Designation: ~~F3278 – 17~~ F3278 – 19

Standard Performance Specification for Hand-Held Metal Detectors Used in Safety and Security[1]

This standard is issued under the fixed designation F3278; 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 performance specification applies to all hand-held metal detectors (HHMDs) used to find metal contraband concealed or hidden on people or other objects with accessible surfaces. This performance specification 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 performance specification is encouraged to add their unique operationally-based requirements to those requirements listed in this baseline performance specification.

1.2 This performance specification describes the use of spherical test objects, instead of actual threat objects or exemplars of threat objects, to test the detection performance of hand-held 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 HHMD to be incorrectly attributed a higher performance capability than that HHMD is capable of providing. To aid agencies wishing to add specific threat objects to their detection performance requirements, included in Annex A1 is the analysis of the probability of detection for different orientations of agency-specific threat objects.

1.3 *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.*

1.4 *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 Specification 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 Measurement Management Systems – Requirements for Measurement Processes and 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

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 ~~14708-3:2008~~14708-3:2017 Implants for Surgery – Active Implantable Medical Devices – Part 3: Implantable Neurostimulators

ISO 14708-4:2008 Implants for Surgery – Active Implantable Medical Devices – Part 4: Implantable Infusion Pumps

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[1] This performance 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 14708-5:2010 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 – Section 1: Immunity for Residential, Commercial, and Light-industrial Environments

IEC 61000-4-2 Electromagnetic Compatibilty (EMC) Part 4: Testing and Measurement Techniques – Section 2: Electrostatic Discharge Immunity Test

IEC 61000-4-3 Electromagnetic Compatibilty (EMC) Part 4: Testing and Measurement Techniques – Section 3: Radiated, Radio-frequency, Electromagnetic Field Immunity Test

IEC 61000-4-8 Electromagnetic Compatibilty (EMC) Part 4: Testing and Measurement Techniques – Section 8: Power Frequency Magnetic Field Immunity Test

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

IEC 60068-2-31:2008-05 Environmental Testing – Part 2:31: Tests – Test Ec: Rough Handling Shocks, Primarily for Equipment-type Specimens

CISPR 22 Information Technology Equipment – Radio Disturbance Characteristics – Limits and Methods of Measurement, Class B, Radiated Disturbance

2.4 *IEEE Standards:*[5]

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

IEEE C95.6 IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0 kHz to 3 kHz

IEEE Std 181-2011 IEEE Standard for Transitions, Pulses, and Related Waveforms

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 Standards:*[7]

ANSI S1.4-1983 Specification for Sound Level Meters

2.7 *CIE Standards:*[8]

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

3. Terminology

3.1 *Definitions:*

3.1.1 *alarm*—an indication (which may be audible, visual, or vibratory, or combinations thereof) that informs the operator of an event, such as metal detection or a detector (HHMD) 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 S/m ± 0.2 S/m and the average magnetic permeability is 1.26×10^{-6} H/m ± 5×10^{-7} H/m.

3.1.3 *detector*—the hand-held metal detector (HHMD) that is held in one hand and is used for finding metal objects concealed on a person or other object.

3.1.4 *detector axis*—an imaginary line passing through and perpendicular to the detector plane ~~that is located within 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.

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[4] Available from International Electrotechnical Commission (IEC), 3, rue de Varembé, 1st Floor, P.O. Box 131, CH-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.

The location of the detector axis relative to the HHMD 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 device used to hold the HHMD in place during testing. The detector holder is constructed of non-ferromagnetic and non-electrically conductive materials.

3.1.6 *detector plane*—an imaginary plane (two-dimensional surface) that ~~is tangential to~~ contains the plane, line, or point on the HHMD surface that is closest to the object being scanned under typical HHMD ~~use.~~ 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. 1.

3.1.7 *detection sensitivity setting*—an adjustment that can be made to the HHMD 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," and "z," where the z axis is parallel to the detector axis and the x axis and the y axis are in the detector plane. The orientation of the test objects is referenced to the measurement coordinate system. See Fig. 2.

3.1.9 *measurement plane*—an imaginary two-dimensional surface over which the HHMDs are tested. 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 size class of the HHMD, 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 HHMD may meet the requirements for one or all size classes, as defined below.

3.1.10.1 *large*—represents threat items such as handguns, and similarly sized objects, or larger, constructed of ferromagnetic or nonferromagnetic metal, or both.

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, constructed of ferromagnetic or nonferromagnetic metal, or both.

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, handcuff keys, handgun rounds, and similarly sized objects, up to the size of a medium object, constructed of ferromagnetic or nonferromagnetic metal, or both.

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, constructed of ferromagnetic or nonferromagnetic metals, or both.

3.1.11 *test object*—an item that is used to test the HHMD 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*—the segment of line along the x axis of the measurement coordinate system that is centered on the detector axis that extends equally on either side of the detector axis.

