Designation: E 1444 – 94a

An American National Standard

Standard Practice for Magnetic Particle Examination[1]

This standard is issued under the fixed designation E 1444; 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.

This specification has been approved for use by agencies of the Department of Defense.

1. Scope

1.1 This practice establishes minimum requirements for magnetic particle examination used for the detection of surface or slightly subsurface discontinuities in ferromagnetic material. This practice is intended as a direct replacement of MIL-STD-1949. Guide E 709 can be used in conjunction with this practice as a tutorial.

1.2 The magnetic particle examination method is used to detect cracks, laps, seams, inclusions, and other discontinuities on or near the surface of ferromagnetic materials. Magnetic particle examination may be applied to raw material, billets, finished and semifinished materials, welds, and in-service parts. Magnetic particle examination is not applicable to nonferromagnetic metals and alloys such as austenitic stainless steels.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 The following documents form a part of this standard practice to the extent specified herein.

2.2 *ASTM Standards:*

A 275/A 275M Test Method for Magnetic Particle Examination of Steel Forgings[2]

A 456 Specification for Magnetic Particle Inspection of Large Crankshaft Forgings[2]

D 96 Test Methods for Water and Sediment in Crude Oil by the Centrifuge Method (Field Procedure)[3]

E 543 Practice for Evaluating Agencies that Perform Nondestructive Testing[4]

E 709 Guide for Magnetic Particle Examination[4]

E 1316 Terminology for Nondestructive Examinations[4]

2.3 *ASNT Document:*

SNT-TC-1A Recommended Practice and Supplement Magnetic Particle Inspection[5]

2.4 *Society of Automotive Engineers (SAE)-AMS Documents:*[6]

AMS 2300 Premium Aircraft-Quality Steel Cleanliness Magnetic Particle Inspection Procedure[7]

AMS 2301 Aircraft Quality Steel Cleanliness Magnetic Particle Inspection Procedure[7]

AMS 2303 Aircraft Quality Steel Cleanliness Martensitic Corrosion Resistant Steels Magnetic Particle Inspection Procedure[7]

AMS 2641 Magnetic Particle Inspection Vehicle[7]

AMS 3040 Magnetic Particles, Nonfluorescent, Dry Method[7]

AMS 3041 Magnetic Particles, Nonfluorescent, Wet Method, Oil Vehicle, Ready-To-Use[7]

AMS 3042 Magnetic Particles, Nonfluorescent, Wet Method, Dry Powder[7]

AMS 3043 Magnetic Particles, Nonfluorescent, Wet Method, Oil Vehicle, Aerosol Packaged[7]

AMS 3044 Magnetic Particles, Fluorescent, Wet Method, Dry Powder[7]

AMS 3045 Magnetic Particles, Fluorescent, Wet Method, Oil Vehicle, Ready-To-Use[7]

AMS 3046 Magnetic Particles, Fluorescent, Wet Method, Oil Vehicle, Aerosol Packaged[7]

AMS 5355 Investment Castings[7]

2.5 *Federal Standards:*[6]

FED-STD-313 Material Safety Data Sheets, Preparation and the Submission of[8]

FED-STD-595 Colors[8]

2.6 *Military Standards:*[6]

MIL-STD-1907 Inspection, Liquid Penetrant and Magnetic Particle Soundness Requirements for Materials, Parts, and Weldments[8]

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[1] This practice is under the jurisdiction of ASTM Committee E-7 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.03 on Liquid Penetrant and Magnetic Particle Methods.

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[2] *Annual Book of ASTM Standards*, Vol 01.05.

[3] *Annual Book of ASTM Standards*, Vol 05.01.

[4] *Annual Book of ASTM Standards*, Vol 03.03.

[5] Available from American Society for Nondestructive Testing, 1711 Arlingate Plaza, P.O. Box 28518, Columbus, OH 43228-0518.

[6] 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.

[7] Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

[8] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

MIL-STD-410 Nondestructive Testing Personnel Qualification and Certification[8]
MIL-STD-1949 Magnetic Particle Inspection, Method of[8]
MIL-STD-2175 Castings, Classification and Inspection of[8]
MIL-STD-45662 Calibration Systems Requirements
MIL-I-83387 Inspection Process, Magnetic Rubber[8]
DoD-F-87935 Fluid, Magnetic Particle Inspection, Suspension (Metric)[8]

2.7 *OSHA Document:*[9]

29CFR 1910.1200 Hazard Communication

2.8 *DoD Contracts*—Unless otherwise specified, the editions of the documents that are DoD adopted are those listed in the issue of the DoDISS (Department of Defense Index of Specifications and Standards) cited in the solicitation.

2.9 *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 examination, which appear in Terminology E 1316, shall apply to the terms used in this practice.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *alternating current (ac)*—an electrical current that reverses its direction of flow at regular intervals.

3.2.2 *ambient light*—the visible light level measured at the specimen surface with the black light(s) on.

3.2.3 *contracting agency*—a prime contractor, subcontractor, or government agency procuring magnetic particle inspection services.

3.2.4 *gauss (G)*—the unit of flux density or induction in the cgs electromagnetic unit system (1 G = 10^{-4} Tesla (T); in air, 1 G is equivalent to 1 oersted (Oe), which equals 79.58 A/m).

3.2.5 *head shot*—the production of circular magnetization by passing current directly through the part being inspected, or central conductor, while being held in contact with the head stocks in a horizontal wet machine.

3.2.6 *magnetic flux*—a conceptualization of the magnetic field intensity based on the line pattern produced when iron filings are sprinkled on paper laid over a permanent magnet. The magnetic field lies in the direction of the flux lines and has an intensity proportional to the line density.

3.2.7 *magnetization*—the process by which the elementary magnetic domains of a material are predominantly aligned in one direction.

3.2.8 *retentivity*—the ability of a material to retain magnetism after the magnetizing force has been removed.

4. Significance and Use

4.1 Magnetic particle examination consists of magnetizing the area to be inspected, 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 perpendicular to the magnetic flux. In order to detect discontinuities in all directions, at least two magnetic fields, perpendicular to one another in a plane parallel to the surface being inspected, shall be used, except when specifically exempted by the contracting agency.

5. General Practice

5.1 *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, such as MIL-STD-1907, containing the necessary information. Applicable drawings or other documents shall specify the acceptance size and concentration of discontinuities for the component, with zoning of unique areas as required by design requirements. These acceptance requirements shall be as approved on or as specified by the contracting agency. Methods for establishing acceptance requirements for large crankshaft forgings are covered in Specification A 456. Methods for establishing requirements for steel forgings are covered in Test Method A 275/A 275M. Methods for classifying metal castings are given in MIL-STD-2175 and AMS 5355. MIL-STD-1907 provides a classification scheme for ferromagnetic forgings, castings, extrusions, and weldments.

