Designation: ~~F3020 – 19~~ F3020 – 19a

~~Performance Standard~~ Standard Performance Specifications and Test Methods for Hand-Worn Metal Detectors Used in Safety and Security[1]

This standard is issued under the fixed designation F3020; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This standard applies to all hand-worn or glove-type metal detectors used to find metal contraband concealed or hidden on people or other objects with hand-accessible surfaces. Hand-worn metal detectors (HWMDs) are significantly different in design compared to the more common hand-held metal detector (HHMD). For example, the HWMD generates a much more localized magnetic field than does the HHMD and the useful field of the HWMD is normal to the plane of the hand whereas the useful field of the HHMD is multi-directional.

1.2 This standard describes baseline-performance requirements, which includes metal object detection performance, safety (electrical, mechanical, fire), electromagnetic compatibility, environmental conditions and ranges, and mechanical durability. The requirements for metal detection performance are unique and, therefore, test methods for these parameters are provided, including the design of test objects. An agency or organization using this standard is encouraged to add their unique operationally-based requirements to those requirements listed in this baseline-performance standard.

1.3 This documentary standard describes the use of spherical test objects, instead of actual threat objects or exemplars of threat objects, to test the detection performance of hand-worn metal detectors. Spherical test objects are used because the detectability of spherical test objects is not orientation dependent, whereas this is not true for non-spherical test objects. This orientation-dependent detectability of non-spherical test objects may allow a HWMD to be incorrectly attributed a higher performance capability than that HWMD is capable of providing. To aid agencies wishing to add specific threat objects to their detection performance requirements, included in ~~Annex A1~~ Appendix X1 is the analysis of the probability of detection for different orientations of agency-specific non-spherical threat objects.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

F3356 Practice for Conformity Assessment of Metal Detectors Used in Safety and Security

2.2 *ISO Standards:*[3]

ISO 17025:2005 General Requirements for the Competence of Testing and Calibration Laboratories

ISO 10012:2003 Quality Assurance Requirements for Measuring Equipment

ISO 14117:2012 Active Implantable Medical Devices—Electromagnetic Compatibility—EMC Test Protocols for Implantable Cardiac Pacemakers, Implantable Cardioverter Defibrillators, and Cardiac Resynchronization Devices

[1] This performance ~~standard~~specification is under the jurisdiction of ASTM Committee F12 on Security Systems and Equipment and is the direct responsibility of Subcommittee F12.60 on Controlled Access Security, Search, and Screening Equipment.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

ISO 14708–1:2000 Implants for Surgery—Active Implantable Medical Devices—Part 1: General Requirements for Safety, Marking, and for Information to be Provided by the Manufacturer
ISO 14708–2:2012 Implants for Surgery—Active Implantable Medical Devices—Part 2: Cardiac Pacemakers
ISO 14708–3:2017 Implants for Surgery—Active Implantable Medical Devices—Part 3: Implantable Devices
ISO 14708–4:2008 Implants for Surgery—Active Implantable Medical Devices—Part 4: Implantable Infusion Pumps
ISO 14708–5:2010 Implants for Surgery—Active Implantable Medical Devices—Part 5: Circulatory Support Devices
ISO 14708–6:2010 Implants for Surgery—Active Implantable Medical Devices—Part 6: Particular Requirements for Active Implantable Medical Devices Intended to Treat Tachyarrhythmia (Including Implantable Defibrillators)
ISO 14708–7:2013 Implants for Surgery—Active Implantable Medical Devices – Part 7: Particular Requirements for Cochlear Implant Systems

2.3 *IEC Standards:*[4]

IEC 61010–1 Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use—Part 1: General Requirements
IEC 61000–6–1 Electromagnetic Compatibility (EMC), Part 6: Generic Standards—Sections 1: Immunity for Residential, Commercial, and Light-Industrial Environments
IEC 61000–4–2 Electromagnetic Compatibility (EMC), Part 4: Testing and Measurement Techniques—Section 2: Electrostatics Discharge Immunity Test
IEC 61000–4–3 Electromagnetnic Compatibility (EMC), Part 4: Testing and Measurement Techniques—Section 3: Radiated, Radiofrequency, Electromagnetic Field Immunity Test
IEC 61000–4–8 Electromagnetic Compatibility (EMC), Part 4: Testing and Measurement Techniques—Section 8: Power Frequency Magnetic Field Immunity Test
IEC 60601–1–2 Medical Electrical Equipment—Part 1–2: General Requirements for Basic Safety and Essential Performance—Collateral Standard: Electromagnetic Disturbances—Requirements and Tests
IEC 60529 2001–2 Degrees of Protection Provided by Enclosures (IP Code)
IEC 60068–2–27: 2008–2 Environmental Testing—Part 2–27: Tests—Test Ea and Guidance: Shock
CISPR 22 Information Technology Equipment—Ratio Disturbance Characteristics—Limits and Methods of Measurement, Class B, Radiated Disturbance

2.4 *IEEE Standard*[5]

IEEE C95.1 Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz
IEEE C95.6 Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0–3 kHz

2.5 *Military Standards:*[6]

MIL-STD-810G Method 501.5 Test Method Standard for Environmental Engineering Considerations and Laboratory Tests, Method 501.5, High Temperature
MIL-STD-810G Method 502.5 Test Method Standard for Environmental Engineering Considerations and Laboratory Tests, Method 502.5, Low Temperature
MIL-STD-810G Method 507.5 Test Method Standard for Environmental Engineering Considerations and Laboratory Tests, Method 507.5, Humidity

2.6 *ANSI Standard:*[7]

ANSI S1.4–1983 Specification for Sound Level Meters

2.7 *CIE Standard:*[8]

CIE S 014–1/E:2006 Colorimetry—Part 1: CIE Standard Colorimetric Observers

3. Terminology

3.1 *Definitions:*

3.1.1 *alarm*—an indication that informs the operator of an event, such as metal detection or a detector (HWMD) status change.

3.1.2 *body simulant*—a material engineered to simulate the average electrical conductivity and magnetic permeability of the human body; the average electrical conductivity is ~~0.8~~0.8 S ~~S/m~~ /m ± ~~0.2~~0.2 S ~~S/m~~ /m and the average magnetic permeability is 1.26×10^{-6} H/m ± 5×10^{-7} H/m.

3.1.3 *detector*—the hand-worn metal detector (HWMD) that is worn on the hand and is used for finding metal objects concealed on a person or other object (see Figs. 1 and 2).

[4] Available from International Electrotechnical Commission (IEC), 3, rue de Varembé, P.O. Box 131, 1211 Geneva 20, Switzerland, http://www.iec.ch.
[5] Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., Piscataway, NJ 08854-4141, http://www.ieee.org.
[6] Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, http://www.access.gpo.gov.
[7] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.
[8] Available from U.S. National Committee of the CIE (International Commission on Illumination), C/o Alan Laird Lewis, 282 E. Riding, Carlisle, MA 01741, http://www.cie-usnc.org.

