NOTE: MIL-STD-2142 has been redesignated as a Test Method Standard. The cover page has been changed for Administrative reasons. There are no other changes to this Document.

METRIC

MIL-STD-2142A(SH)
6 August 1990
SUPERSEDING
DOD-STD-2142 (SH)
1 June 1983
(See 6.6)

DEPARTMENT OF DEFENSE
TEST METHOD STANDARD

MAGNETIC SILENCING CHARACTERISTICS, MEASUREMENT OF (METRIC)

AMSC N/A

FSC 1905

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

FOREWARD

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 55Z3, Department of the Navy, Washington, DC 20362-5101, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

3. The testing of materials and equipment in accordance with the requirements of this standard will ensure that magnetic characteristics have been considered and incorporated into the manufacture of materials and design of equipment. This will result in compatibility of materials and operation of equipment in a complex magnetic environment.

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FIGURES

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APPENDIX B

Test Report Technical Content Requirements

CONTENTS (Continued)

CONTENTS (Continued)

1. SCOPE

1.1 Scope. This standard establishes requirements for methods of measuring and determining the magnetic characteristics (permeability; electrical conductivity; ferrous, stray and eddy current magnetic field strengths) of materials and equipment.

1.1.1 Application. The requirements of this standard should be applied for the acquisition of materials and equipment to be used on nonmagnetic mine warfare ships and craft, as specified in the individual material and equipment specifications or in the contract.

1.2 Classification. Classification is applicable to the type of magnetic field source and the test method for tests established by this standard.

1.2.1 Field sources. Magnetic field sources shall be classified as follows:

Class 1. Ferrous magnetic field.

Class 2. Eddy current magnetic field.

Class 3. Stray magnetic field.

1.2.2 Test methods. Test methods are grouped in sections and designated by a series of numbers in accordance with the following system:

(a) Section 100 - Ferrous magnetic field tests are designated by "1XX".
(b) Section 200 - Eddy current magnetic field tests are designated by "2XX".
(c) Section 300 - Stray magnetic field tests are designated by "3XX".
(d) Section 400 - Electrical conductivity tests are designated by "4XX".
(e) Section 500 - Permeability tests are designated by "5XX".
(f) Section 600 - Final magnetic signature tests are designated by "6XX".

Where "XX" indicates the numerical order of tests from 01 to 99.

1.3 Method of reference. When a specific test method is required for measuring a magnetic characteristic of a material or equipment, the test methods contained herein should be referenced in the applicable document by specifying this standard and the test number.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1. 1 Specification and standards. The following specifications and standards form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

MILITARY

MIL-I-17214	-	Indicator, Permeability; Low-mu (Go-No-Go).

STANDARDS

MILITARY

DOD-STD-2141	-	Definitions and Systems of Units, Magnetic Silencing (Metric).
DOD-STD-2143	-	Magnetic Silencing Requirements for the Construction of Nonmagnetic Ships and Craft (Metric).
MIL-STD-45662	-	Calibration Systems Requirements.

(Unless otherwise indicated, copies of federal and military specifications and standards are available from the Standardization Document Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.1.2 Other Government publication. The following other Government publication forms a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

UNITED STATES DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

Handbook 100 - Copper Wire Tables.

(Application for copies should be addressed to the National Institute Standards and Technology, Information Resources and Services Division, Gathersburg, MD 20899.)

2.2 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DoDISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DoDISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

A 342 - Standard Test Methods for Permeability of Feebly Magnetic Materials.
B 9 - Standard Specification for Bronze Trolley Wire
B 105 - Standard Specification for Hard-Drawn Copper Alloy Wires for Electric Conductors.
B 193 - Standard Test Methods for Resistivity of Electrical Conductor Material.
B 298 - Standard Specification for Silver-Coated Soft or Annealed Copper Wire.
B 355 - Standard Specification for Nickel-Coated Soft or Annealed Copper Wire. (DoD adopted).
B 566 - Standard Specification for Copper-Clad Aluminum Wire.
E 1004 - Standard Test Method for Electromagnetic (Eddy-Currant) Measurements of Electrical Conductivity.

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulation unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 General magnetic silencing terms. The meanings of general magnetic silencing terms used in this standard are in accordance with DOD-STD-2141.

3.1.1 Eddy current magnetic field. An eddy current magnetic field is a magnetic field that is induced in electrically conductive material aboard ship as the ship rolls and pitches in the earth's magnetic field.

3.1.2 Electrical conductivity. Electrical conductivity in a material is defined as the ratio of the conduction current density to the electric field intensity in the material. It is usually expressed as a percentage of the conductivity of pure copper (percent IACS).

3.1.3 Ferrous magnetic field. A ferrous magnetic field is a magnetic field generated by magnetic material. The ferrous magnetic field is the sum of the material's induced and permanent magnetic fields.

3.1.4 IACS. International Annealed Copper Standard.

3.1.5 Magnetic field. As used in this standard, the term magnetic field refers to the magnetic flux density (B), rather than the magnetic field intensity (H).

3.1.6 Magnetic permeability. Magnetic permeability is defined as the ratio of magnetic flux density to the magnetic field intensity in a material. Relative magnetic permeability is the ratio of the permeability of any substance to the permeability of free space. The permeability of free space is $4\pi \times 10^{-7}$ henrys per meter.

3.1.7 Stray magnetic field. The undesired static magnetic field emanating from an electrical conductor.

3.1.8 Test sample. Test sample is used in this standard as an arbitrary definition of equipment which is to be tested in accordance with sections 100, 200, or 300; or material which is to be tested in accordance with sections 100 and 200 of this standard.

3.1.9 Test specimen. Test specimen is used as an arbitrary definition of material which is to be tested in accordance with sections 400 and 500 of this standard. The specimen may be a sample of the material of which the item is made or the entire item itself, depending upon its physical size.

4. GENERAL REQUIREMENTS

4.1 Government furnished material and equipment. Material and equipment furnished by the Government to a contractor shall, unless the test data is furnished by the Government, require testing in accordance with the requirements of this standard by the contractor for conformance to individual material and equipment specifications, or to the contract or purchase order, or to the requirements of DOD-STD-2143.

4.2 Material or equipment tested in accordance with procedures not specified in this standard. If the material or equipment has been previously tested for magnetic characteristics by procedures not included in this standard, the previous test procedures and test plan shall be evaluated by the contracting activity and shall meet equivalent portions of this standard.

4.3 Variations in test methods of sections 100, 200, and 300. Proposed variations in test methods of sections 100, 200, and 300 (for example, rotating the test sample in lieu of the magnetometer mounting ring for magnetic field measurements or rolling the test sample in lieu of the test coil for eddy current field measurements) shall be presented to the contracting activity for approval (see appendix B).

4.4 Testing of identical material and equipment. Material and equipment produced by a contractor, which are identical to those previously produced by the contractor, tested in accordance with this standard and found satisfactory, shall require minimal testing as indicated in the approved test plan, to ascertain conformance with this standard. A copy of the previous test report shall be forwarded with the new test report for comparison and evaluation.

4.5 Test facilities.

4.5.1 Location. Magnetic test facilities shall be located in magnetically clean areas. A magnetically clean area is defined as an area where the ambient magnetic field does not change by more than 1 nanotesla (nT) for the duration of the tests, and where metallic material is not less than 4.6 meters from a magnetic field sensor. An area with a commpensated ambient field (of any value) is defined as magnetically clean as long as the controlled field is steady within 1 nT for the duration of the tests.

4.5.2 Test equipment. The test equipment required by the magnetic test facility shall be as specified in the applicable individual test method.

4.5.3 Descriptions of magnetic test facilities. The descriptions of some prominent magnetic test facilities are given in appendix A. Their inclusion in this standard does not obligate them in any way to perform the tests specified herein.. The tests specified in this standard may be performed at any magnetic test facility which meets the requirements of this standard.

5. DETAILED REQUIREMENTS

5.1 Test conditions (see 6.3 and appendix B). Detailed test conditions shall be as specified in the individual test methods. In addition, the general test conditions of 5.1.1 through 5.1.4 shall apply.

5.1.1 Accessory equipment precaution. Accessory equipment (for example, chart recorders), used in conjunction with equipment measuring magnetic characteristics, shall not affect measurement integrity.

5.1.2 Excess personnel and equipment. The test area shall be kept free of unneccessary equipment and material. Only equipment and personnel essential to the test being performed shall be in the test area.

5.1.3 Test coils (section 100 and 200 test methods). Test coils, either a Helmholtz coil or an equivalent coil array acceptable to the contracting activity, shall produce applied magnetic fields in the three orthogonal directions (triaxial). The magnetic field gradient caused by the coil's field and any magnetic field distortions, from the immediate environment over the volume occupied by the test sample, shall not exceed 0.1 percent of the applied field or 2 nT, whichever is greater. The coil shall generate magnetic fields to an accuracy of at least 0.05 percent of the applied field or 0.25 nT, whichever is greater.

5.1.4 Power supply characteristics (section 300 test methods). Power supplies for equipment to be tested (section 300 test methods) and not supplied as part of the equipment shall have characteristics and tolerances as specified in the equipment's detailed specification.

5.2 Arrangement and operation of equipment to be tested (as required). Detailed test arrangements and conditions of equipment operation, as required, shall be as specified in the individual test methods. In addition, the general arrangement and conditions of operation in 5.2.1 through 5.2.5 shall apply.

5.2.1 Control adjustment. For all modes of operation, controls on the equipment to be tested shall be operated and adjusted as prescribed in the instruction manual, or as required by the equipment specification, to obtain optimum design performance.

5.2.2 Signal inputs. Actual or simulated inputs required to activate, use, or operate all circuits shall be used.

5.2.3 Arrangement and operating conditions. Interconnecting cable assemblies and supporting structures shall simulate actual installation and usage. Shielded leads shall not be used in the test setup, unless they have been specified for use in the intended installation. Cables shall be checked against the installation requirements to verify that no extra shielded wires have been used. Cables and equipment shall be arranged so that there is no shielding interposed between the test sample's cables and the measuring equipment.

5.2.4 Mounting and grounding. Test samples shall be mounted and grounded as when installed aboard ship.

5.2.5 Loads. The equipment under test shall be loaded with the full mechanical and electrical load, or equivalent, for which it is designed. This requirement specifically includes electrical loading of the contacts of mechanisms which are designed to control electrical loads, even though such loads are physically separate from the equipment under test. Operation of voltage regulators and other circuits that function intermittently is required during testing. The loads used shall simulate the resistance, inductance, and capacitance of the actual load. Mechanical devices shall also be operated under load. The device under test shall be actuated by the same means as it will be when installed.

5.3 Measuring equipment. Measuring equipment shall be as specified in the individual test methods. Unless otherwise specified, all laboratory equipment shall be operated as prescribed in respective instruction manuals. This standard shall take precedence in the event of conflict with instruction manuals or other such documents issued by industry.

5.3.1 Identification of spurious responses in measuring equipment. Measurement equipment shall be checked for spurious responses. False data caused by such spurious responses shall be identified on data sheets.

5.3.2 Calibration of measuring equipment. Measuring instruments and accessories used in determining compliance with the requirements of this standard shall be calibrated under an approved program in accordance with MIL-STD-45662.

5.4 Test methods. Except as noted in 5.4.1, the test methods contained in this standard shall be used to determine compliance with the individual material or equipment specifications, the contract or purchase order, or DOD-STD-2143. Unless otherwise specified in the applicable document, any applicable test method may be used for measuring a selected magnetic characteristic.

5.4.1 Final magnetic signature tests (section 600). The final magnetic signature tests of section 600 shall be performed on new nonmagnetic mine warfare ships and craft to ensure compliance with the applicable ship specifications, the contract or purchase order, or DOD-STD-2143. These tests shall be performed by a U.S. Navy Magnetic Silencing Facility (MSF) during Builder Trials.

5.4.2 Organization of this standard. The individual test methods of this standard are divided into six sections as follows:

Section 100 - Ferrous magnetic field tests.
Section 200 - Eddy current magnetic field tests.
Section 300 - Stray magnetic field tests.
Section 400 - Electrical conductivity tests.
Section 500 - Magnetic permeability tests.
Section 600 - Final magnetic signature tests.

SUMMARY OF MAGNETIC FIELD DATA

TEST NUMBER _______ DATE _______

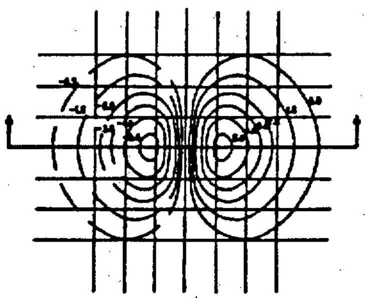
TEST ITEM ______________________________________
____
____

FERROUS ________ STRAY _______ EDDY CURRENT _______

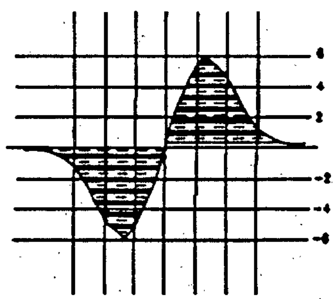
PEAK VERTICAL MAGNETIC FIELD ___________ nT
LOCATION: X = ___ Y = ___ Z = ___

PEAK HORIZONTAL (X) MAGNETIC FIELD ___________ nT
LOCATION: X = ___ Y = ___ Z = ___

PEAK HORIZONTAL (Y) MAGNETIC FIELD ___________ nT
LOCATION: X = ___ Y = ___ Z = ___



VERTICAL



VERTICAL

SECTION A–A

FIGURE 1. Example of magnetic field data summary.

6. NOTES (This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.

6.1 Intended use. This standard is to be used to ensure that the magnetic characteristics of materials and equipment are in accordance with the individual material or equipment specification, the contract or purchase order, or DOD-STD-2143.

6.2 Issue of DODISS. When this standard is used in acquisition the applicable issue of the DODISS must be cited in the solicitation (see 2.1.1 and 2.2).

6.3 Data requirements. The following Data Item Descriptions (DID's) must be listed, as applicable, on the Contract Data Requirements List (DD Form 1423) when this standard is applied on a contract, in order to obtain the data, except where DoD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1423.

Reference Paragraph	DID Number	DID Title	Suggested Tailoring
5.1 and Appendix B	DI-MISC-80653	Test report	- - - - -
Test Method 101	DI-MISC-80653	Test report	- - - - -
Test Method 102	DI-MISC-80653	Test report	- - - - -
Test Method 103	DI-MISC-80653	Test report	- - - - -
Test Method 104	DI-MISC-80653	Test report	- - - - -
Test Method 105	DI-MISC-80653	Test report	- - - - -
Test Method 106	DI-MISC-80653	Test report	- - - - -
Test Method 201	DI-MISC-80653	Test report	- - - - -
Test Method 202	DI-MISC-80653	Test report	- - - - -
Test Method 203	DI-MISC-80653	Test report	- - - - -
Test Method 301	DI-MISC-80653	Test report	- - - - -
Test Method 302	DI-MISC-80653	Test report	- - - - -
Test Method 401	DI-MISC-80653	Test report	- - - - -
Test Method 402	DI-MISC-80653	Test report	- - - - -
Test Method 501	DI-MISC-80653	Test report	- - - - -
Test Method 502	DI-MISC-80653	Test report	- - - - -
Test Method 503	DI-MISC-80653	Test report	- - - - -
Test Method 504	DI-MISC-80653	Test report	- - - - -
Test Method 505	DI-MISC-80653	Test report	- - - - -
Test Method 601	DI-MISC-80653	Test report	- - - - -
Test Method 602	DI-MISC-80653	Test report	- - - - -
Test Method 603	DI-MISC-80653	Test report	- - - - -
Test Method 604	DI-MISC-80653	Test report	- - - - -
Test Method 605	DI-MISC-80653	Test report	- - - - -

The above DID's were those cleared as of the date of this standard. The current issue of DoD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be researched to ensure that only current, cleared DID's are cited on the DD Form 1423.

6.4 Index of test methods. Table I is an index of test methods by method number, superseded method number and title.

TABLE I. Index of test methods.

Test method number	Superseded test method number	Title
101	FF01	Ferrous magnetic field from class 1 source measured at a distance in an ambient magnetic environment.
102	FF02	Ferrous magnetic field from class 1 source measured at a distance in a controlled magnetic environment.
103	FF03	Ferrous magnetic field from class 1 source measured on a horizontal plane in an ambient magnetic environment.
104	FF04	Ferrous magnetic field from a class 1 source measured on a horizontal plane in a controlled magnetic environment.
105	FF05	Ferrous magnetic field from a class 1 source measured by ranging an ambient magnetic environment.
106	---	Ferrous magnetic field from a diesel engine on a horizontal plane in a controlled magnetic environment.
201	EF01	Eddy current magnetic field from a class 2 source measured at a distance in a controlled magnetic environment.

TABLE I. Index of test methods - Continued.

Test method number	Superseded test method number	Title
202	EF02	Eddy current magnetic field from a class 2 source measured on a horizontal plane in a controlled magnetic environment.
203	EF03	Eddy current magnetic field from a class 2 source caused by oscillatory motion in an ambient magnetic field.
301	SF01	Stray magnetic field from a class 3 source measured at a distance in an ambient magnetic environment.
302	SF02	Stray magnetic field from a class 3 source measured on a horizontal plane in an ambient magnetic environment.
401	C01	Percent IACS electrical conductivity by electrical resistivity measurement.
402	C02	Percent IACS electrical conductivity by eddy current measurement.
501	P01	Relative magnetic permeability with go-no-go permeability indicator.
502	P02	Relative magnetic permeability using a modified Fahy low-mu permeameter.
503	P03	Relative magnetic permeability using a Fahy low-mu permeameter.

TABLE I. Index of test methods - Continued.

Test method number	Superseded test method number	Title
504	P04	Relative magnetic permeability by null method.
505	P05	Relative reversible magnetic permeability.
601	---	Initial magnetic calibration.
602	---	Ship service (added service) stray magnetic field test.
603	---	Minesweep generator stray magnetic field test.
604	---	Static electromagnetic roll test.
605	---	Dynamic electromagnetic roll test.

6.5 Subject term (key word) listing.
Conductivity
Eddy current magnetic field
Ferrous magnetic field
Magnetic
Nonmagnetic
Permeability
Stray magnetic field
Testing, magnetic

6.6 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Preparing activity:
Navy - SH
(Project 1905-N018)

APPENDIX A

DESCRIPTION OF MAGNETIC TEST FACILITIES

10. GENERAL

10.1 Scope. This appendix describes the capabilities of three magnetic test facilities. These descriptions are for information only, and in no way obligate the test facilities to perform the tests specified in this standard. The tests specified in this standard may be performed at any magnetic test site that meets the requirements of this standard.

20. APPLICABLE DOCUMENTS

Not applicable.

30. DEFINITIONS

Not applicable.

40. GENERAL REQUIREMENTS

Not applicable.

50. DETAILED REQUIREMENTS

50.1 David Taylor Research Center (DTRC). The Magnetic Fields Laboratory at DTRC, located in Annapolis, Maryland, consists of two buildings: the Test Building and the Instrumentation and Control Building.

50.1.1 Test items. The Magnetic Fields Laboratory at DTRC is capable of measuring the magnetic silencing characteristics of material and equipment, subject to the limitations of 50.1.1.1.

50.1.1.1 Limitations on items under test. Items under test are installed on a nonmagnetic flatbed cart that is approximately 3 meters wide and 4.25 meters long. The cart moves in and out of the Test Building on aluminum "railroad" tracks. When the test item is mounted on the cart, the Test Building can accommodate test items weighing up to 36.29 metric tons. The physical dimensions of the test item are limited by the door opening, which is 3.65 meters wide by 3.04 meter high. Since the top of the cart is 0.66 meters above the main test floor, the height of the test item is limited to 2.38 meters. Diesel engines or gas turbines can be run individually while in the test building.

50.1.2 Test Building. The Test Building is the building in which the item under test is placed. It is constructed entirely of nonmagnetic materials, has four floors, and measures approximately 12.5 meters wide, 15.25 meters deep, and 15.25 meters high. The building was designed so that a large, heavy item could be installed on the top floor, and magnetic field measurements could be made on the three lower floors.

50.1.2.1 Magnetometer probes. The magnetometer probes are mounted on each of the three floors beneath the main test floor. These probes sense only the vertical component of magnetic field, and are connected by cables to the magnetometers located in the Instrumentation and Control Building.

50.1.2.2 Test coils. The test coils are installed on the walls of the Test Building. The coils can generate a magnetic field in the three orthogonal directions over a range of plus or minus 60 microteslas (μT). At the center of the coil system, the magnetic fields are uniform to 0.4 percent over a volume of 6 cubic meters (m^3). The coils are driven by three power supplies located in the Instrumentation and Control Building. Compensation signals are obtained from the power supplies to null out the coil fields at each probe.

50.1.3 Instrumentation and Control Building. The Instrumentation and Control Building contains the eleven magnetometers to which the probes in the test building are sequentially switched. The magnetometers measure the vertical component of magnetic field over a range of plus or minus 100 μT. Each magnetometer has ten ranges; the least sensitive is 100 μT full scale, and the most sensitive is 0.10 μT full scale. Magnetic field data are accurate to plus or minus 2 percent of full scale. A twelfth magnetometer monitors the earth's field variations at a point about 9 meters from the test building. Its function is to furnish appropriate compensation signals to the other magnetometers so that ambient field fluctuations do not produce errors in the data.

50.1.4 Other equipment. Three "quad" cables connect the two buildings and can carry up to a total of 2800 amperes steady-state or 5000 amperes intermittently in either direction between the buildings. A 250 volt direct current (dc) motor starter/controller is available to operate motors up to 261 kilowatts (kW). Motor loading is accomplished with a nonmagnetic water brake dynamometer rated for 373 kW at 1800 revolutions per minute. The nonmagnetic coupling between the motor and dynamometer, however, is rated at 261 kW. Various electrical services are also available for energizing items under test. They are 0 to 28 volts, 2000 amperes dc; 0 to 120 volts, 200 amperes dc; 115 volts, single phase, 60 hertz (Hz); 440 volts, three phase, 60 Hz; and 120 volts, three phase, 400 Hz, 2 kW. A resistive load bank, as well as three water rheostats, are available for loading dc generators. The load bank has selectable resistors that can furnish the following maximum dc loads: 350 volts, 5000 amperes; 240 volts, 5000 amperes; and 240 volts, 2800 amperes. Each of the three water rheostats can furnish a load up to 350 volts, 900 amperes dc. The three rheostats can also be connected in parallel.

50.2 Goddard Space Flight Center (GSFC). The Spacecraft Magnetic Test Facility at GSFC, located in Greenbelt, Maryland, consists of four buildings. They are the Coil System Building, the Magnetometer Building, the Servo Control Building, and the Operations and Instrumentation Building.

50.2.1 Test items. The Spacecraft Magnetic Test Facility at GSFC is capable of measuring the magnetic silencing characteristics of materials and equipment, subject to the limitations of 50.2.1.1.

50.2.1.1 Limitations on items under test. The item under test is mounted on a nonmagnetic dolly that measures 1.97 meters long, 1.50 meters wide, and 0.51 meters high. The dolly rolls on aluminum track which extends from the truck lock through the center of the coil system to the opposite wall of the building. Mounted on top of the dolly is a 1.21 meter diameter turntable to permit rotation of the test object about the vertical axis. The dolly and turntable are capable of handling items weighing up to 2.27 metric tons. The physical dimensions of the test item are limited to the size of the coil access opening, which measures 3.04 meters wide by 3.04 meters high. Since the dolly and turntable are 0.51 meter high, the height of the test item to be mounted on the turntable is limited to 2.53 meters. Because of the clean room environment, test items such as diesel engines and gas turbines cannot be operated inside the coil system building.

50.2.2 Coil system building. The coil system building is the building in which the item under test is placed. It measures 18.9 meters wide, 18.9 meters deep, and 17.1 meters high, including a 5.2 meter deep basement. The building also has a 6.4 meter wide by 9.8 meter deep by 6.1 meter high truck lock attached to the south side. The ambient temperature and humidity inside the building are controlled using underground ducted air and liquid cooling lines connected to the operations and instrumentation building. The central test area of the coils can be maintained at a class 10,000 cleanliness level, and the remaining areas of the coil system building can be maintained at a class 100,000 cleanliness level, if strict control procedures are implemented.

50.2.2.1 Magnetometer probes. Two track-mounted dollies with magnetometer mounting masts are installed in the coil system building. The height of the magnetometers is adjustable from 0 to 3.05 meters above the floor. These dollies travel on tracks mounted 90 degrees apart (North - South and East - West) in the floor. A third dolly is mounted on an overhead track system which follows the North - South centerline of the coil system. A 5.49 meter mast is suspended from this dolly to provide support for a magnetometer with an adjustment range of 0 to 5.49 meters above the coil. Two additional dollies are joined together to create one fixed-height horizontal North - South magnetometer mounting boom. With this fixture it is possible to position the probes at selected distances from the center of the coils to obtain interrelated near and far field data.