5.1.1 *Aircraft-Quality Steel Cleanliness*—The examination of aircraft-quality steel for cleanliness using magnetic particle examination shall be as specified in AMS 2300, 2301, or 2303 as appropriate to the type of steel being inspected. However, inspection of parts fabricated from this material shall be in accordance with the requirements of this practice.

5.2 *Personnel Qualification*—Personnel performing examinations in accordance with this practice shall be qualified and certified in accordance with ASNT Personnel Qualification SNT-TC-1A or MIL-STD-410 for military purposes, or as specified in the contract or purchase order.

5.3 *Agency Qualification*—The agency performing the testing or examination shall meet, as a minimum, the requirements of Practice E 543.

5.4 *Written Procedure*—Magnetic particle examination shall be performed in accordance with a written procedure applicable to the parts or group of parts under testing. The procedure shall be in accordance with the requirements and guidelines of this practice. The procedure shall be capable of detecting the smallest rejectable discontinuities specified in the acceptance requirements. The written procedure may be general if it clearly applies to all of the specified parts being tested and meets the requirements of this practice. All written procedures shall be approved by an individual qualified and certified at Level III for magnetic particle examination in accordance with 5.2. Procedures shall be submitted to the contracting agency when requested.

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

5.4.1.1 Procedure identification number and the date it was written;

5.4.1.2 Identification of the parts to which the procedure

[9] Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

applies; this shall include the material and alloy of which the parts are fabricated;

5.4.1.3 Sequence of magnetic particle examination as related to manufacturing process operation, if applicable;

5.4.1.4 Identification of test parts used for system performance verification (see 7.1.2 and 7.1.3);

5.4.1.5 Areas of the part to be examined (include an illustration–either sketch or photo);

5.4.1.6 Part preparation required before testing;

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

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

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

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

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

5.4.1.12 Type of magnetic particle material (dry or wet, visible or fluorescent, etc.) to be used and the method and equipment to be used for its application and, for the case of wet particles, the particle concentration limits;

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

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

5.4.1.15 Postinspection demagnetization and cleaning requirements.

5.5 *Examination Sequence*—When magnetic particle examination is specified, it shall be performed after the completion of operations that could cause surface or near-surface defects. These operations include, but are not limited to, forging, heat treating, plating, passivation, cold forming, welding, grinding, straightening, machining, and proof loading. Unless otherwise approved by the contracting agency or as approved in 6.1.3, production parts shall be magnetic particle inspected before the application of any coatings. Also, parts heat treated to an ultimate tensile strength of 180 ksi or higher that are heat treated and subsequently electroplated shall be inspected after the electroplating operation.

5.6 *Record of Examination*—The results of all magnetic particle inspections shall be recorded. All recorded results shall be identified, filed, and made available for review by the contracting agency upon request. Records shall provide for traceability to the specific part or lot inspected, and they shall identify the inspection contractor or facility and the procedures used in the inspection, the lot size, and the number of parts accepted.

5.7 *Lighting*:

5.7.1 *Visible Light*—Visible light shall be used when examining with nonfluorescent particles. The intensity of the visible light at the surface of the part undergoing examination shall be maintained at a minimum of 100 fc (1000 lx). The intensity measurement shall be conducted with a suitable illuminance meter with a photopic spectral response.

5.7.1.1 *Ambient Visible Light*—Unless otherwise specified, fluorescent magnetic particle examinations shall be performed in a darkened area with a maximum ambient visible light level of 2 fc (20 lx) measured at the part surface.

5.7.1.2 *Special Visible Internal Light Source*—When examinations of internal surfaces must be performed using special visible light sources, the image produced must have sufficient resolution to effectively evaluate the required discontinuities. Light intensity shall be measured at the expected working distance of the equipment.

5.7.2 *Black Lights*—All black lights shall be checked at the intervals specified in Table 1, and after bulb replacement, for output. A longer period may be used if a plan justifying this extension is prepared by the nondestructive testing facility and approved by the contracting agency. The minimum acceptable intensity is 1000 $\mu W/cm^2$ at the part being examined. Black light reflectors and filters shall be checked daily for cleanliness and integrity. Damaged or dirty reflectors or filters shall be replaced or otherwise corrected as appropriate.

5.7.3 *Internal Part Examination*—Where lamps are physically too large to directly illuminate the examination surface, special lighting shall be used. Internal features such as bores, holes, and passages less than 0.5 in. (12.5 mm) nominal diameter shall not require magnetic particle examination unless otherwise specified by the contracting agency.

5.8 *Materials*:

5.8.1 *Dry Particle Requirements*—Dry particles shall meet the requirements of AMS 3040. In applying AMS 3040, the particles shall show indications as listed in Table 2 on the test ring specimen of Fig. 1 using the following procedure:

5.8.1.1 Place a conductor with a diameter between 1 and 1.25 in. (25 and 31 mm) and a length longer than 16 in. (40 cm) through the center of the ring. Center the ring on the length of the conductor. Magnetize the ring circularly by passing the current specified in Table 2 through the conductor. Using a squeeze bulb or other suitable applicator, apply the particles to the surface of the ring while the current is flowing. Examine the ring within 1 min after current application under a visible light of not less than 100 fc (1000 lx). The number of hole indications shall meet or exceed those specified in Table 2.

5.8.2 *Wet Particle Requirements*—Wet particles shall meet the requirements of AMS 3041, 3042, 3043, 3044, 3045, or 3046, as applicable. In applying these specifications, the particles shall show indications as listed in Table 2 on the test

TABLE 1 Required Verification Intervals

Item	Maximum Time Between Verification
Lighting:	
Black light intensity	1 day
Ambient light intensity	1 day
Visible light intensity	1 day
System Performance using the test piece or ring specimen of Fig. 1	1 day
Wet particle concentration	8 hours, or every shift change
Water break test	1 day
Wet particle contamination	1 week
Equipment calibration check:	
Gaussmeter reading (Teslameter) zero	Prior to Use
Gaussmeter (Teslameter) accuracy	6 months
Ammeter accuracy	6 months
Timer control	6 months
Quick break	6 months
Dead weight check	6 months

TABLE 2 Required Indications When Using the Ring Specimen of Fig. 1

Particles Used	Central Conductor FWDC Amperage	Minimum Number of Holes Indicated
Wet suspension, Fluorescent, or Nonfluorescent	1400	3
	2500	5
	3400	6
Dry powder	1400	4
	2500	6
	3400	7

ring specimen of Fig. 1 using the following procedure:

5.8.2.1 Place a conductor with a diameter between 1 and 1.25 in. (25 and 31 mm) and a length longer than 16 in. (40 cm) through the center of the ring. Center the ring on the length of the conductor. Magnetize the ring circularly by passing the current specified in Table 2 through the conductor. Apply the suspension to the ring using the continuous method. Examine the ring within 1 min after current application (examination of nonfluorescent baths shall be conducted under visible light of not less than 100 fc (1000 lx); examination of fluorescent baths shall be conducted under a black light of not less than 1000 μW/cm^2). The number of hole indications shall meet or exceed those specified in Table 2.

