Designation: A275/A275M – 15

Standard Practice for Magnetic Particle Examination of Steel Forgings[1]

This standard is issued under the fixed designation A275/A275M; 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 standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This practice[2] covers a procedure for magnetic particle examination of steel forgings. The procedure will produce consistent results upon which acceptance standards can be based. This practice does not contain acceptance standards or recommended quality levels.

1.2 Only direct current or rectified alternating (full or half wave) current shall be used as the electric power source for any of the magnetizing methods. Alternating current is not permitted because its capability to detect subsurface discontinuities is very limited and therefore unsuitable.

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

NOTE 1—Guide E709 may be utilized for magnetic particle examination in the field for machinery components originally manufactured from steel forgings.

1.3 The minimum requirements for magnetic particle examination shall conform to practice standards of Practice E1444/E1444M. If the requirements of this practice are in conflict with the requirements of Practice E1444/E1444M, the requirements of this practice shall prevail.

1.4 This practice and the applicable material specifications are expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation [SI units], the material shall be furnished to inch-pound units.

1.5 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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

2. Referenced Documents

2.1 *ASTM Standards:*[3]

A508/A508M Specification for Quenched and Tempered Vacuum-Treated Carbon and Alloy Steel Forgings for Pressure Vessels

A788/A788M Specification for Steel Forgings, General Requirements

E709 Guide for Magnetic Particle Testing

E1444/E1444M Practice for Magnetic Particle Testing

2.2 *Other Document:*

Recommended Practice No. SNT-TC-1A, Supplement B-Magnetic Particle Method[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *indication*—the visual magnetic particle buildup resulting from leakage fields in the magnetic field.

3.1.2 *linear indication*—an indication in which the length is at least three times the width. The minimum length of indications to be considered linear shall be 1/16 in. [1.6 mm].

3.1.3 *magnetic flux*—the product of the magnetic induction and the area of a surface (or cross section) when the magnetic induction is uniformly distributed and normal to the plane of the surface. The concept that the magnetic field is flowing along the lines of force suggests that these lines are therefore "flux" lines, and they are called magnetic flux.

3.1.4 *magnetic particle method of examination*—a method for detecting discontinuities on or near the surface in suitably

[1] This practice is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.06 on Steel Forgings and Billets.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Method SA-275/SA-275M in Section II of that Code.

[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 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**

magnetized materials, which employs finely divided magnetic particles that tend to congregate in regions of leakage fields.

3.1.5 *nonrelevant indications*—indications produced by leakage fields. However, the conditions causing them are present by design or accident, or other features of the part having no relation to the damaging flaws being sought. The term signifies that such an indication has no relation to the discontinuities that might constitute defects.

4. Significance and Use

4.1 For ferromagnetic materials, magnetic particle examination is widely specified for the detection of surface and near surface discontinuities such as cracks, laps, seams, and linearly oriented nonmetallic inclusions. Such examinations are included as mandatory requirements in some forging standards such as Specification A508/A508M.

4.2 Use of direct current or rectified alternating (full or half wave) current as the power source for magnetic particle examination allows detection of subsurface discontinuities.

5. Basis of Application

5.1 When in accordance with the requirements of the inquiry, contract, order, or specifications, forgings are furnished subject to magnetic particle examination, the manufacturer and the purchaser shall be in agreement concerning the following:

5.1.1 The locations on the forgings that are to be subjected to magnetic particle examination.

5.1.2 The type, size, number, location, and orientation of indications that are to be considered injurious.

5.1.3 The method of application of magnetic particles, demagnetization requirements and magnetic field strengths.

5.2 In cases where large undercuts in the forgings are to be taken by the purchaser, the manufacturer shall be given the privilege (when the design permits) of machining slots or grooves in the rough-machined forging to explore the internal conditions prior to shipping.

5.3 Acceptance standards.

6. Personnel Requirements

6.1 Personnel performing the magnetic particle examination to this practice shall be qualified and certified in accordance with a written procedure conforming to Recommended Practice No. SNT-TC-1A or another national standard that is acceptable to both the purchaser and the supplier.

7. Stage of Inspection

7.1 Unless otherwise specified by the purchaser, acceptance inspection shall be performed on a forging in the final machined surface condition and final thermally treated condition (including stress relief) or within 0.030 in. [0.8 mm] of the final machined surface.

8. Magnetizing Apparatus

8.1 Rectified alternating (full or half wave) or direct-current electric power sources may be used. When current is passed through the part itself, the equipment shall consist of contacting or clamping elements with sufficient surface area and clamping pressure to allow the required current to flow without damaging (burning) the part being examined.

8.2 Portable electromagnetic (ac-dc) yokes may be used in the dc mode as a magnetizing apparatus, provided the sensitivity to detect crack-like defects is demonstrated to be at least equivalent to that of the direct-magnetization method.

8.2.1 Portable battery powered electromagnetic yokes are not included in the scope of this practice.

9. Magnetic Particles

9.1 The inspection medium shall consist of finely divided ferromagnetic particles, which may be suspended in a suitable liquid medium, or used in dry powder form.

9.2 The size and shape of the particles, and their magnetic properties, both individually and collectively, are important (see Section 12).