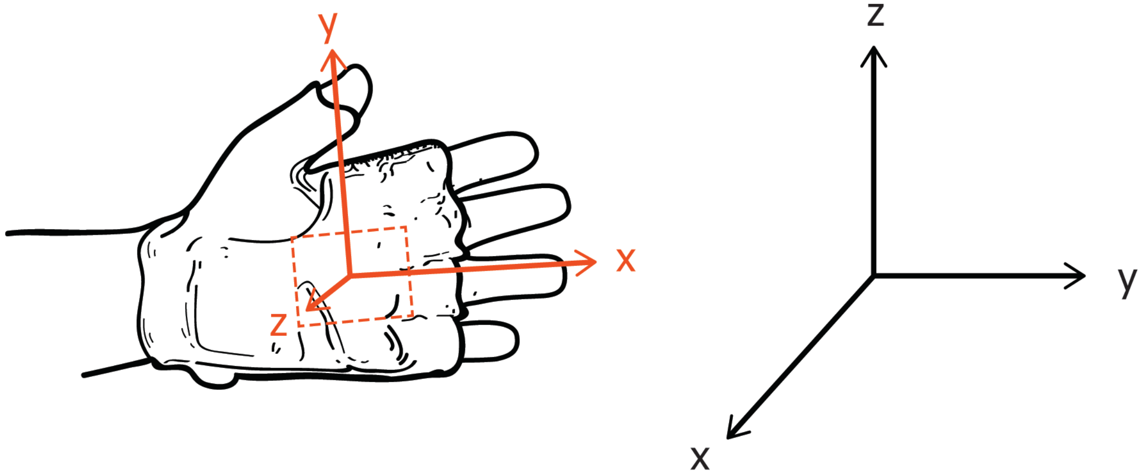
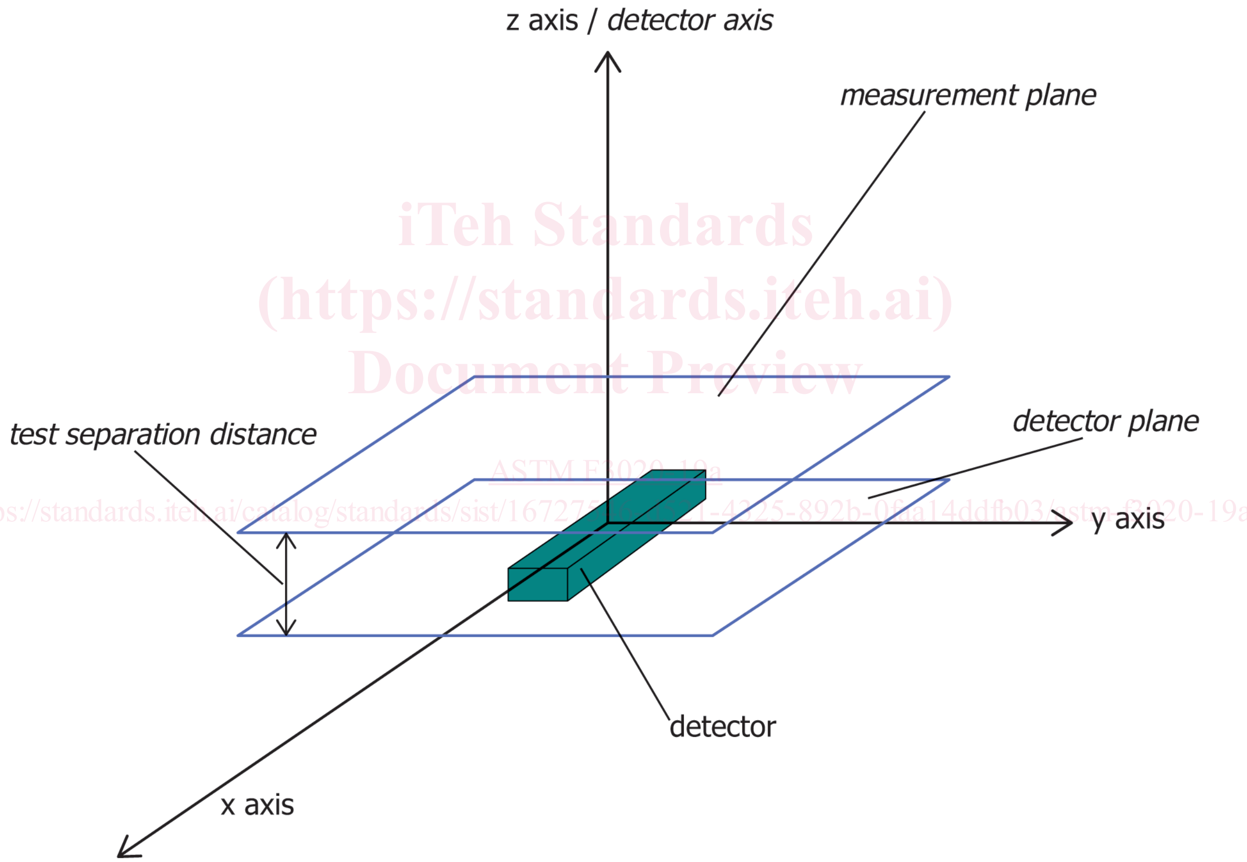


FIG. 1 Diagram of Hand-Worn Metal Detector Showing the Detector Plane (outlined in red) and the Detector Axis (labeled z)



NOTE 1—The x-axis points along the user's arm.

FIG. 2 Diagram of the Measurement Coordinate System Showing the Measurement Coordinate System Axes, One Measurement Plane, and the Detector Plane

3.1.4 *detector axis*—an imaginary line passing through and perpendicular to the detector plane such that the magnetic field around the detector axis has the maximum symmetry; the detector axis is labeled as the "z" axis; the location of the detector axis relative to the HWMD shape and geometry is specified by the manufacturer; the detector axis is the reference for positioning in the detection performance tests (see Fig. 1).

3.1.5 *detector holder*—a rectangular prism made of the body simulant on which the HWMD is worn.

3.1.6 *detector plane*—an imaginary plane (two-dimensional surface) that contains the plane, line, or point on the HWMD surface that is closest to the object being scanned under typical HWMD use and is perpendicular to the detector axis; the detector plane contains two orthogonal axes labeled as the "x" axis and as the "y" axis (see Fig. 2).

3.1.7 *detection sensitivity setting*—an adjustment that can be made to the HWMD that affects its ability to sense metal objects.

3.1.8 *measurement coordinate system*—a mutually orthogonal three-dimensional Cartesian coordinate system referenced to the detector axis and the detector plane; the three axes are labeled ~~"x", "y",~~"x," "y," and ~~"z",~~"z," where the z-axis is parallel to the detector axis and the x-axis and the y-axis are in the detector plane (see Fig. 2).

3.1.9 *measurement plane*—an imaginary two-dimensional surface that is parallel to the detector plane and that is tangential to the plane, line, or point on the test object that is closest to the detector plane; there may be more than one measurement plane; the measurement plane(s) is (are) referenced from the detector plane (see Fig. 2); there is a measurement plane for each object-size class of the HWMD, as shown in Table 1.

3.1.10 *size class*—a classification method based on grouping exemplars of commonly encountered objects that may be either commercially available or readily fabricated from available materials and that are related to customer applications and object sizes; a HWMD may meet the requirements for one or all size classes, as defined below. For each size class, there are exemplars constructed of ferromagnetic metal and exemplars constructed of nonferromagnetic metal.

3.1.10.1 *large*—represents threat items such as handguns; and similarly sized objects, or larger.

3.1.10.2 *medium*—represents threat items such as knives having blade lengths exceeding 7.5 cm, and similarly sized objects, up to the size of a large object.

3.1.10.3 *small*—represents threat items such as, but not limited to, knives having blade lengths less than or equal to ~~7.5 cm,~~ 7.5 cm, handcuff keys, handgun rounds, and similarly sized objects, up to the size of a medium object.

3.1.10.4 *very small*—represents threat items such as t razor blades, hypodermic needles and similarly sized objects, up to the size of a small object.

3.1.11 *test object*—an item that is used to test the HWMD detection performance; test objects accurately simulate the electromagnetic properties of an actual threat or contraband item, such as a weapon or an item that can be used to defeat security devices; the test objects are described in Section 6.

3.1.12 *test object axis*—the imaginary line passing through the center of the test object that is referenced to and has a one-to-one correspondence with the axes of the measurement coordinate system.

3.1.13 *x-axis scan range and y-axis scan range*—the segment of line along the x and y axis of the measurement coordinate system that is centered on the detector axis and that extends equally on either side of the detector axis; the detection performance of the HWMD will be tested along both axes (see Table 2).