5.8.3 *Suspension Vehicles*—The suspension vehicle for the wet method shall be a light petroleum distillate conforming to AMS 2641 (Type I) or DoD-F-87935, or a suitably conditioned water that conforms to the requirements of 5.8.4. When approved by the contracting agency, AMS 2641 (Type II) may be used. The flash point and viscosity shall be in accordance with the requirements of AMS 2641 or DoD-F-87935. The background fluorescence of the suspension vehicle shall be less than the limit specified in DoD-F-87935.

5.8.4 *Conditioned Water Vehicle*—When water is used as a suspension vehicle for magnetic particles, it shall be conditioned suitably to provide for proper wetting, particle dispersion, and corrosion protection. Proper wetting shall be determined by a water break test (see 7.1.4.2). Smoother test surfaces generally require that a greater percent of wetting agent be added than rough surfaces. Nonionic wetting agents are recommended. However, wetting agent additions shall be controlled in all cases by pH measurements to limit the alkalinity of the suspension to a maximum pH of 10.0 and the acidity to a minimum pH of 6.0.

5.8.5 *Particle Concentration*—The concentration of particles in the test 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 and 1.2 to 2.4 mL for nonfluorescent particles shall not be used unless authorized by the contracting agency. Fluorescent particles and nonfluorescent particles shall not be used together.

6. Specific Practice

6.1 *Preparation of Parts for Test*:

6.1.1 *Preinspection Demagnetization*—The part shall be demagnetized before examination 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 inspected 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 inspection.

6.1.3 *Coatings*—Magnetic particle examination shall not be performed with coatings in place that could prevent the detection of surface defects in ferromagnetic substrate. Such coatings normally include paint or chrome plate greater than 0.003 in. (0.08 mm) in thickness and ferromagnetic coatings such as electroplated nickel greater than 0.001 in. (0.03 mm) in thickness. If coatings greater than these limits are present during examination, it must be demonstrated that the minimum rejectable discontinuities can be detected through the maximum coating thickness applied. When such coatings are nonconductive, they must be removed where electrical contact is to be made. In high stress applications when detection of fine defects such as grinding cracks and nonmetallic stringers is required, examination with coatings in place shall be performed only when it has been verified that the minimum rejectable discontinuities can be detected in the presence of the coating.

6.1.4 *Plugging and Masking*—Unless otherwise specified by the contracting agency, small openings and oil holes leading to passages or cavities that could entrap or remain contaminated with inspection media shall be plugged with a suitable nonabrasive material that can be removed readily and, in the case of engine parts, is soluble in oil. Effective masking shall be used to protect those components, such as certain nonmetallics, that may be damaged by contact with the suspension.

6.2 *Magnetization Methods*:

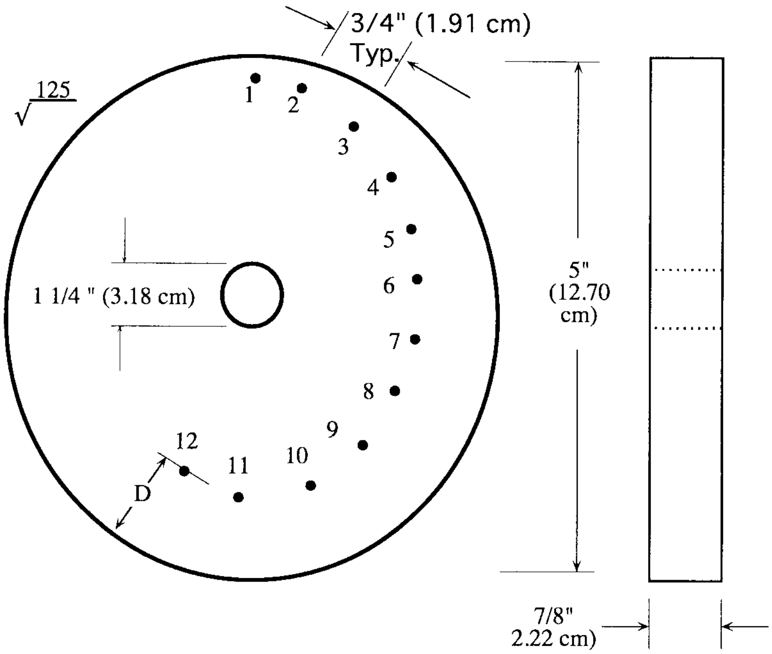
6.2.1 *Types of Magnetizing Current*—The types of currents used for magnetic particle examination are full-wave rectified alternating current (3 or 1 phase), half-wave rectified alternating current, and alternating current. The equipment used shall fulfill the magnetizing and demagnetizing requirements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

6.2.2 *Permanent Magnets*—Permanent magnets are not to be used for magnetic particle examination unless specifically authorized by the contracting agency. When permanent magnets are used, adequate magnetic field strength shall be established in accordance with 7.1.5.4.

6.2.3 *Yokes*—When using yokes (electromagnetic probes) for magnetic particle examination, adequate magnetic field strength shall be established in accordance with 7.1.5.4.

6.2.4 *Magnetizing Current Application*—Alternating current is to be used only for the detection of defects open to the surface. Full-wave rectified alternating current has the deepest possible penetration and must be used for inspection for defects below the surface when using the wet magnetic particle method. Half-wave rectified alternating current is advantageous for the dry powder method because it creates a pulsating unidirectional field that gives increased mobility to the particles.