50.2.2.2 Test coils. The test coil system uses a three-axis Braunbek configuration. The system has two modes of operation. In the static mode, the system can produce fields varying from 0 to plus or minus 60 μT and adjustable to plus or minus 0.1 nT. In the dynamic mode, the resultant field vector, selectable in magnitude from 0 to 60 μT, can be caused to either oscillate or rotate about the coil center at angular velocities up to 100 radians per second. The coil system also has five coils for gradient cancellation. In addition to the coil system, the facility at GSFC also has a 2.9 meter pair of circular perming/deperming coils, controlled from the operations and instrumentation building. The facility also has two smaller Helmholtz coils, one 1.52 meters in diameter and one 1.22 meters in diameter, that are powered by portable perm/deperm consoles.

50.2.3 Operations and instrumentation building. The operations and instrumentation building contains the power supplies, operator's console, and equipment racks for the facility.

50.2.3.1 Magnetometers. The magnetic test facility uses three different types of magnetometers. The proton magnetometer is used as a reference standard and for calibration. It has a range from 20 to 90 μT, with an accuracy of plus or minus 1 nT. The triaxial fluxgate magnetometers, the magnetometers used as test instruments, have a range of 0 to 100 μT, with an accuracy of plus or minus 1 percent. The single axis magnetometer, used as a zero and gradient field sensor, has a range from 0 to 100 μT, with an accuracy of plus or minus 0.2 nT.

50.2.4 Magnetometer building. The magnetometer building serves as a shelter for the sensor of the single-axis magnetometer.

50.2.5 Servo control building. The servo control building contains the machinery used to turn the dolly and turntable during magnetic testing.

50.2.6 Other equipment. The magnetic test facility also has a Mark VI torsionmeter, used for measuring static and magnetic torques. It has a plus or minus 1 X 10^6 Newton-meter resolution and can support 3558 Newtons.

50.3 Naval Surface Warfare Center, White Oak (NSWC). NSWC, located in White Oak, Silver Spring, Maryland, has two different magnetic test facilities. They are the Magnetic Ship Models Facility and the Magnetic Structures Test Facility.

50.3.1 Magnetic Ship Models Facility. The Magnetic Ship Models Facility is used to measure the magnetic signature of ship models. The facility can also assess the impact of the ship's degaussing system on the magnetic signature. For those ships which require deperming, the Magnetic Ship Models Facility can be used to determine the proper deperming cycle.

50.3.1.1 Test items. The Magnetic Ship Models Facility at NSWC is capable of measuring the magnetic silencing characteristics of magnetic ship models, subject to the limitations of 50.3.1.1.1.

50.3.1.1.1 Limitations on items under test. The magnetic ship models must be large enough to accurately represent the magnetic characteristics of the ship, but small enough to be easily handled by the model range. Typically, magnetic models are between 1 and 4 meters long.

50.3.1.2 Coil system. The coil system of the Magnetic Ship Models Facility consists of three mutually perpendicular sets of coils measuring approximately 11 meters by 9 meters by 9 meters. This system can simulate the geomagnetic conditions for any cruising location. The coil system has a feedback circuit to compensate for any variations in the local ambient magnetic field. The coil system is capable of generating magnetic fields from 0 to plus or minus 60 μT in any direction. These fields can be held constant to within approximately 1 nT. The magnetic field generated by the coil system is uniform over an area approximately 3.66 meters by 0.91 meters by 0.91 meters. In this region, the field varies in magnitude by less than plus or minus 0.07 percent.

50.3.1.3 Model range. The model range consists of a model carriage, the overhead track for the carriage, and an athwartship array of magnetometers' sensors. Cruising conditions are simulated by moving the model down the range in a background magnetic field representing the ambient magnetic field that would be encountered at the cruising latitude and heading used for the test. The sensor array is repeatedly scanned as the model moves continuously down the range. Each scan sequence is initiated at a specific position of the model relative to the sensor array. This process generates a data matrix representing the magnetic field on a horizontal plane at a specific distance below the model.

50.3.1.4 Magnetizing and demagnetizing system. The magnetizing and demagnetizing system provides a means of either removing the permanent magnetization from a model or magnetizing a model to simulate prolonged cruises at specific locations and headings. This is accomplished in one of two ways; either by using an ac sine wave field or a dc pulse field. The ac field has a frequency of 60 Hz and an amplitude which cycles from 0 to 5000 μT and back to zero over a period of approximately 1 minute. The dc pulses are about 5 seconds in duration and decrease from their maximum amplitude (up to 5000 μT) to zero over a period of 15 to 20 minutes. The magnetizing and demagnetizing coil has a magnetic axis along the longitudinal axis of the model.

50.3.1.5 Degaussing current distribution system. The degaussing current distribution system can provide up to 40 individual degaussing currents to the model's degaussing coils, even while the model is moving down the range. Current controls are available to provide individual adjustments of the coil currents. A Matrix plug-in board allows a variety of interconnections between the current controls and the model's degaussing coils.

50.3.1.6 Magnetometers. The magnetometers used in the Magnetic Ship Models Facility are the fluxgate type, with an accuracy of plus or minus 1 percent or plus or minus 1 nT, whichever is greater. They are calibrated before each series of measurements by generating a known change in the ambient field and adjusting each magnetometer output to directly read the change.

50.3.2 Magnetic Structures Test Facility. The Magnetic Structures Test Facility at NSWC is similar to, but slightly smaller than the Magnetic Ship Model Range. It is used to measure the magnetic field at various positions around a test sample.

50.3.2.1 Test items. The Magnetic Structures Test Facility at NSWC is capable of measuring the magnetic silencing characteristics of materials and equipment, subject to the limitations of 50.3.2.1.1.

50.3.2.1.1 Limitations on items under test. The item under test is placed on a concrete monolith even with the floor level at the center of the coil system. A turntable is available to allow the test item to be rotated in the coil's field. The length and width of the test item are limited by the dimensions of the monolith, 2.4 meters by 1.8 meters. The height of the test item is limited by the access opening of the coil system. By tilting a portion of the Z coil, an opening 2.4 meters wide by 3.66 meters high is available. Equipment under test cannot be operated while inside the coil system.

50.3.2.2 Coil system. The coil system of the Magnetic Structures Test Facility consists of three sets of orthogonal coils forming a cube that measures 7.3 meters on a side. The coil system is capable of generating magnetic fields ranging in magnitude from 0 to 100 μT. The fields generated by the coil system are uniform to within 0.05 percent over a spherical region 2.5 meters in diameter about the center of the coil system.

50.3.2.3 Magnetometer. The magnetometer used by the Magnetic Structures Test Facililty is a single-axis type, with an accuracy of plus or minus 1 percent or plus or minus 1 nT, whichever is greater. The magnetometer is mounted on a gimbal fixture, allowing it to record the magnetic field at various points around the test sample. If the turntable is used, the combination of it and the gimbal fixture allow the magnetometer to record the magnetic field at any point a specific distance from the center of the test item.

50.3.2.4 Other equipment. The data acquisition system at the facility combines the output of the magnetometer with the output of a turntable position indicator, converts the analog data to digital form, and stores it on a minicomputer magnetic disk. The computer system is capable of performing a spherical harmonic analysis on the test data to calculate the magnetic dipole moment of the test item.

APPENDIX B

Test Reports Technical Content Requirements

10. SCOPE

10.1 Scope. This appendix covers the technical requirements that should be included in test reports when required by the contract or order. This appendix is mandatory only when data item description DI-MISC-80653 is cited on the DD form 1423.

20. APPLICABLE DOCUMENTS

20.1 Government documents.

20.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issue of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation (see 6.2).

STANDARD

DOD-STD-2143 - Magnetic Silencing Requirements for the Construction of Nonmagnetic Ships and Craft (Metric).

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Document Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

30. TEST REPORTS

30.1 Test Reports. When required by the contract or order, test reports shall contain the following information:

(a) Test procedure. When required, a test procedure shall be prepared in accordance with the following (see 6.3):

(1) Section 100 tests - Ferrous source inspection plan.
(2) Section 200 tests - Eddy current source inspection plan.
(3) Section 300 tests - Test procedures.
(4) Section 400 tests - Test procedures.
(5) Section 500 tests - Test procedures.
(6) Section 600 tests - Magnetic signature test plan.

The test procedure shall detail the means of implementation and application of the test methods to be performed to verify compliance with the applicable magnetic requirements of the individual material or equipment specification, the contract or purchase order, or the requirements of DOD-STD-2143. Approval of the test procedure by the contracting activity shall precede the start of formal testing. The test procedure shall include but need not be limited to the following:

(1) Nomenclature, serial numbers and general characteristics of test equipment (for example, sensitivity and dynamic range of magnetometers).
(2) Methods and dates of last calibration of measuring equipment for magnetic characteristics and calculations to show expected accuracy of each.
(3) Dummy loads for test samples (for section 300 test methods) and similar items to be used and their description.
(4) Readout and detector functions to be used in measuring equipment, where applicable.
(5) Nomenclature, description, and modes of operation of the test sample (if applicable).
(6) Control settings, monitored points and sequence of operation of the test sample (if applicable).
(7) Description and magnetic ambient profile of the test site (open space) for sections 100, 200, and 300 test methods.
(8) Detailed step-by-step test procedures and test setups, with maximum use of photographs, drawings, and diagrams.
(9) Expected overall accuracy of measurements.
(10) Personnel required, both designated Government representatives and contractor representatives.
(11) Considerations and regulations regarding the operation of test samples during test (if applicable) and measuring equipment in open areas (for example, FCC or FAA regulations).

(b) Test report. When required, test reports which details the testing procedures, facilities, instrumentation, and data recorded, shall be prepared in accordance with the following (see 6.3):

(1) Section 100 tests - Ferrous source inspection report.
(2) Section 200 tests - Eddy current source inspection report.
(3) Section 300 tests - Test report.
(4) Section 400 tests - Test report.
(5) Section 500 tests - Test report.
(6) Section 600 tests - Magnetic signature test report.

The test report shall be prepared immediately after the performance of the tests. A reproducible copy of the test procedures may be used as a test data log for recording test data taken during performance of the tests. The data shall be entered in the test report from the test data log. Data shall not be transferred from other copies or records, refined, edited, or typed. After the tests are completed, the test report shall be completed by incorporating a test summary, all appendices, and certifications in accordance with the following. The test sample or test specimen shall not be accepted until the final test report is reviewed by the contracting activity.

(c) Classification markings. Security classification markings shall be provided in accordance with the requirements of the contracting activity.

(d) Content.

(e) Title page. The title page shall include a complete identification of the equipment or material used as the test sample or test specimen, including, as applicable, part numbers, serial numbers, name of manufacturer, name of prime contractor, Government acquisition agency, contract number and date.

(f) Results of tests; summations and analyses. The report shall include a summary, which shall give a brief resume of the test results. The summary shall include the results of the test in tabular form and, for magnetic field tests, in graphic (contour map) form. An example of a summary of results is shown on Figure 1. The resume shall contain a statement certifying that the equipment used as the test sample or test specimen meets or does not meet the requirements of the applicable equipment or material specification, the contract or purchase order, or DOD-STD-2143, and that tests were conducted in accordance with accepted test procedures. If the equipment or material fails, the resume shall contain a list of all points where the test sample or test specimen does not meet the requirements of the applicable equipment or material specification, the contract or purchase order, or DOD-STD-2143. Any adjustments, repairs, fuse replacements, failures, or unusual phenomena encountered during the test shall also be described, or a positive statement, to the effect that no adjustments, fuse blowing, or for the signatures of the test engineer, equipment or material manufacturer, prime contractor and Defense Contract Administration Services Officer (DCASO) to certify the content of the summary.

(g) Main body of report. The main body of the report shall present the details of what was tested, how it was tested, what results were obtained, and what results should have been obtained, but were not. This information shall be recorded in a manner such that information can be reviewed without searching through the report to correlate data with procedures. The main body of the report shall include the information specified in the applicable individual test method in addition to the following information:

(1) Nomenclature of measuring equipment.
(2) Serial numbers of measuring equipment.
(3) Date of last calibration of measuring equipment.
(4) Descriptions of procedures used including methods of loading and operating and control settings for test sample, as applicable).
(5) Measured line voltage to test sample for section 300 test methods.
(6) Photographs or diagrams of the test setup and test specimen or test sample with identification.
(7) Photographs or diagrams of the test setup and test specimen or test sample with identification.
(8) Description and size of test facilities.

(9) Ambient magnetic profile of test site and ambient levels with each detector function energized (for sections 100, 200, and 300 only).
(10) Methods and criteria for monitoring for degradation of performance of test samples for section 300 test methods.
(11) Explanation of special terms and abbreviations used in the report.
(12) Settings of control functions for test samples during the tests for section 300 test methods.

(a) Appendices. Appendices shall be included as required to incorporate data which are of a form and content not feasible to include in the body of the report. (Oscillograms are examples of data which are not feasible to include in the body of the report.) Appendices shall also be used to incorporate test reports submitted by other testing activities that perform some of the tests. Each appendix shall be preceded by a title page indicating content (including number of pages) of the appendix and applicable references to the body of the report.

30.2 Test method test reports. When required by the contract or order test method test reports shall contain the following information for each test method.

(a) Test method 101 test report. This test report shall include the following information:

(1) Identification of the test sample.
(2) Identification of the magnetometer used, including manufacturer's number and identification number.
(3) Identification of the gimbal fixture and mounting structure of the test sample.
(4) The value of the earth's magnetic field, measured with the gimbal fixture and mounting structure in place at each of the 26 measurement points prior to the test (Bal(i)).
(5) Position of the test sample with respect to the gimbal structure and magnetic north-south and east-west.
(6) The value of the magnetic field (Bp(i)) of the test sample on the mounting structure within the gimbal fixture measured at each of the 26 measurement points.
(7) The value of the earth's magnetic field, measured with the gimbal fixture and mounting structure in place, at each of the 26 measurement points after the test sample has been removed (Ba(i)).
(8) The difference between the value of the earth's magnetic field measured before testing and the value of the earth's magnetic field measured after the test sample has been removed.
(9) The calculated value of the ferrous magnetic field emanating from the test sample (Bt) at each measurement point.

(10) Magnitude and location of the maximum value of the ferrous magnetic field emanating from the test sample (maximum Ba).

(b) Test method 102 test report. This test report shall include the following information:

(1) Identification of the test sample.
(2) Identification of the test coil system used, including manufacturer's number and identification number.
(3) Identification of the gimbal fixture and mounting structure for the test sample.
(4) Position of the test sample with respect to the test coil.
(5) The value of induced plus permanent magnetic field measured at each of the 26 measurement points with the test sample present within the measurement points with the test sample present within the test coil for each ambient magnetic field specified.
(6) The value of permanent magnetic field measured at each of the 26 measurement points with the test sample present within the test coil for each ambient magnetic field specified.
(7) The calculated induced ferrous magnetic field emanating from the test sample at each of the 26 measurement points for each ambient magnetic field specified.
(8) Magnitude and location of the maximum value of the induced plus permanent, permanent only, and induced only ferrous magnetic field emanating from the test sample for each ambient magnetic field specified.

(c) Test method 103 test report. This test report shall include the following information:

(1) Identification of the test sample.
(2) Identification of the magnetometers used, including manufacturers' number and identification number.
(3) Identification of the mounting frame for the array of the magnetometers' sensors and the mounting structure for the test sample.
(4) The position of and the magnetic field measured by each sensor with the mounting frame for the array of magnetometer's sensors and the mounting frame for the test sample in place prior to testing.
(5) Position of the test sample with respect to the mounting frame for the array of magnetometers' sensors and magnetic north-south and magnetic east-west.
(6) The position of and the magnetic field measured by each sensor with the test sample present.
(7) The position of and the magnetic field measured by each sensor with the test sample removed.

(8) The calculated value of the vertical component of the ferrous magnetic field emanating from the test sample at each measurement position.
(9) Magnitude and location of the maximum value of ferrous magnetic field emanating from the test sample.

(d) Test method 104 test report. This test report shall include the following information:

(1) Identification of the test sample.
(2) Identification of the magnetometers used, including manufacturer's number and identification number.
(3) Identification of the mounting frame for the array of magnetometer's sensors and the mounting structure for the test sample.
(4) Position of the test sample with respect to the test coil.
(5) The position of and the magnetic field (induced plus permanent) measured by each sensor with the test sample present within the test coil for each ambient magnetic field condition specified.
(6) The position of and the magnetic field (perm field) measured by each sensor with the test sample present in the test coil and the test coil set such that the ambient magnetic field equals zero.
(7) The calculated vertical component of the ferrous magnetic field emanating from the test sample at each measurement position.
(8) Magnitude and location of the maximum value of the induced plus permanent, permanent only and reduced only ferrous magnetic field emanating from the test sample for each ambient magnetic field specified.

(e) Test method 105 test report. This test report shall include the following information:

(1) Identification of the test sample.
(2) Identification of the magnetometer used, including manufacturer's number and identification number.
(3) Identification of the track and cart used.
(4) The value of the earth's magnetic field measured prior to the test.
(5) The position of the test sample with respect to the cart.
(6) The magnetic field data output from the continuous recording equipment for each value of cart speed on each track.
(7) The maximum value of magnetic field measured by the continuous recording instrument for each cart speed on each track.
(8) The value of the earth's magnetic field with the test sample removed from the test site.

(f) Test method 106 test report. This test report shall include the following information:

(1) Identification of the engine under test, including manufacturer's number and identification number, when applicable.
(2) Identification of the magnetometers used, including manufacturer's number and identification number.
(3) Identification of the mounting frame for the array of magnetometers' sensors and the mounting structure for the engine.
(4) Position of the engine with respect to the test coil.
(5) For each set of magnetic field measurements taken:
    (1) Value of induced and induced plus perm magnetic field measured at each measurement point with the engine present.
    (2) Value of magnetic field measured at each measurement point with the engine removed.
    (3) Calculated induced value of the vertical component of ferrous magnetic field emanating from the engine at each measurement point.
    (4) Magnitude and location of the maximum induced plus perm, induced only and perm only value of the vertical component of the ferrous magnetic field emanating from the engine.

(g) Test method 201 test report. This test report shall include the following information.

(1) Identification of the test sample.
(2) Identification of the test coil system used, including manufacturer's number and identification number.
(3) Identification of the roll mounting fixture, gimbal fixture and mounting structure for the test sample.
(4) For each magnetic field measurement position:
    (1) Value of the air core magnetic field condition designator.
    (2) Value of the roll angle designator and rate of roll.
    (3) Value of the magnetic field measured with the test sample present within the test coil.
    (4) Value of the magnetic field measured with the test sample removed from within the test coil.
    (5) Calculated value of the eddy current magnetic field emanating from the test sample.
(5) Magnitude and location of the maximum calculated value of eddy current magnetic field emanating from the test sample.

(h) Test method 202 test report. This test report shall include the following information:

(1) Identification of the test sample.
(2) Identification of the magnetometers used, including manufacturer's number and identification number.
(3) Identification of the roll mounting fixture, mounting frame for the array of magnetometers' sensors and the mounting structure for the test sample.
(4) Position of the test sample with respect to the test coil at 0 degree roll angle.
(5) For each magnetic field measurement position:
    (1) Value of the air core magnetic field designator.
    (2) Value of roll angle designator and roll rate.
    (3) Value of the magnetic field measured with the test sample present within the test coil.
    (4) Value of the magnetic field measured with the test sample removed from within the test coil.
    (5) Calculated value of eddy current magnetic field emanating from the test sample.
(6) Magnitude and location of the maximum calculated value of eddy current magnetic field emanating from the test sample.

(i) Test method 203 test report. The test report shall include the following information:

(1) Identification of the test sample.
(2) Identification of the magnetometer used, including manufacturer's number and identification number.
(3) Identification of the pendulum support structure for the test sample.
(4) Value of the earth's magnetic field measured at the start of testing.
(5) Position of the test sample with respect to the pendulum support structure.
(6) Position of the test sample with respect to the pendulum support structure.
(7) For each test angle:
    (1) Maximum value of the eddy current magnetic field emanating from the test sample recorded by the continuous recording equipment.
    (2) Output of the continuous recording equipment for the duration of the test.
(8) Final value of the earth's magnetic field measured with the test sample removed at the conclusion of testing.

(j) Test method 301 test report. This test report shall include the following information:

(1) Identification of the test sample.
(2) Identification of the magnetometer used, including manufacturer's number and identification number.

(3) Identification of the gimbal fixture and mounting structure for the test sample.
(4) Identification of power supplies and loads used with the test sample.
(5) Position of the test sample with respect to the gimbal fixture.
(6) For each magnetic field measurement position:
    (1) Position of the magnetometers' sensor.
    (2) Measured value of magnetic field.
    (3) Operating conditions of the test sample.
(7) Magnitude and location of the maximum value of stray magnetic field emanated by the test sample, and the operating conditions under which it occurred.

(k) Test method 302 test report. This test report shall include the following information:

(1) Identification of the test sample.
(2) Identification of the magnetometers used, including manufacturer's number and identification number.
(3) Identification of the mounting frame for the sensor array and the mounting structure for the test sample.
(4) Identification of power supplies and loads used with the test sample.
(5) Position of the test sample with respect to the gimbal fixture.
(6) For each magnetic field measurement point:
    (1) Position of the magnetometers' sensor.
    (2) Measured value of magnetic field.
    (3) Operating conditions of the test sample.
(7) Magnitude and location of the maximum value of stray magnetic field emanating from the test sample, and the operating conditions under which it occurred.

(l) Test method 401 test report. This test report shall include the following information:

(1) Identification of test specimen.
(2) Kind of material.
(3) Test temperature.
(4) Test length of specimen.
(5) Method of obtaining cross-sectional area:
    (1) If by micrometer, the average values of micrometer readings.
    (2) If by weighing, a record of length, weight, any density determinations that may be made, and calculated cross-sectional areas.
(6) Weight, if used.
(7) Method of measuring resistance
(8) Value of resistance.

(9) Reference temperature.
(10) Calculated value of resistivity at the reference temperature.
(11) Calculated value of percent IACS conductivity at the reference temperature.
(12) Previous mechanical and thermal treatments of the material, if known.

(m) Test method 402 test report. This test report shall include the following information:

(1) Description of the test specimen.
(2) Test temperature.
(3) Thickness of test specimen.
(4) Location of test areas on test specimen.
(5) Identification of measuring instruments, including manufacturer's serial numbers.
(6) Warm-up adjustments of measuring instruments.
(7) Electrical conductivity and how it was obtained from the measurements (by calculation or directly; if by calculation, identify calculations).

(n) Test method 501 test report. This test report shall include the following information:

(1) Identification of the test specimen.
(2) Kind of material.
(3) Serial number of the permeability indicator.
(4) Relative magnetic permeability of the test specimen with respect to the relative magnetic permeabilities of the inserts used in the test procedure.

(o) Test method 502 test report. This test report shall include the following information:

(1) Description of the test specimen.
(2) Identification of the test apparatus used, including manufacturer's number and identification number, where appropriate.
(3) Calculated value of magnetic permeability and identification of the formulas used.

(p) Test method 503 test report. This test report shall include the following information:

(1) Description of the test specimen.
(2) Identification of the test specimen, including manufacturer's number and identification number, when appropriate.
(3) Calculated value of magnetic permeability and the identification of the formulas used.

(q) Test method 504 test report. This test report shall include the following information.

(1) Description of the test specimen.
(2) Identification of test apparatus, including manufacturer's number and identification numbers, where appropriate.
(3) Calculated value of magnetic permeability and identification of the formulas used.

(r) Test method 505 test report. This test report shall include the following information:

(1) Identification of the test specimen.
(2) Kind of material.
(3) Identification of test apparatus, including manufacturer's number and identification number, where appropriate.
(4) Calculated value of permeability with no test specimen in the sense coil.
(5) Calculated value of permeability with test specimen in the sense coil at selected frequencies of the ac power supply.

(s) Test method 601, 602, 603, 604 and 605 test report. The results of this test shall be included in the Magnetic Signature Test Report submitted at the conclusion of final magnetic signature testing.

SECTION 100 - FERROUS MAGNETIC FIELD TEST METHODS

TEST METHOD 101

FERROUS MAGNETIC FIELD FROM A CLASS 1 SOURCE
MEASURED AT A DISTANCE
IN AN AMBIENT MAGNETIC ENVIRONMENT

1. Scope. A ferrous field (class 1) source is an item on or part of a ship or craft, which uses a material in its construction that exhibits a relative magnetic permeability greater than 1.0 (the relative permeability of air). A ferrous field source emanates a ferrous magnetic field which is composed of an induced and permanent magnetic field. The ferrous magnetic field can be compensated for by a degaussing system if the magnitude and direction of the field are known. This test method is used to determine the magnitude of the vertical component of the ferrous magnetic field at a selected number of measurement points that are equidistant from the center of the test sample. This test is accomplished in an ambient (earth's) field environment. Consequently, if this test were conducted at another test site where the earth's magnetic field is significantly different, this method will lead to different test results than those achievable when conducted in a controlled magnetic environment (see test method 102). However, since a controlled magnetic environment requires a complicated test coil and control system, this method provides a rapid and convenient means for measuring the ferrous magnetic field at a fixed distance from the center of the test sample. The distance from the center of the test sample at which the ferrous magnetic field is to be measured is 2 meters unless specified differently in the test sample specifications.

2. Center of the test sample. Center of the test sample refers to the geometric center of the sample.

3. Apparatus.

3.1 Magnetometer. A monoaxial fluxgate magnetometer consisting of a sensor unit and an electronic unit with a minimum sensitivity of 0.25 nT and a dynamic range of plus or minus 113 μT shall be used. The electronic unit shall include as a minimum a meter to measure the field magnitude. A chart recorder may be used to facilitate data collection.