TABLE 2 X-axis and Y-axis Scan Ranges for the Different HWMD Size Classes

Size Class	X-axis and Y-axis Scan Ranges	
	lower limit (cm)	upper limit (cm)
Large	-3.0 ± 0.1	3.0 ± 0.1
Medium	-1.5 ± 0.1	1.5 ± 0.1
Small	-1.0 ± 0.1	1.0 ± 0.1
Very Small	-1.0 ± 0.1	1.0 ± 0.1

4. Requirements for Acceptance

NOTE 1—The HWMD shall meet or exceed the requirements and specifications stated in this section. However, it is only to that HWMD unit under test and at the time of test that a pass/fail assignment can be made with confidence.

NOTE 2—To have confidence that the HWMD unit under test will pass/fail at times other than the time of the initial test or that other units of the same model will pass/fail requires model evaluation based on a product conformity assessment program, such as that described in Specification F3356~~.~~ for Conformity Assessment of Metal Detectors Used in Safety and Security.

NOTE 3—Recommended test report forms are given in ~~Annex A5~~Appendix X5.

4.1 *General Test Conditions and Requirements:*

4.1.1 *Testing and Calibration Laboratories*—Laboratories performing testing and calibration of the HWMD or its components, or both, shall meet the requirements of ISO 17025, as amended.

TABLE 1 Distance Between Measurement Plane and Detector Plane for the Different HWMD Size Classes

Size Class	Distance Between Measurement Plane and Detector Plane (cm)
Large	1.5 -0/+0.25
Medium	1.0 -0/+0.25
Small	1.0 -0/+0.25
Very Small	0.5 -0/+0.25

4.1.2 *Measurement Equipment and Processes*—All measurement equipment and processes shall be certified to ISO 10012–1, as amended

4.2 *Safety Specifications and Requirements:*

4.2.1 *Electrical*—The HWMD shall comply with IEC 61010–1, Section 6, "Protection Against Electrical Shock," as amended.

4.2.2 *Mechanical*—The HWMD shall meet requirements of IEC 61010–1, Section 10, "Equipment Temperature Limits and Resistance to Heat," as amended.

4.2.3 *Thermal*—The HWMD shall meet the requirements of IEC 61010–1, Section 10, "Equipment Temperature Limits and Resistance to Heat," as amended.

4.2.4 *Magnetic Field Exposure*—The magnitude of the electromagnetic field generated by the HWMD shall be less than the exposure limits specified for general public exposure in the ICNIRP[9,10] ~~Guideline~~guidelines (see ~~Annex A4~~X4). These measurements shall be made at points on grid lines that are i) tangential to the current-carrying coil of the HWMD and ii) parallel to the surfaces of an outward projection from the smallest imaginary rectangular prism enclosing that part of the HWMD encasing the current-carrying coils. The separation, s_{grid}, between points on these grid lines shall be 5 mm ± 1 mm and between any parallel tangential lines shall be 5 mm ± 1 mm. The separation between the outward-projected surface and the smallest imaginary rectangular prism shall be 5 mm ± 1 mm. A three-axis magnetic field probe with a -3dB analog bandwidth of $0.1\,f_c \leq f_c \leq 10\,f_c$, where f_c is the nominal center frequency of the generated magnetic field, shall be used for measuring the magnetic field, and the size of its active elements shall be within a volume no larger than $2s_{grid} \times 2s_{grid} \times 2s_{grid}$. ~~and IEEE C95.1.~~If the HWMD has not been demonstrated to meet this requirement, the manufacturer shall provide a warning with the HWMD instructions that states "This device has not been demonstrated as being safe or unsafe for use on people with active implanted or body-worn medical devices, or both."

4.3 *Power Requirement:*

4.3.1 *Battery Life*—The HWMD shall meet the detection performance specification given in 4.4 after operating for at least 8 h as tested in accordance with 5.4 and while using a battery of the type and model recommended by the manufacturer.

4.4 *Detection Performance Specifications*—The ability of the HWMD to sense the presence of a test object will vary with the material, type, and orientation of the test object. Consequently, the test objects are grouped according to their size class and the HWMDs are tested for their ability to detect test objects from within these different size classes. The detection performance specifications shall be tested using the detection sensitivity setting, if applicable, that is specified by the manufacturer to be appropriate for each test object size class. All the tests of ~~5.2~~4.4 requirements shall be performed within an 8 h ± 0.5 h period without adjusting the detector sensitivity setting between tests. The detector sensitivity setting shall not be readjusted during testing, or after changing the battery. The test objects are given in Section 6.

4.4.1 *Detection Sensitivity*—The HWMD shall exhibit an average probability of detection, $p_{d,\ sens}$, ≥ 0.95 with an average confidence level of 0.95 for the test objects in each size class, when each object in the size class is positioned in the appropriate measurement plane (see Table 1) and moving over the appropriate x-axis scan range and y-axis scan range (see Table 2) at a speed of ~~0.5~~0.5 m ~~m/s~~/s ± ~~0.05~~0.05 m ~~m/s~~/s and tested in accordance with 5.2.2. This requirement is met when $p_{LB} \geq p_{d,\ sens}$ as computed per 5.2.2.

4.4.2 *Detection Speed*—The HWMD shall exhibit an average probability of detection $p_{d,\ sp\text{-}sens}$, ≥ 0.95 with an average confidence level of 0.95 for the test objects in each size class, when each object in the size class is positioned in the appropriate measurement plane (see Table 1) and moving over the appropriate x-axis scan range (see Table 2) at a speed of ~~0.2~~0.2 m ~~m/s~~/s ± ~~0.01~~0.01 m ~~m/s,~~/s, 0.5 m ~~0.5 m/s ± 0.01~~/s ± 0.01 m ~~m/s,~~/s, and ~~1.0~~1.0 m ~~m/s~~/s ± ~~0.01~~0.01 m ~~m/s~~/s as tested in accordance with 5.2.3 under the following conditions: (*1*) The delay between subsequent tests of a given test object shall be no more than 5 s ± 0.5 s; and (*2*) The detector sensitivity setting shall not be readjusted between tests of a given test object or between tests of the test objects of a given size class.

This requirement is met when $p_{LB,\ sp} \geq p_{d,sp\text{-}sens}$ as computed per 5.2.3.

4.5 *Interference Specifications and Requirements:*

4.5.1 *Electromagnetic Emission:*

4.5.1.1 *Radiated Disturbance*—The HWMD, when adjusted to meet the requirements of 4.4, shall meet the requirements of CISPR 22, Class B, Radiated disturbance.

4.5.2 *Electromagnetic Susceptibility/Immunity*—The HWMD shall be tested in accordance with the requirements listed in Table 1 of IEC 61000–6–1, as amended, according to the following procedures:

4.5.2.1 *Contact Discharge*—The HWMD, after being adjusted to meet the requirements of 4.4, shall be tested in accordance with IEC 61000–4–2, as amended, for Level 2, contact discharge, and ten trials; and shall subsequently meet the requirements of 4.4 without further adjustment and using the limited set of test objects listed in Section 6.

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[9] ICNIRP, "Guidelines for Limiting Exposure to Time-varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)," International Commission on Non-Ionizing radiation Protection (ICNIRP), Health Physics, April 1998, Volume 74, No. 4, pp. 494–522.

[10] ICNIRP, "Guidelines for Limiting Exposure to Time-varying Electric, Magnetic, and Electromagnetic Fields (1 Hz to 100 GHz)," International Commission on Non-Ionizing radiation Protection (ICNIRP), Health Physics, Volume 99, No. 6, pp. 818–836, 2010.

4.5.2.2 *Radiated RF Electromagnetic Field Immunity*—The HWMD, when adjusted to meet the requirements of 4.4, shall not alarm when tested in accordance with IEC 61000–4–3, as amended, for Level 2.