6.2.5 *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



Hole	1	2	3	4	5	6	7	8	9	10	11	12
Diameter Note 1	0.07 (0.18 cm)	0.07 (0.18 cm)	0.07 (0.18 cm)	0.07 (0.18 cm)	0.07 (0.18 cm)	0.07 (0.18 cm)	0.07 (0.18 cm)	0.07 (0.18 cm)	0.07 (0.18 cm)	0.07 (0.18 cm)	0.07 (0.18 cm)	0.07 (0.18 cm)
"D" Note 2	0.07 (0.18 cm)	0.14 (0.36 cm)	0.21 (0.53 cm)	0.28 (0.71 cm)	0.35 (0.90 cm)	0.42 (1.08 cm)	0.49 (1.26 cm)	0.56 (1.44 cm)	0.63 (1.62 cm)	0.70 (1.80 cm)	0.77 (1.98 cm)	0.84 (2.16 cm)

Notes:

NOTE 1—All hole diameters are ±0.005 in. (±0.01 cm). Hole numbers 8 thru 12 are optional.
NOTE 2—Tolerance on the D distance is ±0.005 in. (±0.01).
NOTE 3—All dimensions are ±0.03 in. (±0.08) or as noted in Notes 1 and 2.
NOTE 4—All dimensions are in inches, except as noted.
NOTE 5—Material is ANSI 01 tool steel from annealed round stock.
NOTE 6—The ring may be heat treated as follows: Heat to 1400 to 1450°F (760 to 790° C). Hold at this temperature for 1 h. Cool at a maximum rate of 40°F/hr (22°C/hr) to below 1000°F (540°C). Furnace or air cool to room temperature. Finish the ring to RMS 25 and protect from corrosion.

FIG. 1 ANSI KETOS Tool Steel Ring

part must be magnetized in at least two directions at right angles to each other. Depending on part geometry, this may consist of circular magnetization in two or more directions, of both circular and longitudinal magnetization, or of longitudinal magnetization in two or more directions. Exceptions necessitated by part geometry, size, or other factors require specific approval of the contracting agency.

6.2.6 *Multidirectional Magnetization*—Multidirectional magnetization may be used to fulfill the requirement for magnetization in two directions if it is demonstrated that it is effective in all critical areas. Artificial flaws that are etched or machined, as shown by a device equal to Fig. 2, may be used to establish field direction. It is vitally important that the field intensity be balanced in all directions so that one direction does not overwhelm another direction. In using this method, the particle application must be timed so that the magnetization reaches its full value in all directions during the time particles are mobile on the surface under testing (that is, the continuous method).

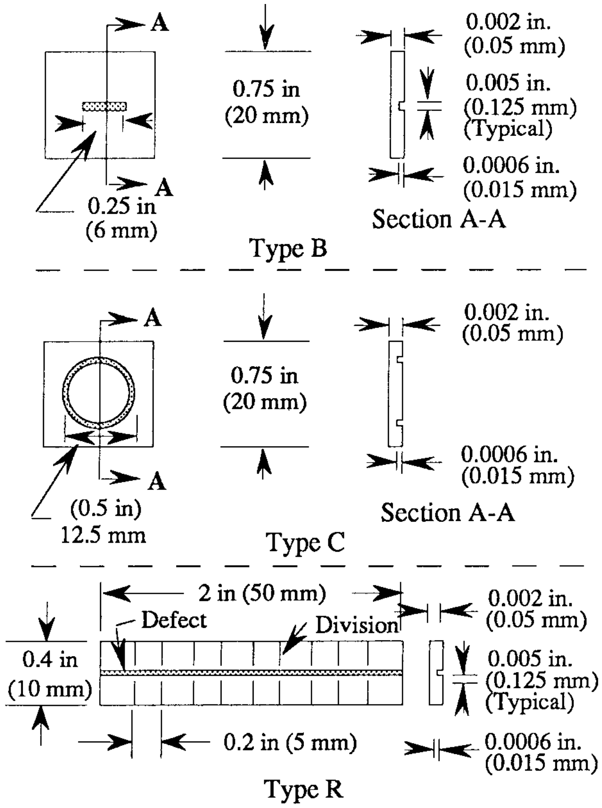
6.2.7 *Direct Magnetization*—Direct magnetization is accomplished by passing current directly through the part under testing. Electrical contact is made to the part using head and tail stock, prods, clamps, magnetic leeches, or by other means. Precaution shall be taken to ensure that the electrical current is not flowing while contacts are being applied or removed and that excessive heating does not occur in the contact area. Unless otherwise specified by the contracting agency, prods shall not be used for the examination of aerospace components (flight hardware) or on finished surfaces.

6.2.8 *Indirect Magnetization*—Indirect part magnetization uses preformed coils, cable wraps, yokes, field flow fixtures, or a central conductor to produce a magnetic field of suitable strength and direction to magnetize the part under test.

6.2.9 *Induced Current Magnetization*—Induced current magnetization (toroidal or circumferential field) is accomplished by inductively coupling a part to an electrical coil to create a suitable current flow in the part as illustrated in Fig. 3. 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.

6.3 *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



Examples of artificial shims used in magnetic particle inspection system verification. (Not drawn to scale.) The shims are made of low carbon steel (1005 steel foil). The artificial flaw is etched or machined on one side of the foil to a depth of 30% of the foil thickness. In use, the shims are firmly attached to the test part (e.g. with tape around the edges) with the flaw toward the part.

FIG. 2 Configuration of Artificial Flaws and Their Designation

particles. Factors that determine the required field strength include the size, shape, and material permeability of the part, the technique of magnetization, the method of particle application, and the type and location of the discontinuities sought. Adequate magnetic field strength may be determined by one or a combination of three methods:

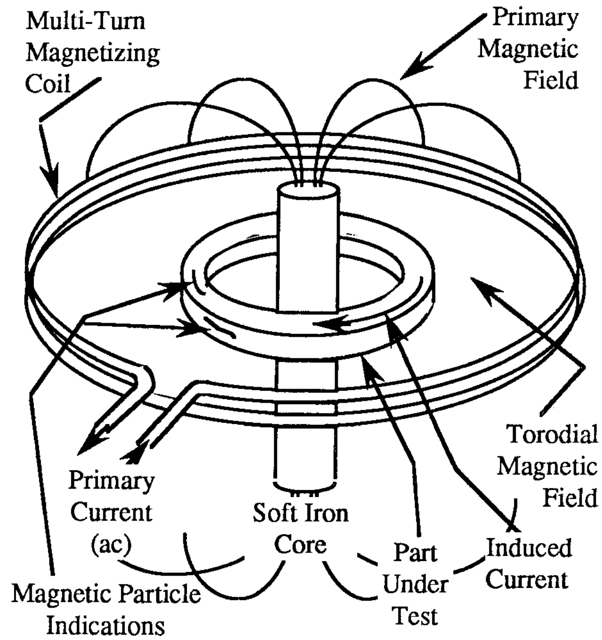
6.3.1.1 By testing parts having known or artificial defects of the type, size, and location specified in the acceptance requirements;

6.3.1.2 By using a Hall effect probe gaussmeter capable of measuring the peak values of the tangent field; and

6.3.1.3 By using the formulas given in 6.3.7.1-6.3.7.4.

6.3.2 When using a Hall effect probe gaussmeter, tangential-field strengths, measured on the part surface, in the range of 30 to 60 G (2.4 to 4.8 kAm^{-1}) peak values are normally adequate magnetization levels for magnetic particle examination. It is important to ensure that field strengths in this range are present in all areas to be inspected on the part.