4. Requirements for Acceptance

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

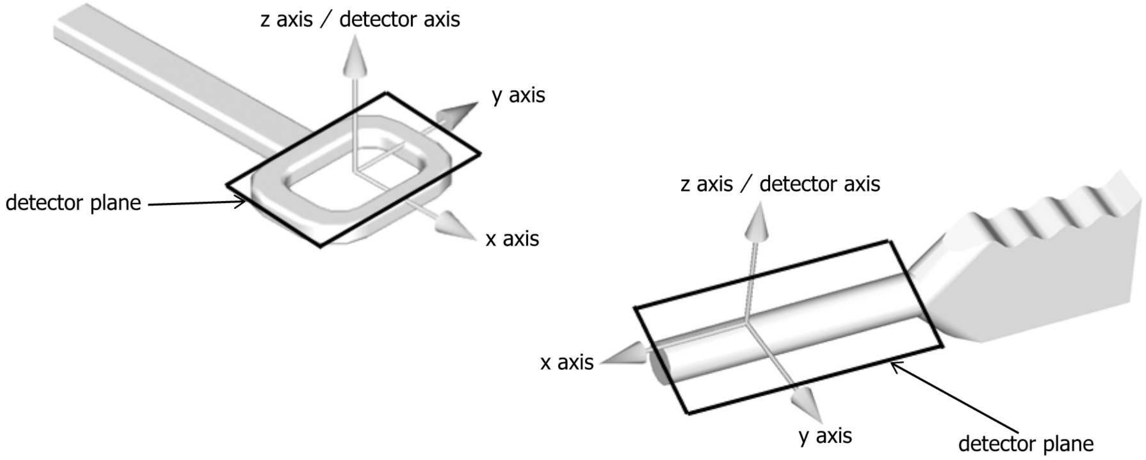

FIG. 1 Diagram of Hand-held Metal Detector Showing the Detector Plane (Labeled and Represented by a Rectangle) and the Detector Axis (Labeled z)

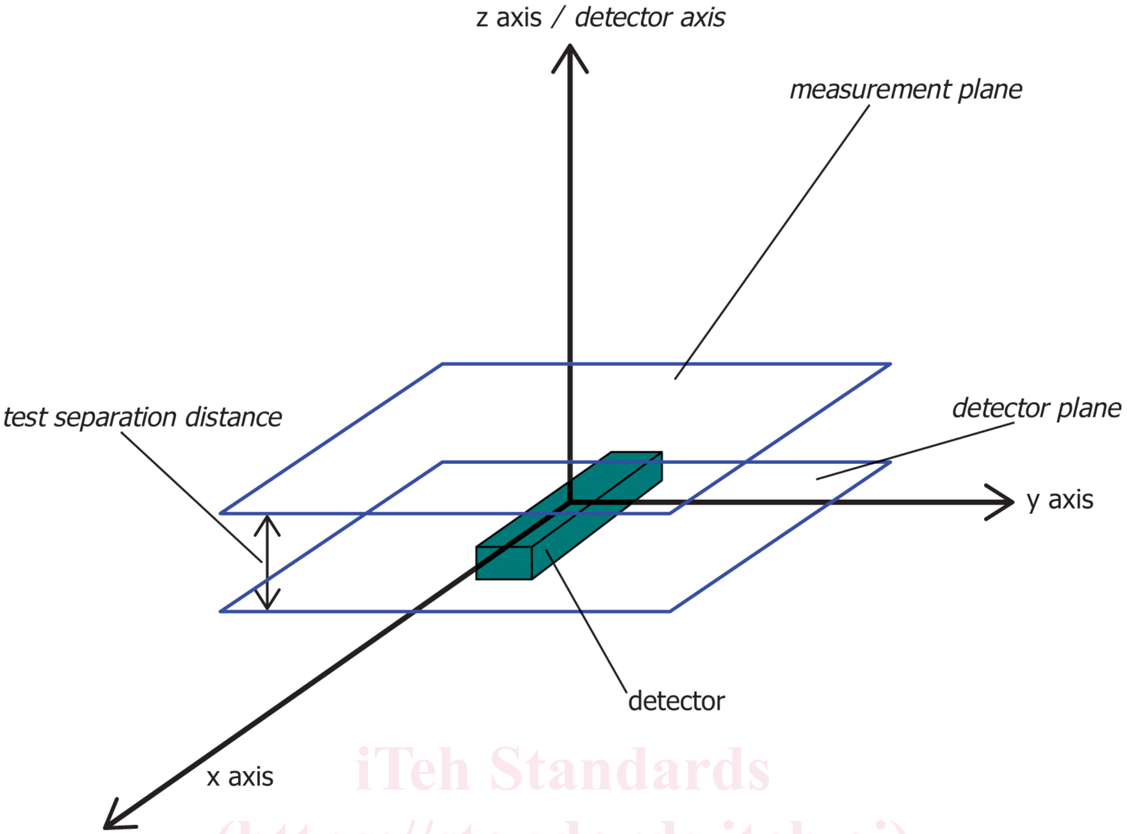

FIG. 2 A Diagram of the Measurement Coordinate System Showing the Measurement Coordinate System Axes, One Measurement Plane, and the Detector Plane. The x axis Points Along the User's Arm