4.5.2.3 *60 Hz Radiated Magnetic Field*—The HWMD, when adjusted to meet the requirements of 4.4, shall not alarm when tested in accordance with IEC 61000–4–8, as amended, for testing at 60 Hz, Level 2, and continuous exposure for ~~30 min ± 5 min.~~30 min ± 5 min.

4.5.3 *Body*—The HWMD shall exhibit a probability of false alarm, $p_{fa,b}$, ≤ 0.05 with a confidence level of 0.95 when placed in contact with the body or body simulant, as tested in accordance with 5.3. This requirement is met when $p_{UB} \leq p_{fa,b}$ as computed per 5.3.2 and meets, without adjustment of the detector sensitivity, the requirements given in 4.4.

4.6 *Environmental Ranges and Conditions*—The HWMD or all of its components and their interconnections shall meet all of the requirements listed in this section. The HWMD shall exhibit no observable changes in the detection performance specification given in 4.4.2 and the electrical safety specification given in 4.2.1. The requirements given in this section shall be applied appropriately for either indoor or indoor/outdoor HWMD models. The tests for the requirements listed in this section shall be performed on the same unit.

4.6.1 *Temperature Stability and Range:*

4.6.1.1 *Indoor*—The HWMD shall operate over the ambient temperature range of at least 0°C to 46°C. The HWMD shall be tested in accordance with MIL-STD-810G Method 501.5, as amended, Procedure II, Steps 1 through 6, relative humidity ~~6 %~~ 6 % ± 3 %, at 46°C ± 3°C. The HWMD then shall be cooled to 0°C ± 3°C within ~~4 h ± 0.5 h~~ 4 h ± 0.5 h and tested in accordance with MIL-STD-810G Method 502.5, as amended, Procedure II, Steps 1 through 7.

4.6.1.2 *Indoor/Outdoor*—The HWMD shall operate over the ambient temperature range of at least -21°C to 65°C. The HWMD shall be tested in accordance with MIL-STD-810G Method 501.5, as amended, Procedure II, Steps 1 through 6, relative humidity ~~6 %~~6 % ± 3 %, at 65°C ± 3°C. The HWMD then shall be cooled to -21°C ± 3°C within ~~4 h ± 0.5 h~~ 4 h ± 0.5 h and tested in accordance with MIL-STD-810G, as amended, Procedure II, Steps 1 through 7.

4.6.2 *Relative Humidity Stability and Range*—The HWMD shall be tested in accordance with the requirements of MIL-STD-810G Method 507.5, as amended, Procedure I, 10 cycles of Cycle B1, as amended.

4.6.3 *Ingress Protection:*

4.6.3.1 *Indoor*—The HWMD shall meet or exceed the requirements for compliance with IEC 60529, as amended, classification IP20.

4.6.3.2 *Indoor/Outdoor*—The HWMD shall meet or exceed the requirements for compliance with IEC 60529, as amended, classification IP54.

4.7 *Mechanical Specifications and Requirements*—The HWMD or all of its components and their interconnections shall meet the requirements of the following standards. All tests listed in this section shall be performed on the same unit. The HWMD shall exhibit no observable changes in the detection performance specification given in 4.4.2 and the electrical safety specification given in 4.2.1.

4.7.1 *Shock*—The HWMD shall be tested in accordance with the requirements of IEC 60068–2–27:2002, as amended, using 100 ± 5 half-sine shock pulses applied to the top (backhand side) and bottom (palm side) of the detector with each shock pulse having a nominal peak acceleration of 40 g (400 m/s^2) and a nominal pulse duration of 6 ms.

4.7.2 *Flexure*—The HWMD shall meet the performance requirements of 4.2.1 and 4.4.2 after being tested in accordance with 5.6.

4.8 *Alarm Requirements*—At least one alarm type, vibratory, audible, or visual, shall be provided and any alarm provided shall meet the applicable requirement given in this section.

4.8.1 *Vibratory Alarm*—The vibratory alarm shall produce a force in the range of ~~0.5 N to 2 N~~ 0.5 N to 2 N in a frequency range of ~~10 Hz to 300 Hz~~ 10 Hz to 300 Hz as measured in accordance with 5.5.2.

4.8.2 *Audible Alarm*—The audible alarms (other than an earphone), if provided, shall produce an alarm-state sound pressure level of ~~75 dB~~75 dB_{SPL} ± ~~5 dB~~5 dB_{SPL} (where 0 dB_{SPL} = 20 µPa root-mean-square in air) at ~~0.8 m ± 0.08 m~~ 0.8 m ± 0.08 m from the HWMD as measured in accordance with 5.5.3. The audible alarm shall be either a frequency-proportional audible alarm or, optionally, a two-state audible alarm: active (alarm state) and inactive (nonalarm state).

4.8.2.1 *Frequency Range*—The frequency range of the audible alarm shall be ~~≥100 Hz and ≤4 kHz~~ ≥ 100 Hz and ≤ 4 kHz as tested in accordance with 5.5.4.

4.8.3 *Visual Alarm*—The visible alarm, if provided, shall be readily perceptible when tested in accordance with 5.5.5. The visual alarms shall be a two-state visual alarm: active (illuminating) and inactive (nonilluminating).

5. Performance Testing Procedures

5.1 *General Test Conditions:*

5.1.1 *Test Location*—The distance between any metal object other than a test object and the closest part of the HWMD shall be greater than 0.5 m.

5.1.2 *Environment*—At the time of the tests, the ambient temperature shall be in the range specified in 4.8 for the appropriate application (indoor or indoor/outdoor); the relative humidity shall be noncondensing.

5.1.3 *Preparations*—New batteries of the type listed in the operator's manual shall be installed at the beginning of the tests and as instructed in any test method. Any setup or calibration adjustments specified in the operator's manual shall be performed if required.

5.2 *Detection Performance Tests*—The detection performance test methods described in this section are based on the use of a computer-controlled three-axis positioning system to control the motion and displacement of the test object relative to the HWMD. Other means of controlling this motion and displacement are acceptable if the positioning and speed values are within the tolerances specified in these test methods.

If the HWMD can be adjusted to provide an alarm for more than one size class, the detection performance test shall be performed for each size class. The detection performance shall be evaluated by the test methods described in this section. The distinction in testing between the different size classes is the difference in the test separation distance between the measurement plane and the test objects.

5.2.1 *Measurement System*—The measurement system shall contain the components necessary to perform the tests described herein. A diagram of the measurement system showing the electrical and mechanical connections between its components shall be provided.

5.2.1.1 *Microphone (Audible Alarm)*—The microphone is the audible and vibratory alarm detector. It shall be used to detect an audible alarm, be capable of detecting the audible alarm described in 4.8.2, and provide an analog output that can be interfaced to the computer controller (see 5.2.1.3).

5.2.1.2 *Light Detector (Visible Alarm)*—The light detector is the visible alarm detector. It shall be used to detect a visible alarm and provide an analog electrical output that can be interfaced to the computer controller (see 5.2.1.3).

5.2.1.3 *Computer Controller*—The computer controller shall have installed and operational all necessary hardware and software for providing instrument control and data acquisition.