6.3.3 *Magnetization Current Levels*—The current values given are peak current values and are applied directly to full-wave rectified current. For other types of current, the operator's manual or the equipment manufacturer should be consulted to determine what correction factor, if any, is to be used to convert the meter reading to equivalent peak currents.



The primary current sets up an oscillating field. This primary magnetic field in duces a current in the ring shaped part under test.

FIG. 3 Example of Induced Current Magnetization

6.3.4 *Prod Current Levels*—When using prods on material ¾ in. (19 mm) in thickness or less, 90 to 115 A/in. of prod spacing (3.5 to 4.5 A/mm) shall be used. For material greater than ¾ in. (19 mm) in thickness, 100 to 125 A/in. of prod spacing (4.0 to 5.0 A/mm) shall be used. Prod spacing shall not be less than 2 in. (50 mm) or greater than 8 in. (200 mm). The effective width of the magnetizing field when using prods is one fourth of the prod spacing on each side of a line through the prod centers.

6.3.5 *Direct Circular Magnetization*—When magnetizing by passing current directly through the part (that is, using head shots), the current shall be from 300 to 800 A/in. of part diameter (12 to 32 A/mm). The diameter of the part shall be taken as the greatest distance between any two points on the outside circumference of the part. Currents will normally be 500 A/in. (20 A/mm) or lower, with the higher currents (up to 800 A/in.) being used to inspect for inclusions or to inspect low-permeability alloys such as precipitation-hardened steels. For tests used to locate inclusions in precipitation-hardened steels, even higher currents, up to 1000 A/in. (40 A/mm), may be used.

6.3.6 *Central Conductor Circular Magnetization*—Circular magnetization may be provided by passing current through a conductor that passes through the inside of the part. In this case, alternating current is to be used only when the sole purpose of the test is to inspect for surface discontinuities on the inside surface of the part. If only the inside of the part is to be inspected, the diameter shall be the greatest distance between two points, 180 degrees apart on the inside circumference. Otherwise, the diameter is determined as in 6.3.5. The following two paragraphs cover centrally located and offset central conductors:

6.3.6.1 *Centrally Located Conductor*—When the axis of the central conductor is located near the central axis of the part, the same current levels as given in 6.3.5 shall apply.

6.3.6.2 *Offset Central Conductor*—When the conductor passing through the inside of the part is placed against an inside wall of the part, the current levels as given in 6.3.5 shall apply, except that the diameter shall be considered the sum of the diameter of the central conductor and twice the wall thickness. The distance along the part circumference (interior) that is effectively magnetized shall be taken as four times the diameter of the central conductor, as illustrated in Fig. 4. The entire circumference shall be inspected by rotating the part on the conductor, allowing for approximately a 10 % magnetic field overlap.

6.3.7 *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 tested (that is, by using a coil shot). This produces a magnetic field parallel to the axis of the coil. For low or intermediate fill factor coils, the effective field extends a distance on either side of the coil center approximately equal to the radius of the coil (see Fig. 5). For cable wrap or high-fill factor coils, the effective distance of magnetization is 9 in. (230 mm) on either side of the coil center (see Fig. 6). For parts longer than these effective distances, the entire length shall be inspected by repositioning the part within the coil, allowing for approximately 10 % effective magnetic field overlap.

6.3.7.1 *Longitudinal Magnetization with Low-Fill Factor Coils*—When the cross-sectional area of the coil is ten or more times the cross-sectional area of the part being inspected, the product of the number of coil turns, *N*, and the current in amperes through the coil, *I*, shall be as follows:

(*1*) For parts positioned to the side of the coil:

$$NI = \frac{K}{L/D} (\pm 10\ \%) \tag{1}$$

where:
K = 45 000 A turns,
L = length of the part, and
D = diameter of the part (measured in the same units as the length).

(*2*) For parts positioned in the center of the coil:

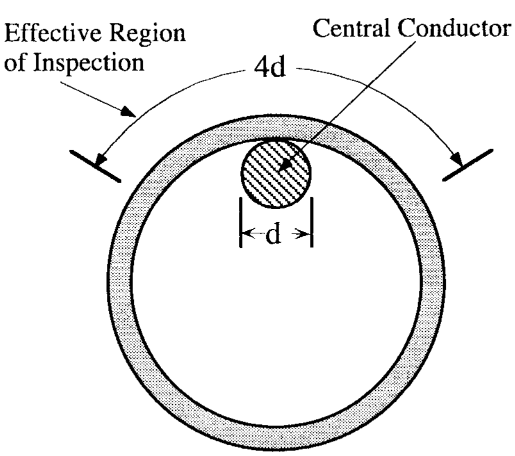


FIG. 4 The Effective Region of Inspection When Using an Offset Central Conductor is Equal to Four Times the Diameter of the Conductor as Indicated