3.2 Gimbal fixture. A nonferrous gimbal fixture, with a circular ring, shall be used for the mounting of the magnetometer's sensor (see Figure 101-1). The ring shall have a radius equal to the distance from the center of the test sample at which the field is to be measured. The magnetometer's sensor shall be mounted on the ring in a manner that will allow sensing at the specified distance. The ring shall lie on a horizontal plane so that it is centered about the center of the test sample within plus or minus 10 centimeters (cm) and can be rotated in 45 degree increments in the plane of the ring and in the plane perpendicular to the plane of the ring (see Figures 101-1 and 101-2). Multiple magnetometers may be used to decrease the number of rotations required for a full set of readings.

3.3 Mounting structure. A nonferrous mounting structure shall be used for positioning the test sample within the gimbal fixture.

4. Test sample. Volume of the test sample is limited by the size of the gimbal fixture and access to the mounting structure within the fixture. Mass of the test sample is limited by the loading limitations of the mounting structure. The test sample shall be identical in composition to the item to be installed and shall be oriented with respect to the vertical component of the earth's magnetic field as it would be in the intended installation.

5. Procedure.

5.1 Prior to measuring the ferrous magnetic field of the test sample, measure the earth's magnetic field with the gimbal fixture and mounting structure in place as they would be for the ferrous field measurements. Start with position 1 (see Figure 101-2) for the magnetometer's sensor. Using the position designators shown on Figure 101-2, record these data and all subsequent data.

5.1.1 With the magnetometer's sensor in position 1, measure the field magnitude.

5.1.2 Rotate the ring of the gimbal fixture plus 45 degrees in the plane of the ring (position 2); measure and record the field magnitude.

5.1.3 Repeat 5.1.2 six times (positions 3 through 8).

5.1.4 Rotate the gimbal fixture plus 45 degrees in the plane of the fixture and then plus 45 degrees in the plane containing the magnetometer's sensor and the point on the fixture 180 degrees from the sensor.

5.1.5 Measure and record the field magnitude (position 9); repeat 5.1.2 and 5.1.3 with the exception that positions plus 90 degrees and plus 270 degrees are eliminated (positions 10 through 14).

5.1.6 Repeat 5.1.4 and 5.1.5 two times (positions 15 through 26).

5.2 Place the test sample on the mounting structure within the gimbal fixture and record the position of the test sample with respect to the gimbal fixture and magnetic north-south and east-west. Measure the ferrous magnetic field of the test sample at all test points by repeating 5.1.1 through 5.1.6.

5.3 Remove the test sample from within the gimbal fixture and remeasure the earth's magnetic field at all test points by repeating 5.1.1 through 5.1.6. If this final measurement of the earth's field at any point differs from the initial measurement at that point by more than 1 nT, the test results are not valid.

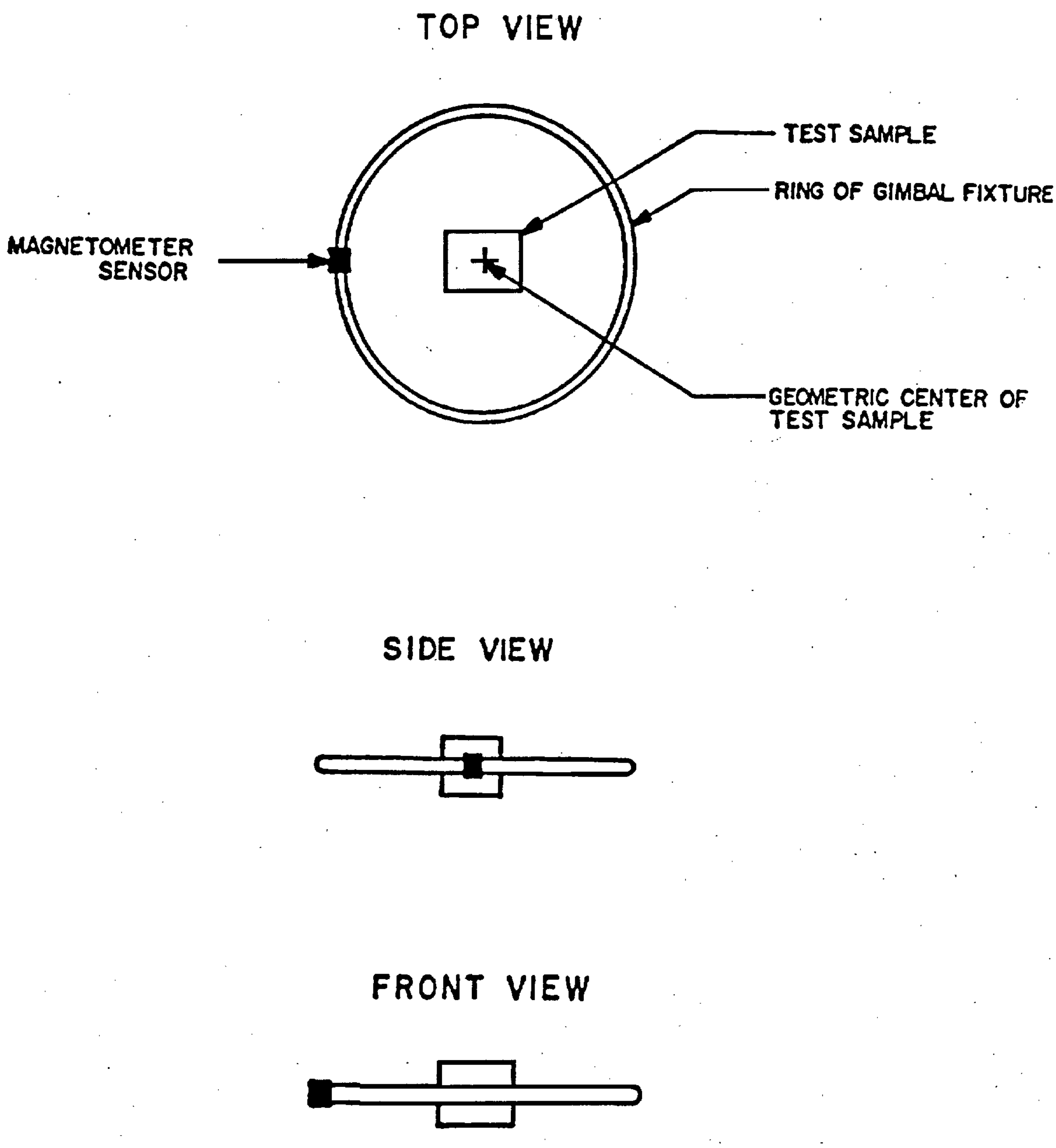


FIGURE 101-1. Configuration of ring for gimbal fixture.

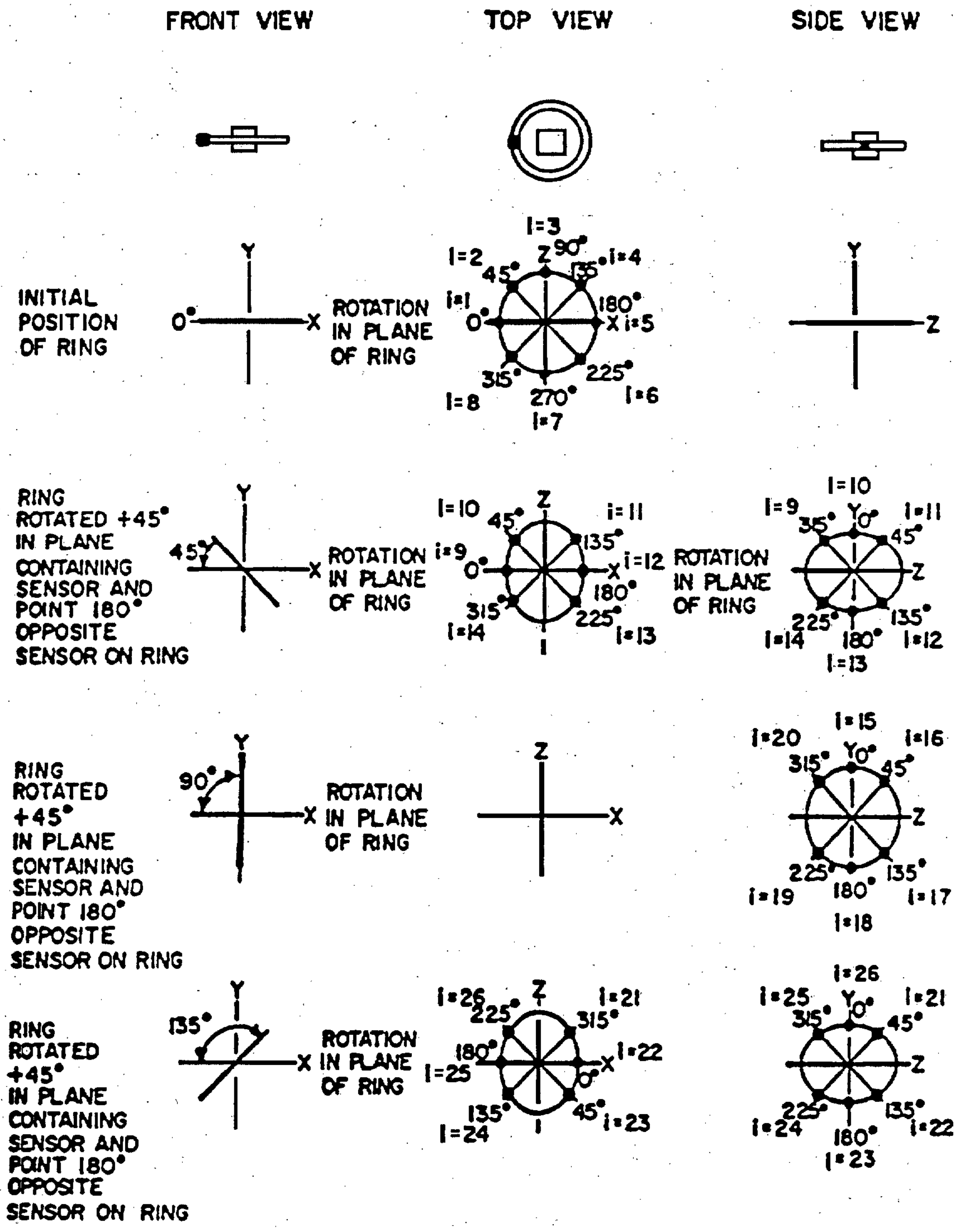


FIGURE 101-2. Magnetometer position designators (i).

6. Calculations. Calculate the difference between the magnetic field with the test sample present within the gimbal fixture and the test sample removed from within the gimbal fixture for each position measured as follows:

$$B_p(i) - B_a(i) = B_t(i);\ i = 1 \text{ to } 26$$

Where:

B_p = measured magnetic field with the test sample present within the gimbal fixture.

B_a = measured magnetic field with the test sample removed from within the gimbal fixture.

B_t = ferrous magnetic (induced plus permanent) field emanating from the test sample.

i = position designator of the magnetometer for each of the positions measured; i = 1 to 26.

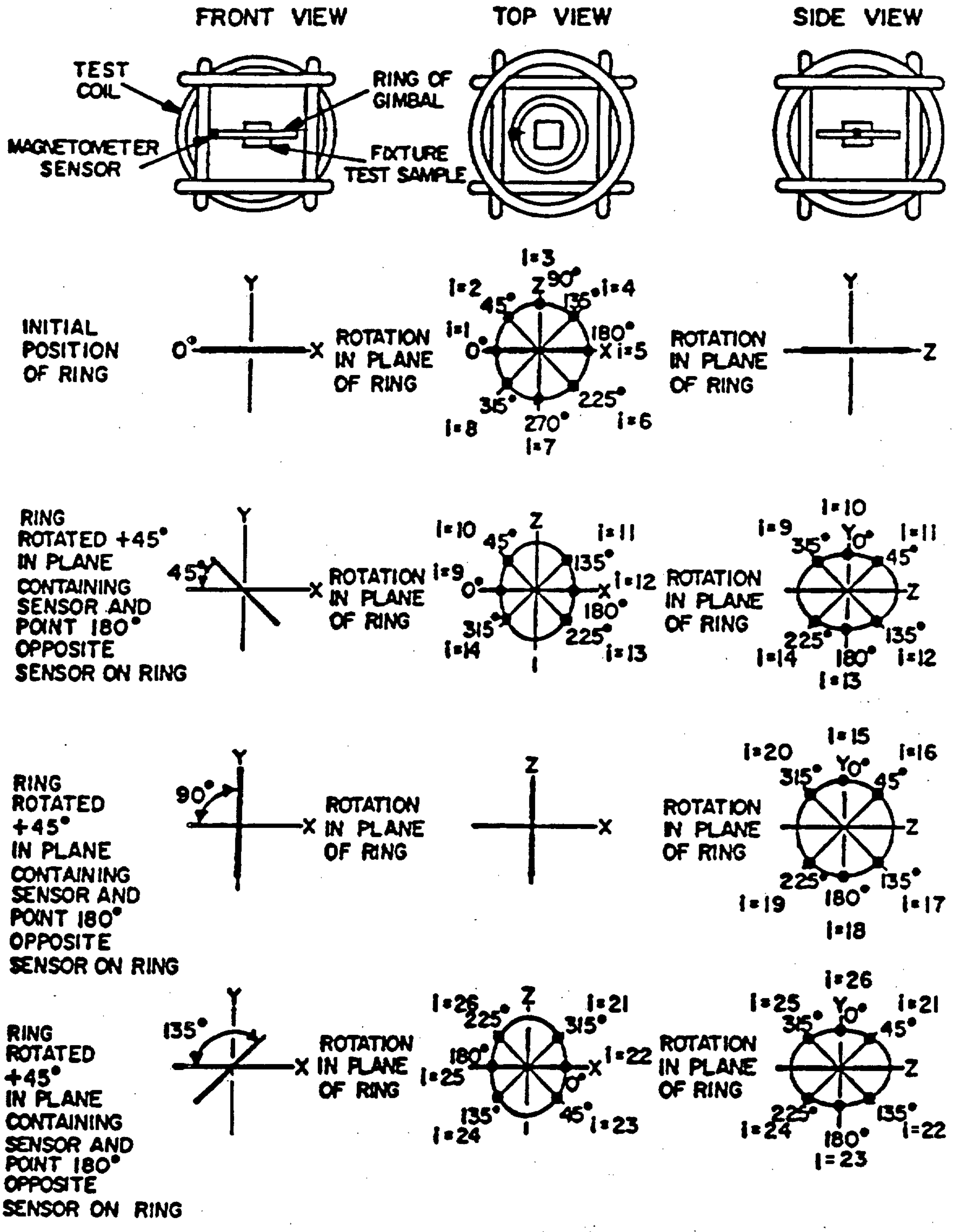


FIGURE 102-1. Magnetometer position designators (i).

TEST METHOD 103

FERROUS MAGNETIC FIELD FROM A CLASS 1 SOURCE MEASURED ON A HORIZONTAL PLANE IN AN AMBIENT MAGNETIC ENVIRONMENT

1. Scope. A ferrous field (class 1) source is an item on or part of a ship or craft, which uses a material in its construction that exhibits a relative magnetic permeability greater than 1.0 (the relative permeability of air). A ferrous field source emanates a ferrous magnetic field, which is composed of an induced and permanent magnetic field. The ferrous magnetic field can be compensated for by a degaussing system if the magnitude and direction of the field are known. In minesweeper applications, the vertical component of the ferrous magnetic field existing in a horizontal plane beneath the surface of the water is usually the most critical component of the ferrous magnetic field. This test method is used to determine the magnitude of the vertical component of the ferrous magnetic field in a horizontal plane that is a given distance below the center of the test sample. This test method, is accomplished in an ambient (earth's) field environment. Consequently, if this test were conducted at another test site where the earth's magnetic field is significantly different, this test method will lead to different test results than those achievable when conducted in a controlled magnetic environment (see test method 104). However, since a controlled magnetic environment requires a complicated test coil and control system, this method provides a rapid and convenient means for measuring the ferrous magnetic field on a horizontal plane at a distance below the center of the test sample. Sensors of the magnetometers may be buried in the earth, which could eliminate the need for special mounting of the test sample. The distance from the center of the test sample to the horizontal plane at which the ferrous magnetic field is to be measured is 7.5 meters unless specified differently in the test sample specification.

2. Center of the test sample. Center of the test sample refers to the geometric center of the sample.

3. Apparatus.

3.1 Magnetometers. Monoaxial fluxgate magnetometers consisting of a sensor unit and an electronic unit with a minimum sensitivity of 0.25 nT and a dynamic range of plus or minus 113 μT shall be used for the horizontal array of magnetometers. Each electronic unit shall include as a minimum a meter to measure the field magnitude, unless automatic data collection equipment is used. The sensors may be multiplexed into a limited number of electronic units which automatically record the field measured by each scanned sensor.

3.2 Mounting frame for the array of magnetometers' sensors. Unless the array of magnetometers' sensors are buried in the earth, a nonferrous, rectangular frame for the mounting of the sensors shall be provided (see Figure 103-1). Unless specified differently in the test sample specification, the sensors mounted on the frame shall be located on a horizontal plane 7.5 meters below the center of the test sample. One sensor shall be located directly below the center of the test sample (center sensor). The remainder of the sensors in the array shall be located at spacings equal to 0.25 of the vertical distance from the center sensor to the center of the test sample. The periphery of the array shall be no closer to the center sensor than one half the vertical distance from the center sensor to the center of the test sample. Each sensor shall be vertical within 0.5 degree.

3.3 Mounting structure. A nonferrous mounting structure shall be used for positioning the test sample with respect to the mounting frame, if required by the location of the magnetometer array.

4. Test sample. Length and width of the test sample are limited by the dimensions of the array of sensors. Mass of the test sample is limited by the loading limitation imposed by the surface on which the sample is located. The test sample shall be identical in composition to the item to be installed and shall be oriented with respect to the vertical component of the earth's magnetic field as it would be in the intended installation.

5. Procedure.

5.1 Prior to measuring the ferrous magnetic field of the test sample, measure the earth's magnetic field with the mounting frame for the array of magnetometer's sensors and mounting structure for the test sample in place as they would be for the ferrous field measurements.

5.1.1 Record the position of and the magnetic field measured by each sensor.

5.2 Place the test sample in position and record the position of the test sample with respect to the mounting frame for the array of magnetometers' sensors and magnetic north-south and east-west.

5.3 Record the position of and the magnetic field measured by each sensor.

5.4 Remove the test sample from the test setup and remeasure the earth's magnetic field at all test points by repeating 5.1.1. If this final measurement of the earth's field at any point differs from the initial measurement by more than 1 nT, the test results are not valid.

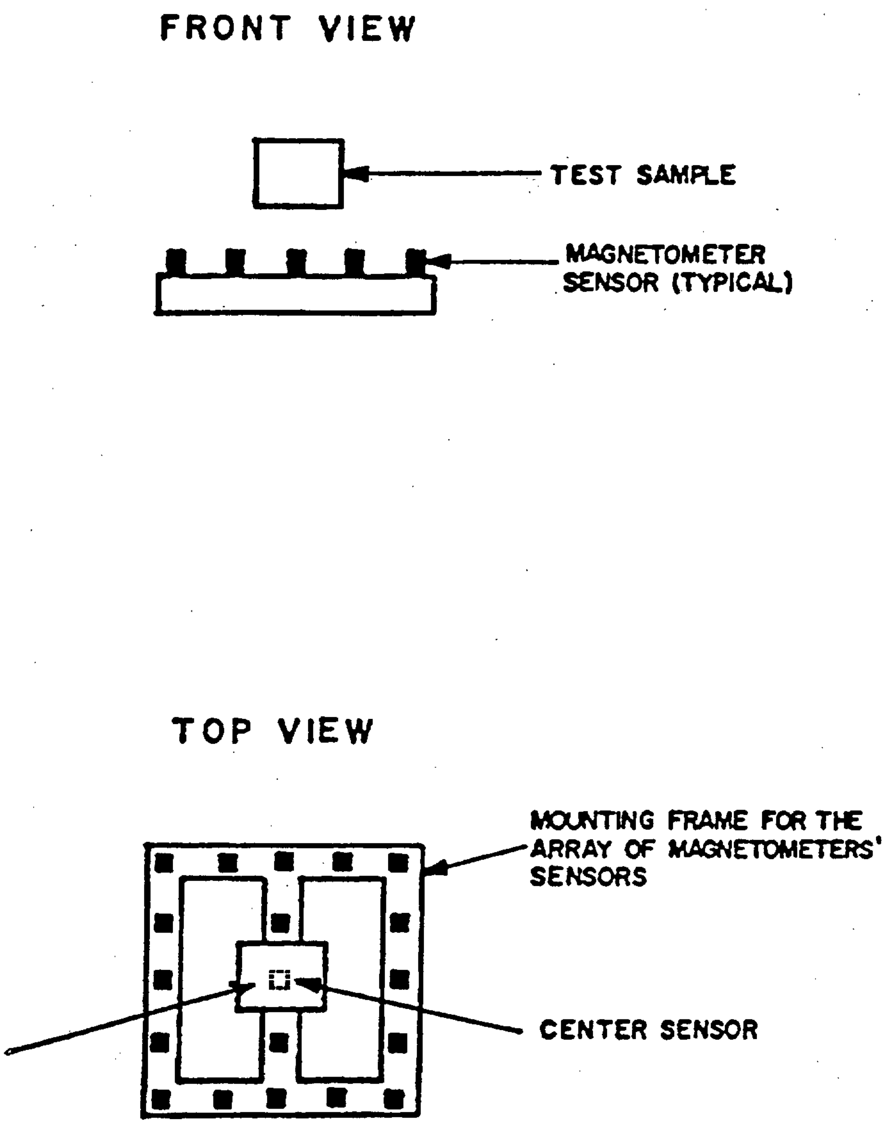


FIGURE 103-1. Configuration of magnetometers' sensors.

6. Calculations. Calculate the difference between the vertical component of the magnetic field with the test sample present and the test sample removed for each position measured as follows:

$$B_p(i) - B_a(i) - B_v(i); \; i = 1 \text{ to } n$$

Where:

B_p = measured magnetic field with the test sample present.

B_a = measured magnetic field with the test sample removed.

B_v = ferrous magnetic field emanating from the test sample.

i = position designator of the magnetometer for each of the positions measured; i = 1 to n.

TEST METHOD 104

FERROUS MAGNETIC FIELD FROM A CLASS 1 SOURCE MEASURED ON A HORIZONTAL PLANE IN A CONTROLLED MAGNETIC ENVIRONMENT

1. Scope. A ferrous field (class 1) source is an item on or part of a ship or craft, which uses a material in its construction that exhibits a relative magnetic permeability greater than 1.0 (the relative permeability of air). A ferrous field source emanates a ferrous magnetic field which is composed of an induced and permanent magnetic field. The ferrous magnetic field can be compensated for by a degaussing system if the magnitude and direction of the field are known. In minesweeper applications, the vertical component of the ferrous magnetic field existing in a horizontal plane beneath the surface of the water is usually the most critical component of the ferrous magnetic field. This test method is used to determine the magnitude of the vertical component of the ferrous magnetic field in a horizontal plane that is a distance below the center of the test sample. This test method is accomplished in a controlled magnetic environment which is created by a test coil system. The distance from the center of the test sample to the horizontal plane at which the ferrous magnetic field is to be measured shall be 7.75 meters unless specified differently in the test sample specification.

2. Center of the test sample. Center of the test sample refers to the geometric center of the sample.

3. Apparatus.

3.1 Test coil system. The test coil system shall consist of the test coil, its power supply, and control system. The test coil, either a Helmholtz coil or an equivalent coil array, shall produce applied magnetic fields in the three orthogonal directions (triaxial). The magnetic field gradient caused by the coil's field and any magnetic field distortion from the immediate environment over the volume occupied by the test sample shall not exceed 0.1 percent of the applied field or 2 nT, whichever is greater. The coil shall generate magnetic fields to a maximum of 60 μT with an accuracy of at least 0.05 percent of the applied field or 0.25 nT, whichever is greater. The power supply shall supply the current required for adequately long periods without drift or fluctuation. A storage battery of adequate capacity is a satisfactory power source. A dc generator may be used, but may require a voltage regulator to maintain a constant output. An ac source with a rectifier may be used, provided the output is well filtered and the voltage is regulated and free of excessive switching transients. The power source should not be used for any other test or load simultaneous with this test.

3.2 Magnetometers. Monoaxial fluxgate magnetometers consisting of a sensor unit and an electronic unit with a minimum sensitivity of 0.25 nT and a dynamic range of plus or minus 113 μT shall be used for the horizontal array of magnetometers. Each electronic unit shall include as a minimum a meter to measure the field magnitude, unless automatic data collection equipment is used. The sensors may be multiplexed into a limited number of electronic units which automatically record the field measured by each scanned sensor.