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

Size Class	Distance Between Measurement Plane and Detector Plane (cm)
Large	8.0 – 0/+ 0.2
Medium	4.0 – 0/+ 0.2
Small	2.0 – 0/+ 0.2
Very Small	0.5 – 0/+ 0.2

TABLE 2 X-axis Scan Range for the Different HHMD Size Classes

Size Class	X-axis Scan Range	
	lower limit (cm)	upper limit (cm)
Large	−7.5 ± 0.1	7.5 ± 0.1
Medium	−6.0 ± 0.1	6.0 ± 0.1
Small	−5.7 ± 0.1	5.7 ± 0.1
Very small	−5.4 ± 0.1	5.4 ± 0.1

NOTE 2—To have confidence that the HHMD 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.

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

4.1 *General Test Conditions and Requirements:*

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

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

4.2 *Safety Specifications and Requirements:*

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

4.2.2 *Mechanical*—The HHMD shall meet the requirements of IEC 61010-1 Section 7, "Protection Against Mechanical Hazards," as amended.

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

4.2.4 ~~*Human Exposure:*~~ *Magnetic Field Exposure—*

~~4.2.4.1 *General*—The magnitude of the electromagnetic field generated by the HHMD at a distance of approximately 5 mm from any surface of the HHMD shall be less than the exposure limits specified for general public exposure in the ICNIRP[8] guideline and IEEE C95.1.~~The magnitude of the electromagnetic field generated by the HHMD shall be less than the exposure limits specified for general public exposure in the ICNIRP [9, 10] guidelines (see Annex A4). These measurements shall be made at points on grid lines that are (*1*) tangential to the current-carrying coil of the HHMD and (*2*) parallel to the surfaces of an outward projection from the smallest imaginary rectangular prism enclosing that part of the HHMD 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. A three-axis magnetic field probe with a –3 dB analog bandwidth of $0.1f_c \leq f_c \leq 10f_c$, 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 $2s_{grid} \times 2s_{grid} \times 2s_{grid}$.

~~4.2.4.2 *Active Implanted and Body-worn Medical Devices*—The magnitude of the electromagnetic field generated by the HHMD shall not cause an active implanted or body-worn medical electronic device to be adversely affected as described in ISO 14117:2012, ISO 14708-1, ISO 14708-2, ISO 14708-3, ISO 14708-4, ISO 14708-5, ISO 14708-6, and ISO 14708-7 and tested in accordance with the same. If adherence to the requirement in 4.2.4.2 has not been demonstrated, the manufacturer shall provide a warning with the HHMD instructions that states "This device has not been demonstrated as being safe for use on people with active implanted or body-worn medical devices, or both."~~

4.3 *Power Requirement:*

4.3.1 *Battery Life*—The HHMD shall ~~operate~~ meet the detection performance specification given in 4.4 after operating for at least 10 h as tested in accordance with 5.5 and while using a battery of the type and model recommended by the manufacturer.

4.4 *Detection Performance Specifications*—The ability of the HHMD to sense the presence of a test object will vary with the material and geometry of the test object and the distance between the test object and the HHMD. In this performance specification, the test objects are spherical to avoid the possibility of incorrectly attributing a higher performance capability to a HHMD than that HHMD is capable of providing. The test objects are grouped according to their size class and the HHMDs 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, 5.3, and 5.4 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 HHMD 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 (see Table 2) ~~with the test object moving~~ at a speed of 0.5 m/s ± 0.05 m/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 HHMD 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) for each required orientation (see Table 2) of the test object axes with respect to the measurement coordinate ~~system, with the test object moving~~ system at a speed of 0.05 m/s ± 0.01 m/s, 0.2 m/s ± 0.01 m/s, 0.5 m/s ± 0.01 m/s, and 1.0 m/s ± 0.01 m/s as tested in accordance with 5.2.2 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 HHMD, 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 HHMD 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 HHMD, 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.

4.5.2.2 *Radiated RF Electromagnetic Field Immunity*—The HHMD, when adjusted to meet the requirements of 4.4, shall not produce an alarm when tested in the absence of a test object and in accordance with IEC 61000-4-3, as amended, for Level 2.

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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.