5.2.2 *Detection Sensitivity Test:*

5.2.2.1 *Initial Procedures*—Ensure that the alarm detector and positioning system are connected to the computer controller. Turn on the alarm detector, computer controller, and positioning system and verify proper operation of the measurement system. Ensure that the HWMD is securely attached to the detector holder and that the detector holder is fixed in position and secured relative to the three-axis positioning system. Attach the test object to the positioning system. Turn on the HWMD and ensure that its output is functioning properly by noting a change in the alarm output as a metal object is brought near the HWMD. Ensure that the test object does not hit any objects while in motion. There is a minimum number of repeats of a given measurement that must be performed to meet the performance requirements for a given confidence interval. This minimum number of measurements, N_T, is given by:

$$N_T = \text{ceil}\left\{\frac{z_\alpha^2 p_0}{1 - p_0}\right\}, \tag{1}$$

where p_0 is equal to the probability of detection specified in 4.4.2; z_α is the critical point of a standard normal distribution and is fixed for a given confidence interval; and ceil$\{x\}$ is a function that returns the smallest integer value that is greater than x. The value of N_T includes the number of test objects of a given test object size class (which is two, one each from a ferromagnetic test object and a nonferromagnetic test object) and the number of scans performed. For example, when p_0 = 0.95 and the confidence level = 0.95, N_T = 52.

Determine the number, $n_{s,\ k}$, of y-axis scans to perform at each x-axis position for a given test object and given the number, n_x, of practicable x-axis positions, and the total number of required scans, n_T. The value of $n_{s,\ k}$ is computed using:

$$n_{s,k} = \max\left\{\frac{n_T}{n_x}, 10\right\}, \tag{2}$$

where the function max$\{x,y\}$ returns the maximum value of x and y.

5.2.2.2 *Performing the Measurement, x-axis Scan Range:*

(1) Set the computer program to perform an x-y scan in the specified measurement plane at the specified speed. The center for the y-axis scans shall be the detector axis and the scans shall each be no less than ~~10 cm ± 1 cm~~ 10 cm ± 1 cm long.

(2) Set the x-axis position to the specified lower x-axis scan range limit.

(3) Scan the y-axis and record any alarm as the y-axis scan is being performed.

(4) Repeat Step *(3)* $n_{s,k}$ times to perform a total of $n_{s,k}$ scans for the current x-axis scan position.

(5) Compute the probability of alarm, $p_{d,sens,obj_k,x_i}$ where x_i is the x-axis scan position and i is the x-axis scan index, and obj_k represents the test object of the given test object size class with index k, using:

~~$$P_{d,sens,k,i} = \frac{1}{n_{s,k}}\sum_{j=1}^{n_s} A_{Pos-sens,k,i,j} \tag{3}$$~~

$$P_{d,sens,k,i} = \frac{1}{n_{s,k}}\sum_{j=1}^{n_{s,k}} A_{Pos-sens,k,i,j} \tag{3}$$

where the index abbreviations: $k = obj_k$, and $i = x_i$ are used and $A_{Pos\text{-}sens,k,i,j}$ is an integer value representing the occurrence of the alarm (0 for the nonalarm state and 1 for the alarm state) for each x-axis scan position.

(6) Increment the x-axis position by ~~0.5 cm ± 0.1 cm.~~ 0.5 cm ± 0.1 cm.

(7) Repeat Steps (*3*) through (*5*) until the x-axis position is at the specified upper *x-axis scan range* limit and record the number of alarms at each x_i, and N_x is the number of x-axis positions scanned.

(8) Repeat Step (*7*) for each of the remaining *K*-1 *test object* of a given size class, where *K* is the number of *test objects* in a given *size class*.*K* = 2 as there is one nonferromagnetic test object and one ferromagnetic test object for each size class.

(9) Upon completion of Step (*8*), compute the average probability of detection along the x axis, $p_{d,sens,x_{axis}}$, using:

$$p_{d,sens,x_{axis}} = \frac{1}{KN_x}\sum_{k=1}^{K}\sum_{i=1}^{N_x} p_{d,sens,k,i} \quad (4)$$

$$p_{d,sens,x_{axis}} = \frac{1}{KN_x}\sum_{k=1}^{K}\sum_{i=1}^{N_x} p_{d,sens,k,i} \quad (4)$$

(10) Compute the average lower bound, $p_{LB,x_{axis}}$, of $p_{d,sens,x_{axis}}$ using:

$$p_{LB,x_{axis}} = P_{d,sens,x_{axis}} - \frac{\sqrt{\sum_{k=1}^{K}\sum_{i=1}^{N_x}(P_{d,sens,k,i} - l_{k,i})^2}}{KN_x} \quad (5)$$

where:

$$l_{k,i} = \frac{p_{k,i} + 0.5\frac{z_\alpha^2}{n_{k,i}} - z_\alpha\sqrt{\frac{p_{k,i}(1-p_{k,i}) + \frac{z_\alpha}{4n_{k,i}}}{n_{k,i}}}}{1 + \frac{z_\alpha^2}{n_{k,i}}} \quad (6)$$

where for these tests $n_{k,i} = n_{s,k}$ as computed in 5.2.2.1. For a 95 % confidence interval, z_a = 1.645, and for a 99 % confidence interval, z_a = 2.326.

5.2.2.3 *Performing the Measurement, y-axis Scan Range:*

(1) Set the computer program to perform an x-y scan in the specified measurement plane at the specified speed. The center for the x-axis scans shall be the detector axis and the scans shall each be no less than ~~10 cm ± 1 cm~~ 10 cm ± 1 cm long.

(2) Set the y-axis position to the specified lower y-axis scan range limit.

(3) Scan the x axis and record any alarm as the x-axis scan is being performed.

(4) Repeat Step (*3*) $n_{s,k}$ times to perform a total of $n_{s,k}$ scans for the current y-axis scan position.

(5) Compute the probability of alarm, $p_{d,sens,obj_k y_i}$, where y_i is the y-axis scan position and *i* is the y-axis scan index, and obj_k represents the test object of the given test object class with index *k*, using:

$$p_{d,sens,k,i} = \frac{1}{n_{s,k}}\sum_{j=1}^{n_{s,k}} A_{Pos-sens,k,i,j}, \quad (7)$$

where the index abbreviations: $k = obj_k$, and $i = x_i$ are used and $A_{Pos\text{-}sens,k,i,j}$ is an integer value representing the occurrence of the alarm (0 for the nonalarm state and 1 for the alarm state) for each y-axis scan position.

(6) Increment the y-axis position by ~~0.5 cm ± 0.1 cm.~~0.5 cm ± 0.1 cm.

(7) Repeat Steps (*3*) through (*5*) until the y-axis position is at the specified upper y-axis scan range limit and record the number of alarms at each y_i, and N_y is the number of y-axis positions scanned.

(8) Repeat Step (*7*) for each of the remaining *K*-1 test object of a given size class, where *K* is the number of test objects in a given class. *K* = 2 as there is one nonferromagnetic test object and one ferromagnetic test object.

(9) Upon completion of Step (*8*), compute the average probability of detection along the y axis, $p_{d,sens,y_{axis}}$, using:

$$p_{d,sens,y_{axis}} = \frac{1}{KN_y}\sum_{k=1}^{K}\sum_{i=1}^{N_y} p_{d,sens,k,i}. \quad (8)$$

(10) Compute the average lower bound, $p_{LB,y_{axis}}$, of $p_{d,sens,y_{axis}}$ using:

$$p_{LB,y_{axis}} = p_{d,sens,y_{axis}} - \frac{\sqrt{\sum_{k=1}^{K}\sum_{i=i}^{N_x}(p_{d,sens,k,i} - l_{k,i})^2}}{KN_y}, \quad (9)$$

where:

$$l_{k,i} = \frac{p_{k,i} + 0.5\frac{z_\alpha^2}{n_{k,i}} - z_\alpha\sqrt{\frac{p_{k,i}(1-p_{k,i}) + \frac{z_\alpha}{4n_{k,i}}}{n_{k,i}}}}{1 + \frac{z_\alpha^2}{n_{k,i}}}, \quad (10)$$

where for these tests $n_{k,i} = n_{s,k}$ as computed in 5.2.2.1. For a 95 % confidence interval, z_a = 1.645, and for a 99 % confidence interval, z_a = 2.326.