3.3 Mounting frame for the array of magnetometers' sensors. A nonferrous, rectangular frame for the mounting of magnetometers' sensors shall be provided (see figure 104-1). The sensors mounted in the frame shall be located on a horizontal plane at the specified distance below the center of the test sample. One sensor shall be located directly below the center of the test sample (center sensor). The remainder of the sensors in the array shall be located at spacings equal to 0.25 of the vertical distance from the center sensor to the center of the test sample. The periphery of the array shall be no closer to the center sensor than one half the vertical distance from the center sensor to the center of the test sample. Each sensor shall be vertical within 0.5 degree.

3.4 Mounting structure. A nonferrous mounting structure shall be used for positioning the test sample within the test coil and over the mounting frame for the array of magnetometers' sensors.

4. Test sample. Volume of the test sample is limited by the size of the test coil and mounting frame for the array of magnetometer's sensors, and access to the mounting structure within them. Mass of the test sample is limited by the loading limitations of the mounting structure. The test sample shall be identical in composition to the item to be installed and shall be oriented with respect to the vertical component of the test coil as it would be in its intended installation.

5. Procedure.

5.1 Energize the test coil system such that the air core volume to be occupied by the test sample is subjected to a vertical magnetic field of 0.0 μT.

5.2 Place the test sample at the center of the test coil. The test sample shall coincide with the center of the test coil within plus or minus 10 cm.

5.3 Record the position of and the magnetic field measured by each sensor.

5.4 Adjust the test coil system so that the air core volume to be occupied by the test sample is subjected to a vertical and horizontal ambient magnetic field as follows:

TABLE 104-I. Ambient magnetic fields for air core volume.

Designator (j)	X (longitudinal component)	Y (athwartship) component	Z(vertical component)
1	40 μT	0.0 μT	0.0 μT
2	0.0 μT	4.0 μT	0.0 μT
3	0.0 μT	0.0 μT	60 μT
4	15 μT	0.0 μT	54 μT
5	0 μT	15 μT	54 μT

For each test coil magnetic field designator (j = 1, 2, 3, 4, and 5), repeat 5.3 through 5.9.

6. Calculations. Calculate the difference between the vertical component of the magnetic field with the test sample present within the test coil and the test sample removed from within the test coil for each position measured as follows:

$$B_m\ (i,j) - B_o\ (i,o) = B_v\ (i,j);\ 1 = 1 \text{ to } n,\ j=1,2,3,4,5$$

Where:

B_m = measured magnetic field with the test sample present. (induced plus perm field)

B_o = measured magnetic field with the test sample present within the test coil and the test coil adjusted such that the magnetic field of the air core volume equals zero (perm fixed).

B_v = ferrous magnetic field emanating from the test sample.

i = position designator of the magnetometer for each of the positions measured; i = 1 to n.

n = total number of magnetometers.

j = designator for air core magnetic field condition; j = 1 corresponds to the following ambient magnetic fields in μT.

TABLE 104.II. Ambient magnetic fields for air core magnetic field conditions.

j	X	Y	Z
0	0	0	0
1	40	0	0
2	0	40	0
3	0	0	60
4	15	0	54
5	0	15	54

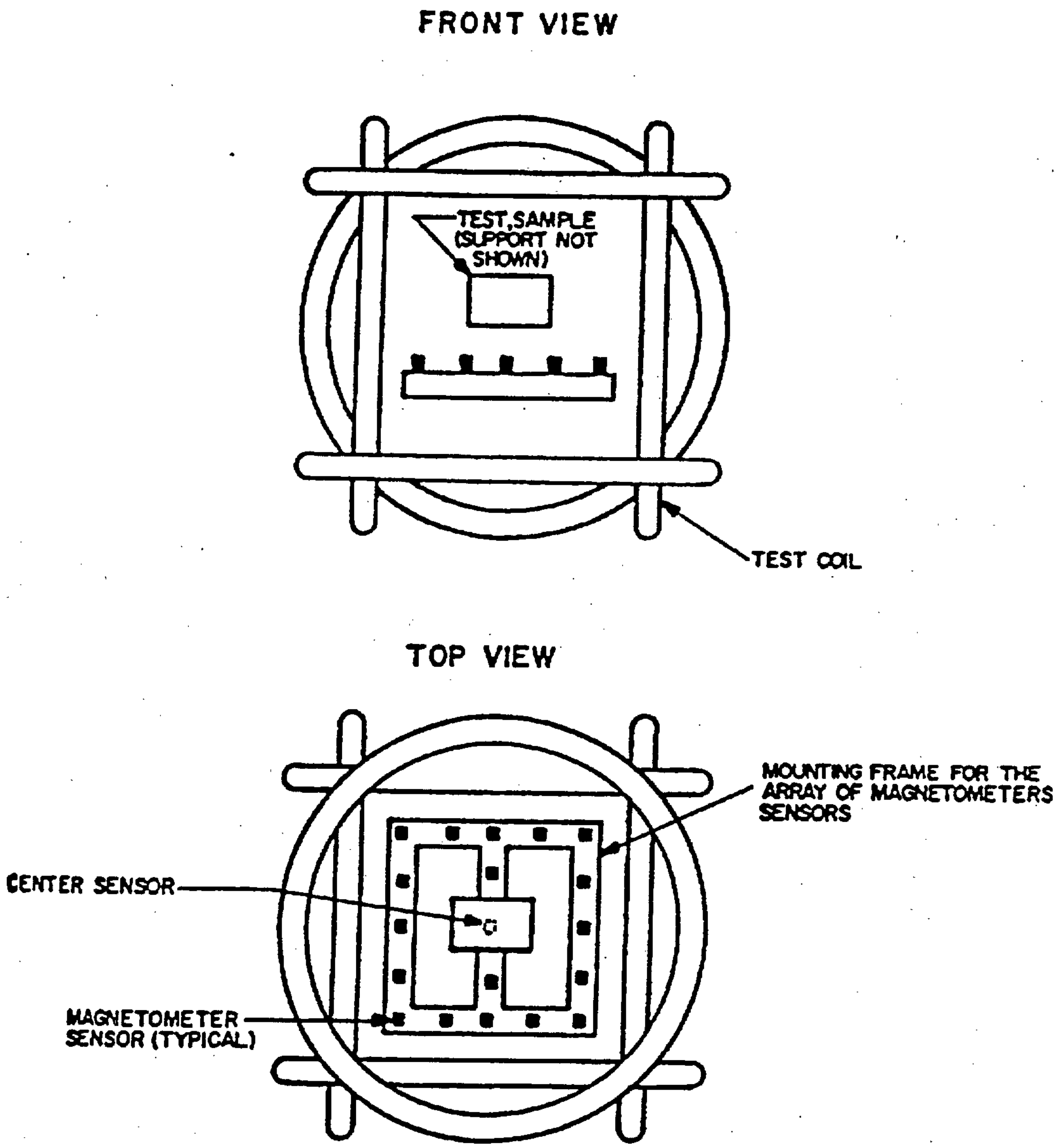


FIGURE 104-1. Configuration of magnetometers' sensors array.

TEST METHOD 105

FERROUS MAGNETIC FIELD FROM A CLASS 1 SOURCE MEASURED BY RANGING IN AN AMBIENT MAGNETIC ENVIRONMENT

1. Scope. A ferrous field (class 1) source is an item on or part of a ship or craft, which uses a material in its construction that exhibits a relative magnetic permeability different from 1.0 (the relative permeability of air). A ferrous field source emanates a ferrous magnetic field which is composed of an induced and permanent magnetic field. The ferrous magnetic field can be compensated for by a degaussing system if the magnitude and direction of the field are known. This test method is used to determine the magnitude of the vertical component of the ferrous magnetic field at a fixed distance below the center of the test sample, as the test sample is moved in a linear direction over the measured point. This test is accomplished in an ambient (earth's) magnetic environment. The distance below the center of the test sample at which the ferrous magnetic field is to be measured is 3 meters unless specified differently in the test sample specification.

2. Center of the test sample. Center of the test sample refers to the geometric center of the sample.

3. Apparatus.

3.1 Track. 450 meters of nonferrous, non-electrically conductive track for the test sample's cart shall be installed in a straight line along both the magnetic north-south and magnetic east-west with intersection at their midpoints (225 meters).

3.2 Cart. A nonferrous, non-electrically conductive cart shall be provided for mounting of the test sample so that it can travel along the test track at constant speeds between 1 meter per second (2 knots) and 4 meters per second (8 knots).

3.3 Magnetometer. A monoaxial fluxgate magnetometer consisting of a sensor unit and an electronic unit with a minimum sensitivity of 0.25 nT and a dynamic range of plus or minus 113 μT shall be used. The electronic unit shall include, as a minimum, a manually controllable field neutralization subsystem to null out the earth's field magnitude and a continuous recording instrument so that the magnitude of the absolute field is continuously read as the test sample is moved. The magnetometer shall be placed inside a nonmagnetic tube, located at the intersection of the two tracks, at the specified distance below the test sample (see figure 105-1).

4. Test sample. Volume of the test sample is limited by the size of the cart. Mass of the test sample is limited by the loading limitations of the cart and track. The test sample shall be identical in composition to the item to be

installed and shall be oriented with respect to the vertical component of the earth's magnetic field as it would be in its intended installation.

5. Procedure.

5.1 With the test sample removed from the test site, measure the earth's magnetic field at the magnetometer's sensor and null it out with the magnetometer's control circuit.

5.2 Mount the test sample on the cart and record its position with respect to the cart.

5.3 Operate the cart with the test sample on it at a constant speed of 1.0 meter per second along the entire length of the magnetic north-south track. Record the magnitude of the field at the sensor on the continuous recording equipment, as the cart is moved along the track.

5.4 Repeat 5.3 at speeds of 2.6 meters per second and 4.1 meters per second.

5.5 Relocate the cart with the test sample on it to the magnetic east-west track and operate it at a constant speed of 2.6 meters per second along the entire length of the track. Record the magnitude of the field at the sensor on the continuous recording equipment as the cart is moved along the track.

5.6 Repeat 5.5 at speeds of 2.6 meters per second and 4.1 meters per second.

5.7 Remove the test sample from the test site and remeasure the earth's magnetic field at the magnetometer's sensor. If this final measurement of the earth's field differs from the initial measurement at that point by more than 1 nT, the test results are not valid.

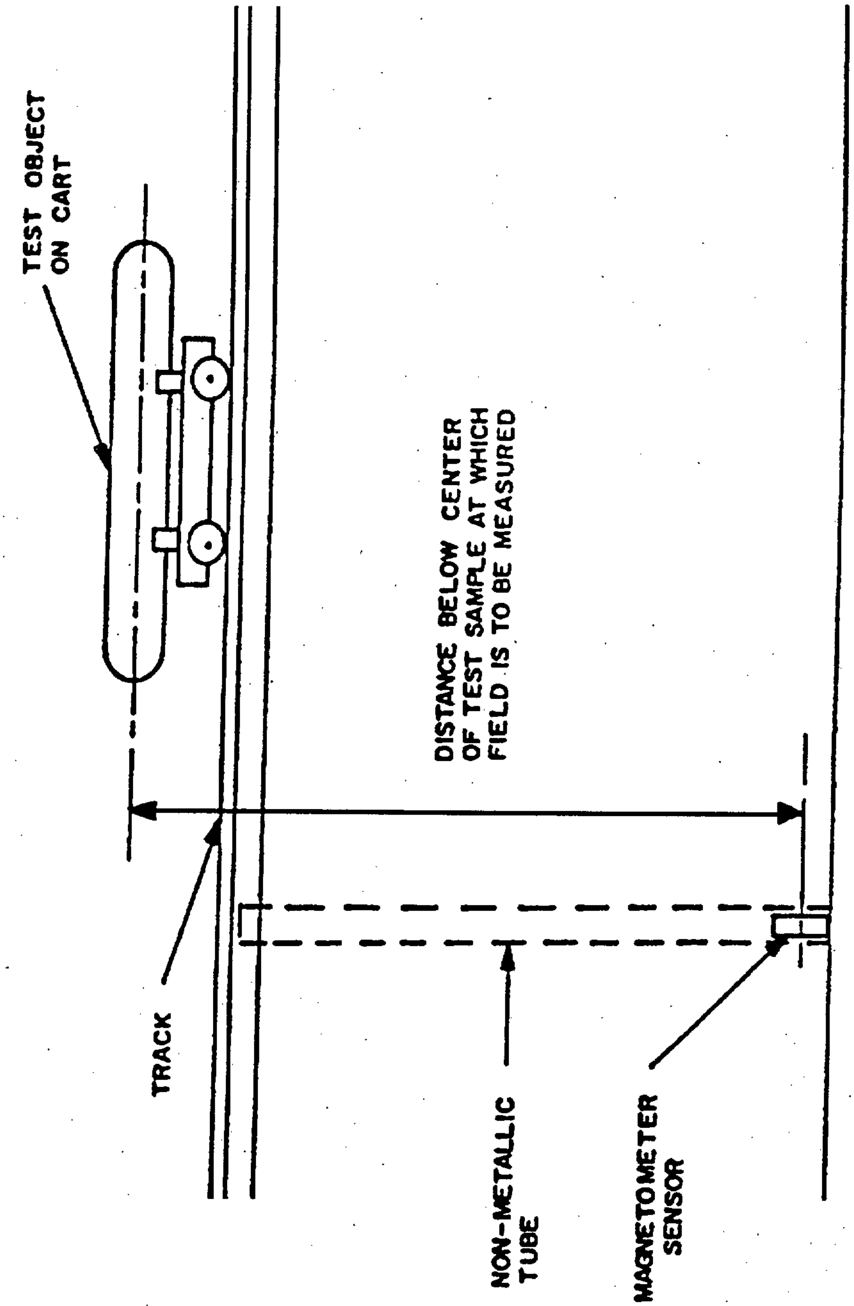


FIGURE 105-1. Configuration of test sample, cart, track and sensor.

TEST METHOD 106

FERROUS MAGNETIC FIELD FROM A DIESEL ENGINE MEASURED ON A HORIZONTAL PLANE IN A CONTROLLED MAGNETIC ENVIRONMENT

1. Scope. A diesel engine is a potentially large source of ferrous magnetic field because of the ferromagnetic materials used in its construction. It is important to determine the magnetic field of a diesel engine for a wide variety of ambient magnetic fields, to simulate what the engine would experience if installed aboard a mine warfare ship engaged in worldwide operations. The various portions of this test method make these field measurements, both to quantify the diesel engine's contribution to the ship's overall magnetic signature, but also to permit comparison of different engines. The information required from the specification of the engine under test is if the engine is equipped with a degaussing system, if dynamic magnetic field tests are required, if large magnetic field tests are required, and the distance from the geometric center of the engine to the measurement plane.

2. Apparatus.

2.1 Test coil system. The test coil system shall consist of the test coil, its power supply, and control system. The test coil, either a Helmholtz coil or an equivalent coil array, shall provide applied magnetic fields in the three orthogonal directions (triaxial). The magnetic field gradient caused by the coil's field and any magnetic field distortion from the immediate environment over the volume occupied by the test sample shall be not greater than 0.1 percent of the applied field or 2 nT, whichever is greater. The power supply shall supply the current required for adequately long periods without drift or fluctuation. A storage battery of adequate capacity is a satisfactory power source. A direct current generator may be used, but may require a voltage regulator to maintain constant output. An alternating current source with a rectifier may be used, provided the output is well filtered and the voltage is regulated and free from excessive switching transients. The power source shall not be used for any other test or load simultaneous with this test.

2.1.1 Test coil system for large magnetic field test (see 4.3), when required. The test coil used for the large magnetic field test shall be a Helmholtz coil or equivalent coil array capable of producing a magnetic field intensity of 2000 μT in each of the three orthogonal directions.

2.2 Magnetometers. Monoaxial fluxgate magnetometers consisting of a sensor unit and an electronic unit with a minimum sensitivity of 0.25 nT and a dynamic range of plus or minus 113 μT shall be used for the horizontal array of magnetometers. Each electronic unit shall include a meter to measure the field magnitude, unless automatic data collection equipment is used. The sensors may be multiplexed into a limited number of electronic units which automatically record the field measured by each scanned sensor.

2.3 Mounting frame for the sensor array. A nonferrous, rectangular frame for the mounting of the magnetometers' sensors shall be provided (see Figure 106-1). The sensors mounted in the frame shall be located on a horizontal plane at the specified distance below the geometric center of the engine under test. One sensor shall be located directly below the geometric center of the engine (center sensor). The remainder of the sensors in the array shall be located at spacings equal to approximately 0.25 of the vertical distance from the center sensor to the geometric center of the engine. The periphery of the array shall be no closer to the center sensor than one half the vertical distance from the center sensor to the geometric center of the engine. Each sensor shall be vertical within 0.5 degree.

2.4 Mounting structure. A nonferrous mounting structure shall be used for positioning the test sample within the test coil and over the sensor array. The mounting structure shall also allow the engine to be moved outside the test coil and, after the appropriate measurements are taken, moved back inside the test coil. One way to achieve this is to construct a nonmagnetic "railroad" track leading from inside the test coil to some location outside, and mount the engine to a nonmagnetic cart designed to roll on the track.

3. Calibration. The magnetometer array shall be calibrated to a reference coil oriented in a horizontal plane before the start of the test. A reference coil is any coil for which the geometry, and therefore the magnetic field characteristics, are precisely known. The calibration procedure is as follows:

(a) Position the coil over the sensor array.
(b) Construct a mathematical model of the coil and sensor array and calculate the magnetic field produced by the coil at each sensor for a specific value of coil current.
(c) Energize the coil with a precisely measured current equal to that used in the mathematical model.
(d) Measure the magnetic field using the sensor array and compare the measured values to the calculated values.
(e) Adjust the magnetometers' calibration controls until the differences between the measured and calculated values are 3 nT or less.

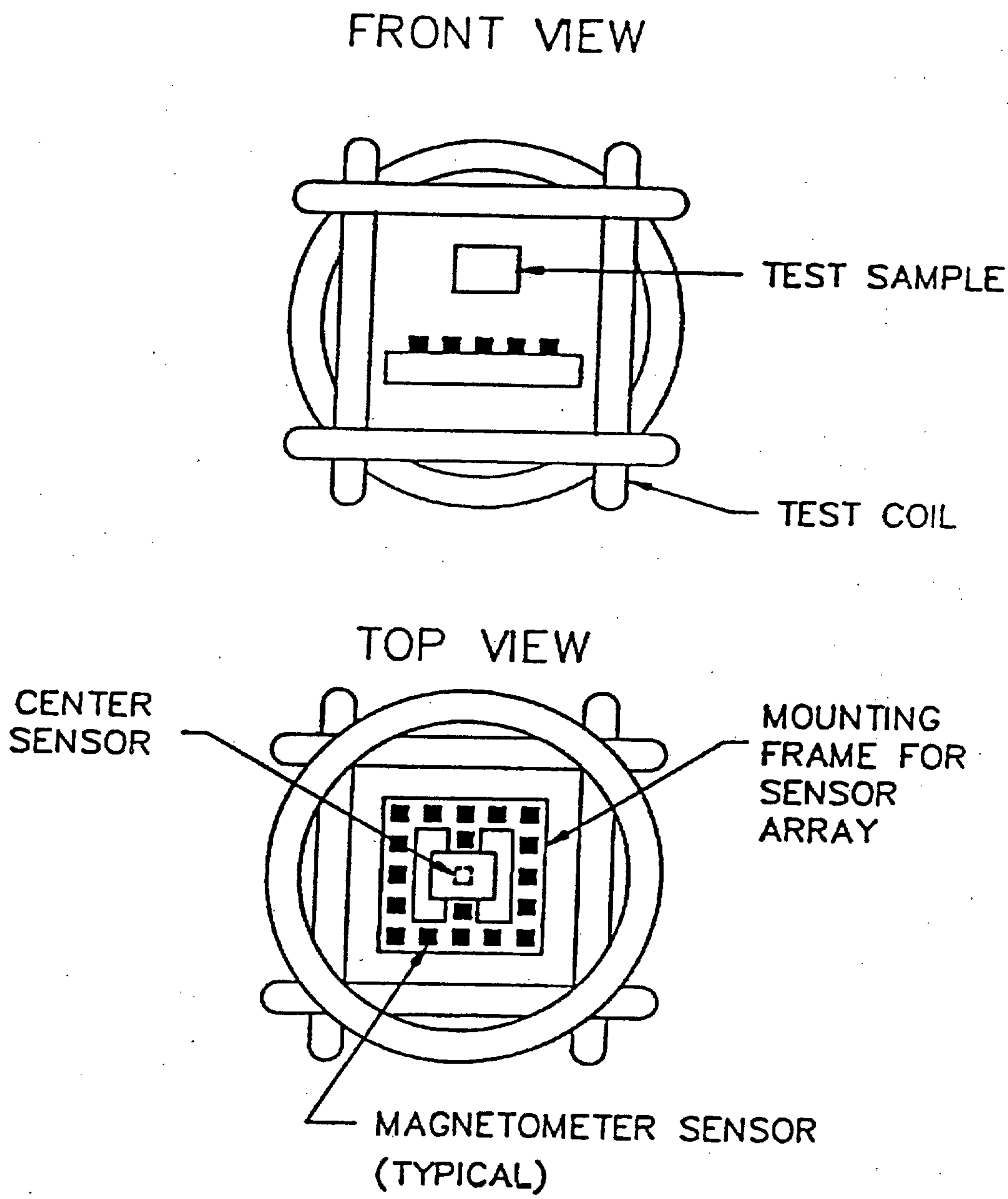


FIGURE 106-1. Mounting frame for magnetometers' sensors.

4. Procedure. Unless otherwise specified in the test engine specification, the basic test procedure shall include the following three options:

(a) Option 1: Static magnetic field test.
(b) Option 2: Dynamic magnetic field test.
(c) Option 3: Large magnetic field test.

The three options shall be exercised unless specifically exempted by the test engine specification.

4.1 Option 1: Static magnetic field test.

4.1.1 Adjust the test coil system so that the air coil volume to be occupied by the test sample is subjected to a vertical and horizontal ambient magnetic field to zero.

4.1.2 Record the position of and the magnetic field measured by each sensor.

4.1.3 Move the engine into position over the sensor array, with its center coinciding with the center sensor.

4.1.4 Record the position of and the magnetic field measured by each sensor (perm).

4.1.5 Set test coil current to generate the desired ambient magnetic field (see Table 105.I, test number 1).

4.1.6 Record the position of and the magnetic field measured by each sensor (perm and induced).

4.1.7 Move the engine outside the test coil.

4.1.8 Repeat 4.1.1 through 4.1.7 for each of the remaining ambient fields listed in Table 106-I.

TABLE 106-I. Ambient magnetic fields for static magnetic field test.

Test number	Ambient magnetic field μT		
	Bx	By	Bz
1	15	0	54
2	0	0	60
3	0	0	-60
4	40	0	0
5	-40	0	0
6	0	40	0
7	0	-40	0
8	35	35	28

4.1.9 If the engine under test is equipped with a degaussing system, energize the system with the appropriate currents (see 4.4) and repeat 4.1.1 through 4.1.8.

4.2 Option 2: Dynamic magnetic field test.

4.2.1 If the engine under test is equipped with a degaussing system, energize the system with the appropriate currents (see 4.4).

4.2.2 Adjust the test coil system so that the air coil volume to be occupied by the test sample is subjected to a vertical and horizontal ambient magnetic field of zero.

4.2.3 Record the position of and the magnetic field measured by each sensor.

4.2.4 Move the engine into position over the sensor array, with its center coinciding with the center sensor, and record the position of and the magnetic field measured by each sensor (perm) (degaussed).

4.2.5 If the engine is equipped with a degaussing system, Turn off the engine's degaussing system, move the engine outside the test coil, and record the position of and the magnetic field measured by each sensor (perm) (degaussed).

4.2.6 Move the engine outside the test coil.

4.2.7 Energize the test coil, adjusting the coil current until the desired ambient magnetic field is generated (see Table 106-II, test number 1).

4.2.8 Record the position of and the magnetic field measured by each sensor (background with test coil energized).

4.2.9 If the engine under test is equipped with a degaussing system, energize the system with the appropriate currents (see 4.4).

4.2.10 Move the engine into position over the sensor array and record the position of and the magnetic field measured by each sensor (Perm and induced, degaussed).

4.2.11 If the engine under test is equipped with a degaussing system, turn off the engine's degaussing system, and record the position of and the magnetic field measured by each sensor (permanent and induced, undegaussed).

4.2.12 Connect the engine's auxiliary systems in accordance with the contractor's specifications.

4.2.13 Start the engine and let it run for 0.5 hour after it reaches normal operating temperature.

4.2.14 Stop the engine, disconnect the auxiliary systems, and allow the engine to cool to ambient temperature.

4.2.15 Once the engine has cooled to ambient temperature, record the position of and the magnetic field measured by each sensor(permanent and induced undegaussed after heat and cooling (H and C).

4.2.16 If the engine is equipped with a degaussing system, energize the system with the appropriate currents (see 4.4) and record the position of and the magnetic field measured by each sensor. (Permanent and induced degaussed after H and C).

4.2.17 Readjust the test coil current to the known value used in 4.2.1 and record the position of and the magnetic field measured by each sensor. (Permanent degaussed after H and C).

4.2.18 If the engine is equipped with a degaussing system, deenergize the system and record the position of and the magnetic field measured by each sensor. (Permanent undegaussed after H and C).

4.2.19 Repeat 4.2.6 through 4.2.18 for each ambient magnetic field specified in Table 106-II.

TABLE 106-II. Ambient magnetic fields for dynamic magnetic field test.