4.5.2.3 *60 Hz and 50 Hz Radiated Magnetic Field*—The HHMD, when adjusted to meet the requirements of 4.4, shall not produce an alarm when tested in the absence of a test object and in accordance with IEC 61000-4-8, as amended, for testing at 60 Hz and 50 Hz, Level 2, and continuous exposure for 30 min ± 5 min.

4.5.3 *Body Interference*—The HHMD, without adjusting the detection sensitivity settings used for the tests given in 4.4, shall exhibit a probability of false alarm, $p_{fa,b,} \leq 0.05$ with a confidence level of 0.95 when operating near 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.

4.5.4 *Metal Interference*—The HHMD, without adjusting the detection sensitivity settings used for the tests given in 4.4, shall exhibit a probability of false alarm, $p_{fa,m,} \leq 0.05$ with a confidence level of 0.95 when operating near a large metal plate, as tested in accordance with 5.4. This requirement is met when $p_{UB} \leq p_{fa,m}$ as computed per 5.4.2.

4.6 *Environmental Ranges and Conditions*—The HHMD or all of its components and their interconnections shall meet all of the requirements listed in this section. The HHMD ~~performance requirements~~ shall exhibit no observable changes in the detection performance specification given in 4.4.2~~of~~ using the limited set of test objects listed in Section ~~4.2~~6 and ~~4.4 shall not be affected by the tests described in this section as demonstrated by subsequent testing per the requirements of~~ the electrical safety specification given in ~~4.2 and 4.4~~4.2.1. The requirements given in this section shall be applied appropriately for either indoor or indoor/outdoor HHMD models. The tests for the requirements listed in this section shall be performed on the same unit.~~ The HHMD, if tested for any of the requirements listed in 4.4, shall exhibit no observable changes in the detection performance specification given in 4.4 using the limited set of test objects listed in Section 6~~.

4.6.1 *Temperature Stability and Range:*

4.6.1.1 *Indoor*—The HHMD shall operate over the ambient temperature range of at least 0 to 46°C. The HHMD shall be tested in accordance with MIL-STD-810G Method 501.5, as amended, Procedure II, Steps 1 through 6, relative humidity 6 % ± 3 %, at 46°C ± 3°C. The HHMD then shall be cooled to 0°C ± 3°C within 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 HHMD shall operate over the ambient temperature range of at least –21°C to 65°C. The HHMD shall be tested in accordance with MIL-STD-810G Method 501.5, as amended, Procedure II, Steps 1 through 6, relative humidity 6 % ± 3 % at 65°C ± 3°C. The HHMD then shall be cooled to –21°C ± 3°C within 4 h ± 0.5 h and tested in accordance with MIL-STD-810G Method 502.5, as amended Procedure II, Steps 1 through 7.

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

4.6.3 *~~Environmental~~Ingress Protection:*

4.6.3.1 *Indoor*—The HHMD shall meet or exceed the requirements for compliance with IEC 60529, as amended, classification IP54.

4.7 *Mechanical Specifications and Requirements*—The HHMD or all of its components and their interconnections shall meet the requirements of the following standards. The requirements of 4.2 and 4.4 shall not be affected by the tests described in this section. All tests listed in this section shall be performed on the same unit. The ~~HHMD, if tested for any of the tests listed in~~ HHMD ~~4.4,~~ shall exhibit no observable changes in the detection performance specification given in ~~4.4~~4.4.2 using the limited set of test objects listed in Section 6 and the electrical safety specification given in 4.2.1.

4.7.1 *Shock*—The HHMD shall be tested in accordance with the requirements of IEC 60068-2-27:2008, as amended, using 100 ± 5 half-sine shock pulses applied to the HHMD along the six directions (1, 0, 0), (0, 1, 0), (0, 0, 1), (–1, 0, 0), (0, –1, 0), and (0, 0, –1) of the measurement coordinate system and with each shock pulse having a nominal peak acceleration of 40.0 g (392 m/s^2) and a nominal pulse duration of 6 ms.

4.7.2 *Free Fall*—The detector shall be tested in accordance with the requirements of IEC 60068-2-31, Procedure 1, as amended, for each direction of the detector axes, a fall height of 1 m, and for two drops for each direction of the orthogonal axes depicted in Fig. 2.

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 an acceleration in the range of 0.2 m/s^2 to 1.0 m/s^2 over a frequency range of 10 Hz to 300 Hz as measured in accordance with 5.6.1.

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_{SPL} ± 5 dB (where 0 dB_{SPL} = 20 µPa root-mean-square in air) at 0.8 m ± 0.08 m from the HHMD as measured in accordance with 5.6.2. 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 as tested in accordance with 5.6.3.

4.8.3 *Visual Alarm*—The visible alarm, if provided, shall produce an alarm-state light level ≥10 lx when tested in accordance with 5.6.4. The visual alarms shall be a two-state visual alarm: active (illuminating) and inactive (nonilluminating).

