Designation: E709 – 21

Standard Guide for Magnetic Particle Testing[1]

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1. Scope*

1.1 This guide[2] covers techniques for both dry and wet magnetic particle testing, a nondestructive method for detecting cracks and other discontinuities at or near the surface in ferromagnetic materials. Magnetic particle testing may be applied to raw material, semifinished material (billets, blooms, castings, and forgings), finished material and welds, regardless of heat treatment or lack thereof. It is useful for preventive maintenance testing.

1.1.1 This guide is intended as a reference to aid in the preparation of specifications/standards, procedures and techniques.

1.2 This guide is also a reference that may be used as follows:

1.2.1 To establish a means by which magnetic particle testing, procedures recommended or required by individual organizations, can be reviewed to evaluate their applicability and completeness.

1.2.2 To aid in the organization of the facilities and personnel concerned in magnetic particle testing.

1.2.3 To aid in the preparation of procedures dealing with the examination of materials and parts. This guide describes magnetic particle testing techniques that are recommended for a great variety of sizes and shapes of ferromagnetic materials and widely varying examination requirements. Since there are many acceptable differences in both procedure and technique, the explicit requirements should be covered by a written procedure (see Section 21).

1.3 This guide does not indicate, suggest, or specify acceptance standards for parts/pieces examined by these techniques. It should be pointed out, however, that after indications have been produced, they must be interpreted or classified and then evaluated. For this purpose there should be a separate code, specification, or a specific agreement to define the type, size, location, degree of alignment and spacing, area concentration, and orientation of indications that are unacceptable in a specific part versus those which need not be removed before part acceptance. Conditions where rework or repair is not permitted should be specified.

1.4 This guide describes the use of the following magnetic particle method techniques.

1.4.1 Dry magnetic powder (see 8.4),

1.4.2 Wet magnetic particle (see 8.5),

1.4.3 Magnetic slurry/paint magnetic particle (see 8.5.7), and

1.4.4 Polymer magnetic particle (see 8.5.8).

1.5 *Personnel Qualification*—Personnel performing examinations in accordance with this guide should be qualified and certified in accordance with ASNT Recommended Practice No. SNT-TC-1A, ANSI/ASNT Standard CP-189, NAS 410, or as specified in the contract or purchase order.

1.6 *Nondestructive Testing Agency*—If a nondestructive testing agency as described in Specification E543 is used to perform the examination, the nondestructive testing agency should meet the requirements of Specification E543.

1.7 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.8 **Warning—**Mercury has been designated by many regulatory agencies as a hazardous material that can cause serious medical issues. Mercury, or its vapor, has been demonstrated to be hazardous to health and corrosive to materials. Caution should be taken when handling mercury and mercury containing products. See the applicable product Safety Data Sheet (SDS) for additional information. Users should be aware that selling mercury or mercury containing products, or both, into your state or country may be prohibited by law.

1.9 *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.*

1.10 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the*

[1] This guide 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.

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[2] For ASME Boiler and Pressure Vessel Code Applications, see related Guide SE-709 in Section II of that Code.

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

Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

D93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester

D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

E165/E165M Practice for Liquid Penetrant Testing for General Industry

E543 Specification for Agencies Performing Nondestructive Testing

E1316 Terminology for Nondestructive Examinations

E1444/E1444M Practice for Magnetic Particle Testing

E3024/E3024M Practice for Magnetic Particle Testing for General Industry

2.2 *SAE: Aerospace Materials Specifications:*[4]

AMS 2300 Premium Aircraft Quality Steel Cleanliness Magnetic Particle Inspection Procedure

AMS 2301 Aircraft Quality Steel Cleanliness Magnetic Particle Inspection Procedure

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

AMS 2641 Vehicle Magnetic Particle Inspection

AMS 3040 Magnetic Particles, Non-fluorescent, Dry Method

AMS 3041 Magnetic Particles, Non-fluorescent, Wet Method, Oil Vehicle, Ready to Use

AMS 3042 Magnetic Particles, Non-fluorescent, Wet Method, Dry Powder

AMS 3043 Magnetic Particles, Non-fluorescent, Oil Vehicle, Aerosol Packaged

AMS 3044 Magnetic Particles, Fluorescent, Wet Method, Dry Powder

AMS 3045 Magnetic Particles, Non-fluorescent, Wet Method, Oil Vehicle, Ready to Use

AMS 3046 Magnetic Particles, Non-fluorescent, Wet Method, Oil Vehicle, Aerosol Packaged

AMS 5062 Steel, Low Carbon Bars, Forgings, Tubing, Sheet, Strip, and Plate 0.25 Carbon, Maximum

AMS 5355 Investment Castings

AMS-I-83387 Inspection Process, Magnetic Rubber

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

2.3 *ASNT Documents:*[5]

SNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

CP-189 ASNT Qualification and Certification of Nondestructive Testing Personnel

2.4 *Federal Standards:*[6]

A-A-59230 Fluid, Magnetic Particle Inspection, Suspension

FED-STD-313 Material Safety Data Sheets Preparation and the Submission of

2.5 *OSHA Document:*[7]

29 CFR 1910.1200 Hazard Communication

2.6 *AIA Documents:*[8]

NAS 410 Nondestructive Testing Personnel Qualification and Certification

2.7 *ISO Standard:*[9]

ISO 7810 Identification Cards—Physical Characteristics

3. Terminology

3.1 For definitions of terms used in the practice, refer to Terminology E1316.

4. Summary of Guide

4.1 *Principle*—The magnetic particle method is based on establishing a magnetic field with high flux density in a ferromagnetic material. The flux lines must spread out when they pass through non-ferromagnetic material such as air in a discontinuity or an inclusion. Because flux lines can not cross, this spreading action may force some of the flux lines out of the material (flux leakage). Flux leakage is also caused by reduction in ferromagnetic material (cross-sectional change), a sharp dimensional change, or the end of the part. If the flux leakage is strong enough, fine magnetic particles will be held in place and an accumulation of particles will be visible under the proper lighting conditions. While there are variations in the magnetic particle method, they all are dependent on this principle, that magnetic particles will be retained at the locations of magnetic flux leakage. The amount of flux leakage at discontinuities depends primarily on the following factors: flux density in the material, and size, orientation, and proximity to the surface of a discontinuity. With longitudinal fields, all of the flux lines must complete their loops though air and an excessively strong magnetic field may interfere with examination near the flux entry and exit points due to the high flux-density present at these points.

