}{\mu_1} + \frac{\ell_2}{\mu_2} + \frac{\ell_3}{\mu_3} + \cdots}$$

For a symmetrical parallel circuit in which each component has the same flux path length, permeance values add directly giving:

$$\text{eff} = \frac{\mu_1 A_1 + \mu_2 A_2 + \mu_3 A_3 + \cdots}{A_1 + A_2 + A_3 + \cdots}$$

3.1.120 Permeability, incremental intrinsic. Incremental intrinsic permeability refers to the ratio of the change in intrinsic induction to the corresponding change in magnetizing force when the mean induction differs from zero ($\mu_{\Delta i}$).

3.1.121 Permeability, incremental. Incremental permeability is the ratio of a change In magnetic flux density to the corresponding change in magnetizing force when the mean induction differs from zero (μ_{Δ}). It equals the slope of a straight line joining the excursion limits of an incremental hysteresis loop. When the change in H is reduced to zero, the incremental permeability, μ_{Δ}, becomes the reversible permeability, μ_{rev}.

3.1.122 Permeability, initial. The limiting value approached by the normal permeability as the applied magnetizing force, H, is reduced to zero (μ_0). The permeability is equal to the slope of the normal induction curve at the origin of linear B and H axes.

3.1.123 Permeability, intrinsic. Intrinsic permeability refers to the ratio of intrinsic induction to the corresponding magnetizing force (μ_i). (See 3.1.145).

3.1.124 Permeability, maximum. Maximum permeability refers to the value of normal permeability for a given material where a straight line from the origin of linear B and H axes becomes tangent to the normal induction curve (μ_m).

3.1.125 Permeability, normal. Normal permeability refers to the ratio of the normal induction to the corresponding magnetizing force (μ). It is equal to the slope of a straight line joining the excursion limits of a normal hysteresis loop, or the slope of a straight line joining any point (H_m, B_m) on the normal induction curve to the origin of the linear B and H axes, 3.1.126 Permeability, relative. Relative permeability refers to the ratio of the absolute permeability of a material to the magnetic constant P_m, giving a pure numeric parameter (μ_r). In the cgs-em system of units, the relative permeability is numerically the same as the absolute permeability.

3.1.127 Permeability, reversible. Reversible permeability refers to the limit of the incremental permeability as the change in magnetizing force approaches zero (μ_{rev}).

3.1.128 Permeability, space. Space permeability refers to the permeability of space (vacuum), μ_u, which is identical with the magnetic constant, P_m.

3.1.129 Permeance. Permeance is the reciprocal of the reluctance (P).,

3.1.130 Reluctance. Reluctance is that quantity ($\mathcal{R}$) which determines the magnetic flux, resulting from a given magnetomotive force, F, around a magnetic circuit.

$$\mathcal{R} = \mathcal{F}/\phi$$

where:

$\mathcal{R}$ = magnetic reluctance,
$\mathcal{F}$ = magnetomotive force, and
ϕ = flux

The reluctance is measured in gilberts per maxwell (magnetic ohms) in the cgs-em system and in amperes per weber in SI.

3.1.131 Reluctivity. Reluctivity is the reciprocal of the permeability of a medium (U).

3.1.132 Remanence. Remanence refers to the maximum value of the remanent induction for a given geometry of the magnetic circuit (Balm)." If there are no air gaps or other inhomogeneities in the magnetic circuit, the remanence, B_{dm}, is equal to the retentivity, B_{rs}; if air gaps or other inhomogeneities are present, B_{dm} will be less than B_{rs}.

3.1.133 Remanent induction. (See 3.1.60.)

3.1.134 Residual induction. (See 3.1.61.)

3.1.135 Resistive element. Resistive element is a material which is inserted in an electrically continuous path or surface of a structure such that the inserted material exhibits an electrical resistance of at least 1 ohm when forming part of the path or surface.

3.1.136 Retentivity. Retentivity is that property of a magnetic material which is measured by its maximum value of the residual induction (B_{rs}). Retentivity is usually associated with saturation induction.