4.8.4 *Alarm Delays*—The maximum delay between activation of all alarms (visual, audible, and vibratory) shall be 200 ms and the maximum difference in duration among all alarms shall be 200 ms, as tested in accordance with 5.7.

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 (see Section 6) and the closest part of the HHMD shall be greater than 1.0 m.

5.1.2 *Environment*—At the time of the tests, the ambient temperature shall be in the range specified in 4.6 for the appropriate application (indoor or indoor/outdoor); the relative humidity shall be noncondensing.

5.1.3 *Preparations*—New or fully-charged 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. In any stand-by feature is available on the HHMD, this feature shall be disabled.

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 HHMD. 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 HHMD 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 ~~of~~between the measurement plane and the detector plane.

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.

5.2.2 *Detection Sensitivity Test:*

5.2.2.1 *Initial Procedures:*

(1) Turn on the measurement system and verify proper operation of the measurement system.

(2) Ensure that the HHMD is securely fixed to the detector holder and that the detector holder is fixed in position and secured to the measurement system.

(3) Attach the test object to the positioning component of the measurement system.

(4) Turn on the HHMD and ensure that its output is functioning properly by noting a change in the alarm output as a metal object is brought near the HHMD.

(5) Ensure that the test object does not hit the detector holder or any other objects while in motion.

(6) 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:

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

where p_0 is equal to the probability of detection specified in 4.4.2; z_c 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 class, and the number of scans performed. For example, when $p_0 = 0.95$ and the confidence level = 0.95, $N_T = 52$. Values of N_T are provided for convenience in Annex A3.

(7) 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 values 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:*

(1) Prepare the measurement system 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 y-axis scans shall each be no less than 40 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:

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

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.

(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 objects of a given size class, where K is the number of test objects in the size class.

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

$$p_{d,sens} = \frac{1}{KN_x}\sum_{k=1}^{K}\sum_{i=1}^{N_x} p_{d,sens,k,i}. \tag{4}$$

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

$$p_{LB} = p_{d,sens} - \frac{\sqrt{\sum_{k=1}^{K}\sum_{i=1}^{N_x}\left(p_{d,sens,k,i} - l_{k,i}\right)^2}}{KN_x}, \tag{5}$$

where

$$l_{k,i} = \frac{p_{k,i} + 0.5\frac{z_c^2}{n_{k,i}} - z_c\sqrt{\frac{p_{k,i}\left(1 - p_{k,i}\right) + \frac{z_c}{4n_{k,i}}}{n_{k,i}}}}{1 + \frac{z_c^2}{n_{k,i}}}, \tag{6}$$

where for these tests $n_{k,i} = n_{s,k}$ as computed in 5.2.2.1. For a 95 % confidence interval, z_c = ~~1.96~~1.645 and for a 99 % confidence interval, z_c = 2.576.

(11) Set $p_d = P_{LB}$, and report this value.

5.2.3 *Detection Speed Test:*

5.2.3.1 *Initial Procedures:*

(1) Turn on the measurement system and verify proper operation of the measurement system.

(2) Ensure that the HHMD is securely fixed to the detector holder and that the detector holder is fixed in position and secured relative to the positioning component of the measurement system.

(3) Turn on the HHMD and ensure that its output is functioning properly by noting a change in the alarm output as a metal object is brought near the HHMD.

(4) Ensure that the test object does not hit the detector holder or any other objects while in motion.

(5) ~~Compute the minimum number of repeats,~~ Use the ~~N_T, of a given measurement that must be performed to meet the performance requirements for a given confidence interval using:~~

$$N_T = \mathrm{ceil}\left\{\frac{z_c^2 p_0}{1 - p_0}\right\}, \tag{7}$$

~~where p_0 is equal to the probability of detection specified in 4.4.2; z_c 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~~ value of N_T ~~includes the number of test objects of a given test object size class, the number of orientations, and the number of scans performed. For example, when~~ computed ~~p_0 = 0.95 and the confidence level = 0.95, N_T = 52. Values of N_T are provided for convenience~~ in ~~Annex A3~~Eq 1.

(6) 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, and the total number of required scans, N_T. The value of $n_{s,k}$ is computed using:

$$n_{s,k} = \max\left\{\frac{N_T}{n_x}, 10\right\}, \tag{7}$$

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

5.2.3.2 *Performing the Measurement:*

(1) Prepare the measurement system 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 40 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:

$$p_{d,sens,k,i,m} = \frac{1}{n_s}\sum_{j=1}^{n_s} A_{Pos-sens,k,i,m,j} \tag{8}$$

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 objects of a given size class, where K is the number of test objects in a given size class.