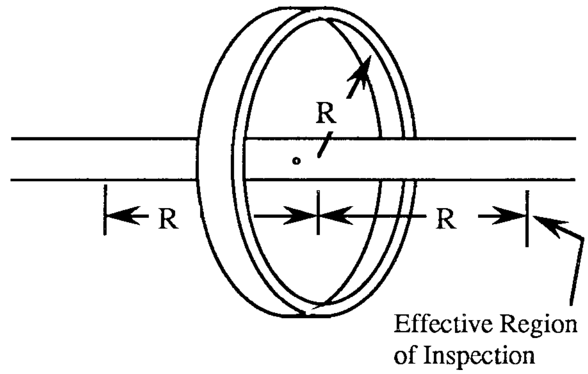


FIG. 5 Effective Region on Inspection for a Low Fill-Factor Coil

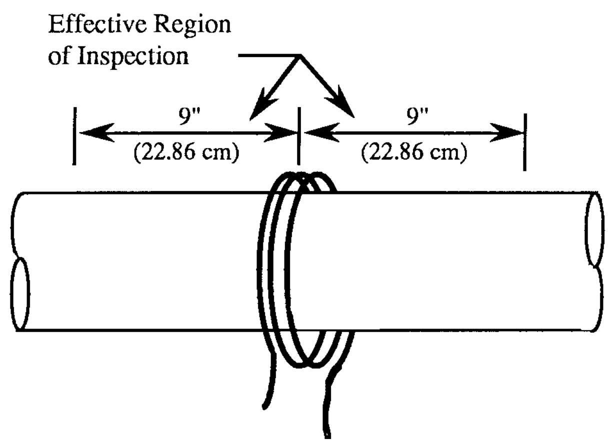


FIG. 6 Effective Region of Inspection for a High Fill-Factor

$$NI = \frac{KR}{(6L/D) - 5} (\pm 10\ \%) \tag{2}$$

where:
R = radius of the coil, mm (or in.),
K = 43 000 A turns per inch if *R* is measured in inches (1690 A turns per mm),
L = length of the part, and
D = diameter of the part (measured in the same units as the length).

If the part has hollow portions, replace *D* with D_{eff} as given in 6.3.7.4. These formulas hold only if *L/D* is greater than 2 and less than 15. If *L/D* is less than 2, pole pieces (pieces of ferromagnetic material with the same diameter as the part being tested) shall be placed on each end of the part to effectively increase the *L/D* to 2 or greater. If the *L/D* is greater than 15, the value of 15 shall be substituted for *L/D*.

6.3.7.2 *Longitudinal Magnetization with Cable Wrap or High-Fill Factor Coils*—When the cross-sectional area of the coil is less than twice the cross-sectional area (including hollow portions) of the part under testing, the product of the number of coils turns, *N*, and the current in amperes through the coil, *I*, shall be as follows:

$$NI = K/\{(L/D) + 2\} (\pm 10\ \%) \tag{3}$$

where:
K = 35 000 A turns,
L = length of the part,

D = diameter of the part (measured in the same units as the length).

If the part has hollow portions, replace D with D_{eff} as given in 6.3.7.4. These formulas hold only if *L/D* is greater than 2 and less than 15. If *L/D* is less than 2, pole pieces (pieces of ferromagnetic material with the same diameter as the part being tested) shall be placed on each end of the part to effectively increase the *L/D* to 2 or greater. If the *L/D* is greater than 15, the value of 15 shall be substituted for *L/D*.

6.3.7.3 *Longitudinal Magnetization for Intermediate-Fill Factor Coils*—When the cross-sectional area of the coil is between two and ten times the cross-sectional area of the part being inspected, the product of the number of turns, *N*, and the current through the coil, *I*, shall be as follows:

$$NI = (NI)_h (10 - \tau)/8 + (NI)_l (\tau - 2)/8 \quad (4)$$

where:

$(NI)_l$ = value of *NI* calculated for low-fill factor coils using 6.3.7.1,

$(NI)_h$ = value of *NI* calculated for high-fill factor coils using 6.3.7.2, and

τ = ratio of the cross-sectional area of the coil to the cross-sectional area of the part (for example, if the coil is 10 in. in diameter and the part is a rod 5 in. in diameter, $\tau = (\pi \times 5^2)/(\pi \times 2.5^2) = 4$).

6.3.7.4 *Calculating the L/D Ratio for a Hollow or Cylindrical Part*—When calculating the *L/D* ratio for a hollow or cylindrical part, D shall be replaced with an effective diameter, D_{eff}, calculated using the following:

$$D_{eff} = 2[(A_t - A_h)/\pi]^{1/2} \quad (5)$$

where:

A_t = total cross-sectional area of the part, and

A_h = cross-sectional area of the hollow portions of the part.

For cylindrical parts, this is equal to the following:

$$D_{eff} = [(OD)^2 - (ID)^2]^{1/2} \quad (6)$$

where:

OD = outside diameter of the cylinder, and

ID = inside diameter of the cylinder.

6.4 *Particle Application*:

6.4.1 *Continuous Method*—In the dry continuous method, magnetic particles are applied to the part while the magnetizing force is present. In the wet continuous method, the magnetizing current, or force, shall be applied simultaneously with or immediately after diverting the suspension. Application of the magnetic particles (see 6.4.4 and 6.4.5) and the magnetization method shall be as prescribed in the paragraphs referenced herein.

6.4.2 *Residual Magnetization Method*—In the residual magnetization method, the magnetic particles are applied to the test part immediately after the magnetizing force has been discontinued. The residual method is not as sensitive as the continuous method, but it can be useful, for example, in detecting in-service induced fatigue cracks on the surface of material with a high retentivity. It is also useful for the examination of parts in areas in which, because of geometric constraints, the continuous method cannot be used. The residual method shall be used only when specifically approved by the contracting agency or when it has been documented that it can detect defects or artificial defects in test parts. The test parts shall have the same material and processing steps, and similar geometry to, the actual parts being inspected.

6.4.3 *Prolonged Magnetization*—When using polymers, slurries, or paints, prolonged or repeated periods of magnetization are necessary because of lower magnetic particle mobility in the high-viscosity vehicles.

6.4.4 *Dry Magnetic Particle Application*—When using dry particles, the flow of magnetizing current shall be initiated prior to application of the magnetic particles to the surface under testing and terminated after powder application has been completed and any excess blown off. The duration of the magnetizing current shall be at least ½ s, and precaution shall be taken to prevent any damage of the part due to overheating or other causes. Dry powder shall be applied in a manner such that a light, uniform, dust-like coating settles on the surface of the test part while the part is being magnetized. Specially designed powder blowers or shakers using compressed air or hand power shall be used. The applicators shall introduce the particles into the air in a manner such that they reach the part surface in a uniform cloud with a minimum of force. After the powder is applied, and before the magnetizing force is removed, excess powder shall be removed by means of a dry air current with sufficient force to remove the excess particles, but not strong enough to disturb particles held by a leakage field that is indicative of discontinuities. In order to recognize the broad, fuzzy, lightly held powder patterns formed by near-surface discontinuities, the formation of indications must be observed carefully during both powder application and removal of the excess powder. Sufficient time for the formation and examination of indications shall be permitted during the testing process. The dry particle method shall not be used to inspect aerospace components (flight hardware) without specific approval of the contracting agency.