3.1.137 Roll field. The magnetic field caused by the rolling of the ship; that is, it is the difference between the ship's field while rolling and the field while upright and not rolling. The roll field is usually changing from moment to moment. The roll field is the vector sum of the eddy current field and the tilt field. The tilt field is the difference between the ship's field when the ship has a list but is not rolling and the field when the ship is upright and not rolling. The eddy current field is the field due to the eddy currents induced in the conducting material of or on the ship by the rolling of the ship in the earth's magnetic field.

3.1.138 Ship. A ship is a water surface vehicle with a hull, which has a beam greater than 4.5 meters

3.1.139 Ship service stray magnetic field. Ship service stray magnetic field is the stray magnetic field emanating from any stray magnetic field source other than from a magnetic minesweep generator stray magnetic field source.

3.1.140 SI (Systeme International d'Unites; International System of Units). The SI rationalized system of units is a system for measuring physical quantities in which the basic units are the meter, kilogram, second, ampere, and kelvin (see ASTM E 380 or IEEE 268).

3.1.141 Stabilization. Stabilization refers to a treatment of magnetic material designed to increase the permanency of its magnetic properties or conditions.

3.1.142 Stray magnetic field. Stray magnetic field is the undesired static magnetic field emanating from an electrical conductor.

3.1.143 Stray magnetic field of a ship. The stray magnetic field of a ship is composed of the ship service stray field and the magnetic minesweep generator stray field. The stray field sources are the electric currents In cables and wiring associated with the operation of the equipment of the ship or craft.

3.1.144 Stray magnetic field source. Stray magnetic field source refers to any electrical circuit, item or equipment emanating a stray magnetic field.

3.1.145 Susceptibility. Susceptibility refers to the ratio of the intrinsic induction B_i, due to the magnetization of a material to the induction in space due to the influence of the corresponding magnetizing force, H (K).

$$\kappa = B_i/\Gamma_m H = \mu_r - 1$$

where:

Γ_m = magnetic constant, and
μ_r = relative permeability,

The above equations apply to an isotropic material if SI is used. In the classical cgs-em system of units:

$$\kappa = B_i/4\pi\Gamma_m H = (\mu_r - 1)/4\pi$$

3.1.146 Susceptibility, mass. The susceptibility divided by the density of a body is called the susceptibility per unit mass, X, or simply the mass susceptibility:

$$\chi = \kappa/\delta$$

where: δ = density.

3.1.147 symmetrically cyclically magnetized condition. A magnetic material is in a symmetrically cyclically magnetized condition (SCM) when, under the influence of a magnetizing force that varies cyclically between two equal positive and negative limits, its successive hysteresis loops or flux-current loops are both identical and symmetrical with respect to the origin of the axes.

3.1.148 Tesla. Tesla is the unit of magnetic flux density in the SI. The tesla is equal to 1 Wb/m^2 or 10^4 gauss.

3.1.149 Total field magnetometer. Total field magnetometer is a magnetometer which measures the total magnetic field rather than the magnetic field in one spatial plane only.

3.1.150 Undesired magnetic field. Undesired magnetic field is a magnetic field that serves no useful purpose and is not confined within its source.

3.1.151 Vertical magnetometer. A vertical magnetometer is a magnetometer which measures only the vertical component of the magnetic fields

3.1.152 Volt-ampere. Volt-ampere refers to the unit of apparent power.

3.1.153 Watt. Watt is a unit of active power. One watt is a power of one joule/second.

3.1.154 Weber. Weber is the unit of magnetic flux in SI. The weber is the magnetic flux whose decrease to zero when linked with a single turn induces in the turn a voltage whose time integral is one volt-second. One weber equals 10^8 maxwells. See magnetic flux (3.1.83).

4. GENERAL REQUIREMENTS

4.1 Not applicable.

5. DETAILED REQUIREMENTS

5.1 Abbreviations. Abbreviations which are used to designate types of tests for measuring magnetic silencing characteristics shall be as follows:

C - Electrical conductivity
EF - Eddy current magnetic field
FF - Ferrous magnetic field
P - Permeability
SF - Stray magnetic field

5.2 Units, symbols and prefixes of magnetic quantities" Units, symbols and prefixes used in magnetic silencing are in accordance with the International System of Units (SI). However, since some test instruments still measure magnetic quantities in terms of centimeter-grant-second (cgs) units, a conversion table is provided to convert from cgs units to SI units (see 5.2.4).