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

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

$$p_{d,sp-sens} = \frac{1}{KN_xM}\sum_{k=1}^{K}\sum_{i=1}^{N_x}\sum_{m=1}^{M} p_{d,sens,k,i,m}. \tag{9}$$

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

$$p_{LB,sp} = p_{d,sp-sen} - \frac{\sqrt{\sum_{k=1}^{K}\sum_{i=1}^{N_x}\sum_{m=1}^{M}\left(p_{d,sens,k,i,m} - l_{k,i,m}\right)^2}}{KN_xM}, \tag{10}$$

where:

$$l_{k,i,m} = \frac{p_{k,i,m} + 0.5\frac{z_c^2}{n_{k,i,m}} - z_c\sqrt{\frac{p_{k,i,m}\left(1 - p_{k,i,m}\right) + \frac{z_c}{4n_{k,i,m}}}{n_{k,i,m}}}}{1 + \frac{z_c^2}{n_{k,i,m}}}, \tag{11}$$

where for these tests $n_{k,i,m} = k_{s,k}$ as computed in 5.2.2.1. For a 95 % confidence interval, z_c = ~~1.96~~1.645 and for a 99 % confidence interval z_c = 2.576.

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

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

5.3.1 *Initial Procedures:*

(1) The body simulant test object, if used, shall be constructed of a material exhibiting an electrical conductivity of 0.8 S/m ± 0.2 S/m and magnetic permeability of 1.26×10^{-6} H/m ± 5×10^{-7} H/m and be a rectangular prism with a thickness (direction parallel to z axis) of 3 cm ± 0.5 cm, a length (direction parallel to x axis) of 20 cm ± 0.5 cm, and a width (direction parallel to y axis) of 10 cm ± 0.5 cm.

(2) ~~Compute the minimum number of repeats,~~ Use the ~~N_T, of the measurement that must be performed to meet the performance requirements for a given confidence interval using:~~

~~$N_T = \mathrm{ceil}\left\{\frac{z_c^2 p_0}{1 - p_0}\right\}$ (13)~~

~~where p_0 is equal to $(1 - p_{fa,b})$, where $p_{fa,b}$ is specified in 4.5.3; z_c 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~~ value ~~x. The value~~ of N_T ~~includes the number of test objects of a given test object size class, and the number of scans performed. For example, when~~ computed ~~p_0 = 0.95 and the confidence level = 0.95, N_T = 52. Values of N_T are provided for convenience~~ in ~~Annex A3~~Eq 1.

(3) Turn on the measurement system and verify proper operation of the measurement system. Ensure that the HHMD is securely held by 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 HHMD and ensure that its output is functioning properly by noting a change in the alarm output as a metal object is brought near the HHMD.

5.3.2 *Performing the Measurement:*

(1) Sweep the HHMD over the body simulant test object or clean torso at a velocity of approximately 1 m/s while maintaining an approximate separate of 5 mm between the HHMD and the body simulant or 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:

$$p_{fa,b} = \frac{1}{N_T}\sum_{j=1}^{N_T} A_{Pos-b,j}, \tag{12}$$

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 interface test.

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

$$p_{UB} = \frac{p_{fa,b} + 0.5\frac{z_c^2}{N_T} + z_c\sqrt{\frac{p_{fa,b}(1 - p_{fa,b}) + \frac{z_c^2}{4N_T}}{N_T}}}{1 + \frac{z_c^2}{N_T}} \quad (13)$$

and record and report this value.

5.4 *Metal Interference Test:*

5.4.1 *Initial Procedures:*

(1) The metal test panel shall be cold-finished sheet carbon steel UNS G10150 to G10200, 1 m ± 0.1 m by 1 m ± 0.1 m by 0.75 mm ± 0.13 mm thick. The panel shall be mounted or supported in a manner that keeps the panel flat.

(2) ~~Compute the minimum number of repeats,~~ Use the ~~N_T, of the measurement that must be performed to meet the performance requirements for a given confidence interval using:~~

~~$N_T = \mathrm{ceil}\left\{\frac{z_c^2 p_0}{1 - p_0}\right\}$,~~ (16)

~~where p_0 is equal to $(1-p_{fa,b})$, where $p_{fa,b}$ is specified in 4.5.3; z_c 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~~ value of N_T ~~includes the~~computed in Eq 1~~number of test objects of a given test object size class, the number of orientations, and the number of scans performed. For example, when p_0 = 0.95 and the confidence level = 0.95, N_T = 52.~~

5.4.2 *Performing the Measurement:*

(1) Position the HHMD with its detector plane parallel to and 0.5 m ± 0.05 m from the plane of the test panel and with the detector axis centered with respect to the center of the test panel. Parallel is 0° ± 1°. Turn on the HHMD and without changing the HHMD performance settings note and perform a y-axis scan across the detector axis using the same parameters as in 5.2.2. Record any alarms. Repeat this y-axis scan $N_T - 1$ times to yield a total of N_T scans and compute the average alarm occurrence using:

$$p_{fa,m} = \frac{1}{N_T}\sum_{j=1}^{N_T} A_{Pos-m,j}, \quad (14)$$

where $A_{Pos\text{-}m,j}$ 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 $p_{fa,m}$ is the probability of false alarm for the metal interference test.