Test number	Ambient magnetic field μT		
	Bx	By	Bz
1	0	0	60
2	0	0	-60
3	40	0	0
4	-40	0	0
5	0	40	0
6	0	-40	0
7	18	0	54
8	-18	0	54

4.3 Option 3: Large magnetic field test.

4.3.1 Position the large magnetic field test coil (see 2.1.1) over the sensor array such that the center of the test coil coincides with the center sensor.

4.3.2 Adjust the test coil system so that the air coil volume to be occupied by the test sample is subjected to a vertical and horizontal ambient magnetic field of zero.

4.3.3 Record the position of and the magnetic field measured by each sensor (background, ambient zero).

4.3.4 Move the engine into position over the sensor array and record the position of and the magnetic field measured by each sensor (permanent, undegaussed).

4.3.5 If the engine is equipped with a degaussing system, energize the system with the appropriate currents (see 4.4) and record the position of and the magnetic field measured by each sensor (permanent degaussed).

4.3.6. Turn off the engine's degaussing system.

4.3.7 Energize the test coil and adjust the coil current to generate the desired ambient magnetic field (see Table 106-III, test number 1).

4.3.8 After 30 minutes, deenergize the test coil.

4.3.9 Readjust the coil current to the known value used in 4.3.2 and record the position of and the magnetic field measured by each sensor (permanent after large magnetic field exposure undegaussed).

4.3.10 If the engine is equipped with a degaussing system, energize the system with the appropriate currents (see 4.4) and record the position of and the magnetic field measured by each sensor (permanent after large magnetic field exposure degaussed).

4.3.11 Repeat 4.3.6 through 4.3.10 for each ambient magnetic field shown in Table 106-III.

TABLE 106-III. Ambient magnetic fields for large magnetic field test.

Test number	Ambient magnetic field μT		
	Bx	By	Bz
1	1000	0	0
2	0	1000	0
3	0	0	1000

4.4 Final comparison testing. At the conclusion of testing, the tests specified in 4.1.1 through 4.1.4 shall be repeated to determine the cumulative effects of the magnetic field testing on the engine's magnetic signature as follows:

(a) The permanent currents in the degaussing system shall not be changed during tests from start to finish.

(b) The induced currents shall not be changed except in direct proportion to the inducing field changes.

5. Calculations. Calculate the difference between the magnetic field measured with the engine inside the test coil and with the engine outside the test coil for each position measured as follows:

$$B_m(i,j) - B_o(i,o) = B_v(i,j); \; i = 1 \text{ to } n, \; j = 1 \text{ to } m$$

Where:

$B_m(i,j)$ = measured induced plus permanent magnetic field with the engine present.

$B_o(i,j)$ = measured magnetic permanent field with the engine present.

$B_v(i,j)$ = induced ferrous magnetic field emanating from the engine.

i = position designator of the magnetometer for each of the positions measured.

n = total number of magnetometers.

j = test number designator for each set of measurements taken with the engine both inside and outside the test coil.

m = total number of tests.

SECTION 200 - EDDY CURRENT MAGNETIC FIELD TEST METHODS

TEST METHOD 201

EDDY CURRENT MAGNETIC FIELD FROM A CLASS 2 SOURCE
MEASURED AT A DISTANCE
IN A CONTROLLED MAGNETIC ENVIRONMENT

1. Scope. An electrically conductive material will generate within itself eddy currents when it is oscillated in a magnetic field. These eddy currents, in turn, will create an eddy current magnetic field. Eddy current field (class 2) sources aboard a ship or craft will emanate eddy current magnetic fields as they roll and pitch in the earth's magnetic field. Consequently, the magnitude of eddy current magnetic fields needs to be controlled aboard minesweepers that sweep for magnetic-influence mines. This test method is used to determine the magnitude of the normal component of the eddy current magnetic field at a number of measurement points that are equidistant from the center of the test sample. This test is accomplished in a controlled magnetic environment which is created by a test coil system that is rotated about the test sample of the eddy current field source. Alternatively, the test sample may be rotated in the magnetic field created by the test coil system. Required information from the specifications for the test sample for this test method is the distance from the center of the test sample of which the eddy current magnetic field is to be measured.

2. Center of the test sample. Center of the test sample refers to the geometric center of the sample.

3. Apparatus.

3.1 Test coil system. The test coil system shall consist of the test coil, its power supply and control system. The test coil, either a Helmholtz coil or an equivalent coil array, shall produce applied magnetic fields in the three orthogonal directions (triaxial). The magnetic field gradient caused by the coil's field and any magnetic field distortion from the immediate environment over the volume occupied by the test sample shall not exceed 0.1 percent of the applied field or 2 nT, whichever is greater. The coil shall generate magnetic fields to a maximum of 54 μT with an accuracy of at least 0.05 percent of the applied field or 0.25 nT, whichever is greater. The power supply shall supply the current required for adequately long periods, without drift or fluctuation. A storage battery of adequate capacity is a satisfactory power source. A dc generator may be used, but may require a voltage regulator to maintain a constant output. An ac source with a rectifier may be used, provided the output is well filtered and the voltage is regulated and free of excessive switching transients. The power source should not be used for any other test or load simultaneously with this test.

3.2 Roll mounting fixture for test coil. The test coil shall be mounted on a roll mounting fixture which shall roll the test coil at a rate of 5 to 7 cycles per minute in one plane to an angle of 45 degrees on either side of the vertical in increments of 15 degrees. The magnitude of the vertical and horizontal components of the magnetic field occupied by the air core volume specified in the test procedures shall rotate as the test coil rotates and shall be maintained at the same values and tolerances throughout the rotation.

3.3 Magnetometer. A monoaxial fluxgate magnetometer consisting of a sensor unit and an electronic unit with a minimum sensitivity of 0.25 nT and a dynamic range of plus or minus 113 μT shall be used. The electronic unit shall include a continuous reading instrument to measure the field magnitude as the test coil rotates through its roll angle.

3.4 Gimbal fixture. A nonferrous, non-electrically conductive gimbal fixture, with a circular ring, shall be used for the mounting of the magnetometers' sensor (see Figure 201-1). The ring shall have a radius equal to the distance from the center of the test sample at which the field is to be measured. The magnetometer's sensor shall be mounted on the ring in a manner that will allow sensing at the specified distance. The ring shall lie on a horizontal plane so that it is centered about the center of the test coil within plus or minus 10 cm and can be rotated in 45 degree increments in the plane of the ring and in the plane perpendicular to the plane of the ring (see Figure 201-1). Multiple magnetometers may be used to decrease the number of rotations required for a full set of readings.

3.5 Mounting structure. A nonferrous, non-electrically conductive mounting structure shall be used for positioning the test sample within the test coil and gimbal fixture.

4. Test sample. Volume of the test sample is limited by the size of the test coil and gimbal structure, access to the mounting structure within them, and clearance distances for the roll of the test coil. Mass of the test sample is limited by the loading limitations of the mounting structure. The test sample shall be identical in composition to the item to be installed and shall be oriented with respect to the horizontal and vertical components of the test coil, as it would be in its intended installation.

5. Procedure.

5.1 Energize the test coil system such that the air core volume to be occupied by the test sample is subjected to a vertical magnetic field of 54 μT and a horizontal magnetic field of 15 μT.

5.2 Place the test sample in position, so that it is oriented with respect to the roll plane of the coil as it would be oriented to the athwartship direction aboard the ship or craft. Record the position of the test sample with respect to the test coil. The center of the test sample shall coincide with the center of the test coil at 0 degrees roll angle within plus or minus 10 cm.

5.3 Place the magnetometer's sensor in position 1 (see Figure 201-1).

5.4 Rotate the test coil in its roll plane through an angle of 15 degrees from one side of the vertical to the other side and back to vertical(starboard orientation plus (+) degrees and port orientation minus (-) degrees) at a rate between 5 to 7 cycles (0 to 15 degrees, back to 0, to minus15 degrees and back to 0) per minute.

5.5 Record the test coil roll angle and rate. Record the position of the magnetometer's sensor. Measure the maximum field magnitude during the roll from the continuous recording instrument.

5.6 Repeat 5.4 and 5.5 for 30 degrees and 45 degrees roll angles.

5.7 Rotate the ring of the gimbal fixture plus 45 degrees in the plane of the ring; repeat 5.4 through 5.6 (position 2).

5.8 Repeat 5.7 six times (positions 3 through 8).

5.9 Rotate the ring of the gimbal fixture plus 45 degrees in the plane of the ring and then plus 45 degrees in the plane containing the magnetometer's sensor and the point on the ring 180 degrees from the sensor.

5.10 Repeat 5.4 through 5.7 with the exception that positions plus 90 degrees and plus 270 degrees are eliminated (positions 9 through 14).

5.11 Repeat 5.9 and 5.10 two times (positions 15 through 26).

5.12 Remove the test sample from within the test coil and repeat 5.4 through 5.11.

5.13 Reinsert the test sample within the test coil so that it is orientated with respect to the roll plane of the coil as it would be orientated to the forward-aft direction aboard the ship or craft. Record the position of the test sample with respect to the test coil. The center of the test sample shall coincide with the center of the test coil at 0 degrees roll angle within plus or minus 10 cm.

5.14 Repeat 5.4 through 5.12. Test coil roll plane angles are plus (+) degrees for forward pitch and minus (-) degrees for aft pitch.

5.15 Adjust the test coil system so that the air core volume to be occupied by the test sample is subjected to a vertical magnetic field component of 12.6 μT and a horizontal magnetic field component of 42.7 μT.

5.16 Repeat 5.2 through 5.14.

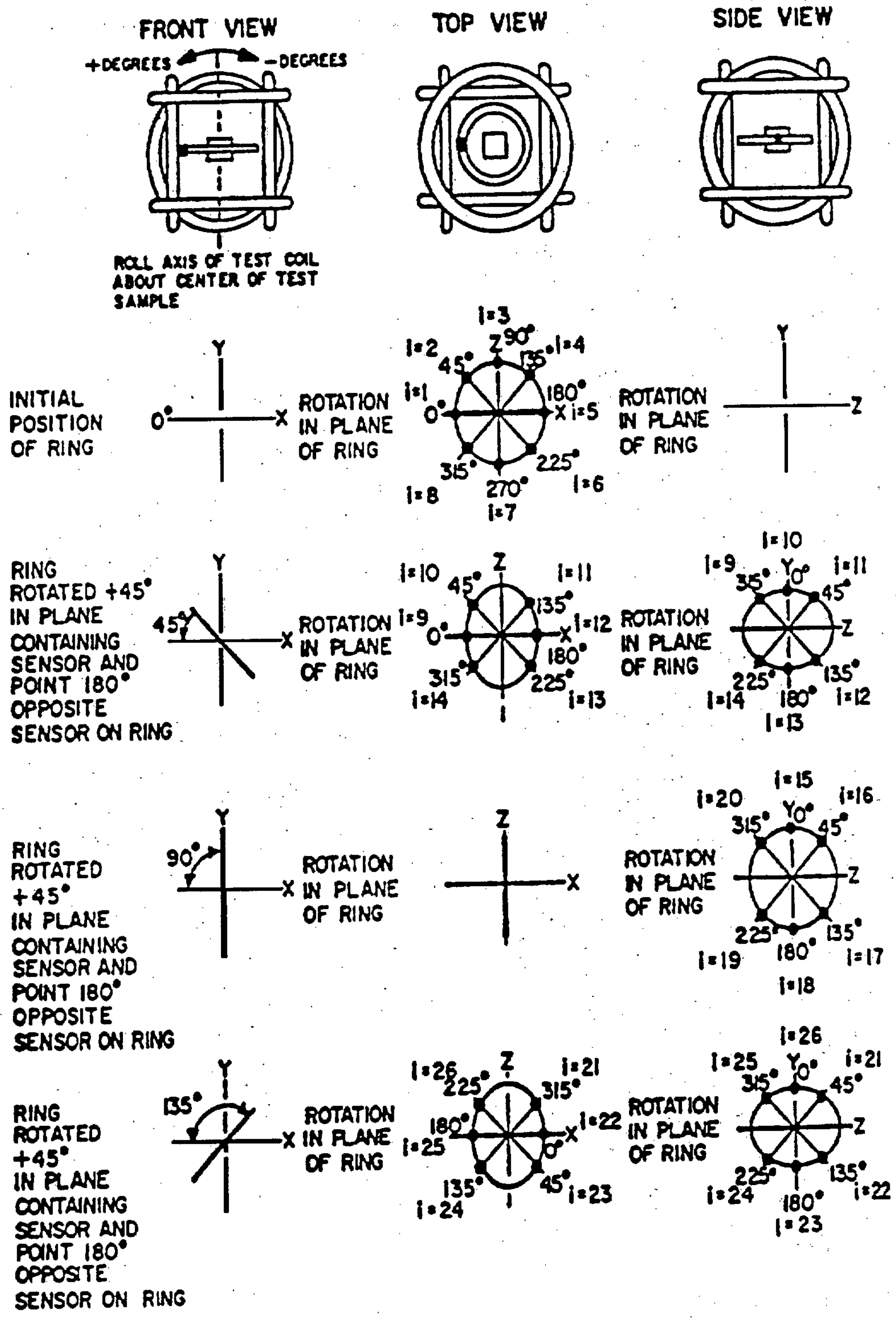


FIGURE 201-1. Magnetometer position designators (i).

6. Calculations. Calculate the difference between the magnetic field with the test sample present within the test coil and the test sample removed from within the test coil for each position measured as follows:

$$B_p\,(k,j,k) - B_a\,(i,j,k) = B_t\,(i,j,k);\ i = 1 \text{ to } 26,\ j = 1,2,\ k = 1,2,3.$$

Where:

B_p = measured magnetic field with the test sample present within the test coil.

B_a = measured magnetic field with the test sample removed from within the test coil.

B_t = eddy current magnetic field emanating from the test sample.

i = position designator of the magnetometer for each of the positions measured; i = 1 to 26.

j = designator for air core magnetic field condition; j = 1 corresponds to the field of 54 μT vertical and 15 μT horizontal; j = 2 corresponds to the field of 12.6 μT vertical and 42.7 μT horizontal.

k = designator for test coil roll angle; k = 1 corresponds to a roll angle of 15 degrees; k = 2 corresponds to a roll angle of 45 degrees.

TEST METHOD 202
EDDY CURRENT MAGNETIC FIELD FROM A CLASS 2 SOURCE MEASURED ON A HORIZONTAL PLANE IN A CONTROLLED MAGNETIC ENVIRONMENT

1. Scope. An electrically conductive material will generate within itself eddy currents when it is moved in a magnetic field. These eddy currents, in turn, will create an eddy current magnetic field. Eddy current field (class 2) sources aboard a ship or craft will emanate eddy current magnetic fields as they roll and pitch in the earth's magnetic field. Consequently, the magnitude of eddy current magnetic fields needs to be controlled aboard minesweepers that sweep for magnetic-influence mines. The vertical component of the eddy current magnetic field emanated on a horizontal plane beneath the surface of the water is usually the most critical component of the eddy current magnetic field. This test method is used to determine the magnitude of the vertical component of the eddy current magnetic field on a horizontal plane that is a distance below the center of the test sample. This method is distinguished from test method 201 which measures the field at points that are equidistant from the center of the test sample. This test method, like test method 201, is accomplished in a controlled magnetic environment which is created by a test coil system rotating about the test sample. Alternatively, the test sample may be rotated in the magnetic field created by the test coil system. Required information from the specifications for the test sample for this test method is the distance from the center of the test sample to the horizontal plane at which the eddy current magnetic field is to be measured.

2. Center of the test sample. Center of the test sample refers to the geometric center of the sample.

3. Apparatus.

3.1 Test coil system. The test coil system shall consist of the test coil, its power supply and control system. The test coil, either a Helmholtz coil or an equivalent coil array, shall produce applied magnetic fields in the three orthogonal directions (triaxial). The magnetic field gradient caused by the coil's field and any magnetic field distortion from the immediate environment over the volume occupied by the test sample shall not exceed 0.1 percent of the applied field or 2 nT , whichever is greater. The coil shall generate magnetic fields to a maximum of 54 μT with an accuracy of at least 0.05 percent of the applied field or 0.25 nT, whichever is greater. The power supply shall supply the current required for adequately long periods without drift or fluctuation. A storage battery of adequate capacity is a satisfactory power source. A dc generator may be used, but may require a voltage regulator to maintain a constant output. An ac source with a rectifier may be used, provided the output is well filtered and the voltage is regulated and free of excessive switching transients. The power source should not be used for any other test or load simultaneously with this test.

3.2 Roll mounting fixture for test coil. The test coil shall be mounted on a roll mounting fixture which shall roll the test coil at a rate of 5 to 7 cycles per minute in one plane through an angle of 45 degrees on either side of the vertical in increments of 15 degrees. The magnitude of the vertical and horizontal components of the magnetic field occupied by the air core volume specified in the test procedures shall rotate as the test coil rotates and shall be maintained at the same values and tolerances throughout the rotation.

3.3 Magnetometers. Monoaxial fluxgate magnetometers consisting of a sensor unit and an electronic unit with a minimum sensitivity of 0.25 nT and a dynamic range of plus or minus 113 μT shall be used for the horizontal array of magnetometers. Each electronic unit shall include as a minimum a continuous reading instrument to measure the field magnitude, as the test coil rotates through its roll angle.

3.4 Mounting frame for the array of magnetometers' sensors. A nonferrous, non-electrically conductive rectangular frame for the mounting of magnetometers' sensors shall be provided (see figure 202-1). The sensors mounted on the frame shall be located on a horizontal plane at the specified distance below the center of the test sample. One sensor shall be located directly below the center of the test sample (center sensor). The remainder of the sensors in the array shall be located at spacings equal to 0.25 of the vertical distance from the center sensor to the center of the test sample. The periphery of the array shall be no closer to the center sensor than one half the vertical distance from the center sensor to the center of the test sample. Each sensor shall be vertical within 0.5 degree.

3.5 Mounting structure. A nonferrous, non-electrically conductive mounting structure shall be used for positioning the test sample within the test coil and over the mounting frame for the array of magnetometer's sensors.

4. Test sample. Volume of the test sample is limited by the size of the test coil and mounting frame for the array of magnetometer's sensors, access to the mounting structure within them, and clearance distances for the roll of the test core. Mass of the test sample is limited by loading limitations of the mounting structure. The test sample shall be identical in composition to the item to be installed and shall be oriented, with respect to the horizontal and vertical components of the test coil, as it would be in its intended installation.

5. Procedure.

5.1 Energize the test coil system such that the air core volume to be occupied by the test sample is subjected to a vertical magnetic field of 54 μT and a horizontal magnetic field of 15 μT.

5.2 Place the test sample in position, so that it is oriented with respect to the roll plane of the coil as it would be oriented to the athwartship direction aboard the ship or craft. Record the position of the test sample with respect to the test coil and the array of magnetometers' sensors. The center of the test sample shall coincide with the center of the test coil at 0 degrees roll within plus or minus 10 cm.

5.3 Rotate the test coil in its roll plane through an angle of 15 degrees from one side of the vertical to the other side and back to vertical(starboard orientation plus (+) degrees and port orientation (-) degrees) at a rate between 5 to 7 cycles (0 to plus 15 degrees, back to 0, to minus 15 degrees and back to 0) per minute.

5.4 Record the test coil roll angle and rate. Measure the maximum field magnitude during the roll from the continuous reading instrument.

5.5 Repeat 5.3 and 5.4 for roll angles of 30 degrees and 45 degrees.

5.6 Remove the test sample from within the test coil and repeat 5.3 through 5.5.

5.7 Reinsert the test sample within the coil, so that it is oriented with respect to the roll plane of the coil as it would be oriented to the forward-aft direction aboard the ship or craft. Record the position of the test sample with respect to the test coil. The center of the test sample shall coincide with the center of the test coil at 0 degrees roll angle within plus or minus 10 cm.

5.8 Repeat 5.3 through 5.6. Test coil roll plane angles are plus (+) degrees for forward pitch and minus (-) degrees for aft pitch.

5.9 Adjust the test coil system so that the air core volume to be occupied by the test sample is subjected to a vertical magnetic field component of 12.6 μT and a horizontal magnetic field component of 42.7 μT.

5.10 Repeat 5.2 through 5.8.

6. Calculations. Calculate the difference between the vertical component of the magnetic field with the test sample present within the test coil and the test sample removed from within the test coil for each position measured for the three test coil roll angles, as follows:

$$B_p(i,j,k) - B_a(i,j,k) = B_v(i,j,k); \; i = 1 \text{ to } n, \; j = 1, 2, \; k = 1, 2, 3$$

Where:

B_p = measured magnetic field with the test sample present.

B_a = measured magnetic field with the test sample removed.

B_v = eddy current magnetic field emanating from the test sample.

i = position designator of the magnetometer for each of the positions measured; i = 1 to n.

n = total number of magnetometers in the array.

j = designator for air core magnetic field condition; j = 1 corresponds to the field of 54 μT vertical and 15 μT horizontal; j = 2 corresponds to the field of 12.6 μT vertical and 42.7μT horizontal.

k = designator for test coil roll angle; k = 1 corresponds to a roll angle of 15 degrees; k = 2 corresponds to a roll angle of 45 degrees.

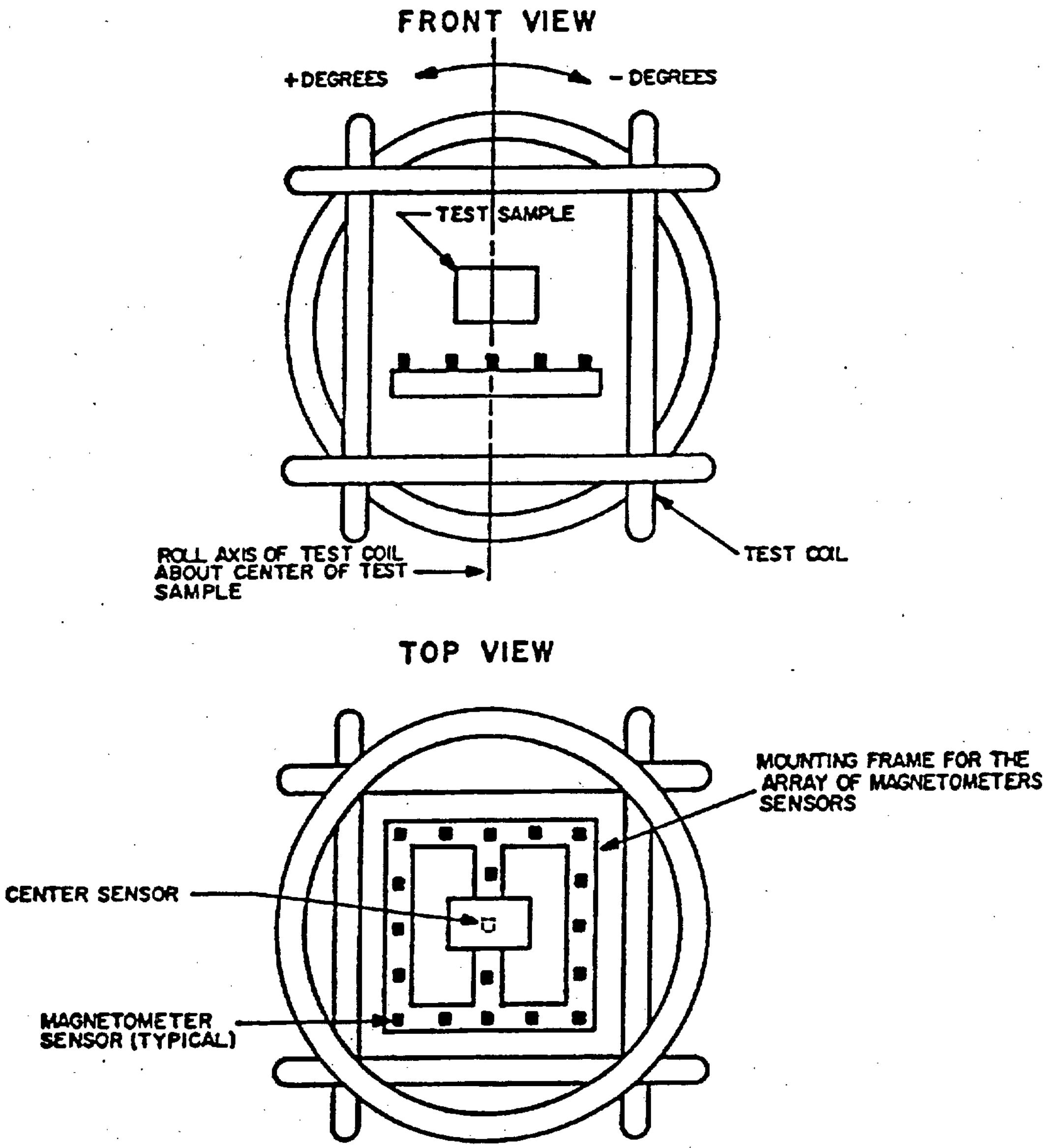


FIGURE 202-1. Configuration of mounting frame for sensors.