6.4.5 *Wet Magnetic Particle Application*—Fluorescent or nonfluorescent particles suspended in a liquid vehicle at the required concentration shall be applied either by gently spraying or flowing the suspension over the area to be inspected. Proper sequencing and timing of part magnetization and application of particle suspension are required to obtain the proper formation and retention of indications. This generally requires that the stream of suspension be diverted from the part simultaneously with, or slightly before, energizing the magnetic circuit. The magnetizing current shall be applied for a duration of at least ½ s for each application, with a minimum of two shots being used. The second shot should follow the first in rapid succession. It should come after the flow of suspension has been interrupted and before the part is examined for indications. Under special circumstances, such as the use of automated equipment or for critical parts, the ½-s duration and the two-shot requirement may be waived provided it is demonstrated that the test procedure given in 5.4 can detect known defects in representative test parts. 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 hence care must be exercised to prevent high-velocity flow over critical surfaces.

6.4.6 *Magnetic Slurry/Paint Application*—Magnetic paints or slurries are applied to the part with a brush, squeeze bottle, or aerosol can before or during the magnetization operation. This method is for special applications, such as overhead or underwater examination. This method shall be used only when specifically approved by the contracting agency.

6.4.7 *Magnetic Polymer Application*—Polymerizable material containing magnetic particles shall be held in contact with the test part during the period of its cure. Before curing takes place, and while the magnetic particles are still mobile, the part shall be magnetized to the specified level. This requires prolonged or repeated periods of magnetization. This method is for special applications, such as bolt holes, which cannot be tested readily by the wet or dry method, and shall be used only when specifically approved by the contracting agency. MIL-I-83387 establishes the inspection process for magnetic rubber.

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

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 *Transparent Tape*—For dry particle indications, by applying transparent adhesive-backed tape to which the indications will adhere and placing it on an approved form along with information giving its location on the part.

6.6.3 *Strippable Film*—By covering the indication with a spray-on strippable film that fixes the indications in place and placing the resultant reproduction on an approved form along with information giving its location on the part.

6.6.4 *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 *Postinspection Demagnetization and Cleaning*—Unless directed otherwise by the contracting agency, all parts shall be demagnetized, cleaned, and corrosion protected after examination.

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, hold the part approximately 1 ft (30 cm) in front of the coil and then move it slowly and steadily through the coil and at least 3 ft (100 cm) beyond the end of the coil. Repeat this process as necessary. Rotate and tumble parts of complex configuration while passing through the field of the coil.

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 magnetic field probe or strength meter shall not detect fields with an absolute value above 3 G (240 Am^{-1}) anywhere on the part.

6.7.2 *Postinspection Cleaning*—Cleaning shall be done with a suitable solvent, air blower, or by other means. Parts shall be inspected to ensure that the cleaning procedure has removed magnetic particle residues from coolant holes, crevices, passage ways, etc., since such residue could have an adverse effect on the intended use of the part. Care shall be taken to remove all plugs, masking, or other processing aids that may affect the intended use of the part. Parts shall be protected from any possible corrosion or damage during the cleaning process and shall be treated to prevent the occurrence of corrosion after final inspection.

7. Quality Control

7.1 *System Performance*:

7.1.1 *System Performance Verification*—The overall performance of the magnetic particle examination system, including the equipment, materials, and the lighting environment being used, shall be verified initially and at regular intervals thereafter. The required verification intervals are stated in Table 1. Records of the verification results shall be maintained and retained for the time period specified in the contract. Frequency of calibration for current and voltage measuring devices, ammeter shunts, timers, and gaussmeters used in the verification shall comply with the requirements of MIL-STD-45662 or Table 1, as specified by the cognizant Level III.

7.1.2 *Use of Test Parts with Discontinuities*—A reliable method for inspection system verification is the use of representative test parts containing defects of the type, location, and size specified in the acceptance requirements. If correct magnetic particle indications can be produced and identified in these representative parts, the overall system and inspection procedure is verified. Parts used for verification will be demagnetized, cleaned thoroughly following the examination, and checked under black or visible light, as appropriate to the examination process, to ensure that residual indications do not remain.

7.1.3 *Fabricated Test Parts with Artificial Discontinuities*—When actual production parts with known discontinuities of the type, location, and size needed for verification are not available or are impractical, fabricated test parts with artificial discontinuities shall be used. Artificial discontinuities may be fabricated to meet a particular need or may be commercially available magnetic field indicators or shims as shown in Fig. 2 and Fig. 7. All applicable conditions for the use of such test parts, as described in 7.1.2, shall apply. When commercial devices are used, their magnetic properties, flaw types, and surface condition shall be as close to the production part as possible.

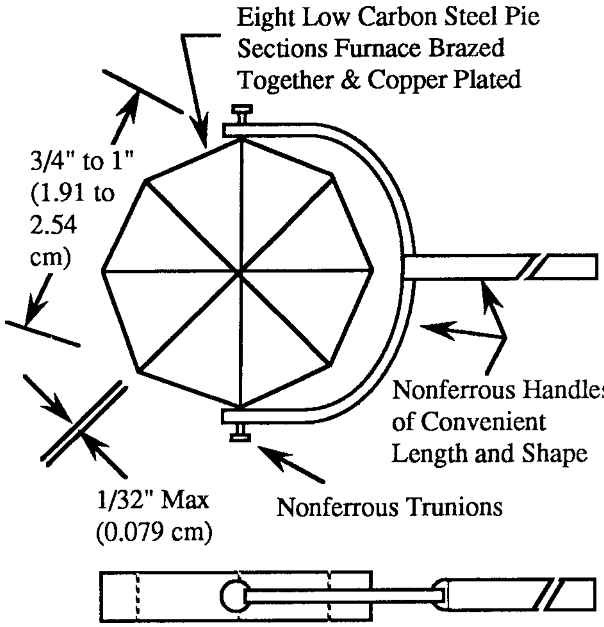


FIG. 7 Pie-field Indicator for Use in Magnetic Particle Inspection System Verification (All Dimensions are in Inches)

7.1.4 *Suspension Vehicle Tests* (Not required for aerosol can solutions):

7.1.4.1 *Concentration/Contamination Tests*—Particle concentration and contamination shall be determined upon start up, at regular intervals thereafter, and whenever the bath is changed or adjusted. The required testing intervals are stated in Table 1.