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

$$p_{UB} = \frac{p_{fa,m} + 0.5\frac{z_c^2}{N_T} + z_c\sqrt{\frac{p_{fa,m}(1 - p_{fa,m}) + \frac{z_c^2}{4N_T}}{N_T}}}{1 + \frac{z_c^2}{N_T}}. \quad (15)$$

5.5 *Battery Life Test:*

5.5.1 *Initial Procedures:*

(1) Install in the HHMD new or fully charged batteries of the type specified by the manufacturer.

(2) Ensure that the alarm detector and positioning system are connected to the computer controller.

(3) Turn on the measurement system and verify proper operation of the measurement system.

(4) Ensure that the HHMD is securely fixed to the detector holder and that the detector holder is fixed in position and secured relative to the positioning component of the measurement system.

(5) Attach the test object with the proper orientation to the positioning system.

(6) Turn on the HHMD and ensure that its output is functioning properly by noting a change in the alarm output as a metal object is brought near the HHMD.

(7) Ensure that the test object does not hit the detector holder or any other objects while in motion.

5.5.2 *Performing the Measurement:*

(1) Prepare the measurement system to perform a series of 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 40 cm long. The duration of this series of scans shall be ~~8~~10 h ± 0.1 h. The delay between scans shall be 30 s ± 2 s.

(2) After completion of Step (*1*), perform ten 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 40 cm long. The delay between scans shall be less than 2 s. Compute the alarm rate, r_{alarm}, using:

$$r_{alarm} = \frac{N_{alarms}}{10}, \tag{16}$$

where N_{alarms} is the number of alarms that were observed in step b.

(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.

5.6 *Alarm Tests:*

5.6.1 *Vibratory Alarm Test:*

(1) Place vibration detector in contact with that part of the HHMD closest to the component that produces the vibratory alarm.

(2) Measure the vibration of the vibratory alarm in all three orthogonal Cartesian directions with the HHMD power applied and the alarm in the nonalarm state and compute the vibration magnitude, v_{na}, as the vector norm (L2 norm) of these measurements.

(3) Cause the HHMD to produce an alarm, and again measure and record the vector norm of the vibration magnitude, v_{na+a}.

(4) Compute the different between two vibration magnitudes, using:

$$v_a = v_{na+a} - v_{na}, \tag{17}$$

where v_a is the vibration magnitude produce by the alarm.

(5) Repeat this measurement five times and calculate the average value of v_a.

(6) Record and report the average value.

5.6.2 *Audible Alarm Test:*

(1) Perform the test in an anechoic chamber. Position the sound pressure meter 0.80 m ± 0.02 m from the HHMD.

(2) Measure the sound pressure level, P_{na}, with the HHMD power applied and the alarm in the nonalarm state.

(3) Cause the HHMD 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:

$$P_a = 10\log_{10}\left(10^{\frac{P_{na+a}}{10}} - 10^{\frac{P_{na}}{10}}\right). \tag{18}$$

(4) Repeat this measurement five times and calculate the average value of P_a.

(5) Record and report the average P_a.

(6) For frequency proportional alarms, P_a shall be measured and reported at the following frequencies within the frequency band of the audible signal: lowest operational limit, f_{low}, of the audible alarm frequency band; highest operational limit, f_{hi}, of the audible alarm frequency bands; and the middle frequency, f_{mid}, where

$$f_{mid} = \frac{f_{hi} + f_{low}}{2}. \tag{19}$$

5.6.3 *Audible Alarm Frequency Range Test:*

(1) Perform the test in an anechoic chamber.

(2) Position the sound pressure meter 0.80 m ± 0.02 m from the HHMD and connect this device to an audio frequency measurement system.

(3) Turn the HHMD power on and cause the HHMD to produce an alarm.

(4) Repeat this measurement five times and calculate the average value of the audio frequency.

(5) Record and report the average audio frequency measured by the audio frequency measurement system.

5.6.4 *Visual Alarm Test:*

(1) Position the HHMD 0.80 m ± 0.02 m from in contact with the illumination meter, with the line perpendicular (90° ± 5°) to the plane of the input aperture of the illumination meter and the line perpendicular (90° ± 5°) to the output aperture of the visual alarm nominally collinear.

(2) Perform the test at a location where the ambient illumination is 1000 lx ± 100 lx.

(3) Turn on the HHMD and move a metal object near the HHMD to cause an alarm.