TEST METHOD 203

EDDY CURRENT MAGNETIC FIELD FROM A CLASS 2 SOURCE CAUSED BY OSCILLATORY MOTION IN AN AMBIENT MAGNETIC ENVIRONMENT

1. Scope. An electrically conductive material will generate within itself eddy currents when it is moved in a magnetic field. These eddy currents, in turn, will create an eddy current magnetic field. Eddy current magnetic field (class 2) sources aboard a ship or craft will emanate eddy current magnetic fields as they roll and pitch in the earth's magnetic field. Consequently, the magnitude of eddy current magnetic fields needs to be controlled aboard minesweepers that sweep for magnetic-influence mines. This test method is used to determine the magnitude of the vertical component of the eddy current magnetic field at a fixed distance below the center of the test sample, as the test sample is moved in an oscillatory manner over the measured point. This test is accomplished in an ambient (earth's) magnetic environment. Required information from the specifications for the test sample for this test method is the distance below the center of the test sample at which the eddy current magnetic field is to be measured.

2. Center of the test sample. Center of the test sample refers to the geometric center of the sample.

3. Apparatus.

3.1 Pendulum support structure. A pendulum support structure shall be constructed of wooden poles, binding cable and test sample support cable (see Figure 203-1). The height and breadth of the stucture shall allow a 45 degree movement from the vertical of the test sample support cable with the test sample attached in the vertical and lateral oscillatory directions.

3.2 Magnetometer. A monoaxial fluxgate magnetometer consisting of a sensor unit and an electronic unit with a minimum sensitivity of 0.25 nT and a dynamic range of 113 μT shall be used. The electronic unit shall include, as a minimum, a manually controllable field neutralization subsystem to null out the earth's field magnitude and a continuous recording instrument so that the magnitude of the absolute field is continuously read as the test sample is moved. The magnetometer shall be placed inside a nonmagnetic tube, located directly below the center of the test sample when the test sample support cable is at 0 degrees with respect to the vertical, at the distance specified (see Figure 203-1).

4. Test sample. Volume of the test sample is limited by the dimensions of the pendulum support structure. Mass of the test sample is limited by the loading limitations on the pendulum support structure. The test sample shall be identical in composition to the item to be installed and shall be oriented, with respect to the vertical component of the earth's magnetic field, as it would be in the intended installation.

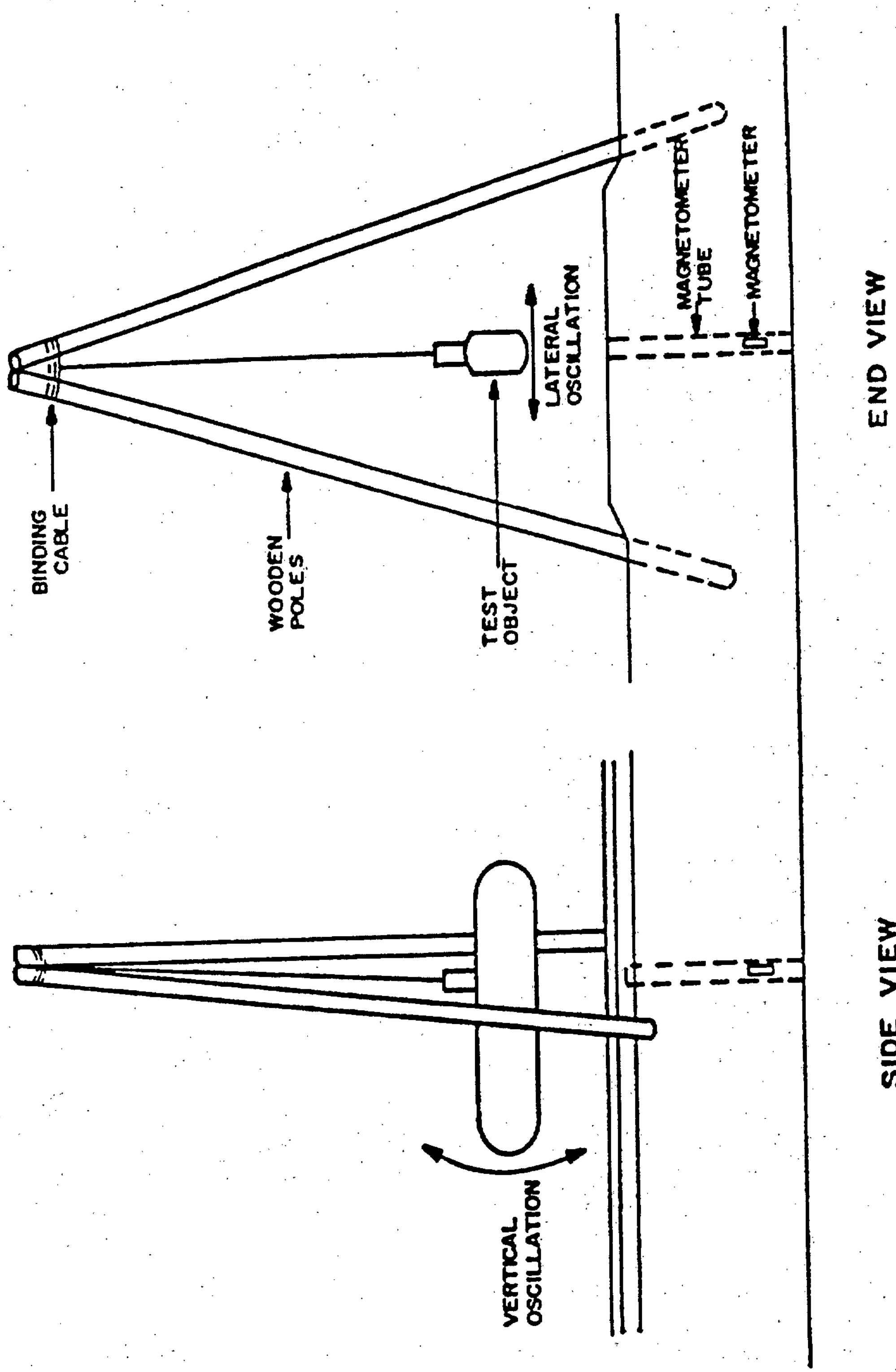


FIGURE 203-1. Configuration of test sample, structure and sensor.

5. Procedure.

5.1 With the test sample removed from the test site, measure the earth's magnetic field at the magnetometer's sensor and null it out with the magnetometer's control circuit.

5.2 Mount the test sample on the pendulum support structure and record its position with respect to the structure.

5.3 Raise the test sample in the vertical direction so that the test sample support cable is at an angle of 15 degrees with the vertical. Release the test sample and record the magnitude of the field at the sensor on the continuous recording equipment, as the test sample oscillates in the vertical direction.

5.4 Repeat 5.3 for 30 degrees and 60 degrees.

5.5 Raise the test sample in the lateral direction so that the test sample support cable is at an angle of 15 degrees with the vertical. Release the test sample and record the magnitude of the field at the sensor on the continuous recording equipment, as the test sample oscillates in the lateral direction.

5.6 Repeat 5.5 for 30 degrees and 60 degrees.

5.7 Remove the test sample from the pendulum support structure and remeasure the earth's magnetic field at the magnetometer's sensor. If this final measurement of the earth's field differs from the initial measurement at that point by more than 1 nT, the test results are not valid.

SECTION 300 - STRAY MAGNETIC FIELD TEST METHODS

TEST METHOD 301

STRAY MAGNETIC FIELD FROM A CLASS 3 SOURCE MEASURED AT A DISTANCE IN AN AMBIENT MAGNETIC ENVIRONMENT

1. Scope. Minesweepers are carefully built of nonmagnetic materials wherever possible. When magnetic materials are necessary, their magnetic field is accurately compensated for by a degaussing system. However, the stray magnetic field caused by dc carrying conductors of ship machinery, such as those found in the generators which produce the large currents for the minesweeping cables, cannot be compensated for by the usual degaussing techniques, since they are not constant nor as predictable a source of magnetic fields as the sources which consist primarily of magnetic materials. The stray magnetic field caused by these stray magnetic field (class 3) sources must be measured, to ensure that they are minimized in accordance with their specifications. This test method is used to determine the magnitude of the normal component of the stray magnetic field at a number of measurement points that are equidistant from the center of the test sample. This test is accomplished in an ambient (earth's) field environment. Consequently, variations in the earth's field at the test site must be automatically compensated for so that accurate results can be achieved. Required information from the specifications for the test sample for this test method is the distance from the center of the test sample at which the stray magnetic field is to be measured.

2. Center of the test sample. Center of the test sample refers to the geometric center of the test sample.

3. Apparatus.

3.1 Magnetometer. A monoaxial fluxgate magnetometer consisting of a sensor unit and an electronic unit with a minimum sensitivity of 0.25 nT and a dynamic range of plus or minus 113 μT shall be used. The electronic unit shall include as a minimum an automatically controllable field neutralization subsystem to null out the earth's field magnitude and a meter to measure the absolute field magnitude. A chart recorder may be used to facilitate data collection.

3.2 Gimbal fixture. A nonferrous gimbal fixture, with a circular ring, shall be used for the mounting of the magnetometer's sensor (see Figure 301-1). The ring shall have a radius equal to the distance from the center of the test sample at which the field is to be measured. The magnetometer's sensor shall be mounted on the ring in a manner that will allow sensing at the specified distance. The ring shall lie on a horizontal plane so that it is centered about the center of the test sample within plus or minus 10 cm and can be rotated in 45 degree increments in the plane of the ring and in the plane perpendicular to the plane of the ring (see Figures 301-1 and 301-2). Multiple magnetometers may be used to decrease the number of rotations required for a full set of readings.

3.3 Mounting structure. A nonferrous mounting structure shall be used for positioning the test sample within the gimbal fixture.

3.4 Power supplies. Electrical power supplies shall be provided as required to operate the test sample over its full operating range.

3.5 Loads. Mechanical and electrical loads shall be provided as required to operate the test sample over its full operating range.

4. Test sample. Volume of the test sample is limited by the size of the gimbal fixture and access to the mounting structure within the fixture. Mass of the test sample is limited by the loading limitations of the mounting structure. The test sample shall be identical to the equipment to be installed and shall be oriented with respect to the vertical component of the earth's magnetic field, as it would be in its intended installation. The test sample shall operate over its full operating range, including overload conditions.

5. Procedure.

5.1 Place the test sample in position and record the position of the test sample with respect to the gimbal fixture.

5.2 Connect all power and control circuits as they would be connected in the actual installation.

5.3 Energize all power and control circuits to rated ouput and as further specified in the test plan approved by the contracting activity.

5.4 Place the magnetometer's sensor in position 1 (see Figure 301-2); measure and record the field magnitude.

5.5 Rotate the ring of the gimbal fixture plus 45 degrees in the plane of the ring; measure and record the field magnitude (position 2).

5.6 Repeat 5.5 six times (positions 3 through 8).

5.7 Rotate the ring of the gimbal fixture plus 45 degrees in the plane of the ring and then plus 45 degrees in the plane containing the magnetometer's sensor and the point on the ring 180 degrees from the sensor.

5.8 Measure and record the field magnitude (position 9). Repeat 5.5 and 5.6 with exception that positions plus 90 degrees and plus 270 degrees are eliminated (positions 10 through 14).

5.9 Repeat 5.7 and 5.8 two times (positions 15 through 26).

5.10 Conduct additional test cycles consisting of 5.3 through 5.9.

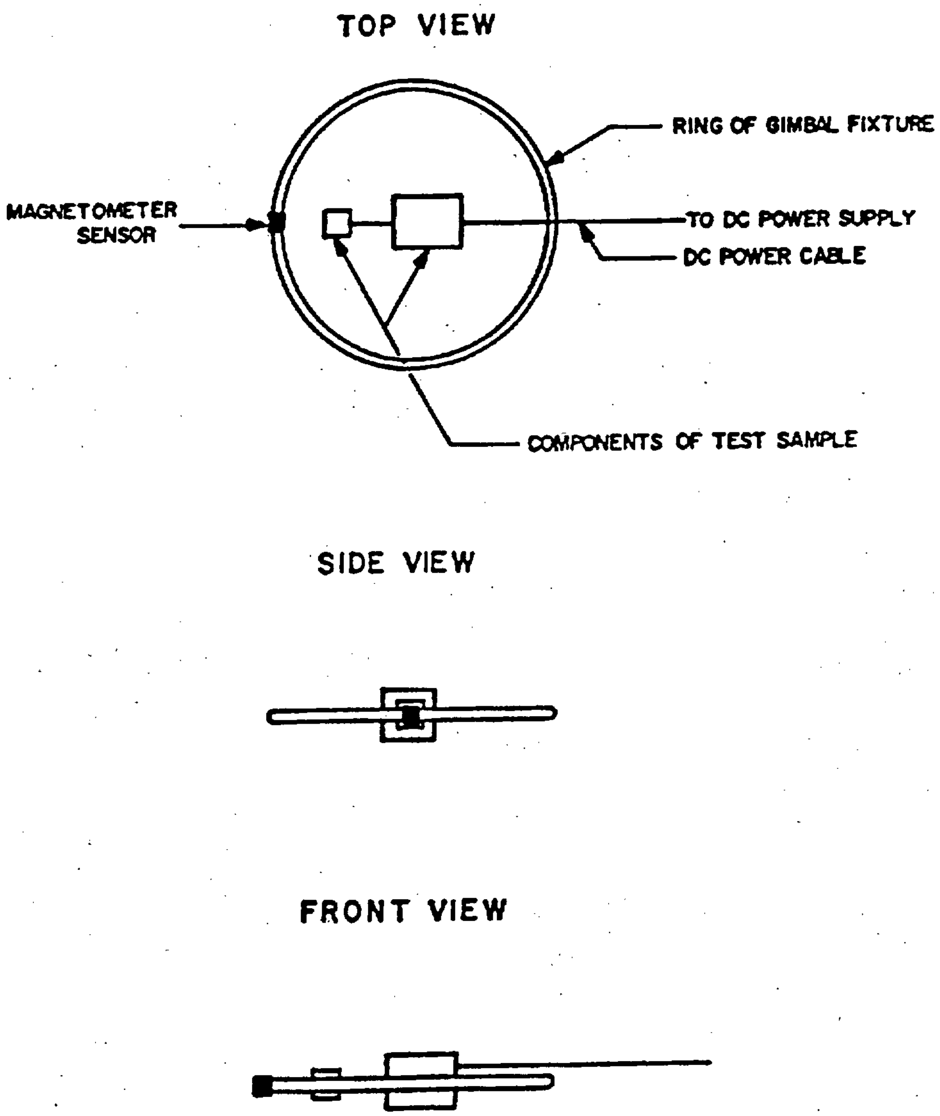


FIGURE 301-1. Configuration of ring for gimbal fixture.

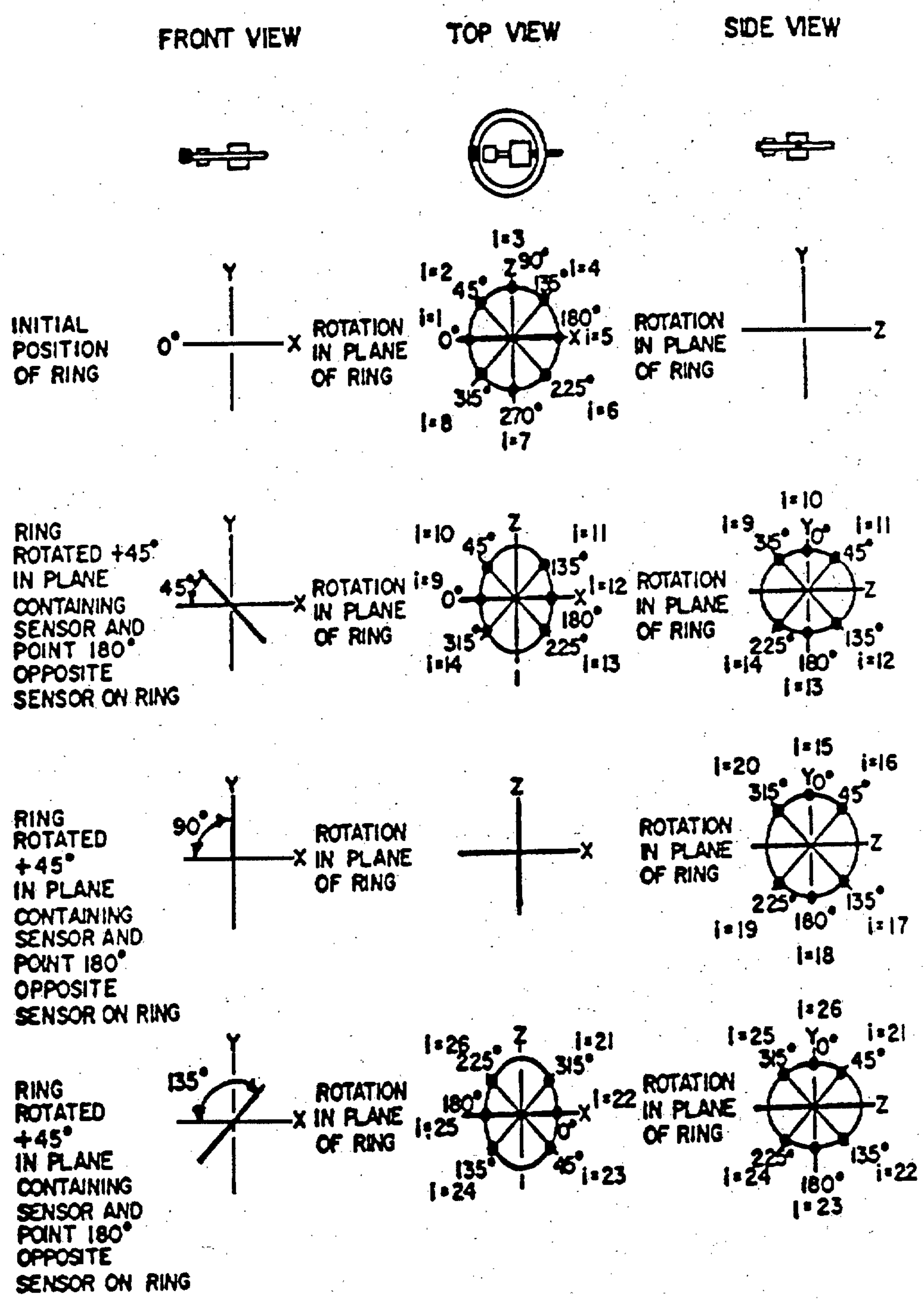


FIGURE 301-2. Magnetometer position designators (i).

TEST METHOD 302

STRAY MAGNETIC FIELD FROM A CLASS 3 SOURCE MEASURED ON A HORIZONTAL PLANE IN AN AMBIENT MAGNETIC ENVIRONMENT

1. Scope. Minesweepers are carefully built of nonmagnetic materials wherever possible. When magnetic materials are necessary, their magnetic field is accurately compensated for by a degaussing system. However, the stray magnetic field caused by dc carrying conductors of ship machinery, such as those found in the generators which produce the large currents for the minesweeping cables, cannot be compensated for by the usual degaussing techniques, since they are not constant nor as predictable a source of magnetic fields as the sources which consist primarily of magnetic materials. The stray magnetic field caused by these stray magnetic field (class 3) sources must be measured, to ensure that they are minimized in accordance with their specifications. In minesweeper applications, the vertical component of the stray magnetic field emanated on a horizontal plane beneath the surface of the water is usually the most critical component of the stray magnetic field. This test method is used to determine the magnitude of the vertical component of the stray magnetic field on a horizontal plane that is a distance below the center of the sample. This method is distinguished from test method 301, which measures the field at points that are equidistant from the center of the test sample. This test method, like test method 301, is accomplished in an ambient (earth's) field environment. Consequently, variations in the earth's field at the test site must be automatically compensated for so that accurate results can be achieved. Required information from the specifications for the test sample for this test method is the distance from the center of the test sample to the horizontal plane at which the stray magnetic field is to be measured.

2. Center of the test sample. Center of the test sample refers to the geometric center of the test sample.

3. Apparatus.

3.1 Magnetometers. Monoaxial fluxgate magnetometers consisting of a sensor unit and an electronic unit with a minimum sensitivity of 0.25 nT and a dynamic range of plus or minus 113 μT shall be used for the horizontal array of magnetometers. Each electronic unit shall include, as a minimum, an automatically controllable field neutralization subsystem to null out the earth's field magnitude and a meter to measure the absolute field magnitude. If an automatic data collection system is used, the sensors may be multiplexed into a limited number of electronic units which automatically record the field measured by each sensor.

3.2 Mounting frame for the array of magnetometers. A nonferrous, rectangular frame for the mounting of the magnetometers' sensors shall be provided (see Figure 302-1). The sensors mounted on the frame shall be located on a horizontal plane at the specified distance below the center of the test sample. One sensor shall be located directly below the center of the test sample (center sensor). The remainder of the sensors in the array shall be located at spacings equal to 0.25 of the vertical distance from the center sensor to the center of the test sample. The periphery of the array shall be no closer to the center sensor than one half the vertical distance from the center sensor to the center of the test sample. Each sensor shall be vertical within 0.5 degree.

3.3 Mounting structure. A nonferrous mounting structure shall be used for positioning the test sample with respect to the mounting frame.

3.4 Power supplies. Electrical power supplies shall be provided as required, to operate the test sample over its full operating range.

3.5 Loads. Mechanical and electrical loads shall be provided as required, to operate the test sample over its full operating range.

4. Test sample. Length and width of the test sample are limited by the dimensions of the sensor array. Mass of the test sample is limited by the loading limitations imposed by the surface on which the sample is located. The test sample shall be identical in composition to the item to be installed and shall be oriented with respect to the vertical component of the earth's field as it would be in the intended installation.

5. Procedure.

5.1 Place the test sample in position and record the position of the test sample with respect to the sensor array.

5.2 Connect all power and control circuits as they would be connected in the actual installation.

5.3 Energize all power and control circuits to rated output and as further specified in the test plan approved by the contracting activity.

5.4 Record the position of and the magnetic field measured by each sensor.

5.5 Conduct additional test cycles consisting of 5.3 through 5.4.

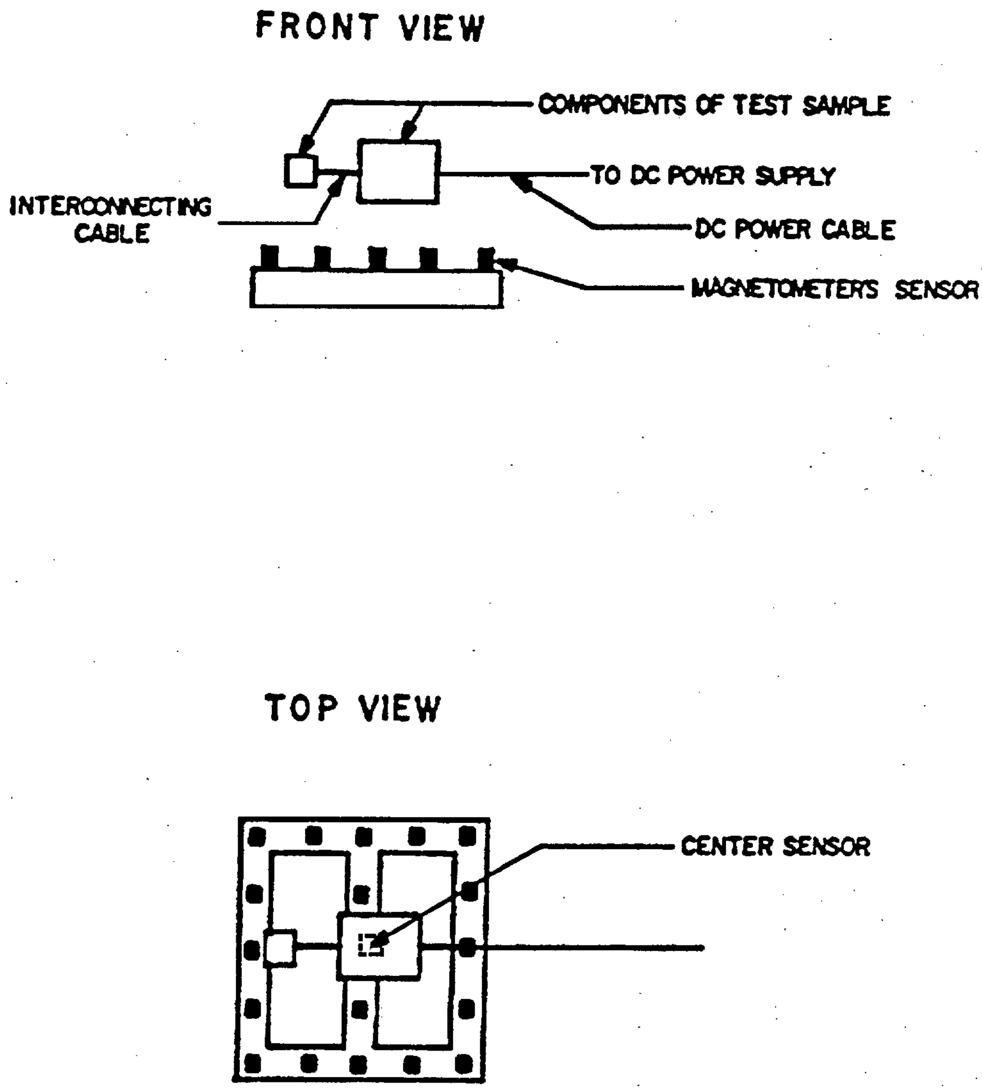


FIGURE 302-1. Configuration of mounting frame for sensors.