5.2.1 Units. Units used in magnetic silencing shall be in accordance with table I.

TABLE I. Units for magnetic quantities

Magnetic quantity	SI system		cgs system	
	Units	Symbol	Units	Symbol
Field strength Flux	Ampere/meter Weber	A/m Wb	Oersted Maxwell	Oe M
Flux density	Tesla	T	Gauss	G
Permeability/	Henry/meter	H/m	Gauss/Oersted	G/Oe
Conductivity/	Siemens/meter	s/m	mho/centimeter	Ω^{-1}/cm
Resistivity2/	ohm-meter	$\Omega \cdot$m	ohm-centimeter	$\Omega \cdot$cm

1/ In the cgs system, the permeability of free space (μ_o) is unity. Therefore, the relative permeability of a medium is μ_r, which requires no conversion constant, and is itself a pure number.
2/ Both conductivity and resistivity are not magnetic terns but electrical circuit terms.

5.2.2 Symbols. Symbols used in magnetic silencing shall be in accordance with table 11.

TABLE II. Symbols for magnetic quantities.

Symbol	Term
a	cross-sectional area
A	cross-sectional area limiting area surface area
AE	alternating electric field
AM	athwartship magnetization alternating magnetic field

TABLE II. Symbols for magnetic quantities. - Continued

Symbol	Term
B	magnetic flux density normal induction
ΔB	excursion range of induction
B_d	remanent induction
B_{dm}	remanence
B_i	intrinsic induction
B_m	maximum induction in a hysteresis loop
B_r	residual induction
B_{rs}	retentivity
B_s	saturation induction
CM	cyclically magnetized condition
D_B	demagnetizing coefficient
EAM	equilibrium athwartship magnetization
ELM	equilibrium longitudinal magnetization
EVM	equilibrium vertical magnetization
F	magnetomotive force
H	magnetizing force magnetic field strength
ΔH	excursion range of magnetizing force
H_c	coercive force
H_{ci}	intrinsic coercive force
H_{cs}	coercivity
H_d	demagnetizing force
H_g	air-gap magnetizing force
H_m	maximum magnetizing force in a hysteresis loop

TABLE II. Symbols for magnetic quantities. - Continued

Symbol	Term
H_{max}	maximum magnetizing force in a flux-current loop
IACS	international annealed copper standards
IAM	induced athwartship magnetization
ILM	induced longitudinal magnetization
IVM	induced vertical magnetization
J	magnetic polarization
LM	longitudinal magnetization
ℓ	flux path length
m	magnetic moment
M	magnetization
m	total mass of a specimen
N_D	demagnetizing factor
p	magnetic pole strength
PAM	permanent athwartship magnetization
PLM	permanent longitudinal magnetization
PVM	permanent vertical magnetization
P	permeance
R	reluctance
R_s	insulation resistance
SCM	symmetrically cyclically magnetized condition
SE	static electric field
SM	static magnetic field
T_c	curie temperature
VM	vertical magnetization
Γ_m	magnetic constant

TABLE II. Symbols for magnetic quantities. - Continued

Symbol	Term
δ	density
κ	susceptibility
μ	normal permeability
μ_{abs}	absolute permeability
μ_d	differential permeability
μ_Δ	incremental permeability
μ_{eff}	effective circuit permeability
μ_i	intrinsic permeability
$\mu_{\Delta i}$	incremental intrinsic permeability
μ_m	maximum permeability
μ_o	initial permeability
μ_r	relative permeability
μ_υ	space permeability (also Γ_m)
μ_{rev}	reversible permeability
υ	reluctivity
π	the numeric 3.1416
ϕ	magnetic flux
χ	mass susceptibility

5.2.3 Prefixes. Prefixes expressing decimal factors used in magnetic silencing shall be in accordance with table III.

TABLE III. Prefixes expressing decimal factors.

Factor	Prefix	Symbol
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

5.2.4 Conversion factors. Conversion factors shall be in accordance with ASTM A 340 as indicated in table IV.

TABLE IV. Conversion factors.