5.2.2.4 *Computing the Average Probability of Detection*—Compute the average probability, p_d, of detection using:

$$p_d = \frac{p_{LB,x_{axis}} + p_{LB,y_{axis}}}{2}, \tag{11}$$

and record and report this value.

5.2.3 *Detection Speed Test:*

5.2.3.1 *Initial Procedures:*

(1) Ensure that the alarm detector and positioning system are connected to the computer controller. Turn on the alarm detector, computer controller, and positioning system and verify proper operation of the measurement system. Ensure that the HWMD is securely attached to the detector holder and that the detector holder is fixed in position and secured relative to the three-axis positioning system. Attach the test object to the positioning system. Turn on the HWMD and ensure that its output is functioning properly by noting a change in the alarm output as a metal object is brought near the HWMD. Ensure that the test object does not hit any objects while in motion.

(2) Use the value of N_T computed in Eq 1.

(3) Determine the number, $n_{s,k}$, of y-axis scans to perform at each x-axis position for a given test object and given the number, n_x, of practicable x-axis positions, and the total number of required scans, n_T. The value of $n_{s,k}$ is computed using:

$$n_{s,k} = \max\left\{\frac{n_T}{n_x}, 10\right\}, \tag{12}$$

where the function max{x,y} returns the maximum value of x and y.

5.2.3.2 *Performing the Measurement:*

(1) Set the computer program to perform an x-y scan in the specified measurement plane at the specified speed. The center for the y-axis scans shall be the detector axis and the scans shall each be no less than 10 cm ± 1 cm long.

(2) Set the x-axis position to the specified lower x-axis scan range limit.

(3) Scan the y axis and record any alarm as the y-axis scan is being performed.

(4) Repeat Step (*3*) $n_{s,k}$ times to perform a total of $n_{s,k}$ scans for the current x-axis scan position.

(5) Compute the probability of alarm, $p_{d,sens,obj_k x_i s_m}$, where x_i is the x-axis scan position and i is the x-axis scan index, obj_k represents the test object of the given test object size class with index k, and s_m represents the different speeds with index m, using:

$$p_{d,sens,k,i,m} = \frac{1}{n_s}\sum_{j=1}^{n_s} A_{Pos-sens,k,i,m,j} \tag{13}$$

where the index abbreviations: $k = obj_k$, $i = x_i$, and $m = s_m$ are used and $A_{Pos\text{-}sens,k,i,m,j}$ is an integer value representing the occurrence of the alarm (0 for the nonalarm state and 1 for the alarm state) for each x-axis scan position.

(6) Increment the x-axis position by 0.5 cm ± 0.1 cm.

(7) Repeat Steps (*3*) through (*6*) until the x-axis position is at the specified upper x-axis scan range limit and record the number of alarms at each x_i, and N_x is the number of x-axis positions scanned.

(8) Repeat Step (*7*) for each of the remaining K-1 test object of a given size class, where K is the number of test objects in a given size class. K = 2 as there is one nonferromagnetic test object and one ferromagnetic test object.

(9) Repeat Step (*8*) for each of the M test speeds.

(10) Upon completion of Step (*9*), compute the average probability of detection, $p_{d,sp\text{-}sens}$, using:

$$p_{d,sp-sens} = \frac{1}{KN_xM}\sum_{k=1}^{K}\sum_{i=1}^{N_x}\sum_{m=1}^{M} p_{d,sens,k,i,m} \tag{14}$$

(11) Compute the average lower bound, $p_{LB,sp}$, of $p_{d,sp\text{-}sens}$ using:

$$p_{LB,sp} = p_{d,sp-sen}\frac{\sqrt{\sum_{k=1}^{K}\sum_{i=1}^{N_x}\sum_{m=1}^{M}(p_{d,sens,k,i,m} - l_{k,i,m})^2}}{KN_xM}, \tag{15}$$

where:

$$l_{k,i,m} = \frac{p_{k,i,m} + 0.5\frac{z_\alpha^2}{n_{k,i,m}} - z_\alpha\sqrt{\frac{p_{k,i,m}(1 - p_{k,i,m}) + \frac{z_\alpha}{4n_{k,i,m}}}{n_{k,i,m}}}}{1 + \frac{z_\alpha^2}{n_{k,i,m}}} \tag{16}$$

where for these tests $n_{k,i,m} = n_{s,k}$ as computed in 5.2.2.1. For a 95 % confidence interval, z_a = 1.645, and for a 99 % confidence interval, z_a = 2.326.

(12) Record and report $p_{LB,sp}$.

5.3 *Body Interference Test*—This test may be performed using a body simulant test object, as described in 5.3.1 and 5.3.2 or a clean torso, as described in 5.3.3 and 5.3.4. A clean torso is defined here as the torso of a person that is free of any metal objects.

5.3.1 *Initial Procedures, Using the Body Simulant Test Object:*

(1) Ensure that the alarm detector and positioning system are connected to the computer controller. Turn on the alarm detector, computer controller, and positioning system and verify proper operation of the measurement system. Ensure that the HWMD is securely attached to the detector holder and that the detector holder is fixed in position and secured relative to the three-axis positioning system. Attach the test object to the positioning system. Turn on the HWMD and ensure that its output is functioning properly by noting a change in the alarm output as a metal object is brought near the HWMD. Ensure that the test object does not hit any objects while in motion.

(2) This test will require the use of a body simulant test object. This test object shall be constructed of a material exhibiting an electrical conductivity of ~~0.8~~0.8 S ~~S/m~~/m ± ~~0.2~~0.2 S ~~S/m~~/m and magnetic permeability of 1.26 × 10^{-6} H ~~H/m~~/m ± 5 × 10^{-7} H ~~H/m~~/m and be a rectangular prism ~~3 cm ± 0.5 cm~~ 3 cm ± 0.5 cm thick (parallel to z-axis), ~~20 cm ± 1 cm~~ 20 cm ± 1 cm long (parallel to x-axis), and ~~10 cm ± 1 cm~~ 10 cm ± 1 cm wide (parallel to y-axis).

(3) Use the value of N_T computed in Eq 1.

5.3.2 *Performing the Measurement, Using the Body Simulant Test Object:*

(1) Set the computer program to perform a y-axis scan passing the body simulant test object through the detector axis ±0.1 cm in the appropriate measurement plane at a speed of ~~0.5~~0.5 m ~~m/s~~/s ± ~~0.05~~0.05 m ~~m/s.~~/s. The center of the y-axis scan shall be the detector axis in the appropriate measurement plane, and the y-axis scan shall be ~~20 cm ± 0.1 cm~~ 20 cm ± 0.1 cm long. Perform the y-axis scan and record any alarm occurrence with the alarm detector. Repeat this y-axis scan N_T one time to yield a total of N_T scans and compute the average alarm occurrence using:

$$p_{fa,b} = \frac{1}{N_T}\sum_{j=1}^{N_T} A_{Pos-b,j}, \tag{17}$$

where $A_{Pos\text{-}b,j}$ is an integer value representing the occurrence of the alarm (0 for the nonalarm state and 1 for the alarm state), j is the scan repeat index, and $p_{fa,b}$ is the probability of false alarm for the body interference test.

(2) Compute the upper bound, p_{UB}, of $p_{fa,b}$ using:

$$P_{UB} = \frac{p_{fa,b} + 0.5\frac{z_\alpha^2}{N_T} + z_\alpha\sqrt{\frac{p_{fa,b}(1 - p_{fa,b}) + \frac{z_\alpha^2}{4N_T}}{N_T}}}{1 + \frac{z_\alpha^2}{N_T}} \tag{18}$$

and record and report this value.