SECTION 400 - ELECTRICAL CONDUCTIVITY TEST METHODS

TEST METHOD 401

PERCENT IACS ELECTRICAL CONDUCTIVITY BY ELECTRICAL RESISTIVITY MEASUREMENT

1. Scope. This method is used for determining the electrical conductivity of electrically conductive material in accordance with the standard test method of ASTM B 193. Percent IACS conductivity is determined by measuring the resistivity of the material and then converting the resistivity into percent IACS conductivity using the appropriate conversion factor. The conductivity may be calculated on a volume or weight basis. This method provides accuracy of plus or minus 0.30 percent on test specimens having resistances of 0.00001 ohm (Ω) or more. Weight resistivity accuracy may be adversely affected by possible inaccuracies in the assumed density of the material.

2. Resistivity. Resistivity is the electrical resistance of a body of unit length, and unit cross-sectional area or unit weight.

2.1 Volume resistivity. Volume resistivity is commonly expressed in ohms for a theoretical conductor of unit length and cross-sectional area. It may be calculated using the following equation:

$$r_v = (A/L) \times R$$

Where:

r_v = volume resistivity in ohms-square millimeters per meter ($\Omega mm^2/m$)

A = cross-sectional area in mm^2

L = gauge length, used to determine R, in m

R = measured resistance, in Ω

2.2 Weight resistivity. Weight resistivity is commonly expressed in ohms for a theoretical conductor of unit length and weight. It may be calculated using the following equation:

$$r_w = (W/(L_1 \times L_2)) \times R$$

Where:

r_w = weight resistivity in ohms-grams per square meter ($\Omega g/m^2$)

W = weight of the test specimen, in g

L_2 = length of the test specimen, in m

L_1 = gage length, used to determine R, in m

R = measured resistance, in Ω

3. Apparatus. Resistance shall be measured with a Kelvin-type double bridge or a potentiometer if the resistance of the test specimen is less than 1 Ω. If the resistance of the test specimen is not less than 1 Ω, a Wheatstone bridge may be used. Where applicable, a Hoopes conductivity bridge may be used.

4. Test specimen. The test specimen may be in the form of a wire, strip, rod, bar, tube, or shape. It shall be of uniform cross section throughout its length within plus or minus 0.75 percent of the cross-sectional area. Wherever possible, the test specimen shall be the full cross section of the material it represents, if the full cross section is such that the uniformity of the cross-sectional area can be accurately determined.

4.1 Characteristics. The test specimen shall have the following characteristics:

(a) A resistance of not less than 0.00001 Ω in the test length between potential contacts.
(b) A test length of at least 0.3 m.
(c) A diameter, thickness, width, or other dimension suitable to the limitations of the resistance measuring instrument.
(d) No surface cracks or defects visible to the unaided normal eye, and substantially free from surface oxide, dirt, and grease.
(e) No joints or splices.

5. Procedure.

5.1 Determinations of the dimensions and weight of the test specimen shall be made with instruments accurate to plus or minus 0.05 percent. In order to ensure this accuracy in measuring the length between potential contacts, the surface in contact shall be a substantially sharp knife-edge when using a Kelvin-type double bridge or a potentiometer.

5.2 The cross-sectional dimensions of the test specimen shall be determined by micrometer measurements, and a sufficient number of measurements shall be made to obtain the mean cross section to within plus or minus 0.10 percent. If any dimension of the test specimen is less than 2.540 mm and cannot be measured to the required accuracy, the cross section shall be determined from the weight, density, and length of the test specimen.

5.3 When the density is unknown, it shall be determined by weighing a specimen first in air and then in a liquid of known density at the test temperature, which shall be room temperature to avoid errors due to convection currents. Care shall be exercised to remove all air bubbles from the test specimen when weighing it in the liquid. The density shall be calculated from the following equation:

$$\delta = (W_a \times d)/(W_a - W_l)$$

Where:

δ = density of the test specimen, in grams per cubic centimeter (g/cm^3)

W_a = weight of the test specimen in air, in g

W_l = weight of the test specimen in the liquid, in g

d = density of the liquid at the test temperature, in g/cm^3

5.4 When potential leads are used, the distance between each potential contact and the corresponding current contact shall be not less than 1.5 times the cross-sectional perimeter of the specimen. The yoke resistance (between the reference standard and the test specimen) shall be appreciably smaller than that of either the reference standard or the test specimen unless a suitable lead compensation method is used, or it is known that the coil and lead ratios are sufficiently balanced so that variations in yoke resistance will not decrease the bridge accuracy below stated requirements.

5.5 Resistance measurements shall be made to an accuracy of plus or minus 0.15 percent. To ensure a correct reading, the reference standard and the test specimen shall be allowed to come to the same temperature as the surrounding medium. If the reference standard is made of manganin, it is possible to obtain correct readings with the test specimen at reference temperatures other than room temperature. In all resistance measurements, the measuring current raises the temperature of the medium. Therefore, care shall be taken to keep the magnitude of the current low, and the time of its use short enough so that the change in resistance cannot be detected with the galvanometer. To eliminate errors due to contact potential, two readings, one direct and one with current reversed, shall be taken in direct succession. Check tests are recommended, whereby the test specimen is turned end for end and the test is repeated. Surface cleaning of the specimen at current and potential contact points may be necessary to obtain good electrical contact.

6. Temperature correction. When the measurement is made at any other than a reference temperature, the resistance may be corrected for moderate temperature differences to what it would be at the reference temperature by using the following equation:

$$R_T = R_t/(1 + \alpha_T(t-T))$$

Where:

R_T = resistance at reference temperature T.

R_t = resistance at measured temperature t.

α_T = known or given temperature coefficient of resistance of the specimen being measured at reference temperature T.

T = reference temperature.

t = temperature at which measurement is made.

The parameter α_T in the above equation, varies with conductivity and temperature. For copper of 100 percent conductivity and a reference temperature of 20 degrees Celsius(°C), its value is 0.00393. Values at other conductivities and temperatures can be found in NBS Handbook 100 . Table 401-I lists temperature coefficients for common electrical conductor materials.

7. Calculation. Percent IACS conductivity is calculated as follows:

(a) Volume basis:

$$c_v = (1/r_v) \times 1.7241$$

Where:

c_v = percent IACS conductivity (volume basis).
r_v = volume resistivity in $\Omega mm^2/m$.

(b) Weight basis:

$$c_w = (1/r_w) \times 15.328 \times (1/\delta)$$

Where:

c_w = percent IACS conductivity (weight basis).
r_w = weight resistivity in $\Omega g/m^2$.
δ = density in g/cm^3

TABLE 401-I. Density and temperature coefficient of resistance for electrical conductor materials.

Material	Approximate density, δ, at 20°C, g/cm^3	Temperature coefficient of resistance, α, at 20°C
Copper, percent IACS:		
100	8.89	0.00393
98.40	8.89	0.003897
98.16	8.89	0.00386
97.80	8.89	0.00384
97.66	8.89	0.00384
97.40	8.89	0.00383
97.16	8.89	0.00382
96.66	8.89	0.00380
96.61	8.89	0.00380
96.16	8.89	0.00378
94.16	8.89	0.00366
Silver-coated copper, ASTM B 298:		
Class A	8.91	0.00393
Class B	8.93	0.00393
Class C	8.95	0.00394
Class D	8.99	0.00394
Class E	9.05	0.00395
Nickel-coated copper, ASTM B 355:		
Class 2	8.89	0.00395
Class 4	8.89	0.00397
Class 7	8.89	0.00400
Class 10	8.89	0.00404
Class 27	8.89	0.00422
Bronze, ASTM B 9:		
Alloy 40	8.89	0.00157
Alloy 55	8.89	0.00224
Alloy 80	8.89	0.00322

TABLE 401-I. Density and temperature coefficient of resistance for electrical conductor materials - Continued.

Material	Approximate density, δ, at 20°C, g/cm³	Temperature coefficient of resistance, α, at 20°C
Copper alloy, ASTM B 105: 1/		
Grade 8.5	8.78	0.00042
Grade 13	8.78	0.00063
Grade 15	8.54	0.00072
Grade 20	8.89	0.00079
Grade 30	8.89	0.00118
Grade 40	8.89	0.00157
Grade 55	8.89	0.00224
Grade 80	8.89	0.00322
Grade 85	8.89	0.00342
Copper-clad aluminum, ASTM B 566		
Class 10A and 10H	3.32	0.00405
Class 15A and 15H	3.63	0.00404
Aluminum 1350, percent IACS		
61.8	2.705	0.00408
61.5	2.705	0.00406
61.4	2.705	0.00406
61.3	2.705	0.00405
61.2	2.705	0.00404
61.0	2.705	0.00403
Aluminum alloy:		
5005-H19	2.700	0.00353
6201-T81	2.690	0.00347
Aluminum-clad steel	6.590	0.0036
Copper-clad steel:		

See footnote at end of table.

TABLE 401-I. Density and temperature coefficient of resistance for electrical conductor materials - Continued.

Material	Approximate density, δ, at 20°C, g/cm^3	Temperature coefficient of resistance, α, at 20°C
Grade 30A, HS, and EHS	8.15	0.00378
Grade 40A, HS, and EHS	8.25	0.00378
Galvanized steel (telephone and telegraph):		
Class A coating:		
Grade EBB	7.83	0.0056
Grade BB	7.83	0.0046
Grade Steel	7.83	0.0042
Class B coating:		
Grade EBB	7.80	0.0056
Grade BB	7.80	0.0046
Grade Steel	7.80	0.0042
Class C coating:		
Grade EBB	7.77	0.0056
Grade BB	7.77	0.0046
Grade Steel	7.77	0.0042

1/ Various compositions are permitted for some of the grades in ASTM B 105 and the density value given may not apply to all materials supplied to these specifications. In case of doubt, the density value should be determined or obtained from the manufacturer.

TEST METHOD 402

PERCENT IACS ELECTRICAL CONDUCTIVITY BY EDDY CURRENT MEASUREMENT

1. Scope. This method is used for determining the electrical conductivity of nonmagnetic metals and alloys in accordance with the standard test method of ASTM E 1004. Percent IACS electrical conductivity is determined by measuring the resistance of a material to eddy current and converting this resistance to conductivity. This method provides a convenient and rapid means for determining the conductivity of materials by using commercially available electrical conductivity instruments. However, this method is less accurate than test method 401. The value of conductivity obtained using this test method can be significantly affected by the flatness and smoothness of the surface and the nonuniformities within the test specimen.

2. Apparatus. The basic test apparatus consists of a coil in a detector tip.

3. Test specimen. The test specimen shall have a flat surface. The degree of flatness and smoothness can affect the test results significantly.

4. Reference standards. Prior to testing, the test instrument shall be calibrated to a reference standard. Electrical conductivity standards are classified as either primary or secondary standards.

4.1 Primary standards. Primary standards have a value of conductivity assigned through direct comparison with a standard calibrated in accordance with test method 401, or they have been calibrated by an agency which has access to standards calibrated in terms of fundamental units. The primary standards are kept in a laboratory environment and are used only to calibrate secondary standards.

4.2 Secondary standards. Secondary standards are those calibrated against primary standards. These standards are used to calibrate the test instrument during use.

5. Procedure.

5.1 Select the probe coil to be used based on the dimensions of the test specimen. When the coil is placed on the test specimen, there shall be not less than two coil diameters from the edge of the coil to any edge of the test specimen.

5.2 Connect the probe coil to the instrument.

5.3 Switch on the instrument and allow it to warm up for not less than the length of time recommended by the instrument manufacturer.

5.4 Make all necessary setup and control adjustments in accordance with the instrument manufacturer's recommendation.

5.5 Calibrate the instrument to a reference standard, and compensate for surface roughness and varying coil-to-test specimen separation (lift-off), in accordance with the instrument manufacturer's instructions. Calibrate at the start of the test run and at least once every hour of continuous operation, or whenever improper functioning of the system is suspected.

5.6 Place the probe coil on the test specimen and read the results from the display.

5.7 Verify the calibration of the test instrument at the end of testing each lot. If the calibration is found to exceed the limits set by the user, recalibrate the system and retest all of the test specimens tested since the last acceptable calibration.

SECTION 500 - MAGNETIC PERMEABILITY TEST METHODS

TEST METHOD 501

RELATIVE MAGNETIC PERMEABILITY WITH GO-NO-GO PERMEABILITY INDICATOR

1. Scope. This method is used for determining whether the relative magnetic permeability of a feebly magnetic material exceeds a specific value (1.2, 1.6, 2.0, or 2.5). This is accomplished by using permeability inserts or standards that have known relative magnetic permeabilities with a permeability indicator. This test is a convenient and rapid method of identifying suspect material with a limited degree of accuracy.

2. Apparatus. Test apparatus shall be a low-mu (go-no-go) permeability indicator in accordance with MIL-I-17214 and associated permeability inserts of 1.2, 1.6, 2.0, and 2.5 relative magnetic permeability (see Figure 501-1). The tip of the indicator's magnet shall be free of any adhering particles.

3. Test specimen. The test specimen may be a plate, sheet, bar, rod, or irregular-shaped object. The test area of the specimen shall be clean and free from oxide scale.

4. Procedure. Refer to Figure 501-1.

4.1 Select a permeability insert and place it into the seat of the permeability indicator.

4.2 While holding the end of the indicator opposite the insert and magnet in one hand, place the projecting end of the indicator's magnet in contact with the test area of the specimen.

4.3 Move the indicator in a direction normal to the contact surface of the test area of the test specimen.

4.4 If the indicator's magnet breaks contact with the insert, the test specimen has a higher relative magnetic permeability than that of the insert. If the magnet breaks contact with the test area of the specimen, the test specimen has a lower magnetic permeability than that of the insert.

4.5 Repeat 4.1 through 4.4 with other appropriate permeability inserts so that the relative magnetic permeability of the test specimen can be bracketed between that of two inserts or be established as higher than 2.5 or lower than 1.2.

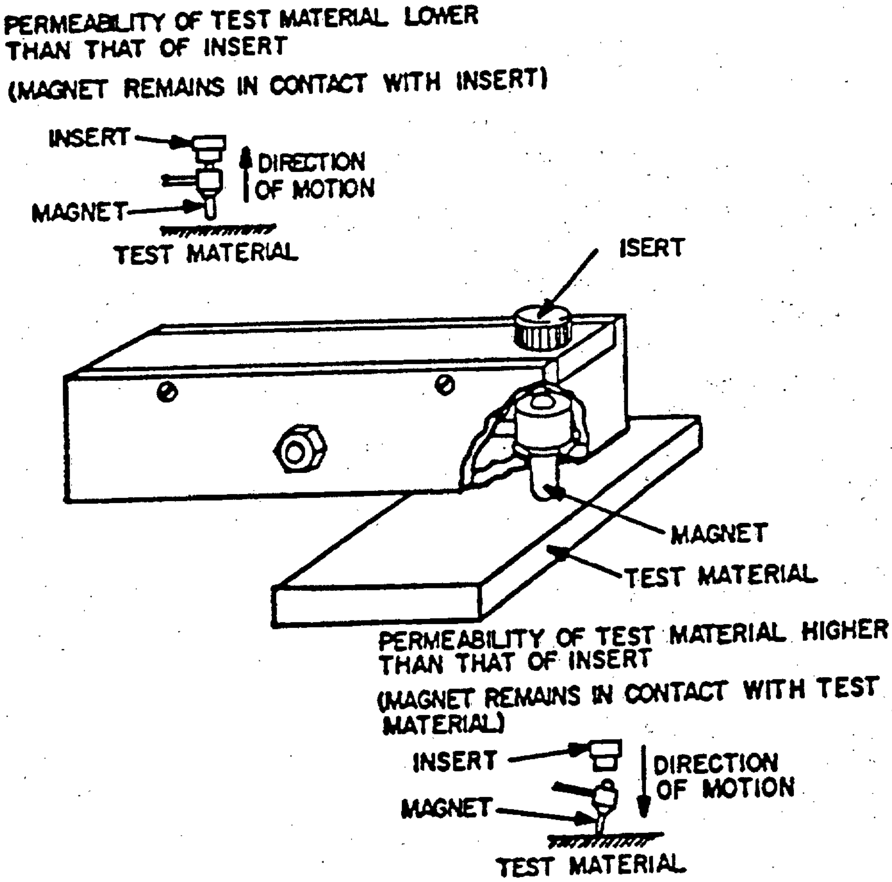


FIGURE 501-1. Use of low-mu (go-no-go) permeability indicator.

TEST METHOD 502

RELATIVE MAGNETIC PERMEABILITY USING A MODIFIED FAHY LOW-MU PERMEAMETER

1. Scope. This method is used for determining the relative magnetic permeability of materials having a permeability not greater than 4.0 in accordance with standard test method number 1 of ASTM A 342.

2. Apparatus.

2.1 Power supply. The power supply shall be capable of providing steady dc power for the circuits shown on Figures 502-1 and 502-2.

2.2 Permeameter. The permeameter shall be one consisting of a magnetizing solenoid with two test coils mounted midway between the ends of the solenoid for measuring induction and magnetizing force, and a compensating coil and mutual inductor, or air flux balancing resistor, in accordance with the following requirements.

2.2.1 Magnetizing solenoid. The magnetizing solenoid, C1, shall have a minimum length of 300 mm, and a ratio of length to equivalent diameter of not less than 4. The magnetizing winding shall be uniformly wound and capable of producing a substantially uniform field of at least 30,000 μT over the length of the test coils without overheating.

2.2.2 Magnetic flux density test coil. The test coil B1, used for measuring magnetic flux density, shall have not less than 2000 turns, a length not greater than 25.4 mm, and a cross-sectional area not greater than 10 times that of the test specimen. This limitation on cross-sectional area does not apply when the permeability of the test specimen is not greater than 1.05.

2.2.3 Magnetizing force test coil. The test coil H1, used for measuring magnetizing force, shall have the same length as coil B1. The area-turns shall be determined by the sensitivity of the available galvanometer.

2.2.4 Compensating coil. The compensating coil, B1', shall be of the same length as coil B1.

2.3 Standard mutual inductor. The standard mutual inductor, Lm, shall be of a suitable value for calibrating circuits B and H.

2.4 Calibrating resistances. The calibrating resistances, RB and RH, shall be decade resistance boxes used in conjunction with the standard mutual inductor to calibrate circuits B and H.

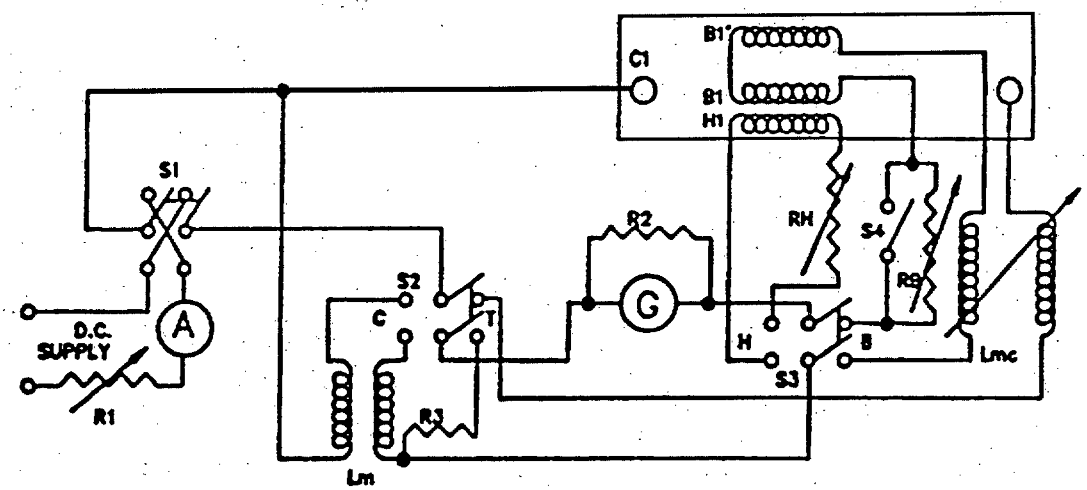


FIGURE 502-1. Circuit diagram for test method 502.

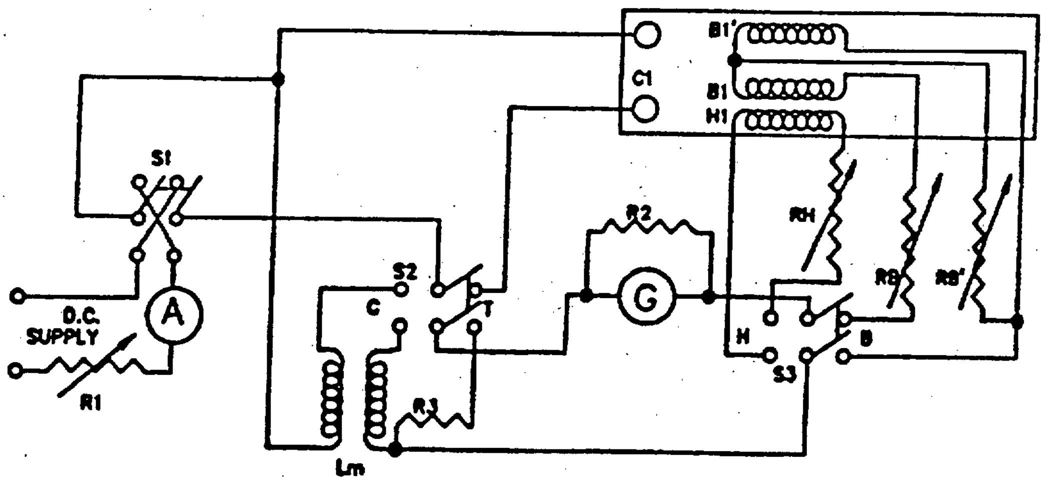


FIGURE 502-2. Alternative circuit diagram for test method 502.

2.5 Galvanometer. The galvanometer, G, shall be either a fluxmeter or a ballistic galvanometer of high sensitivity, and having suitable characteristics for magnetic testing.

2.6 Compensating variable mutual inductor. The compensating variable mutual inductor, Lmc, shall be of low value and shall be used in conjunction with coil B1 to compensate for the air flux enclosed by coil B1, so that the intrinsic induction may be measured directly.

2.7 Air flux compensating resistor. The air flux compensating resistor, RB', is used in conjunction with coil B1' to compensate for the air flux enclosed by coil B1 so that the intrinsic induction may be measured directly.

2.8 Substitution resistor. During the test, to avoid errors from stray field pickup, the secondary of the calibrating mutual inductor Lm is removed and replaced by the substitution resistor, R3, which is adjusted to have a resistance equal to that of the Lm secondary.

2.9 Miscellaneous current control equipment. Miscellaneous current control equipment, such as multirange ammeter, rheostats, and reversing switch, shall be used in the magnetizing circuit.

3. Test specimen. The test specimen shall be a straight bar, rod, wire, or strip, of uniform cross section. The cross-sectional area shall be not less than 0.2 square centimeters (cm^2). The length shall be not less than 100 mm and the ratio of length to diameter or equivalent diameter (the diameter of a circle having the same cross-sectional area as the test specimen) shall be as follows:

Permeability	Dimensional ratio
Under 1.1	4 or over
1.1 to 2.0 (inclusive)	20 or over
2.0 to 4.0	30 or over

This method can be used with smaller dimension-ratio test specimens when used for comparing similar specimens for quality control purposes. The absolute values may, however, not meet the 2 percent accuracy limits.

4. Procedure.

4.1 Before inserting the test specimen in the solenoid, obtain an exact balance to nullify the effect of air flux in coil B1, by reversing the highest magnetizing current to be used in the test and adjusting the compensating means.

4.2 Calibrate circuit H (figure 502-1 or 502-2) by reversing a current I' in the primary of Lm and adjusting RH to obtain a suitable galvanometer deflection. The galvanometer deflection can be made direct reading by adjusting RH so that the galvanometer deflection, in mm, is some simple multiple of H, in amperes per meter (A/m). Determine the calibrating current using the following equation:

$$I' = 4\pi(H \times aN)/(L_m \times 10^8)$$

Where:

I' = current to be maintained in the primary of the standard inductor, in amperes

H = Maximum value of magnetizing force necessary for tests, in A/m

aN = area-turns of coil H1, where the area is in cm^2

Lm = inductance of the standard inductor, in millihenries (mH).

4.3 Place the test specimen in position, adjust the magnetizing force to the desired test value, then adjust the sensitivity of circuit B to give a suitable test deflection on reversal of the magnetizing current, and then calibrate circuit B using the following equation:

$$Bi = [(Lm \times I')/NAD'] \times D$$

Where:

Bi = magnetic flux density of test specimen, in nT.

Lm = inductance of the standard inductor, in mH

I' = current maintained in the primary winding of the standard inductor to obtain calibration deflection, in amperes

N = number of turns in coil B1

A = cross-sectional area of the test specimen, in cm^2

D' = calibration deflection, in mm

D = test deflection, in mm

π = 3.14159

5. Calculation. Calculate the relative permeability as follows:

$$\mu_r = (Bi)/(4\pi \times 10^{-2} \times H)$$

Where:

μ_r = relative permeability of the test specimen

Bi = magnetic flux density of the test specimen, in nT

H = value of magnetizing force, in A/m

π = 3.14159

6. Bias. For specimens having a satisfactory degree of uniformity along their length and tested at a definite temperature, the bias of the permeability measurement should be within 2 percent.