(1) Determination of Wet Particle Concentration—Agitate the particle suspension a minimum of 30 min to ensure uniform distribution of particles throughout the bath. Place a 100-mL sample of the agitated suspension in a pear-shaped centrifuge tube (of the size and shape specified in Test Methods D 96, except graduated to 1 mL in 0.05-mL increments). Demagnetize the sample and allow the tube to stand undisturbed for at least 60 min if using the petroleum distillate in AMS 2641 or 30 min settling time for conditioned water suspension. Read the volume of settled particles. If the concentration is out of the tolerance stated in the written procedure (or that given in 5.8.5), add the particles or suspension vehicle, as required, and redetermine the particle concentration. If the settled particles appear to be loose agglomerates rather than a solid layer, take a second sample. If the second sample also appears agglomerated, replace the entire suspension. Thirty-minute settling times, or other accelerated tests, may be used if they have been verified to give results equivalent to the procedure described in this paragraph.

(2) Determination of Wet Particle Contamination—Perform the tests specified in 7.1.4.1 (*1*). In addition, for fluorescent baths, examine the liquid above the precipitate with black light. The liquid shall be comparable to the fluorescence of the original solution. Examine the graduated portion of the tube, under both black light (for fluorescent baths only) and visible light (for both fluorescent and nonfluorescent baths), for striations or bands, different in color or appearance. Bands or striations may indicate contamination. If the total volume of the contaminants, including bands or striations, exceeds 30 % of the volume of magnetic particles, or if the liquid is noticeably fluorescent, the bath must be replaced.

7.1.4.2 *Water Break Test*—In this test of water-based vehicles, a clean part with a surface finish the same as the parts to be tested is flooded with the conditioned water, and the appearance of the surface is noted after flooding is stopped. If a continuous even film forms over the entire part, sufficient wetting agent is present. If the film of suspension breaks, exposing bare surface, insufficient wetting agent is present or the part has not been cleaned adequately.

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

7.1.5.1 *Ammeter Accuracy*—To check the equipment ammeter, a calibrated ammeter shall be connected in series with the output circuit. Comparative readings shall be taken at three output levels encompassing the useable range of the equipment. The equipment meter reading shall not deviate by more than ±10 % of full scale from the current value shown by the calibrated ammeter. (When measuring half-wave alternating current, the current values shown by the calibrated dc ammeter readings shall be doubled.) The frequency of the ammeter check is specified in Table 1.

7.1.5.2 *Timer Control Check*—On equipment using a timer to control the current duration, the timer should be checked to within ±0.1 s using a suitable electronic timer.

7.1.5.3 *Magnetic Field Quick Break Check*—On equipment that uses a quick break feature, proper functioning of this circuit shall be verified. The test may be performed using a suitable oscilloscope or other applicable method as specified by the equipment manufacturer.

7.1.5.4 *Dead Weight Check*—Yokes and permanent magnetics (when allowed) shall be dead weight tested at intervals as stated in Table 1. Alternating current yokes shall have a lifting force of at least 10 lb (45 N), with a 2 to 4-in. (50 to 100-mm) spacing between legs. Direct current yokes shall have a lifting force of at least 30 lb (135 N), with a 2 to 4-in. (50 to 100-mm) spacing between legs, or 50 lb (225 N), with a 4 to 6-in. (100 to 150-mm) spacing.

7.2 *Marking of Inspected Parts*—Unless otherwise specified by the contracting agency, 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. 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. When subsequent processing would remove the identification, the applicable marking shall be affixed to the record accompanying the finished parts or assembly. Bolts and nuts and other fastener products may be identified as having met the requirements of magnetic particle examination by marking each package conspicuously.

7.2.1 *Impression Stamping, Ink Stamping, Laser Marking,* *or Vibro Engraving*—Impression stamping, ink stamping, laser marking, or vibro engraving shall 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 inspector's markings. Impression stamping shall be located only in the area provided adjacent to the part number or inspector's stamp unless otherwise specified by the contracting agency.

7.2.2 *Etching*—When impression stamping, ink stamping, laser marking, or vibro engraving is prohibited, parts shall be etched using an etching fluid or other means and a method of application acceptable to the contracting agency. The etching process and location shall not affect the functioning of the part adversely.

7.2.3 *Dyeing*—When stamping, vibro engraving, or etching is not permissible, identification shall be accomplished by dyeing.

7.2.4 *Other Identification*—Other means of identification, such as tagging, shall be used for parts that have a construction 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.

7.2.5 *Identifying Symbols and Color Markings*:

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

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

(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 % inspected parts, the letter "M" with a circle around it will be employed.

7.2.5.2 *Lot Inspection*—When items are accepted by means of a sampling procedure, each item of an accepted lot shall be marked as follows:

(1) Dyeing—When dyeing is applicable, a dye of acceptable adherence that is predominantly orange (per FED-STD-595) shall be employed.

(2) Stamping, Vibro Engraving, or Etching—When impression stamping, vibro engraving or etching is used to mark lot inspected parts, the letter" M" shall be employed.

7.3 *Eye Glasses*—When using fluorescent materials, inspectors shall not wear eye glasses that are photochromic or that have permanently darkened lenses. This is not intended to prohibit the use of eyeglasses with lenses treated to absorb ultraviolet light.

7.4 *Safety*—The safe handling of magnetic particles (wet or dry), oil vehicles water baths, and water conditioner concentrates are 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.

7.4.1 *Flammability*—Flash point of oil vehicles shall be in accordance with AMS 2641 or DoD-F-87935. The suppliers' MSDS shall certify the flash point.

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

7.4.3 *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.

7.4.4 *Black Light*—It is recommended that the intensity of black light incident on unprotected skin or eyes not exceed 1000 $\mu W/cm^2$. Cracked or broken ultraviolet filters shall be replaced immediately. Broken bulbs can continue to radiate ultraviolet energy and must be replaced immediately. Spectacles designed to absorb ultraviolet wavelength radiation are suggested for close, high, black light intensity examination.

7.5 *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 examination.

8. Keywords

8.1 dye; fluorescent; magnetic particle; nondestructive evaluation; nondestructive examination; nondestructive testing

APPENDIX

(Nonmandatory Information)

X1. MEASUREMENT OF TANGENTIAL FIELD STRENGTH

X1.1 Care must be exercised when measuring the tangential applied field strengths specified in 6.3.2. The active area of the Hall effect probe should be no larger than 0.2 in. (5 mm) by 0.2 in. (5 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 should be set to read the peak value during the shot. The gaussmeter should have a frequency response of 0 to 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 should be shielded or twisted to prevent reading errors due to voltage induced during the large field changes encountered during magnetic particle examination.