5.3.3 *Initial Procedures, Using the Clean Torso:*

(1) Ensure that the alarm detector is connected to the computer controller. Turn on the alarm detector and computer controller, and verify proper operation of the measurement system. Ensure that the HWMD is securely attached to a clean hand, which is a hand free of any metal, from the tips of the fingers of that hand to the elbow of the same arm as the hand being used. Turn on the HWMD and ensure that its output is functioning properly by noting a change in the alarm output as a metal object is brought near the HWMD.

(2) Use the value of N_T computed in Eq 18.

5.3.4 *Performing the Measurement, Using the Clean Torso:*

(1) Place the HWMD against the clean torso and record any alarms.

(2) Repeat Step (*1*) N_T 1 times to yield a total of N_T scans and compute the average alarm occurrence using Eq 17.

(3) Compute the upper bound, p_{UB}, of $p_{fa,b}$ using Eq 18 and record and report this value.

5.4 *Battery Life Test:*

5.4.1 *Initial Procedures*—Install in the HWMD new or fully charged batteries of the type specified by the manufacturer. Ensure that the alarm detector and positioning system are connected to the computer controller. Turn on the alarm detector, computer controller, and positioning system and verify proper operation of the measurement system. Ensure that the HWMD is securely attached to the detector holder and that the detector holder is fixed in position and secured relative to the three-axis positioning system. Attach the test object to the positioning system. Turn on the HWMD and ensure that its output is functioning properly by noting a change in the alarm output as a metal object is brought near the HWMD. Ensure that the test object does not hit any objects while in motion.

5.4.2 *Performing the Measurement:*

(1) Set the computer program to perform a series of x-y scans of a large size test object in the measurement plane for a large size test object at a speed of about 0.5 m/s. The center for the y-axis scans shall be the detector axis and the scans shall each be approximately 10 cm long. The duration of this series of scans shall be 8 h ± 0.1 h. The delay between scans shall be 30 s ± 2 s.

(2) After completion of Step (*1*), set the computer program to perform ten each x-y scans of a small size test object in the measurement plane for a small size test object at a speed of about 0.5 m/s. The center for the y-axis scans shall be the detector axis and the scans shall each be approximately 10 cm long. The delay between scans shall be less than 2 s. Compute the alarm rate, r_{alarm}, using:

$$r_{alarm} = \frac{N_{alarms}}{10}, \tag{19}$$

where N_{alarms} is the number of alarms that were observed in Step (*2*).

(3) If $r_{alarm} \geq p_{d,sens}$, then record and report this as passing the battery life requirement, otherwise record and report as not passing the battery life requirement.

5.5 *Alarm Tests:*

5.5.1 *Equipment:*

5.5.1.1 *Waveform Recorder*—The waveform recorder requirements are:

bandwidth:	≥10 MHz
input connector:	coaxial, preferably BNC
input impedance:	≥1 M Ω
number of input channels:	≥2

5.5.1.2 *Sound Pressure Level Meter*—The sound pressure level meter shall comply with ANSI S1.4-1983 for Type 2, A-weighting, reference pressure 20 μPa.

5.5.1.3 *Audio Frequency Measurement System*—The system for measuring the fundamental audio frequency of an audible alarm shall be capable of measuring a frequency difference with an accuracy of 1 Hz and be capable of providing a new measurement within 4 s after a change in frequency.

5.5.1.4 *Microphone/Acoustic Detector*—The acoustic detector requirements are:

bandwidth:	≥10 kHz
output connector:	coaxial, preferably BNC
output impedance:	≥50 Ω

5.5.1.5 *Vibration Detector (Accelerometer)*—The vibration detector requirements are:

bandwidth:	≤5 Hz to ≥1.2 kHz
output connector:	coaxial, preferably BNC
output impedance:	≥50 Ω

5.5.1.6 *Illumination Meter*—The illumination meter shall be capable of measuring light levels of 25 lm/m² and 10 ~~000~~ 000 lm ~~lm/m/~~m² with an error of not more than 10 %. The integrated spectral response shall be within 10 % of the Commission Internationale de l'Eclairage (CIE, the International Commission on Illumination) [23] photopic curve.

5.5.1.7 *Light Detector*—The light detector requirements are:

bandwidth:	≥10 kHz
output connector:	coaxial, preferably BNC
output impedance:	≥50 Ω

5.5.2 *Vibratory Alarm Test*—Place the vibratory alarm detector in contact with that part of the HWMD closest to the component that produces the vibratory alarm. Measure the vibration magnitude, v_{na}, with the detector power applied and the alarm in the nonalarm state. Cause the HWMD to produce an alarm, and again measure and record the vibration magnitude, v_{na+a}. Compute the difference between two vibration magnitudes, using:

$$v_a = v_{na+a} - v_{na}, \tag{20}$$

where v_a is the vibration magnitude produced by the alarm. Record and report this value.

5.5.3 *Audible Alarm Test*—Perform the test in an anechoic chamber. Position the audible detector/microphone 0.80 m ± 0.02 m from the HWMD. Measure the sound pressure level, P_{na}, with the HWMD power applied and the alarm in the nonalarm state. Cause the HWMD to produce an alarm, and again measure and record the sound pressure level, P_{na+a}. Compute the sound pressure level generated by the alarm, P_{a}, using:

$$P_a = 10\log_{10}\left(10^{\frac{P_{na+a}}{10}} - 10^{\frac{P_{na}}{10}}\right). \tag{21}$$

Record and report P_a.

5.5.4 *Audible Alarm Frequency Range Test*—Perform the test in an anechoic chamber. Position the audible detector/microphone 0.80 m ± 0.02 m from the HWMD and connect this device to the audio frequency measurement system (described in 5.5.1.3). Turn the HWMD power on and cause the HWMD to produce an alarm. Record and report the audio frequency measured by the audio frequency measurement system.

5.5.5 *Visual Alarm Test*—Position the HWMD 0.80 m ± 0.02 m from the light detector, with the line perpendicular to the plane of the input aperture of the light detector and the line perpendicular to the output aperture of the visual alarm nominally collinear. Perform the test at a location where the ambient illumination is 10 ~~000~~ 000 lm ~~lm/m/~~m² ± ~~1000~~ 1000 lm ~~lm/m/~~m². Turn on the HWMD and move a metal object near the HWMD to cause an alarm. Measure the light level, E_{na}, with the HWMD power applied and the alarm in the nonalarm state. Cause the HWMD to produce an alarm, and again measure and record the light level, E_{na+a}. Compute the different between light levels, using:

$$E_a = E_{na+a} - E_{na}, \tag{22}$$

where E_a is the light level produced by the alarm. Record and report this value.

5.6 *Flexure Test*—This test shall be performed with the HWMD worn on the appropriate hand and secured according to the manufacturer's instructions.

(1) Activate the HWMD using the on button or switch.

(2) Verify the HWMD is working by noting a positive alarm indication when the HWMD is brought near the appropriate test object.

(3) Using the hand wearing the HWMD, grasp a non-metallic, non-conductive tube with a nominally 2 cm diameter.

(4) Release the tube and fully extend the fingers and thumb of the hand in Step (*3*).

(5) Repeat Steps (*3*) and (*4*) 20 times within 60 s.

(6) Perform the tests required by 4.2 and 4.4.

(7) Record and report if the requirements of 4.2 and 4.4 have been met.

6. Test Objects

6.1 The test objects are spherically shaped and constructed of either aluminum or steel. The diameters of these spherical test objects and the metal used for the different classification of HWMD performance are given in Table 3.

6.2 The electrical conductivity and magnetic relative permeability of the metals used in the construction of test objects is shown in Table 4. The test objects constructed for testing of the HWMD shall exhibit electrical conductivity and magnetic relative permeability values as shown in Table 2 within the tolerances shown in this table with 95 % confidence for a nominal temperature of 20°C ± 10°C. The values shown with the footnoted references are based on values obtained in the literature; all other values are based on measurements performed at the National Institute of Standards and Technology.