TEST METHOD 503

RELATIVE MAGNETIC PERMEABILITY USING A FAHY LOW-MU PERMEAMETER

1. Scope. This method is used for determining the relative magnetic permeability of materials having a permeability of not greater than 4.0 in accordance with standard test method number 2 of ASTM A 342.

2. Apparatus.

2.1 Power supply. The power supply shall be capable of providing steady direct current (dc) power for the circuit shown on figure 503-1.

2.2 Permeameter. The permeameter shall be one consisting of a magnetizing solenoid with two test coils mounted midway between the ends of the solenoid for measuring induction and magnetizing force, and a compensating coil and mutual inductor, or air flux balancing resistor, in accordance with the following requirements.

2.2.1 Magnetizing solenoid. The magnetizing solenoid, C1, shall have a minimum length of 300 mm, and a ratio of length to equivalent diameter of not less than 4. The magnetizing winding shall be uniformly wound and capable of producing a substantially uniform field of at least 30,000 μT over the length of the test coils without overheating.

2.2.2 Magnetic flux density test coil. The test coil B1, used for measuring magnetic flux density, shall have not less than 2000 turns, a length not greater than 25.4 mm, and a cross-sectional area not greater than 10 times that of the test specimen. This limitation on cross-sectional area does not apply when the permeability of the test specimen is not greater than 1.05.

2.2.3 Magnetizing force test coil. The test coil H1, used for measuring magnetizing force, shall have the same length as coil B1. The area-turns shall be determined by the sensitivity of the available galvanometer.

2.2.4 Balancing resistor. The balancing resistor, R0, is used in conjunction with coil H1 to compensate for the air flux in coil B1, so that the magnetic flux density may be measured directly.

2.3 Standard mutual inductor. The standard mutual inductor, Lm, shall be of a suitable value for calibrating circuits B and H.

2.4 Calibrating resistances. The calibrating resistances, RB and RH, shall be decade resistance boxes used in conjunction with the standard mutual inductor to calibrate circuits B and H.

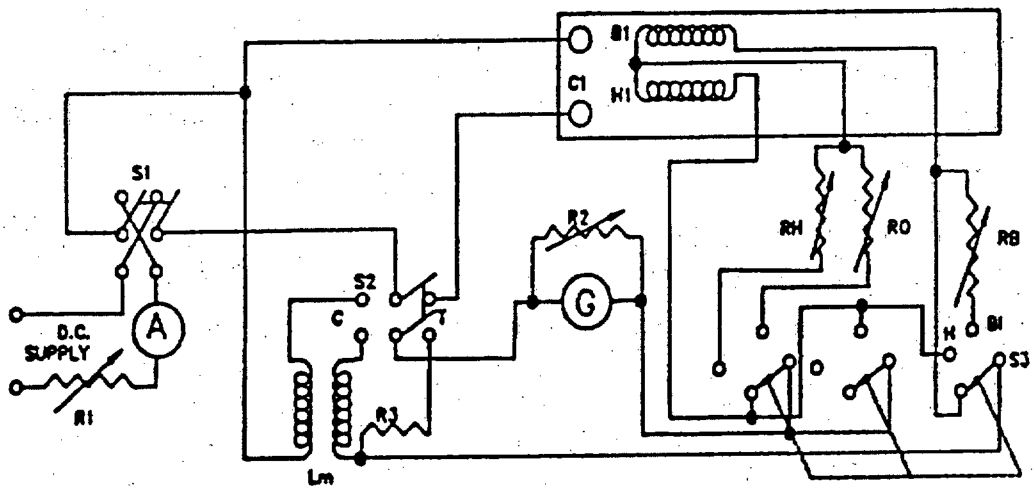


FIGURE 503-1. Circuit diagram for test method 503.

2.5 Galvanometer. The galvanometer, G, shall be either a fluxmeter or a ballistic galvanometer of high sensitivity, and having suitable characteristics for magnetic testing.

2.6 Special switch. The special switch, S3, is used in conjunction with H1 and Ro to compensate for the air flux enclosed by coil B1, so that the magnetic flux density may be measured directly.

2.7 Substitution resistor. During the test, to avoid errors from stray field pickup, the secondary of the calibrating mutual inductor Lm is removed and replaced by the substitution resistor, R3, which is adjusted to have a resistance equal to that of the Lm secondary.

2.8 Miscellaneous current control equipment. Miscellaneous current control equipment, such as multirange ammeter, rheostats, and reversing switch, shall be used in the magnetizing circuit.

3. Test specimen. The test specimen shall be a straight bar, rod, wire, or strip, of uniform cross section. The cross-sectional area shall be not less than 0.2 cm^2. The length shall be not less than 100 mm and the ratio of length to diameter or equivalent diameter (the diameter of a circle having the same cross-sectional area as the test specimen) shall be as follows:

Permeability	Dimensional ratio
Under 1.1	4 or over
1.1 to 2.0 (inclusive)	20 or over
2.0 to 4.0	30 or over

This method can be used with smaller dimension-ratio test specimens when used for comparing similar specimens for quality control purposes. The absolute values may, however, not meet the 2 percent accuracy limits.

4. Procedure.

4.1 Before inserting the test specimen in the solenoid, obtain an exact balance to nullify the effect of air flux in coil B1, by reversing the highest magnetizing current to be used in the test and adjusting the compensating means.

4.2 Calibrate circuit H (figure 502-1 or 502-2) by reversing a current I' in the primary of Lm and adjusting RH to obtain a suitable galvanometer deflection. The galvanometer deflection can be made direct reading by adjusting RH so that the galvanometer deflection, in mm, is some simple multiple of H, in amperes per meter (A/m). Determine the calibrating current using the following equation:

$$I' = 4\pi(H \times aN)/(L_m \times 10^8)$$

Where:

I′ = current to be maintained in the primary of the standard inductor, in amperes

H = Maximum value of magnetizing force necessary for tests, in A/m

aN = area-turns of coil H1, where the area is in cm^2

Lm = inductance of the standard inductor, in mH.

$4\pi \times 10^{-8} = 0.1$ Mo, where Mo = $4\pi \times 10^{-7}$ Henrys per meter, the permeability of free space.

4.3 Place the test specimen in position, adjust the magnetizing force to the desired test value, then adjust the sensitivity of circuit B to give a suitable test deflection on reversal of the magnetizing current, and then calibrate circuit B using the following equation:

$$Bi = [(Lm \times I')/NAD'] \times D$$

Where:

Bi = magnetic flux density of test specimen, in nT.

Lm = inductance of the standard inductor, in mH

I′ = current maintained in the primary of the standard inductor to obtain calibration deflection, in amperes

N = number of turns in coil B1

A = cross-sectional area of the test specimen, in cm^2

D′ = calibration deflection, in mm

D = test deflection, in mm

π = 3.14159

5. Calculation. Calculate the relative permeability as follows:

$$\mu_r = (Bi)/(4\pi \times 10^{-2} \times H)$$

Where:

μ_r = relative permeability of the test specimen

Bi = magnetic flux density of the test specimen, in nT

H = value of magnetizing force, in A/m

π = 3.14159

6. Bias. For specimens having a satisfactory degree of uniformity along their length and tested at a definite temperature, the bias of the permeability measurement should be within 2 percent.

TEST METHOD 504

RELATIVE MAGNETIC PERMEABILITY BY NULL METHOD

1. Scope. This method is used for determining the relative magnetic permeability of materials having a permeability not greater than 4.0 in accordance with standard test method number 3 of ASTM A 342. This method uses a permeameter with a nulling circuit that can provide accurate permeability measurements to within 2 percent.

2. Apparatus.

2.1 Power supply. The power supply shall be a device capable of providing steady dc power to the circuit shown on figure 504-1, such as a storage battery or suitably designed rectifier circuit.

2.2 Magnetizing solenoid. The magnetizing solenoid, C1, shall have a length of not less than 300 mm and a ratio of length to equivalent diameter of not less than 10. The magnetizing winding shall be uniformly wound and capable of producing a substantially uniform field of not less than 35,000 μT over the middle 20 mm of the length of the interior of the solenoid. The number of turns per centimeter of length shall be definitely known to within 1 percent.

2.3 Test coil. The test coil, B1, shall have not less than 200 turns, a length not greater than 20 mm, and a cross-sectional area not greater than 10 times that of the test specimen.

2.4 Standard variable mutual inductor. The standard variable mutual inductor, Lm, shall be a calibrated variable mutual inductor, graduated in microhenries.

2.5 Compensating mutual inductor. The compensating mutual inductor, Lmc, shall be an adjustable air-cored mutual inductor. It shall be used to compensate for the mutual inductance of coil B1 and solenoid C1 with only air in coil B1.

2.6 Galvanometer. The galvanometer, G, shall be a short-period reflecting galvanometer of sufficient sensitivity to detect a change of 0.005 in permeability of the specimen.

2.7 Miscellaneous current control equipment. Miscellaneous current control equipment, such as ammeter, rheostats, and reversing switch, shall be used in the magnetizing circuit as shown on figure 504-1.

3. Test specimen. The test specimen shall be a straight bar, rod, wire, or strip, of uniform cross section. The cross-sectional area shall be not

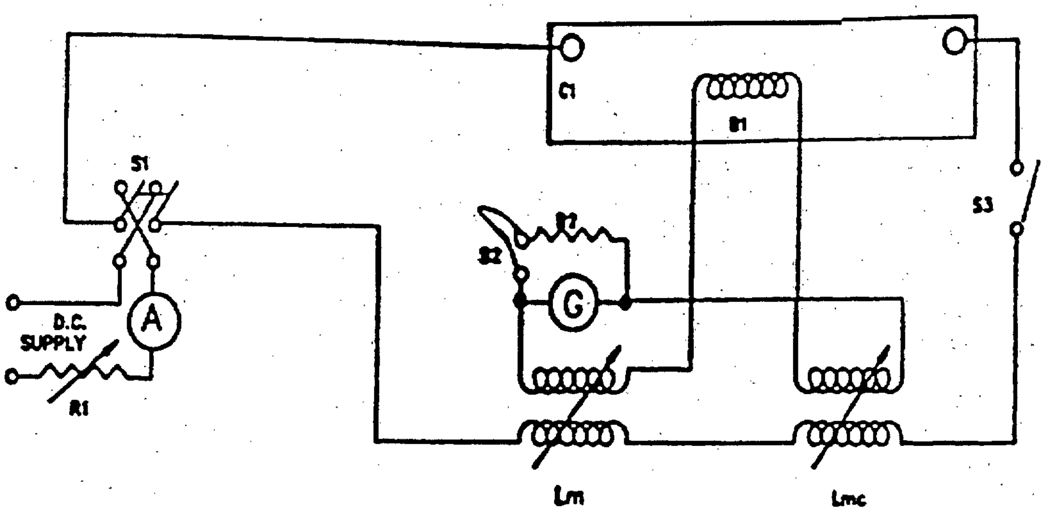


FIGURE 504-1. Circuit diagram for test method 504.

less than 0.2 square centimeters (cm^2). The length shall be not less than 100 mm and the ratio of length to diameter or equivalent diameter (the diameter of a circle having the same cross-sectional area as the test specimen) shall be as follows:

Permeability	Dimensional ratio
Under 1.1	4 or over
1.1 to 2.0 (inclusive)	20 or over
2.0 to 4.0	30 or over

This method can be used with smaller dimension-ratio test specimens when used for comparing similar specimens for quality control purposes. The absolute values may, however, not meet the 2 percent accuracy limits.

4. Procedure.

4.1 Before inserting the test specimen in the solenoid, set inductor Lm at the zero point of its scale, and adjust inductor Lmc until, on reversing the magnetizing circuit, the galvanometer indicates a balance.

4.2 Place the test specimen in position in coil B1, inside the solenoid, and adjust inductor Lm until the galvanometer indicates a balance on reversing the magnetizing circuit. Read the increment of induction, resulting from the presence of the test specimen, on the inductor scale.

5. Calculation.

5.1 Calculate the permeability as follows:

$$\mu = 1 + [(Lm \times 10^3)/4\pi NnA]$$

Where:

μ = permeability

Lm = mutual inductance of Lm, in mH, when balanced with the test specimen in place

n = number of turns per centimeter of length of solenoid

N = number of turns of coil B1

A = cross-sectional area of test specimen, in cm^2

6. Bias. For specimens having a satisfactory degree of uniformity along their length and tested at a definite temperature, the bias of the permeability measurement should be within 2 percent.

TEST METHOD 505

RELATIVE REVERSIBLE MAGNETIC PERMEABILITY

1. Scope. This method is used for determining the relative reversible magnetic permeability of feebly magnetic materials. An alternating current is applied to a sense coil in which the test specimen is placed. A direct current is applied to a reference coil surrounding the sense coil. The voltage drop across the sense coil reflects the coil's inductance. In turn, the inductance is proportional to the permeability of the sense coil's core, which consists of air and the test specimen. Consequently, knowing the geometry of both the sense coil and core, as well as the coil's electrical response, the core's relative reversible permeability at selected frequencies of the alternating current driving the sense coil can be determined by calculation. This method should result in a permeability measurement with plus or minus 2 percent accuracy.

2. Reversible permeability. Reversible permeability is the limit of the incremental permeability as the change in magnetizing force approaches zero.

3. Apparatus.

3.1 Dc power supply. The dc power supply shall be a source of steady dc power with constant output voltage, V, for the electrical circuit shown in Figure 505-1. The constant voltage, V, shall be determined from the following equation:

$$V = \frac{100 \times Ro}{No \times \pi \times Lo} \times (Do^2 + Lo^2)^{1/2}$$

Where:

Ro = dc resistance of the reference coil in ohms.

No = number of turns on the reference coil.

Do = mean diameter of the reference coil in meters.

Lo = length of the reference coil in meters.

π = 3.14159

100 = constant with the units of amperes.

3.2 Ac power supply. The ac power supply shall be a source of alternating power of approximate sine wave voltage form with a frequency of fo Hz and a root mean square (rms) voltage of Vd volts for the electrical circuit shown on Figure 505-1.

3.3 Sense coil. The sense coil shall be a multilayered, solenoidal inductance coil which contains the test specimen. The sense coil length, Li, must be very short relative to the length of the test specimen in order to achieve good resolution of permeability versus length. The coil diameter, Di, should be made as small as possible to maximize the percentage of coil core area occupied by the test specimen. An adequate number of turns, Ni, should be used to ensure a reasonable change in ac voltage for the smallest permeability change to be measured.

3.4 Reference coil. The reference coil shall be a solenoidal inductance coil which provides a dc reference magnetic field for conducting the test.

3.5 Driver resistor. The driver resistor, Rd, shall be in series with the sense coil and the ac power supply. The resistance shall be not less than 1000 times greater than the impedance of the sense coil. This will minimize current deviations caused by changes in the magnitude of the sense coil's impedance.

3.6 Voltmeter. The voltmeter shall have a range scale as required to measure the ac rms voltage drop, Vs, across the sense coil.

4. Test specimen. The test specimen shall consist of a straight bar, rod, wire, or strip of uniform cross section. The length shall be not less than ten times the sense coil's length and not greater than the reference coil's length.

5. Procedure.

5.1 Apply and maintain the constant voltage V from the dc power supply across the leads to the reference coil.

5.2 Apply and maintain the ac power supply with rms voltage of Vd volts and fo Hz to the sense coil and series driver resistor.

5.3 Before inserting the test specimen in the sense coil, obtain a reading of Vs from the voltmeter. Calculate the permeability with no test specimen present in the sense coil from the formula in section 6. If the test setup has been properly accomplished, this relative permeability should be that for air (approximately 1.0).

5.4 Insert the test specimen in the sense coil and measure from the voltmeter and record the ac voltage drop Vs across the sense coil.

5.5 Adjust the frequency of the ac power supply and repeat 5.4.

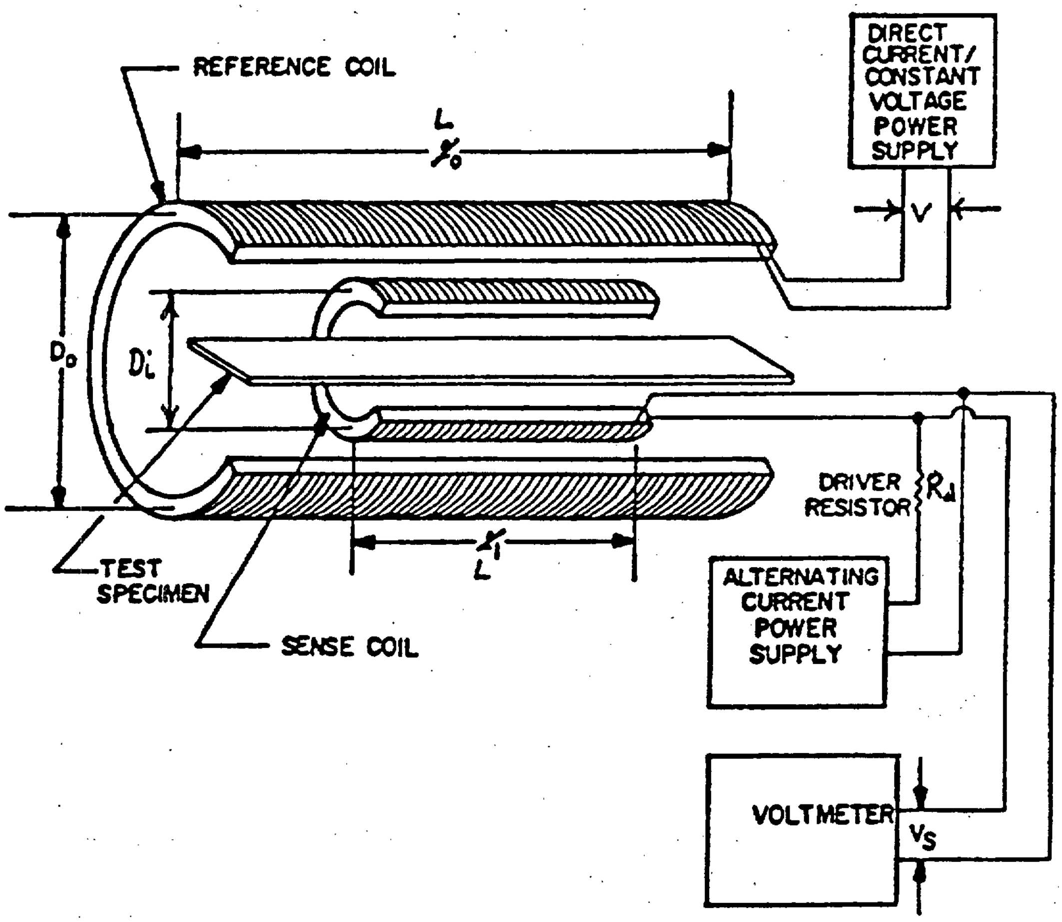


FIGURE 505-1. Typical test setup for measurement of relative reversible magnetic permeability.

5.6 Repeat 5.5 as required to measure the permeability over the selected frequency range.

5.7 The voltmeter may be supplemented by voltage recording equipment for future data reduction, or a computer which will continuously output permeability data based upon the current value of Vs and the formula in section 6. A swept frequency spectrum analyzer may be used to measure permeability versus frequency of the ac power supply over a continuous range.

6. Calculation.

6.1 Calculate the relative reversible permeability (μ_r) as follows:

$$\mu_r = \frac{1}{2 \times A} \times \left[\frac{Li[(Vs^2 \times Rd^2) - Ri^2(Vd - Vs)^2]^{1/2}}{\mu o \times Ni^2 \times \pi \times fo \times K \times (Vd - Vs)} - \frac{\pi \times Di^2 - 4A}{2} \right]$$

Where:

Ni = number of turns on the sense coil.

Di = mean diameter of the sense coil in meters.

Li = length of the sense coil in meters.

Vs = ac voltage drop across the sense coil in rms volts.

Rd = resistance of the driver resistor in ohms.

Ri = dc resistance of the sense coil in ohms.

Vd = amplitude of the ac power supply in rms V.

μo = magnetic permeability of free space ($4\pi \times 10^{-7}$ Henry/meter).

fo = frequency of the sinusoidal ac power supply in Hz.

A = cross-sectional area of the test specimen perpendicular to the sense coil axis in square meters.

K = $[1 + 0.45(Di/Li) + 0.64(t/Di) + 0.84(t/Li)]^{-1}$

t = radial difference between the outermost and innermost coil layer of the sense coil in meters.

π = 3.14159

SECTION 600 - FINAL MAGNETIC SIGNATURE TESTS

TEST METHOD 601

INITIAL MAGNETIC CALIBRATION

1. Scope. A nonmagnetic mine warfare ship or craft must be carefully designed so that its magnetic signature is minimized. The magnetic signature can then be further reduced with a properly calibrated degaussing system. This test method measures the undegaussed magnetic signature of the ship, generates the degaussing coil effect curves for the ship, and calibrates the degaussing system such that the magnetic signature of the ship is minimized.

2. Apparatus. This test shall be performed at a U.S. Navy Magnetic Silencing Facility (MSF).

3. Procedure.

3.1 Run the ship over the MSF range.

3.2 The MSF shall measure the undegaussed magnetic signature of the ship.

3.3 Energize the degaussing system as directed by the MSF.

3.4 Adjust the degaussing system as directed by the MSF.

3.5 The MSF will measure the degaussed magnetic signature of the ship.

4. Results. The MSF will furnish the results of this test to the contractor.

TEST METHOD 602

SHIP SERVICE (ADDED SERVICE) STRAY MAGNETIC FIELD TEST

1. Scope. The dc ship service equipment and circuits aboard nonmagnetic mine warfare ships and craft are potentially large sources of stray magnetic field. The magnitude of this stray magnetic field must be accurately determined so that it can be compensated for. This test measures the stray magnetic field generated by the ship service dc equipment and circuits.

2. Apparatus. This test shall be performed at a U.S. Navy Magnetic Silencing Facility (MSF).

3. Procedure.

3.1 Run the ship over the MSF range.

3.2 Energize and identify the ship service dc equipment and circuits as directed by the MSF.

3.3 The MSF will measure the stray magnetic fields generated by the ship service d.c. equipment and circuits.

4. Results. The MSF will furnish the results of this test to the contractor.

TEST METHOD 603

MINESWEEP GENERATOR STRAY MAGNETIC FIELD TEST

1. Scope. A minesweep generator is a large source of stray magnetic field because of the magnitudes of the direct current generated. The magnitude of this stray magnetic field must be accurately determined so that it can be compensated for. This test measures the stray magnetic field generated by a minesweep generator installed on a nonmagnetic mine warfare ship or craft.

2. Apparatus. This test shall be performed at a U.S. Navy Magnetic Silencing Facility (MSF).

3. Procedure.

3.1 Run the ship over the MSF range.

3.2 Energize the minesweep generator as directed by the MSF.

3.3 The MSF will measure the stray magnetic field generated by the minesweep generator.

4. Results. The MSF will furnish the results of this test to the contractor.

TEST METHOD 604

STATIC ELECTROMAGNETIC ROLL TEST

1. Scope. The earth's magnetic field creates an induced magnetic field in magnetic material. Since even nonmagnetic mine warfare ships and craft contain some magnetic material, the effect of this induced magnetization must be determined. The induced magnetic field changes as the ship's heading and location change, as well as when the ship rolls or pitches. This test measures the induced vertical magnetization and the induced athwartship magnetization of the ship.

2. Apparatus. This test shall be performed at a U.S. Navy Magnetic Silencing Facility (MSF).

3. Procedure.

3.1 Run the ship over the MSF range.

3.2 Operate the ship as directed by the MSF.

3.3 The MSF will measure the induced vertical magnetization and the induced athwartship magnetization of the ship.

4. Results. The MSF will furnish the results of this test to the contractor.

TEST METHOD 605

DYNAMIC ELECTROMAGNETIC ROLL TEST

1. Scope. The rolling motion of a ship in the earth's magnetic field induces eddy currents in electrically conductive material on board. These eddy currents in turn generate eddy current magnetic fields. These magnetic fields are potentially dangerous aboard nonmagnetic mine warfare ships and craft, and therefore must be carefully controlled. This test measures the eddy current magnetic field of the ship.

2. Apparatus. This test shall be performed at a U.S. Navy Magnetic Silencing Facility (MSF).

3. Procedure.

3.1 Run the ship over the MSF range.

3.2 Operate the ship as directed by the MSF.

3.3 The MSF will measure the eddy current magnetic field of the ship.

4. Results. The MSF will furnish the results of this test to the contractor.

(TO DETACH THIS FORM, CUT ALONG THIS LINE.)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
MIL-STD-2142A(SH)	Magnetic Silencing Characteristics, Measurement of (Metric)

3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION *(Mark one)*
	☐ VENDOR
	☐ USER
b. ADDRESS *(Street, City, State, ZIP Code)*	☐ MANUFACTURER
	☐ OTHER *(Specify)*: ______

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional	b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional
c. MAILING ADDRESS *(Street, City, State, ZIP Code)* – Optional	8. DATE OF SUBMISSION *(YYMMDD)*

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