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

[4] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

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

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

[7] Available from Occupational Safety and Health Administration (OSHA), 200 Constitution Ave., NW, Washington, DC 20210, http://www.osha.gov.

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

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

4.2 *Method*—While this practice permits and describes many variables in equipment, materials, and procedures, there are three steps essential to the method:

4.2.1 The part must be magnetized.

4.2.2 Magnetic particles of the type designated in the contract/purchase order/specification should be applied while the part is magnetized or immediately thereafter.

4.2.3 Any accumulation of magnetic particles must be observed, interpreted, and evaluated.

4.3 *Magnetization:*

4.3.1 *Ways to Magnetize*—A ferromagnetic material can be magnetized either by passing an electric current through the material or by placing the material within a magnetic field originated by an external source. The entire mass or a portion of the mass can be magnetized as dictated by size and equipment capacity or need. As previously noted, in order to be detectable, the discontinuity must interrupt the normal path of the magnetic field lines. If a discontinuity is open to the surface, the flux leakage attracting the particles will be at the maximum value for that particular discontinuity. When that same discontinuity is below the surface, flux leakage evident on the surface will be a lesser value.

4.3.2 *Field Direction*—If a discontinuity is oriented parallel to the magnetic field lines, it may be essentially undetectable. Therefore, since discontinuities may occur in any orientation, it may be necessary to magnetize the part or the area of interest twice or more sequentially in different directions by the same method or a combination of different methods (see Section 13) to induce magnetic field lines in a suitable direction in which to perform an adequate examination.

4.3.3 *Field Strength*—The magnetic field must be of sufficient strength to indicate those discontinuities which are unacceptable, yet must not be so strong that an excess of local particle accumulation masks relevant indications (see Section 14).

4.4 *Types of Magnetic Particles and Their Use*—There are various types of magnetic particles available for use in magnetic particle testing. They are available as dry powders (fluorescent and nonfluorescent) ready for use as supplied (see 8.4), powder concentrates (fluorescent and nonfluorescent) for dispersion in water or suspending in light petroleum distillates (see 8.5), magnetic slurries/paints (see 8.5.7), and magnetic polymer dispersions (see 8.5.8).

4.5 *Evaluation of Indications*—When the material to be examined has been properly magnetized, the magnetic particles have been properly applied, and the excess particles properly removed, there will be accumulations of magnetic particles remaining at the points of flux leakage. These accumulations show the distortion of the magnetic field and are called indications. Without disturbing the particles, the indications must be examined, classified, compared with the acceptance standards, and a decision made concerning the disposition of the material that contains the indication.

4.6 *Typical Magnetic Particle Indications:*

4.6.1 *Surface Discontinuities*—Surface discontinuities, with few exceptions, produce sharp, distinct patterns (see Annex A1).

4.6.2 *Near-surface Discontinuities*—Near-surface discontinuities produce less distinct indications than those open to the surface. The patterns tend to be broad, rather than sharp, and the particles are less tightly held (see Annex A1).

5. Significance and Use

5.1 The magnetic particle method of nondestructive testing indicates the presence of surface and near-surface discontinuities in materials that can be magnetized (ferromagnetic). This method can be used for production examination of parts/components or structures and for field applications where portability of equipment and accessibility to the area to be examined are factors. The ability of the method to find small discontinuities can be enhanced by using fluorescent particles suspended in a suitable vehicle and by introducing a magnetic field of the proper strength whose orientation is as close as possible to 90° to the direction of the suspected discontinuity (see 4.3.2). A smoother surface or a pulsed current improves mobility of the magnetic particles under the influence of the magnetic field to collect on the surface where magnetic flux leakage occurs.

6. Equipment

6.1 *Types*—There are a number of types of equipment available for magnetizing ferromagnetic parts and components.

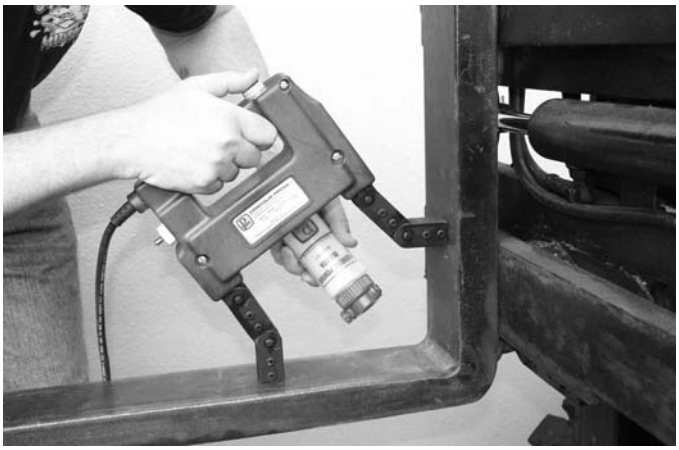

FIG. 1 (a) Articulating Yoke Method of Part Magnetization