TABLE 3 Sphere Diameters for the Test Objects Representing Different HWMD Detection Size Classifications that are Fabricated from a Nonferromagnetic Metal, Aluminum per UNS A96061, and a Ferromagnetic Metal, Steel per UNS G10180

Classification	Sphere Diameter	
	Aluminum, UNS A96061	Steel, UNS G10180
Class 1 (large size)	70 mm ± 1 mm	45 mm ± 1 mm
Class 2 (medium size)	40 mm ± 0.5 mm	25 mm ± 1 mm
Class 3 (small size)	24 mm ± 0.5 mm	15 mm ± 0.5 mm
Class 4 (very small size)	8 mm ± 0.25 mm	5 mm ± 0.25 mm

TABLE 4 Electromagnetic Properties of the Metals Used in the Construction of the Spherical Test Objects

Metal	UNS Designation	Electrical Conductivity (S/m)		Relative Magnetic Permeability	
		mean	tolerance	mean	tolerance
Aluminum	UNS A96061	2.78×10^7	3.2×10^6	1	N/A
Steel	UNS G10180	4.15×10^6	9.3×10^5	270[A]	30

[A] *Review of Quantitative Nondestructive Evaluation*, ed. by D. O. Thompson and D. E. Chimenti, Vol. 25, American Institute of Physics, 2006.

ANNEXES

(Mandatory Information)

A1. TEST PROCEDURE FOR NON-SPHERICAL TEST OBJECTS (INFORMATIVE)

NOTE A1.1—This test procedure is provided to aid agencies wishing to measure the probability of detection of agency-specific non-spherical threat objects.

A1.1 Detection Sensitivity Test, Non-Spherical Test Objects

NOTE A1.2—The user of the standard shall define three mutually orthogonal axes of the test object that are referenced to and have a one-to-one correspondence with the axes of the measurement coordinate system.

A1.1.1 *Initial Procedures:*

(1) Ensure that the alarm detector and positioning system are connected to the computer controller. Turn on the alarm detector, computer controller, and positioning system and verify proper operation of the measurement system. Ensure that the HWMD is securely attached to the detector holder and that the detector holder is fixed in position and secure relative to the three-axis positioning system. Attach the test object with the proper orientation to the positioning system. Turn on the HWMD and ensure that its output is functioning properly by noting a change in the alarm output as a metal object is brought near the HWMD. Ensure that the test object does not hit any objects while in motion.

(2) Use the value of N_T computed in Eq 1.

(3) Determine the number, $n_{s,k}$ of y-axis scans to perform at each x-axis position for a given test object and given the number, n_x, of practicable x-axis positions, the number of n_o, of orientations relative to the detector that are required for the test object (defined by the user of the standard), and the total number of required scans, n_T. The value of $n_{s,k}$ is computed using:

$$n_{s,k} = \max\left\{\frac{n_T}{n_x n_0}, 10\right\}, \tag{A1.1}$$

where the function max$\{x,y\}$ returns the maximum value of x and y. Note, the value of n_o is dependent on the test object because each test object may have a different set of required orientations.

A1.2 Performing the Measurement, x-axis Scan Range

(1) Set the computer program to perform an x-y scan in the specified measurement plane at the specified speed. The center for the y-axis scans shall be the detector axis and the scans shall each be no less than 10 cm ± 1 cm long.

(2) Set the x-axis position to the specified lower x-axis scan range limit.

(3) Scan the y axis and record any alarm as the y-axis scan is being performed.

(4) Repeat Step *(3)* $n_{s,k}$ times to perform a total of $n_{s,k}$ scans for the current x-axis scan position.

(5) Compute the probability of alarm, $p_{d,sens,ojb_k}, ornt_h, x_i$, where x_i is the x-axis scan position and i is the x-axis scan index, $ornt_h$ is the orientation of the test object with orientation index h, and obj_k represents the test object of the given test object size class with index k, using:

$$p_{d,sens,k,h,i} = \frac{1}{n_s}\sum_{j=1}^{n_s} A_{Pos-sens,k,h,i,j} \tag{A1.2}$$

where the index abbreviations: $k = obj_k$, $h = ornt_h$, and $i = x_i$ are used and $A_{Pos-sens,k,h,i,j}$ is an integer value representing the occurrence of the alarm (0 for the nonalarm state and 1 for the alarm state) for each x-axis scan position.

(6) Increment the x-axis position by 0.5 cm ± 0.1 cm.

(7) Repeat Steps *(3)* through *(5)* until the x-axis position is at the specified upper x-axis scan range limit and record the number of alarms at each x_i, and N_x is the number of x-axis positions scanned.

(8) Repeat Steps *(2)* through *(6)* for the same test object and for each of the remaining *H*-1 unique orientations of that test object, where *H* is the number of unique orientations of the test object specified for testing in Section 6.

(9) Repeat Step *(7)* for each of the remaining *K*-1 test object of a given size class, where *K* is the number of test objects in a given size class.

(10) Upon completion of Step *(9)*, compute the average probability of detection, $p_{d,sens}$, using:

$$p_{d,sens} = \frac{1}{KHN_x}\sum_{k=1}^{K}\sum_{h=1}^{H}\sum_{i=t}^{N_x} p_{d,sens,k,h,i} \tag{A1.3}$$

(11) Compute and record the average lower bound, $p_{LB,x_{axis}}$, of $p_{d,sens}$, using:

$$p_{LB,x_{axis}} = p_{d,sens} - \frac{\sqrt{\sum_{k=1}^{K}\sum_{h=1}^{H}\sum_{i=i}^{N_x}(p_{d,sens,k,h,i} - l_{k,h,i})^2}}{KHN_x}, \tag{A1.4}$$

where:

$$l_{k,h,i} = \frac{p_{k,h,i} + 0.5\frac{z_\alpha^2}{n_{k,h,i}} - z_\alpha\sqrt{\frac{p_{k,h,i}(1 - p_{k,h,i}) + \frac{z_a}{4n_{k,h,i}}}{n_{k,h,i}}}}{1 + \frac{z_\alpha^2}{n_{k,h,i}}}, \tag{A1.5}$$

where for these tests $n_{k,h,i} = n_{s,k}$ as computed in 5.2.2.1. For a 95 % confidence interval, z_a = 1.645, and for a 99 % confidence interval, z_a = 2.326.

A1.3 Performing the Measurement, y-axis Scan Range

(1) Repeat A1.2 for the y-axis scan range instead of the x-axis scan range and record $p_{LB,yaxis}$.

A1.4 Compute the Average Probability, p_d, of Detection Using:

(1)

$$p_d = \frac{p_{LB,x_{axis}} + p_{LB,y_{axis}}}{2}, \tag{A1.6}$$

and record and report this value.

APPENDIXES

(Nonmandatory Information)

X1. TEST PROCEDURE FOR NON-SPHERICAL TEST OBJECTS (INFORMATIVE)

NOTE X1.1—This test procedure is provided to aid agencies wishing to measure the probability of detection of agency-specific non-spherical threat objects.

X1.1 Detection Sensitivity Test, Non-Spherical Test Objects

NOTE X1.2—The user of the standard shall define three mutually orthogonal axes of the test object that are referenced to and have a one-to-one correspondence with the axes of the measurement coordinate system.

X1.1.1 *Initial Procedures:*

(1) Ensure that the alarm detector and positioning system are connected to the computer controller. Turn on the alarm detector, computer controller, and positioning system and verify proper operation of the measurement system. Ensure that the HWMD is securely attached to the detector holder and that the detector holder is fixed in position and secure relative to the three-axis positioning system. Attach the test object with the proper orientation to the positioning system. Turn on the HWMD and ensure that its output is functioning properly by noting a change in the alarm output as a metal object is brought near the HWMD. Ensure that the test object does not hit any objects while in motion.

(2) Use the value of N_T computed in Eq 1.