(4) Measure the light level, E_{na}, with the HHMD power applied and the alarm in the nonalarm state.

(5) Cause the HHMD to produce an alarm, and again measure and record the light level, E_{na+a}.

(6) Compute the light level increase, E_a, due to the alarm indicator using:

$$E_a = E_{na+a} - E_{na}. \tag{20}$$

(7) Repeat this measurement five times and calculate the average value of E_a.

(8) Record and report the average value.

5.7 *Alarm Decay Test*—Activation of an alarm shall be defined as the instant the alarm has increased to half its amplitude, where the amplitude is defined as the difference between the high (alarm state) and low (no alarm state) output of the alarm. Deactivation of an alarm shall be defined as the instant the alarm has decreased to half its amplitude. The duration of the alarm is defined as the difference between its first and second transition instants. The first transition instant is the instant the amplitude of alarm attains half its amplitude, which happens during activation of the alarm. The second transition instant is the instant amplitude of the alarm decreases to half its amplitude, which happens during deactivation of the alarm.

5.7.1 *Initial Procedures:*

(1) Position appropriate alarm detectors to capture the output of each possible HHMD alarm.

(2) Connect the output of these alarm detectors to a multichannel waveform recorder (such as an oscilloscope).

5.7.2 *Performing the Measurement:*

(1) Produce an alarm by passing a ferromagnetic large size test object across the detector axis (x-axis position) at the large size test separation distance (see Table 1) at a speed of 1.0 m/s ± 0.01 m/s. The y-axis scan length shall be at least the maximum width of the HHMD along the y-axis plus two times the maximum dimension of the test object but no less than 20 cm ± 1 cm long.

(2) Start recording (trigger) the waveforms from each alarm detector when the test object motion begins (±1 ms) until 200 ms ± 1 ms after the test object motion stops or all alarms cease, whichever is later. The time resolution of the recorded waveform should be at least 500 µs (that is, the interval between waveform samples shall be less than or equal to 500 µs). Time t = 0 is the first point in the recorded waveform.

(3) Determine the 50 % reference level instant (instant at which the waveforms achieve a level equal to 50 % of amplitude, and as defined in IEEE Std 181) for each transition in the waveforms. There should be two transitions each, the first transition corresponding to activation of the alarm and the second transition to the deactivation of the alarm.

(4) Record both transitions for the waveform corresponding to each alarm. As an example, label these reference level instants as $t_{i,1}$ and $t_{i,2}$ where the *i* subscript denotes an alarm detector and the 1 and 2 subscript denotes the first and second transitions.

(5) Compute the alarm duration, t_d, using:

$$t_d = t_{i,2} - t_{i,1}. \tag{21}$$

(6) Record and report the set of alarm durations and note if the difference between any of these durations exceeds the requirement.

(7) To compute the delay, $D_{i,j,}$ between alarms use:

$$D_{i,j} = |t_{i,1} - t_{j,1}|. \tag{22}$$

(8) Repeat Steps (*1*) through (*7*) five times and calculate the average value of each $D_{i,j}$.

(9) Record and report these delays and note if these values exceed the specification.

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 HHMD 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 HHMD shall exhibit electrical conductivity and magnetic relative permeability values as shown in Table 2 within the tolerances shown in Table 4 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 HHMD 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)	40 mm ± 0.1 mm	25 mm ± 0.1 mm
Class 2 (medium size)	15 mm ± 0.03 mm	12 mm ± 0.03 mm
Class 3 (small size)	9 mm ± 0.02 mm	7 mm ± 0.02 mm
Class 4 (very small size)	6 mm ± 0.01 mm	4 mm ± 0.01 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*—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.

(2) Turn on the alarm detector, computer controller, and positioning system and verify proper operation of the measurement system.

(3) Ensure that the HHMD 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.

(4) Attach the test object with the proper orientation to the positioning system.

(5) Turn on the HHMD and ensure that its output is functioning properly by noting a change in the alarm output as a metal object is brought near the HHMD.

(6) Ensure that the test object does not hit any objects while in motion.

(7) ~~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,~~ Use the ~~N~~$_T$~~, is given by:~~

$$N_T = \text{ceil}\left\{\frac{z_c^2 p_0}{1 - p_0}\right\}, \tag{A1.1}$$

~~where p~~$_0$ ~~is equal to the probability of detection specified in 4.4.2~~; ~~z~~$_c$ ~~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~~ value ~~x. The value~~ of N_T ~~includes the~~computed in Eq 1~~number of test objects of a given test object size class, the number of orientations, and the number of scans performed. For example, when p~~$_0$ ~~= 0.95 and the confidence level = 0.95, N~~$_T$ ~~= 52.~~

(8) 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, 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:

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

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.

A1.1.2 *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 40 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, $p_{d,sens,obj_k,ornt_h,x_i}$, 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: