



Designation: E1444/E1444M – 21

## Standard Practice for Magnetic Particle Testing for Aerospace<sup>1</sup>

This standard is issued under the fixed designation E1444/E1444M; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the U.S. Department of Defense.*

### 1. Scope\*

1.1 This practice establishes minimum requirements for magnetic particle testing used for the detection of surface or slightly subsurface discontinuities in ferromagnetic material. This practice is intended for aerospace applications using the wet fluorescent method. Refer to Practice [E3024/E3024M](#) for industrial applications. Guide [E709](#) can be used in conjunction with this practice as a tutorial.

NOTE 1—This practice replaces MIL-STD-1949.

1.2 The magnetic particle testing method is used to detect cracks, laps, seams, inclusions, and other discontinuities on or near the surface of ferromagnetic materials. Magnetic particle testing may be applied to raw material, billets, finished and semi-finished materials, welds, and in-service parts. Magnetic particle testing is not applicable to non-ferromagnetic metals and alloys such as austenitic stainless steels. See [Appendix X1](#) for additional information.

1.3 Portable battery powered electromagnetic yokes are outside the scope of this practice.

1.4 All areas of this practice may be open to agreement between the cognizant engineering organization and the supplier, or specific direction from the cognizant engineering organization.

1.5 This standard is a combined standard, an ASTM standard in which rationalized SI units and inch-pound units are included in the same standard, with each system of units to be regarded separately as standard.

1.5.1 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.6 *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.*

1.7 *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 The following documents form a part of this practice to the extent specified herein.

2.2 *ASTM Standards*:<sup>2</sup>

[E543 Specification for Agencies Performing Nondestructive Testing](#)

[E709 Guide for Magnetic Particle Testing](#)

[E1316 Terminology for Nondestructive Examinations](#)

[E2297 Guide for Use of UV-A and Visible Light Sources and Meters used in the Liquid Penetrant and Magnetic Particle Methods](#)

[E3022 Practice for Measurement of Emission Characteristics and Requirements for LED UV-A Lamps Used in Fluorescent Penetrant and Magnetic Particle Testing](#)

[E3024/E3024M Practice for Magnetic Particle Testing for General Industry](#)

2.3 *ASNT Documents*:<sup>3</sup>

[SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing](#)

[ANSI/ASNT CP-189 Standard for Qualification and Certification of NDT Personnel](#)

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee [E07](#) on Nondestructive Testing and is the direct responsibility of Subcommittee [E07.03](#) on Liquid Penetrant and Magnetic Particle Methods.

Current edition approved Sept. 1, 2021. Published October 2021. Originally approved in 1991. Last previous edition approved in 2020 as E1444/E1444M – 20. DOI: 10.1520/E1444\_E1444M-21.

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

<sup>3</sup> Available from American Society for Nondestructive Testing (ASNT), P.O. Box 28518, 1711 Arlingate Ln., Columbus, OH 43228-0518, <http://www.asnt.org>.

\*A Summary of Changes section appears at the end of this standard

#### 2.4 SAE-AMS Documents:<sup>4,5</sup>

- AMS 2175 Castings, Classification and Inspection of
- AMS 2641 Magnetic Particle Inspection Vehicle
- AMS 3044 Magnetic Particles, Fluorescent, Wet Method, Dry Powder
- AMS 3045 Magnetic Particles, Fluorescent, Wet Method, Oil Vehicle, Ready-To-Use
- AMS 3046 Magnetic Particles, Fluorescent, Wet Method, Oil Vehicle, Aerosol Packaged<sup>5</sup>
- AMS 5355 Investment Castings
- AS 4792 Water Conditioning Agents for Aqueous Magnetic Particle Inspection
- AS 5282 Tool Steel Ring Standard for Magnetic Particle Inspection
- AS 5371 Reference Standards Notched Shims for Magnetic Particle Inspection
- SAE AMS-STD-595 Colors Used in Government Procurement

#### 2.5 Federal Standard:<sup>4,6</sup>

- FED-STD-313 Material Safety Data, Transportation Data and Disposal Data for Hazardous Materials Furnished to Government Activities

#### 2.6 Military Standards:<sup>4,6</sup>

- A-A-59230 Fluid, Magnetic Particle Inspection, Suspension
- MIL-STD-1949 Inspection, Magnetic Particle

#### 2.7 OSHA Document:<sup>7</sup>

- 29 CFR 1910.1200 Hazard Communication

#### 2.8 ANSI Document:<sup>4,8</sup>

- ANSI/NCSL Z540.3 General Requirement for Calibration Laboratories and Measuring Test Equipment

#### 2.9 ISO Standards:<sup>9</sup>

- ISO 10012 Measurement Management Systems—Requirements for Measurement Processes and Measuring Equipment (ISO 10012 is not intended as a substitute for, or as an addition to, the requirements of ISO/IEC 17025.)
- ISO 9712 Non-destructive Testing — Qualification and Certification of NDT Personnel
- ISO/IEC 17025 General Requirements for the Competence of Testing and Calibration Laboratories

#### 2.10 AIA Document:<sup>10</sup>

- NAS 410 NAS Certification and Qualification of Nondestructive Test Personnel

#### 2.11 ASD-STAN Document:<sup>11</sup>

- EN 4179 Qualification and Approval of Personnel for Non-Destructive Testing

2.12 *Order of Precedence*—In the event of conflict between the text of this practice and the referenced documents cited herein, the text of this practice takes precedence.

### 3. Terminology

3.1 *Definitions*—The definitions relating to magnetic particle testing, which appear in Terminology E1316, shall apply to the terms used in this practice.

### 4. Significance and Use

4.1 *Description of Process*—Magnetic particle testing consists of magnetizing the area to be examined, applying suitably prepared magnetic particles while the area is magnetized, and subsequently interpreting and evaluating any resulting particle accumulations. Maximum detectability occurs when the discontinuity is positioned on the surface and perpendicular to the magnetic flux.

4.2 This practice establishes the basic parameters for controlling the application of the magnetic particle testing method. This practice is written so that it can be specified on the engineering drawing, specification, or contract. It is not a detailed how-to procedure to be used by the examination personnel and, therefore, must be supplemented by a detailed written procedure that conforms to the requirements of this practice.

### 5. General Practice

5.1 *Personnel Qualification*—Personnel performing examinations in accordance with this practice shall be qualified and certified in accordance with SNT-TC-1A, ANSI/ASNT CP-189, NAS 410, EN4179, ISO 9712, or as specified in the contract or purchase order.

5.2 *Agency Qualification*—The agency performing this practice may be evaluated in accordance with Specification E543.

5.3 *Written Procedure*—Magnetic particle testing shall be performed in accordance with a written procedure applicable to the part or group of parts under examination. The procedure shall be in accordance with the requirements of this practice. The process, when conducted in accordance with the written procedure, shall be capable of detecting discontinuities specified in the acceptance criteria. The written procedure may be general if it clearly applies to all of the specified parts being examined and meets the requirements of this practice. All written procedures, including technique sheets for specific parts, shall be approved by an individual qualified and certified at Level 3 (III) for magnetic particle testing in accordance with the requirements of 5.1. Procedures shall be submitted to the cognizant engineering organization for review, or approval, or both, when requested.

<sup>4</sup> Copies of standards, specifications, drawings, and publications required by manufacturers in connection with specification acquisition should be obtained from the contracting activity or as directed by the contracting officer.

<sup>5</sup> Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, <http://www.sae.org>.

<sup>6</sup> Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, <http://dodssp.daps.dla.mil>.

<sup>7</sup> Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, <http://www.access.gpo.gov>.

<sup>8</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

<sup>9</sup> Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <https://www.iso.org>.

<sup>10</sup> Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, <http://www.aia-aerospace.org>.

<sup>11</sup> Available from ASD-STAN, [asd-stan.org](http://asd-stan.org).

5.3.1 *Elements of the Written Procedure*—The written procedure shall include at least the following elements, either directly or by reference to the applicable documents:

5.3.1.1 Name and address of facility to which the procedure applies, containing the unique procedure identification number and the date it was written;

5.3.1.2 Identification of the part(s) to which the procedure applies; this shall include the material, or alloy, or both;

5.3.1.3 For new components, sequence of magnetic particle testing as related to manufacturing process operation (for example, post plating, after heat treat, etc.);

5.3.1.4 Identification of test parts used for system performance verification (see 7.1.1 and 7.1.2);

5.3.1.5 Process controls (see Table 1);

5.3.1.6 Identification of the areas of the part to be examined and include an illustration, a drawing, or photos as necessary;

5.3.1.7 Part preparation required before examination;

5.3.1.8 Directions for positioning the item with respect to the magnetizing equipment;

5.3.1.9 The type of magnetizing current and the equipment to be used;

5.3.1.10 Method of establishing the magnetization (head, coil, yoke, cable wrap, etc.);

5.3.1.11 Directions of magnetization to be used, the order in which they are applied, and any demagnetization procedures to be used between shots;

5.3.1.12 The current level, or the number of ampere turns, to be used and the duration of its application;

5.3.1.13 Type of magnetic particle material to be used, the particle concentration limits, and the method and equipment to be used for its application. If a suspension dwell time is required, the length of suspension drain time prior to examination shall be defined;

5.3.1.14 Type of records and method of marking parts after examination;

5.3.1.15 Acceptance requirements to be used for evaluating indications, arc burns, and disposition of parts after evaluation;

5.3.1.16 Post-examination demagnetization and cleaning requirements; and

5.3.1.17 The method and measurement frequency will be defined for meeting the minimum examination intensity for all UV-A lamps, including battery-powered lamps. Any requirements for documentation of the measurements will also be defined.

5.4 *Examination Sequence*—Perform magnetic particle examination after all operations which might cause or reveal discontinuities. Such operations include, but are not limited to, forging, heat treating, electroplating, forming, welding, grinding, straightening, machining, and proof loading.

5.4.1 Perform magnetic particle examination prior to shot peening (to provide a beneficial compressive layer) and prior to applying protective finishes such as priming, painting, plating (see 5.4.3 through 5.4.3.5), or other coatings.

5.4.2 In-process examinations may not be substituted for final examination.

5.4.3 *Plating and Coatings*—Examine parts which will receive either a plating or coating as follows:

5.4.3.1 Examination is required prior to all non-electroplated coatings.

5.4.3.2 Electroplated surfaces with a final plating thickness of 0.0008 in. [0.02 mm] or less shall be examined either before or after electroplating, or grinding, or both.

5.4.3.3 Electroplated surfaces with a final plating thickness of between 0.0008 in. [0.02 mm] and 0.0050 in. [0.13 mm] shall be examined both before and after electroplating, or grinding, or both, of electroplated surfaces.

(1) Electroplated surfaces with a final plating thickness of 0.0050 in. [0.13 mm] or greater shall be examined before electroplating, or grinding, or both, of electroplated surfaces.

(2) Magnetic particle examination after electroplating is not required for steels with a tensile strength less than or equal to 160 ksi.

**TABLE 1 Process Controls and Calibrations**

Item	Maximum Time Between Verification <sup>A</sup>	Paragraph
Lighting: <sup>B</sup>		
Visible light intensity	Weekly	7.3.1.1
Ambient light intensity	Weekly	7.3.1.2
UV-A lamp intensity	Daily	7.3.2, 7.4.5
Battery powered	Prior to and after each use	7.4.5.2
UV-A lamp intensity check		
UV-A lamp integrity <sup>C</sup>	Daily	7.3.2
System Performance: <sup>B</sup>	Daily	7.1, 7.1.1, 7.1.2
Wet particle concentration	8 hours, or every shift change	7.2.1.1
Wet particle contamination: <sup>B</sup>	1 week	7.2.1.2
Water break test	Daily	7.2.2
Equipment calibration check: <sup>B</sup>		
Ammeter accuracy	6 months	7.4.1
Timer control	6 months	7.4.2
Quick break	6 months	7.4.3
Yoke dead weight check	6 months	7.4.4
UV-A Radiometer and Photometer	6 months	7.4.7
Hall-Effect Gaussmeter or Field Indicator accuracy	6 months	7.4.6

<sup>A</sup> When the test system is in operation.

<sup>B</sup> The maximum time between verifications may be reduced or extended when substantiated by actual technical/reliability data.

<sup>C</sup> Need not be recorded.

5.4.3.4 Use caution when examining parts with an electroplated nickel coating as indications may form from the resulting leakage fields within the nickel plating itself.

5.4.3.5 For in-service examination, plating or coatings do not require removal prior to examination unless they are damaged, or they interfere with the examination process.

#### 5.5 Materials:

5.5.1 *Wet Particle Requirements*—Wet particles shall meet the requirements of AMS 3044, 3045, or 3046, as applicable.

5.5.2 *Suspension Vehicles*—The suspension vehicle for the wet method shall be a light petroleum distillate conforming to AMS 2641 (Type I) or A-A-59230, or a suitably conditioned water that conforms to the requirements of 5.5.3. When approved by the contracting agency, AMS 2641 (Type II) may be used. When specified, the oil suspension vehicle shall meet the salient characteristics specified in A-A-59230.

5.5.3 *Conditioned Water Vehicle*—When water is used as a suspension vehicle for magnetic particles, the conditioning agents used shall comply with AS 4792. Proper wetting shall be determined by a water break test (see 7.2.2). Smoother surfaces generally require a greater percent of wetting agent than rough surfaces. Foaming of the bath must be minimized to the point that it does not interfere with the examination process.

5.5.3.1 *Water Vehicle Conditioning Agents*—Any agents added to the water vehicle for any purpose shall conform to the requirements of the particle manufacturer.

5.5.4 *Particle Concentration*—The concentration of particles in the suspension bath shall be as specified in the written procedure. Particle concentrations outside of the range of 0.1 to 0.4 mL in a 100 mL bath sample for fluorescent particles shall not be used.

5.6 *Safety*—The safe handling of magnetic particles and oil vehicles, water baths, and water conditioner concentrates is governed by the suppliers' Material Safety Data Sheets (MSDS). Material Safety Data Sheets, conforming to 29 CFR 1910.1200, or equivalent, must be provided by the supplier to any user and shall be prepared in accordance with FED-STD-313.

5.6.1 *Flammability*—Flash point of oil vehicles shall be in accordance with AMS 2641, Type I carriers. The suppliers' MSDS shall certify the flash point.

5.6.2 *Personnel Hazards*—Precautions against inhalation, skin contact, and eye exposure are detailed in the suppliers' MSDS. These precautions shall be observed.

5.6.3 *Electrical Hazards*—Magnetizing equipment shall be maintained properly to prevent personnel hazards from electrical short circuits. Care must be taken to reduce arcing and the possible ignition of oil baths.

5.6.4 *UV-A Lamps*—Replace cracked or broken ultraviolet filters immediately. Broken filters can allow harmful ultraviolet energy to be emitted and must be replaced immediately. Spectacles designed to absorb ultraviolet energy are suggested for close, high-intensity UV-A examination. LED UV-A lamps used for evaluation purposes shall comply with Practice E3022. See 7.3.2.

## 6. Specific Practice

### 6.1 Preparation of Parts for Testing:

6.1.1 *Pre-examination Demagnetization*—The part shall be demagnetized per 6.7.1 before testing if prior operations have produced a residual magnetic field that may interfere with the examination.

6.1.2 *Surface Cleanliness and Finish*—The surface of the part to be examined shall be essentially smooth, clean, dry, and free of oil, scale, machining marks, or other contaminants or conditions that might interfere with the efficiency of the examination.

6.1.3 *Plugging and Masking*—Plugging and masking are required when specified by the cognizant engineering organization.

6.1.4 All areas on the part where electrical contact is made shall be sufficiently clean to prevent electrical arcing.

6.1.5 *Aircraft-Quality Steel Cleanliness*—The examination of aircraft-quality steel for cleanliness using magnetic particle testing shall be as appropriate to the type of steel being inspected. However, testing of parts fabricated from this material shall be in accordance with the requirements of this practice.

### 6.2 Magnetization Methods:

6.2.1 *Types of Magnetizing Current*—The types of currents used for magnetic particle testing are full-wave rectified current (1 or 3 phase), half-wave rectified current, and alternating current. The equipment used shall fulfill the magnetizing and demagnetizing requirements adequately, as outlined herein, without damage to the part under examination, and it shall include the necessary features required for safe operation.

6.2.2 *Yokes*—When using yokes (electromagnetic probes) for magnetic particle testing, they shall meet the requirements of 7.4.4.

6.2.3 *Magnetizing Current Application*—Alternating current is to be only used for the detection of discontinuities open to the surface. Full-wave direct current has the deepest possible penetration and must be used for examination of sub-surface discontinuities when using the wet magnetic particle method. Half-wave direct current can also be used for examination of sub-surface discontinuities, and due to the pulsating nature of the waveform, it has the advantage of increased particle mobility.

6.2.4 *Magnetic Field Directions*—Discontinuities are difficult to detect by the magnetic particle method when they make an angle less than 45° to the direction of magnetization. To ensure the detection of discontinuities in any direction, each part must be magnetized in a minimum of two directions at approximately right angles to each other. Depending on part geometry, this may consist of circular magnetization in two or more directions, multiple circular and longitudinal magnetization, or of longitudinal magnetization in two or more directions.

NOTE 2—For further guidance, see Guide E709.

6.2.5 *Multidirectional Magnetization*—Multidirectional magnetization may be used to fulfill the requirement for magnetization in two or more directions if it is demonstrated that it is effective in all areas, which require examination as

practical. Test parts in accordance with 6.3.1.1 or shims manufactured to the requirements of AS 5371, or as otherwise approved by the cognizant engineering organization, shall be used to verify field direction, strength, and balance in multidirectional magnetization. Balancing of the combined magnetic field is critical and an adequate balance must be visually demonstrated to be effective in all areas which require examination. The particle application must be timed so that the magnetization levels reach full value in all directions while the particles are mobile on the surface under examination. The residual method shall only be used with the approval of the cognizant engineering organization.

**6.2.6 Direct Magnetization**—Direct magnetization is accomplished by passing current directly through the part under examination. Electrical contact is made to the part using head and tail stock, clamps, or by other means. Caution shall be taken to ensure that the electrical current is not flowing while contacts are being applied or removed and that excessive heating does not occur in any area of the part. Unless otherwise specified by the cognizant engineering organization, prods or magnetic leaches shall not be used for the examination of aerospace components or flight hardware.

**6.2.7 Indirect Magnetization**—Indirect part magnetization uses pre-formed coils, cable wraps, yokes, field (flux) flow fixtures, or a central conductor to induce a magnetic field in a part when no direct electrical contact is made.

**6.2.7.1 Offset Internal Conductor Circular Magnetization**—The circular field from an offset internal conductor is illustrated in Fig. 1. The extent of the field is dependent upon the fill factor of the bar or pipe used and the amperage applied. The effective radial field coverage of the magnetizing shot shall be verified per paragraph 6.3.1. Examination shall be performed on all relevant surfaces prior to rotation of the hollow part on the conductor to provide full radial coverage.

**6.2.8 Induced Current Magnetization**—Induced current magnetization (toroidal or circumferential field) is accomplished by inductively coupling a part to an electrical coil in order to create a suitable current flow within the part as illustrated in Fig. 2. This method is often advantageous on

ring-shaped parts with a central aperture and with an  $L/D$  ratio less than three, especially where the elimination of arcing or burning is of vital importance.

**6.2.9 Parallel Current Induced Magnetization**—This method of magnetization may occur when a ferromagnetic part is placed alongside and parallel to a current-carrying conductor. A magnetic field will be induced in the part that is more transverse than circular. This type of magnetization shall not be used for magnetic particle testing unless approved by the cognizant engineering organization.

**6.2.10 Magnetization of Aerospace Lifting Hardware**—The use of permanent magnets, electromagnetic yokes, or coil wraps on aerospace lifting hardware must be approved by the cognizant engineering organization.

### 6.3 Magnetic Field Strength:

**6.3.1 Magnetic Field Strength**—The applied magnetic field shall have sufficient strength to produce satisfactory indications, but it must not be so strong that it causes the masking of relevant indications by nonrelevant accumulations of magnetic particles. Adequate magnetic field strength may be determined by one or a combination of the following methods:

**6.3.1.1** In unidirectional, or multidirectional magnetizing applications, by examining parts having known or artificial discontinuities of the type, size, and location specified in the acceptance requirements or by using the notched shims as defined in Annex A1;

**6.3.1.2** In unidirectional magnetizing applications only, by using a Hall-Effect probe gaussmeter capable of measuring the peak values of the tangential field as described in Annex A4. Tangential-field strengths shall have a minimum value of 30 Gauss ( $30 \times 10^{-4}$  Tesla [T]) when measured at the part surface using a transverse Hall-Effect probe gaussmeter as described in Annex A4. The maximum Gauss value derived is limited by the restrictions of 6.3.1. See Guide E709 for additional guidance.

**6.3.2 Longitudinal Magnetization Using Coils**—Longitudinal magnetization is often accomplished by passing current through a coil encircling the part, or section of the part, to be examined (that is, by using a coil shot). This produces a magnetic field parallel to the axis of the coil. The actual effective distance must be demonstrated based on the particular part to be examined. For parts longer than these effective distances, the entire length shall be examined by repositioning the part within the coil, allowing for approximately 10% effective magnetic field overlap. See 6.3.1 for field strength methods that can be used in coil magnetization.

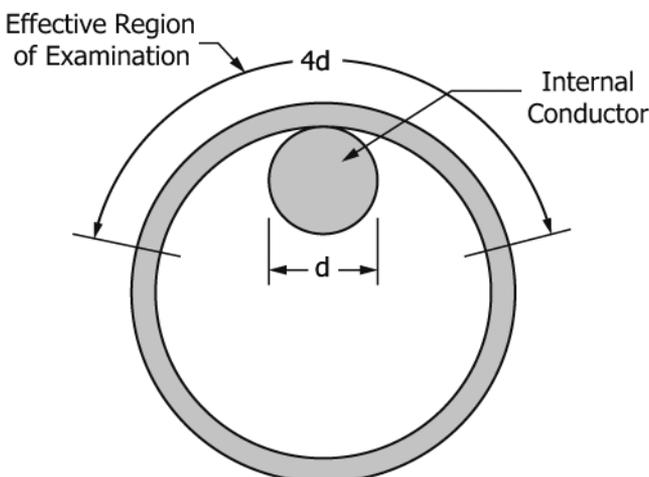
**6.3.3 Magnetizing Current Shots**—In a series of magnetizing shots, unless there is an interim demagnetization operation, the amperage value shall proceed from a lower to a higher selection.

**6.3.4 Coil Shots**—The value of the coil shot expressed in ampere-turns (AT) is considered to be the current multiplied by the number of coil turns.

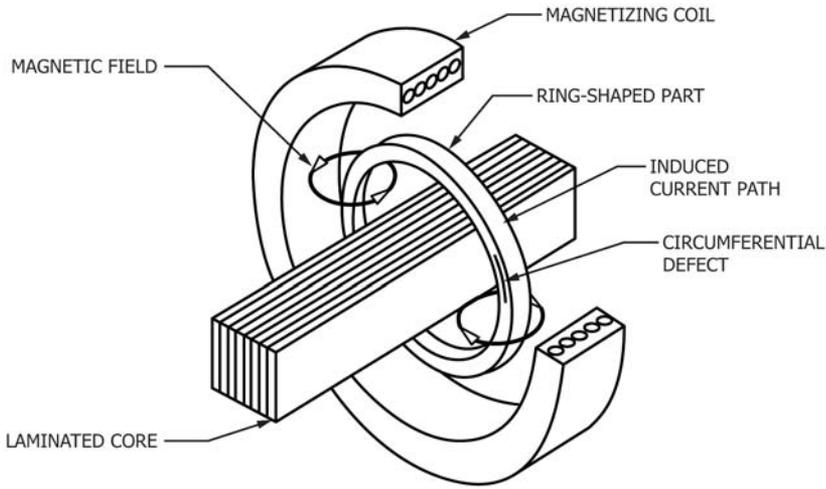
**6.3.5** The specimen under test shall have a minimum  $L/D$  ratio of 2 for proper coil magnetization.

### 6.4 Particle Application:

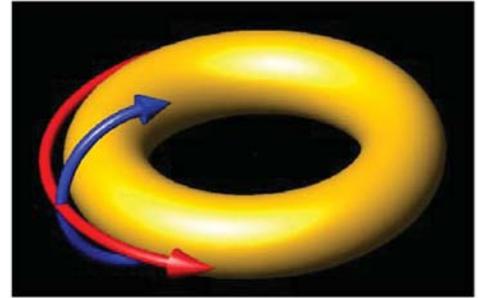
**6.4.1 Wet Magnetic Particle Application, Continuous Method**—Fluorescent particles suspended in a liquid vehicle at



**FIG. 1 The Effective Region of Examination When Using an Offset Internal Conductor is Approximately Equal to Four Times the Diameter of the Conductor as Indicated**



**Figure A**



(The eddy current is represented in red and the resulting magnetic field is represented in blue.)

**Figure B**

NOTE 1—Only a changing magnetic field will generate a resulting eddy current in the ring-shaped part, such as when the magnetic field in the magnetizing coil suddenly collapses, or when using a moving waveform such as AC; no eddy current is produced in the part by a non-moving waveform. The resultant toroidal shaped magnetic field may be used to detect circumferential discontinuities in the part.

**FIG. 2 Example of Induced Current Magnetization**

the required concentration shall be applied by gently spraying or flowing the suspension over the area to be examined.

6.4.1.1 Proper sequencing and timing of part magnetization and application of particle suspension are required to obtain the proper formation and retention of indications. This requires that the stream of suspension be diverted from the part simultaneously with, or slightly before, energizing the magnetic circuit.

6.4.1.2 The magnetizing current shall be applied for a duration of at least 0.5 second for each application, with a minimum of two shots being used. The second shot shall follow the first while the particles are still mobile on the surface of the part.

6.4.1.3 Under special circumstances, such as the use of automated equipment or for critical parts, the 0.5-second duration and the two-shot requirement may be waived, provided it is demonstrated that the procedure can detect known discontinuities in reference parts.

6.4.1.4 Care shall be exercised to prevent any damage to the part due to overheating or other causes. Weakly held indications on highly finished parts are readily washed away, and care must be exercised to prevent high-velocity flow over critical surfaces. Surfaces to be examined shall not be handled or contacted until the examination is complete.

6.4.1.5 Particle application by continuous immersion shall be used only when specifically approved by the cognizant engineering organization or when it has been documented that it can detect discontinuities or artificial discontinuities in parts under examination.

6.4.2 *Residual Magnetization Method*—In the residual magnetization method, the magnetic particles are applied to the part under examination after the magnetizing force has been discontinued. The residual method is not as sensitive as the continuous method. It can be useful on materials with high retentivity. It is also useful for the examination of parts or areas

of parts, which because of geometric constraints, cannot be examined with the continuous method. The residual method shall be used only when specifically approved by the cognizant engineering organization or when it has been documented that it can detect discontinuities or artificial discontinuities in parts under examination. The test parts shall have the same material and processing steps, and similar geometry, to the actual parts being examined.

6.5 *Evaluation*—Following magnetization, particle application and before demagnetizing, the parts shall be examined for indications. All indications will be identified as relevant or nonrelevant. Relevant indications will be compared to the proper accept/reject criteria and the parts accepted or rejected accordingly.

6.5.1 *Eye Glasses*—Personnel shall not wear eye glasses that are photochromic (transition lenses) or that have permanently darkened lenses. This is not intended to prohibit the use of eyeglasses with lenses treated to absorb ultraviolet light.

6.5.2 *Dark Adaptation*—Personnel must wait at least 1 min after entering a darkened area for their eyes to adjust to the low-level lighting before performing fluorescent magnetic particle testing.

6.5.3 *Acceptance Requirements*—The acceptance requirements applicable to the part or group of parts shall be incorporated as part of the written procedure either specifically or by reference to other applicable documents containing the necessary information. When parts are zoned, the acceptance criteria for each zone shall be specified.

6.6 *Recording of Indications*—When required by the written procedure, the location of all rejectable indications shall be marked on the part, and permanent records of the location, direction, and frequency of indications may be made by one or more of the following methods:

6.6.1 *Written Description*—By recording the location, length, direction, and number of indications in sketch or tabular form.

6.6.2 *Photography*—By photographing or video recording the indications themselves, the tape, or the strippable film reproduction and placing the photograph in a tabular form along with information giving its location on the part.

6.7 *Post Examination Demagnetization and Cleaning*—All parts shall be demagnetized and cleaned after final examination. Apply corrosion protection as required.

6.7.1 *Demagnetization:*

6.7.1.1 When using AC demagnetization, the part shall be subjected to a field with a peak value greater than, and in nearly the same direction as, the field used during examination. This AC field is then decreased gradually to zero. When using an AC demagnetizing coil, the part is passed through the coil while the current is flowing. For effective demagnetization, parts having complex configurations may require rotating or tumbling while passing through the field of the coil prior to the current being shut off. Repeat this process as necessary.

6.7.1.2 When using DC demagnetization, the initial field shall be higher than, and in nearly the same direction as, the field reached during examination. The field shall then be reversed, decreased in magnitude, and the process repeated (cycled) until an acceptably low value of residual field is reached.

6.7.1.3 Whenever possible, parts that have been magnetized circularly shall be magnetized in the longitudinal direction before being demagnetized. After demagnetization, a calibrated field indicator shall not detect magnetic flux fields with an absolute value above 3 G ( $3 \times 10^{-4}$  T) anywhere on the part.

6.7.2 *Post-examination Cleaning*—Cleaning shall be done with a suitable solvent, air blower, or by other means.

6.7.2.1 Parts shall be examined to ensure that the cleaning procedure has removed magnetic particle residues from holes, crevices, passage ways, etc. Such residue could have an adverse effect on the intended use of the part.

6.7.2.2 Care shall be taken to remove all plugs, masking, or other processing aids that may affect the intended use of the part.

6.7.2.3 Parts shall be protected from corrosion or damage as required.

6.8 *Record of Examination*—Results of all final magnetic particle examinations shall be recorded. All recorded results shall be identified, filed, and made available to the cognizant engineering organization upon request. Records shall provide for traceability to the specific part or lot inspected. As a minimum, the records shall include: identification of the procedure used, disposition of the examination; identification of the inspector's examination stamp, electronic ID, or signature; and the date of examination. Records shall be kept for a minimum of three years or as otherwise specified in the purchase order or contract.

6.9 *Marking of Accepted Parts*—If specified by the cognizant engineering organization, parts that have been accepted using magnetic particle examination shall be marked in accordance

with the applicable drawing, purchase order, contract, or as specified herein prior to leaving the testing facility.

6.9.1 Marking shall be applied in such a manner and location as to be harmless to the part. The identification shall not be obliterated or smeared by subsequent handling and, when practicable, placed in a location that will be visible after assembly.

6.9.1.1 When subsequent processing would remove the identification, the applicable marking shall be affixed to the record accompanying the finished parts or assembly.

6.9.1.2 Bolts and nuts and other fastener products may be identified as having met the requirements of magnetic particle testing by marking each package conspicuously.

6.9.2 *Impression Stamping, Ink Stamping, Laser Marking, Dyeing, Vibro Engraving, or Etching*—Impression stamping, ink stamping, laser marking, dyeing, vibro engraving, or etching may be used when permitted or required by the applicable written procedure, detail specification or drawing, or when the nature of the part is such as to provide for impression stamping of part numbers or other examination personnel markings. Impression stamping shall be located only in the area provided adjacent to the part number or examination personnel's stamp.

6.9.3 *Other Identification*—Other means of identification, such as tagging, may be used for parts that have a configuration or function precluding the use of stamping, vibro engraving, or etching, as in the case of completely ground or polished balls, rollers, pins, or bushings.

6.10 *Identifying Symbols and Color Markings:*

6.10.1 *One-Hundred Percent Examination*—When items are examined and accepted by 100 % examination, each item shall be marked as follows:

6.10.1.1 *Dyeing*—When dyeing is applicable, a dye of acceptable adherence which is predominantly blue (in accordance with SAE AMS-STD-595) shall be employed. However, if a color conflict is incurred with any other method, magnetic particle examination may be indicated by two adjacent blue dots or other suitable means.

6.10.1.2 *Stamping, Laser Marking, Vibro Engraving, or Etching*—When impression stamping or ink stamping, laser marking, vibro engraving, or etching is used to mark 100 % examined parts, the letter "M" with a circle around it shall be employed.

6.10.2 *Marking Accepted Lots*—When items are accepted by means of a sampling procedure, each item of an accepted lot shall be marked as follows:

6.10.2.1 *Dyeing*—When dyeing is applicable, a dye of acceptable adherence that is predominantly orange (in accordance with SAE AMS-STD-595) shall be employed.

6.10.2.2 *Stamping, Laser Marking, Vibro Engraving, or Etching*—When impression stamping, vibro engraving, or etching is used to mark lot examined parts, the letter "M", without a circle around it, shall be employed.

## 7. Quality Control

7.1 *System Performance Verification*—The overall performance of the magnetic particle testing system, including the equipment, materials, and the lighting environment being used,



any diode element is not operational, the condition shall be corrected, or the unit replaced. The operational check may be performed by placing a white sheet of paper over the lamp filter to view the transmitted light from each diode. These checks of cleanliness/integrity/LED functionality need not be recorded. UV-A LED lamps used to inspect parts shall comply with the requirements of Practice E3022.

**7.3.3 Restricted Area Examination**—Where lamps are physically too large to directly illuminate the examination surface, special lighting sources, such as UV-A pencil lights, or UV-A light guides, or remote visual examination equipment shall be used. As specified in Table 1 or prior to use, the intensity of UV-A pencil lamps, UV-A light guides, borescopes, or remote UV-A examination equipment shall be measured at the expected working distance and shall provide at least  $1000 \mu\text{W}/\text{cm}^2$  [ $10 \text{ W}/\text{m}^2$ ] at the intended examination surface. When using a borescope, the image or interpretation area being viewed must have sufficient resolution to effectively evaluate the indication.

**7.4 Equipment Calibration**—Magnetic particle testing equipment shall be checked for performance and accuracy at the time of purchase and at intervals thereafter as indicated in Table 1, whenever malfunction is suspected, when specified by the cognizant engineering organization, or whenever electrical maintenance that might affect equipment accuracy is performed.

**7.4.1 Ammeter Accuracy**—To check the equipment's ammeter(s), a suitable calibrated shunt test kit with a resolution equal to or greater than the meter under test shall be connected in series with the output circuit. Comparative readings shall be taken at a minimum of three output levels encompassing the usable range of the equipment. The equipment meter reading shall not deviate by more than  $\pm 10\%$  or 50 amperes, whichever is greater, from the current value shown by the calibrated ammeter. (When measuring half-wave rectified current, the current values shown by the calibrated FW-Rectified ammeter readings shall be doubled.) The frequency of the ammeter check is specified in Table 1. Machine output repeatability shall not vary more than  $\pm 10\%$  or 50 amperes, whichever is greater, and the machine under test shall be marked with the value representing the lowest repeatable current level.

**7.4.2 Timer Control Check**—On equipment using a timer to control the current duration, the timer should be calibrated to within  $\pm 0.1$  s using a suitable electronic timer. Comparative readings shall be taken at a minimum of three output levels encompassing the usable output range of the equipment.

**7.4.3 Magnetic Field Quick Break Check**—On equipment that uses a quick break feature, proper functioning of this circuit shall be verified. The check may be performed using a

suitable oscilloscope or other applicable method as specified by the equipment manufacturer.

**7.4.4 Dead Weight Check**—Yokes shall be dead weight checked at the interval as specified in Table 1. Alternating current yokes shall be capable of lifting at least 10 lb [4.5 kg], with a 2 to 6 in. [50 to 150 mm] spacing between legs. Direct current yokes shall be capable of lifting at least 30 lb [13.5 kg], with a 2 to 4 in. [50 to 100 mm] spacing between legs, or 50 lb [22.5 kg], with a 4 to 6 in. [100 to 150 mm] spacing.

**7.4.5 UV-A Lamps**—Portable, hand-held, permanently mounted or fixed UV-A lamps used to inspect parts shall be checked for intensity as specified in Table 1 and as defined by the Written Procedures (see 5.3.1). A longer period may be used if a plan justifying this extension is prepared by the NDT facility and approved by the cognizant engineering organization. The minimum acceptable intensity is  $1000 \mu\text{W}/\text{cm}^2$  [ $10 \text{ W}/\text{m}^2$ ] at 15 in. [38.1 cm] from the front of the filter to the face of the sensor. UV-A lamps shall be checked at the interval specified in Table 1 for cleanliness and integrity and shall be cleaned, repaired, or replaced as appropriate. Replace cracked or broken ultraviolet filters immediately. LED UV-A lamps used to inspect parts shall be checked daily to ensure all diode elements are operational. If any diode element is not operational, the condition shall be corrected, or the unit replaced. The operational check may be performed by placing a white sheet of paper over the lamp filter to view the transmitted light from each diode.

**7.4.5.1 UV-A lamps that use a UV-A LED source** shall comply with the requirements of Practice E3022.

**7.4.5.2 Battery-powered UV-A lamps** used to inspect parts shall have their intensity measured as required in Table 1, and as defined by the Written Procedures (see 5.3.1). The minimum UV-A irradiance shall be maintained  $1000 \mu\text{W}/\text{cm}^2$  at 15 in. [38.1 cm] during the period of examination.

**7.4.6 Hall-Effect Gauss/Tesla Meters and Field Indicators**—All Hall-Effect gaussmeters and field indicators shall be calibrated and reading taken at a minimum of three points in each dynamic range and each polarity, in addition to zero.

**7.4.7 UV-A Radiometers and Photometers**—UV-A radiometers and illuminance photometers shall be calibrated at the interval specified in Table 1 in accordance with ANSI/NCSL Z540.3, or ISO 10012, or ISO/IEC 17025. All radiometers and photometers shall have a digital display.

NOTE 4—More information on UV-A radiometers and photometers can be found in Guide E2297.

## 8. Keywords

8.1 dye; fluorescent; FP; FPI; magnetic particle; MPI; MT; nondestructive evaluation; nondestructive examination; nondestructive testing; NDT

## ANNEXES

## (Mandatory Information)

## A1. INSTRUCTIONS FOR THE USE OF AS 5371 STANDARD NOTCHED SHIMS

A1.1 *Application of Shims*—The Reference Standard Notched Shims of AS 5371, as shown in Annex A2, require specific handling, attachment, and care for accurate indication of magnetic field strength and direction. To select amperage settings for multi-directional magnetization, the use of AS 5371 shims or parts described in 6.3.1.1 is mandatory.

A1.2 Shims 0.002 in. [0.05 mm] thick shall be used on curved or complex surfaces.

A1.3 Shims are manufactured of low carbon steel and must be protected from corrosion when not in use. They may be submerged in a solvent such as MEK or naphtha for storage. Before attaching the shim to the part, both the shim and part shall be clean and dry. Prior to use, the protective coating shall be removed from both faces of the QQI. Care shall be utilized when removing the protective coating. Excessive pressure to remove the coating may imprint the face of the QQI, presenting nonrelevant indications during technique development.

NOTE A1.1—Polar solvents such as water, will break down the cynoacrolate based (super glue) adhesives commonly used to apply these shims.

A1.4 The shim shall be placed in intimate contact with the part with the flaw side next to the material to be examined.

A1.5 The shim shall be securely fastened to the part by using an adhesive or tape (such as Scotch Brand 191, 471, or 600 series<sup>12</sup>) that prevents the magnetic particle suspension from entering between the shim and part. Whatever means is used to secure the shim to the part shall not interfere with the visibility of the indications.

A1.6 Tape may be used to secure the shim and shall have the following properties: (1) Good adhesion to steel, (2) impervious to the suspension used, and (3) the tape shall be non-fluorescent under UV-A.

A1.7 If the tape becomes loose and allows the suspension to seep under the shim, the tape and shim shall be carefully removed from the test piece. The shim and the part shall be cleaned and dried, and then the shim shall be reattached to the test piece.

A1.8 Re-use of the shims is acceptable, provided they are not distorted when removed and intimate contact is achieved when replaced.

A1.9 *Determining Field Strength and Direction*—Use of the circle or cross configuration shims will indicate fields in any direction.

A1.9.1 In developing a magnetic particle procedure, first determine the locations the shims should be placed to ensure adequate coverage to monitor the field strength and direction, and then attach the shims.

A1.9.2 Using the continuous method, begin by starting with the amperage selection at a minimum level and increasing the amperage slowly until the shim indications are readily observed. When magnetized, one leg of the X will be indicated perpendicular to the field direction and the circle shim will show quadrants that are approximately perpendicular to the direction of the applied field.

A1.9.3 In multi-directional magnetization, longitudinal and circular fields shall be determined separately as follows:

A1.9.3.1 Field strength for the first direction shall be determined by slowly increasing the amperage until a satisfactory indication is observed on each shim.

A1.9.3.2 Record the amperage setting and indication results.

A1.9.3.3 Demagnetize the part and carefully clean the shims prior to determining the amperage in the next direction.

A1.9.3.4 Field strength for the second direction shall be determined by incrementally increasing the amperage until a satisfactory indication is observed on each shim.

A1.9.3.5 Record the amperage setting and indication results.

A1.9.4 Place the selector switch in the multi-directional mode and magnetize the part at the previously recorded settings. If the entire circle on the shims is observed, the fields are in balance. If any portion of the circle has a weak indication, adjust the amperage accordingly and repeat the field verification process until the magnetic fields are balanced.

A1.9.5 Use care when applying the suspension to the shims. Proper shim indications may not form unless the suspension is applied in a gentle manner.

A1.10 The shims are made of a low retentivity and high permeability material that cannot be used for indicating residual fields when developing magnetic particle testing procedures.

A1.11 In unidirectional applications, the actual field strength measurements can be obtained by placing a Hall Effect probe adjacent to the shim or at a nearby location where probe placement can easily be replicated.

<sup>12</sup> The 191, 471, and 600 series are trademarks of Scotch Brand.

**A2. REFERENCE STANDARD NOTCHED SHIMS FOR MAGNETIC PARTICLE TESTING IN ACCORDANCE WITH AS 5371**

A2.1 The following standard flawed shims are typically used to establish proper field direction and ensure adequate field strength during technique development in magnetic particle testing. The shims shown in Fig. A2.1 may be used to ensure the establishment of fields in the unidirectional magnetization method and to ensure the establishment and field balance in the multidirectional magnetization method.

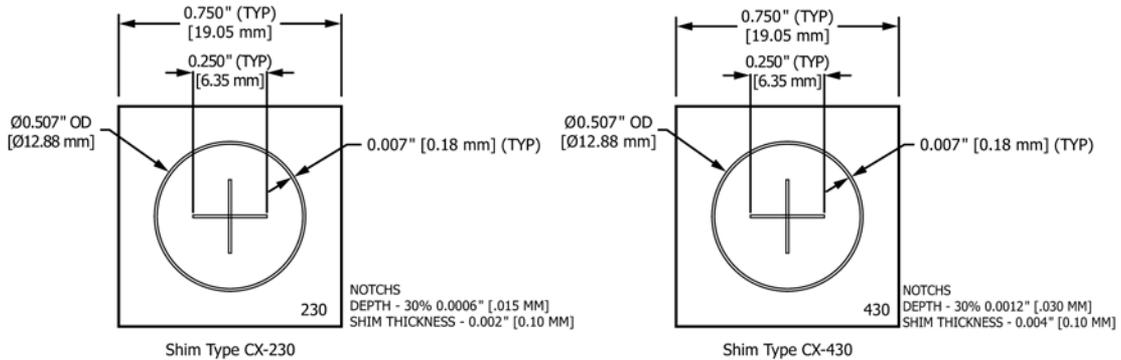
A2.1.1 Except for shims illustrated in Fig. A2.2, the shims are available in two thicknesses, 0.002 in. [0.05 mm] and 0.004 in. [0.10 mm]. Thinner shims are used when the thicker shims cannot conform to the part surface in the area of interest.

A2.1.2 The shims are available in two sizes, 0.75 in. [19 mm] square for Figs. A2.1 and A2.3 and 0.79 in. [20 mm] square for Fig. A2.2

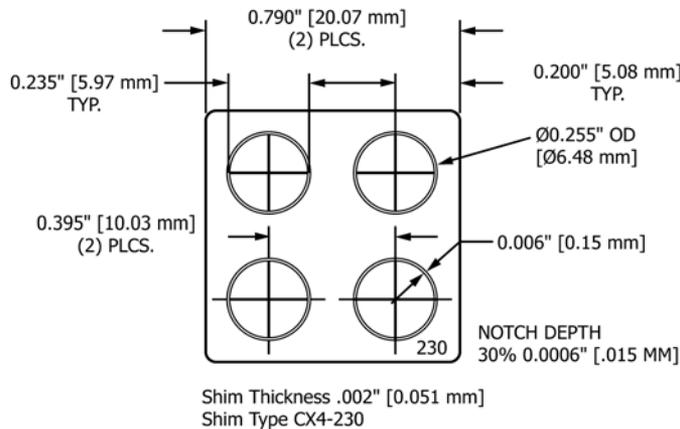
square of Fig. A2.2. The shims of Fig. A2.2 are cut, by the user, into four 0.395 in. [10 mm] square shims for use in restricted areas.

A2.1.3 Shims shall be low carbon steel, AMS 5062, or equivalent.

A2.1.4 Shims shall be used as specified in AS 5371. Shims are placed in the area(s) of interest with the notches toward the surface of the part being examined. Use enough shims by placing the shims in multiple areas to ensure proper field directions and strengths are obtained.



**FIG. A2.1 Shims for Magnetic Particle Testing**



**FIG. A2.2 Shims for Magnetic Particle Testing**

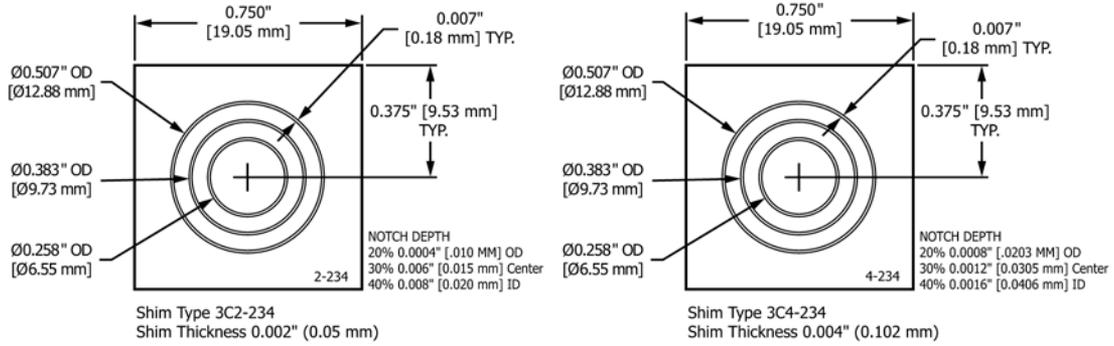
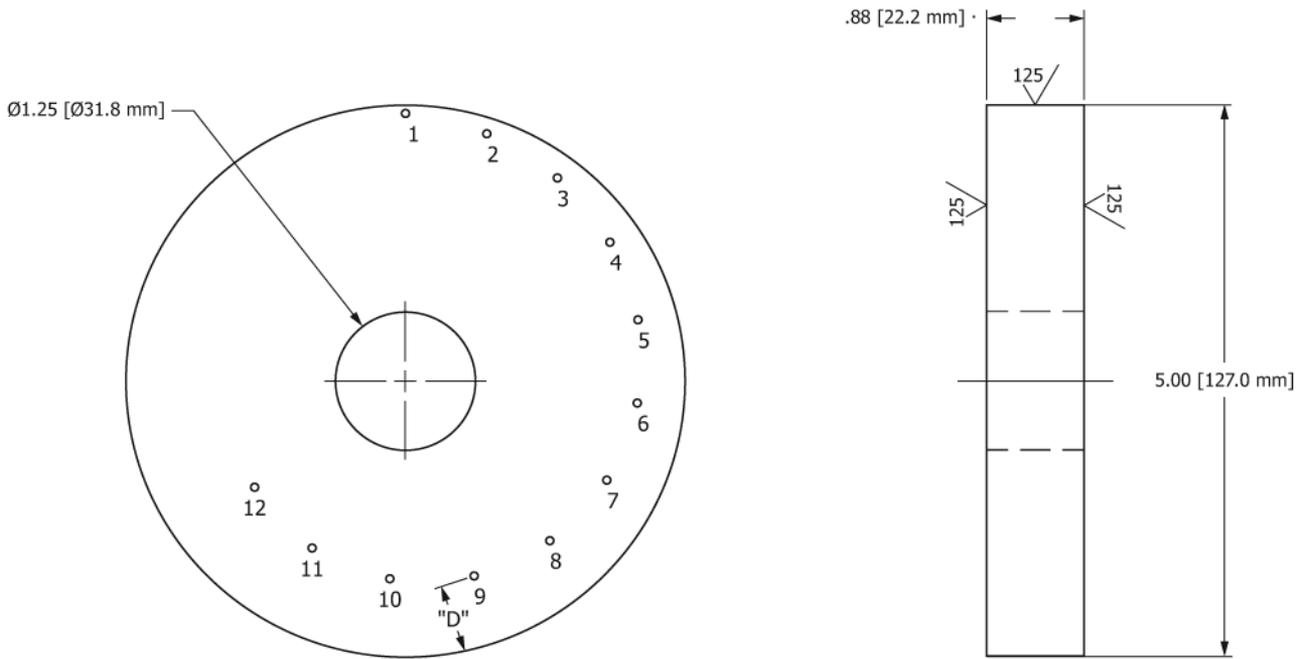


FIG. A2.3 Shims for Magnetic Particle Testing

A3. AS 5282 TOOL STEEL RING SPECIMEN FOR SYSTEM PERFORMANCE TEST

A3.1 A ring specimen similar to Fig. A3.1 may be used to perform the system performance verification of 7.1.



Hole	1	2	3	4	5	6
Diameter	0.07	0.07	0.07	0.07	0.07	0.07
Note 1	[1.78	[1.78	[1.78	[1.78	[1.78	[1.78
	mm]	mm]	mm]	mm]	mm]	mm]
"D"	0.07	0.14	0.21	0.28	0.35	0.42
Note 2	[1.78	[3.56	[5.33	[7.11	[8.89	[10.67
	mm]	mm]	mm]	mm]	mm]	mm]
Hole	7	8	9	10	11	12
Diameter	0.07	0.07	0.07	0.07	0.07	0.07
Note 1	[1.78	[1.78	[1.78	[1.78	[1.78	[1.78
	mm]	mm]	mm]	mm]	mm]	mm]
"D"	0.49	0.56	0.63	0.70	0.77	0.84
Note 2	[12.45	[14.22	[16.00	[17.78	[19.56	[21.34
	mm]	mm]	mm]	mm]	mm]	mm]

NOTE 1—All hole diameters are ±0.005 in. [±0.13 mm]. Rings with holes 10 through 12 are optional.

NOTE 2—Tolerance on the D distance is ±0.005 in. [±0.13 mm].

NOTE 3—All other dimensions are ±0.03 in. [±0.76 mm].

FIG. A3.1 Tool Steel Ring Specimen

**TABLE A3.1 Amperage and Hole Indication Requirements for AS 5282 Rings**

NOTE 1—All amperage values have a tolerance of  $\pm 50A$ .

Type of Suspension	Amperage FW or HW Rectified	Minimum Number of Holes Indicated
Fluorescent Oxide (Wet)	500	3
	1000	5
	1500	6
	2500	7
	3500	9

#### A4. MEASUREMENT OF TANGENTIAL FIELD STRENGTH

**A4.1 Hall-Effect Meter Usage Overview**—Care must be exercised when measuring the tangential applied field strengths as specified in **A4.2**. The active area of the Hall-Effect probe shall be no larger than 0.2 in. [5.1 mm] by 0.2 in. [5.1 mm] and should have a maximum center location 5 mm from the part surface. The plane of the probe must be perpendicular to the surface of the part at the location of measurement to within 5 degrees. This is difficult to accomplish by hand orientation; therefore, the probe should be held in a jig or fixture of some type. If the current is being applied in shots, or if alternating current or half-wave rectified alternating current is being used, the gaussmeter shall be set to read the peak value during the shot. The gaussmeter shall have a frequency response of \*300 Hz or higher. The direction and magnitude of the tangential field on the part surface can be determined by two measurements made at right angles to each other at the same spot. The gaussmeter probe leads shall be shielded or twisted to prevent reading errors due to voltage induced during the large field changes encountered during magnetic particle testing.

NOTE A4.1—Lack of effective bandwidth could have a significant effect on the resultant value when measuring fields generated by pulse-width modulated MPI equipment.

**A4.2 Hall-Effect Meter Tangential Field Strengths**—A minimum tangential applied field strength of 30 G ( $2.4 \text{ kAM}^{-1}$ ) should be adequate when using single vector equipment. Stronger field strengths are allowed, but it must not be so strong that it causes the masking of relevant indications by nonrelevant accumulations of magnetic particles. Due to the complex number of variables, the use of Gaussmeters should not be the sole source of determining an acceptable field on multi-directional techniques.

**A4.3 Circular Magnetism Hall-Effect Meter Measurement**—On a part with consistent diameter or thickness, the transverse probe may be placed anywhere along

the length of the part as the tangential circular field is consistent across the length. The transverse probe should be positioned upright such that the circular field is normal to the major dimension of the Hall-Effect sensor and within  $5^\circ$  of perpendicularity to the part. More than one measurement should be taken to ensure consistent readings. On parts with more than one diameter/thickness, multiple measurements should be taken to ensure a minimum measurement of 30 gauss on all areas to be examined. Measurement is made of the applied field, that is, during the magnetizing shot, not the residual flux field.

**A4.4 Longitudinal Magnetism Hall-Effect Meter Measurement**—On a part with consistent diameter or thickness, the probe may be placed anywhere along the length of the part, except near the poles, as the tangential longitudinal field is consistent across the length, except at the poles. Measurement near the poles will yield a skewed reading due to detection of the normal flux field at each pole. Also, measurement near any geometry change that would produce a non-relevant flux leakage should be avoided. The probe should be positioned within  $5^\circ$  of perpendicularity to the part and such that the longitudinal field is normal to the major dimension of the Hall-Effect sensor. More than one measurement should be taken to ensure consistent readings. The Hall-Effect probe may be placed within the coil or outside the vicinity of the coil if the part is longer than the width of the coil. On parts with more than one diameter/thickness, multiple measurements should be taken to ensure a minimum measurement of 30 gauss on all areas to be examined. Measurement is made of the applied field, that is, during the magnetizing shot, not the residual flux field.

APPENDIXES

(Nonmandatory Information)

X1. SUITABILITY OF MATERIALS FOR MAGNETIC PARTICLE TESTING

X1.1 Some materials are far more suitable for magnetic particle testing than others. In some cases, liquid penetrant testing may be a more reliable testing method.

X1.2 Some of the precipitation hardening (PH) steels are austenitic in the annealed or low heat treat ranges. Austenitic materials cannot be examined by the magnetic particle testing method.

X1.3 Care must be taken with low permeability steels, such

as the PH steels, to use a high enough amperage to provide proper field strength.

X1.4 Steels with very high permeability are easily magnetized but should not be examined with the residual method.

X1.5 Fig. X1.1 is a tabulation of stainless and corrosion resistant steels and their suitability for examination with the magnetic particle testing method.

X1.6 Aluminum and aluminum based alloys, copper and

Table of Steels for ASTM E1444/E1444M

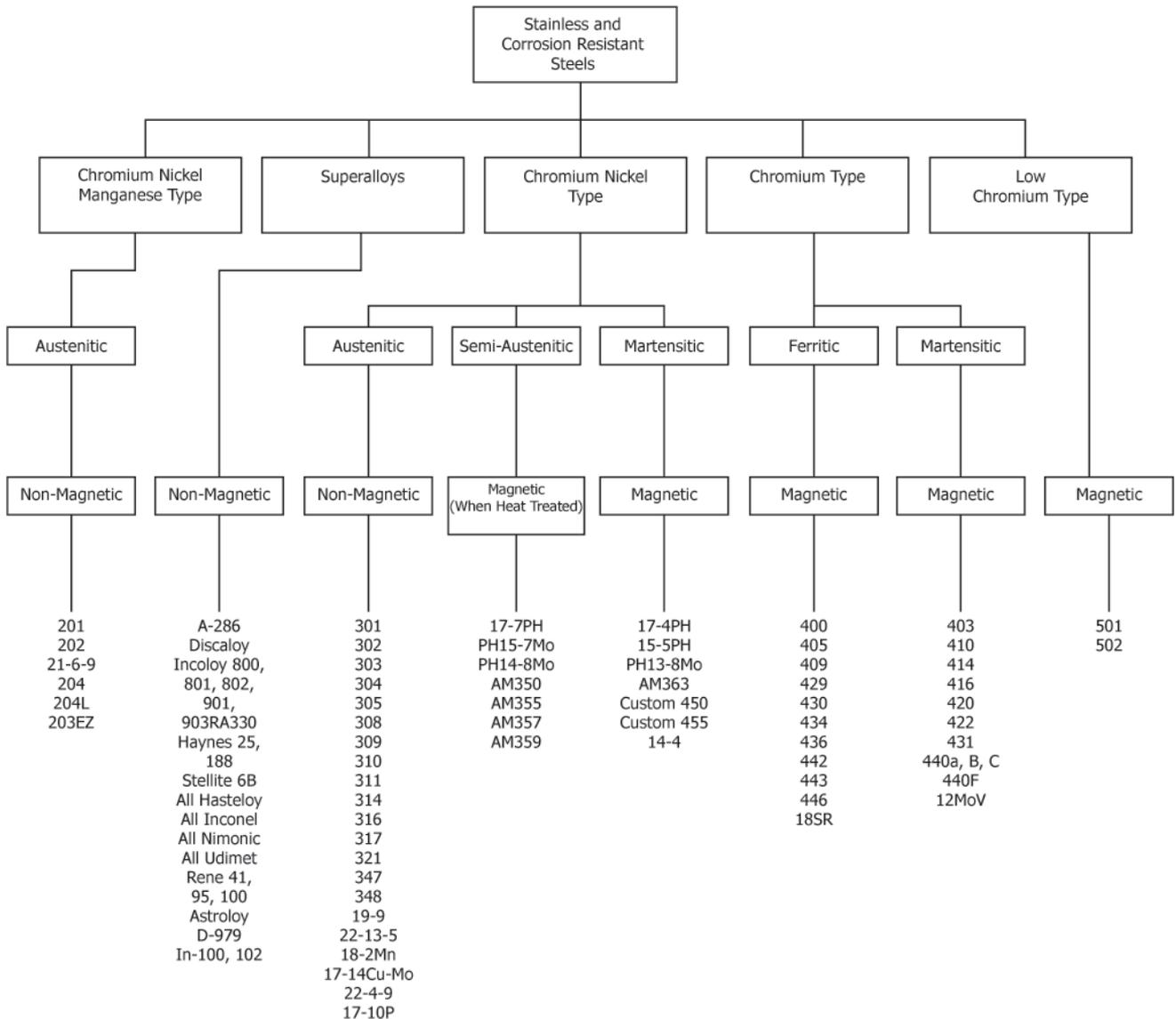


FIG. X1.1 Tabulation of Stainless and Corrosion Resistant Steels

copper based alloys, and nickel based alloys cannot be examined by the magnetic particle testing method.

X1.7 All low-alloy carbon steels, 1000 series (1020, 1050, 1117, 1340, etc.), 4000 series (4130, 4330 4340M, and so

forth), 5000, 6000, 8000, 9000 series, HY 80, HY 100, 9Ni-4Co, and Maraging steels are ferro-magnetic and can be examined with the magnetic particle testing method.

## **X2. FORMULAS FOR DETERMINING PROPER CURRENT VALUES FOR CIRCULAR MAGNETISM**

X2.1 For guidance using formulas for determining current values, see Guide E709.

## **X3. FORMULAS FOR DETERMINING PROPER CURRENT VALUES FOR COILS**

X3.1 For guidance using formulas for determining current values, see Guide E709.

### **SUMMARY OF CHANGES**

Committee E07 has identified the location of selected changes to this standard since the last issue (E1444/E1444M – 20) that may impact the use of this standard. (Sept. 1, 2021)

- (1) Updates were made in 6.2.7.1, 7.1, and 7.4.7. (2) Fig. 1 was updated.

Committee E07 has identified the location of selected changes to this standard since the last issue (E1444/E1444M – 16<sup>e1</sup>) that may impact the use of this standard. (Dec. 1, 2020)

- (1) Updated the title to include “for Aerospace.”  
(2) Added 1.3, 5.3.1.17, 6.2.7.1, 6.3.3, 6.3.4, 6.3.5, A4.2, A4.3, and A4.4  
(3) Replaced “Cognizant Engineering Organization” with “cognizant engineering organization” throughout the document for consistency.  
(4) Replaced “standard practice” with “practice” throughout.  
(5) Added and removed referenced documents from Section 2 based on updates made in the text.  
(6) Updated 5.2 to say “The agency performing this practice may be evaluated in accordance with Specification E543” to conform with Practice E1417.  
(7) Made edits to 5.1, 5.3, 5.3.1.1, 5.3.1.6, 5.3.1.10, 5.3.1.13, 5.3.1.15, 5.4.3.2, 5.5.4, 5.6.4, 6.1.1, 6.1.3, 6.2.4, 6.2.6, 6.2.10, 6.3.1.2, 6.4.1, 6.4.1.4, 6.5, 6.5.1, 6.5.3, 6.9, 7.1, 7.2.1.1, 7.2.2, 7.2.3, 7.3.1.1, 7.3.2, 7.4.1, 7.4.2, 7.4.4, 7.4.5.2, A1.3, A1.6, and A4.1.  
(8) In Table 1, changed the title and changed UV-A integrity check to daily.  
(9) Deleted previous 5.5.1, 6.2.2, 6.3.1.3, 6.4.1, 6.4.1.1, 6.4.1.2, 6.4.4, 6.4.5, 6.4.6, 6.6.2, 6.6.3, and 7.4.8  
(10) Reworded 7.2.1.2, 7.3.3, 7.4.5, 7.4.7, and A1.7.  
(11) Changed title of 7.4.6 to read “Hall-Effect Gauss/Tesla Meters and Field Indicators.”  
(12) Deleted previous Annex A3, Appendix X2, and Appendix X5 entirely.  
(13) Appendix X2: deleted the previous text and subsections and replaced with “For guidance using formulas for determining current values, see Guide E709. See 6.2.7.1.”  
(14) Appendix X3: deleted the previous text and subsections and replaced with “For guidance using formulas for determining current values, see Guide E709.”

*ASTM International takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.*

*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.*

*This standard is copyrighted by ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States. Individual reprints (single or multiple copies) of this standard may be obtained by contacting ASTM at the above address or at 610-832-9585 (phone), 610-832-9555 (fax), or [service@astm.org](mailto:service@astm.org) (e-mail); or through the ASTM website ([www.astm.org](http://www.astm.org)). Permission rights to photocopy the standard may also be secured from the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, Tel: (978) 646-2600; <http://www.copyright.com/>*