Multiply	By	To obtain
	Magnetic Moment, m	
Maxwell-centimeter (dipole)	10^{-10}	weber-meter (dipole)
Weber-meter (dipole)	10^{10}	maxwell-centimeter (dipole)
Gamma-cubic centimeter (dipole)	10^{-7}	ma-n-centimeter (dipole)
Gamma-cubic centimeter (dipole)	10^{-15}	weber-meter (dipole)
Ampere-square centimeter (loop)	10^{-4}	ampere-square meter (loop)
Ampere-square meter (loop)	10^{4}	ampere-square centimeter (loop)
Ampere-square meter (loop)	10.7639	ampere-square foot (loop)
Ampere-square foot (loop)	0.0929	ampere-square meter (loop)
	Mass	
Pounds	453.59	grams
Pounds	0.45359	kilograms
Grams	0,0022046	pounds
Kilograms	2.2046	pounds
	Length	
Feet	30.480	centimeters
Inches	2.5400	centimeters
Centimeters	0.032808	feet
Centimeters	0.39370	inches
Inches	0.025400	meters
Meters	39.370	inches
	Area	
Square feet	929.04	square centimeters
Square inches	6.4516	square centimeters
Square centimeters	1.0764×10^{-3}	square feet
Square centimeters	0.15500	square inches
Square inches	6.4516×10^{-4}	square meters
Square meters	1.5500×10^{3}	square inches
Square centimeters	10^{-4}	square meters
Square meters	10^{4}	square centimeters
	Sinusoidal Waveform	
Peak current or voltage	0.70711	rms current or voltage
Peak current or voltage	0.63662	average current or voltage
Rms current or voltage	1.4142	peak current or voltage
Rms current or voltage	0.90032	average current or voltage
Average current or voltage	1.5708	peak current or voltage
Average current or voltage	1.1107	rms current or voltage

TABLE IV. Conversion factors. - Continued

Multiply	By	To obtain
Magnetic Flux Density, B		
Gausses	6.4516	lines per square inch
Gausses	6.4516×10^{-8}	webers per square inch
Gausses	10^{-4}	webers per square meter (teslas)
Lines per square inch	0.15500	gausses
Lines per square Inch	1.5500×10^{-5}	webers per square meter (tealas)
Lines per square inch	10^{-8}	webers per square inch
Webers per square inch	1.5500×10^{7}	gausses
Webers per square inch	10^{8}	lines per square inch
Webers per square inch	1550	webers per square meter (teslas)
Magnetizing Force, H		
Oersteds	2.0213	ampere-turns per inch
Oersteds	0.79577	ampere-turns per centimeter
Oersteds	79.577	ampere-turns per meter
Ampere-turns per centimeter	1.2566	oersteds
Ampere-turns per centimeter	2.5400	ampere-turns per inch
Ampere-turns per centimeter	100.00	ampere-turns per meter
Ampere-turns per inch	0.49474	oersteds
Ampere-turns per inch	0.39370	ampere-turns per centimeter
Ampere-turns per inch	39.370	ampere-turns per meter
Ampere-turns per meter	0.012566	oersteds
Ampere-turns per meter	10^{-2}	ampere-turns per centimeter
Ampere-turns per meter	0.025400	ampere-turns per inch
Permeability, μ		
Gausses per oersted	3.1918	lines per ampere-turn Inch
Gausses per oersted	3.1918×10^{-8}	webers per ampere-turn inch
Gausses per oersted	1.2566 X 10-6	webers per ampere-turn meter
Webers per ampere-turn meter	7.9577×10^{5}	gausses per oersted
Webers per ampere-turn meter	2.5400×10^{6}	lines per ampere-turn inch
Webers per ampere-turn meter	0.025400	webers per ampere-turn inch
Webers per ampere-turn inch	3.1330×10^{7}	gausses per oersted
Webers per ampere-turn inch	10^{8}	lines per ampere-turn inch
Webers per ampere-turn inch	39.370	webers per ampere-turn meter
Lines per ampere-turn inch	0.31330	gausses per oersted
Lines per ampere-turn inch	39.370×10^{-8}	webers per ampere-turn meter
Lines per ampere-turn inch	10^{-8}	webers per ampere-turn inch

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