10. Surface Preparation

10.1 The sensitivity of the magnetic particle examination will depend to a considerable extent upon the condition of the surface being tested. Defects may be satisfactorily revealed on shot-blasted or otherwise cleaned forged surfaces, or on surfaces having small amounts of heat-treating scale without any special surface preparation; however, loose scale must be removed. To reveal fine defects, the surfaces to be inspected should be smooth machined to at least a 250-µin. [6.35-µm] finish where the definition for surface finish is as per Specification A788/A788M.

10.2 The surfaces shall be free of grease, oils, or other substances to which the particles may adhere.

10.3 Rough surfaces hamper the mobility of magnetic powders due to mechanical trapping which in turn produces false indications. Such areas should be surface ground. If grinding is impractical, a paper tape overlay (as described in 15.1.1.2) may eliminate the problem.

11. Methods of Magnetization

11.1 The forging may be magnetized either by passing current through the piece or by inducing a magnetic field by means of a central conductor or by coils.

11.1.1 *Continuous Method*—In the continuous method, the inspection medium is applied to the surface under inspection while the current is still flowing. The current source generates high amperage current in pulses of up to 1-s duration. The duration of this flow shall allow at least three pulses of current or in the case where machines supply continuous current flow a minimum shot of ⅕ to ½-s duration should be applied.

11.1.2 *Surge Method*—In the surge method a high-magnetizing force is applied and then reduced to a lower continuous value, which is maintained during application of the inspection medium.

11.2 At least two separate examinations shall be carried out on each area. The second examination shall be with the lines of magnetic flux approximately perpendicular to those used for the first examination in that area. A different means of

magnetizing may be used for the second examination. Magnetizing in more than one direction cannot be accomplished simultaneously.

NOTE 2—An exception to the above rule is overall sequential multivector magnetization whereby several magnetizing circuits are provided for sequentially magnetizing a part in multiple directions depending upon the locations of the current connectors. By this technique, flaws of any orientation can be detected with a single application of magnetic particles.

11.3 The two general types of magnetization with regard to direction are longitudinal and circular, as follows:

11.3.1 *Longitudinal*—When a forging is magnetized longitudinally, the magnetic flux lines are usually parallel to the axis of the piece. A longitudinally magnetized piece always has definite poles readily detectable by compass or magnetometer. Longitudinal magnetization is usually accomplished by placing the forging within a solenoid, often formed by wrapping cable around the piece (Fig. 1). For special applications, magnetic yokes can be used (Fig. 2) when requirements of 8.2 are met.

11.3.2 *Circular*—Circular magnetization is obtained by passing a current directly through the piece (Fig. 3), or induced through a conductor (Fig. 4), or conductors threaded (Fig. 5) through an opening in the piece. Localized circular magentization may be obtained by passing current through the local areas by use of prod-type contacts (Fig. 6).

11.4 The magnetic field is confined almost entirely to the piece and there may be no external manifestation of the magnetized condition. Indications will appear strongest in the direction perpendicular to the direction of the magnetic field.

11.5 *Field Strength*—The minimum field strength that will reveal and permit classification of all objectionable defects shall be used. The maximum field strengths practical are the ones just below the point at which excessive adherence of the particles begins to occur over the surface being inspected.

11.5.1 *Coil Magnetization*—When coil magnetization is used, the magnetic field strength is directly proportional to the current (ampere-turns if a coil or solenoid is used) and inversely proportional to the thickness of the section being inspected.

11.5.1.1 *Longitudinal Magnetization*—For encircling coils (Fig. 1), the turns of the coil shall be kept closely together. The field strength decreases as distance from the coil increases and

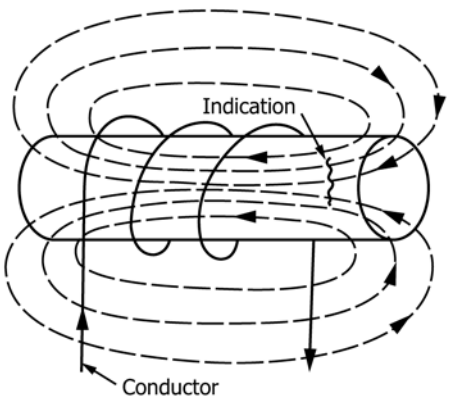

FIG. 1 Longitudinal Magnetization

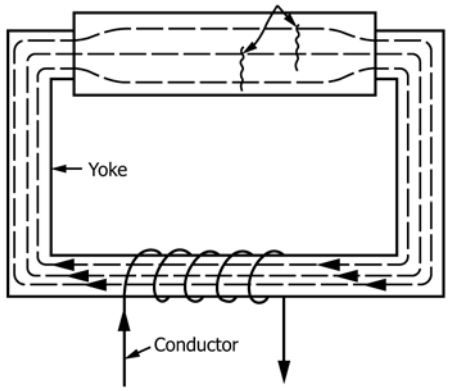

FIG. 2 Longitudinal Magnetization, with Yoke

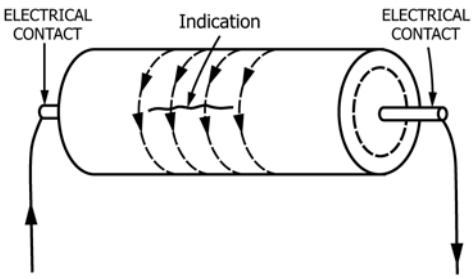

FIG. 3 Circular Magnetization, Current Directly Through Forging

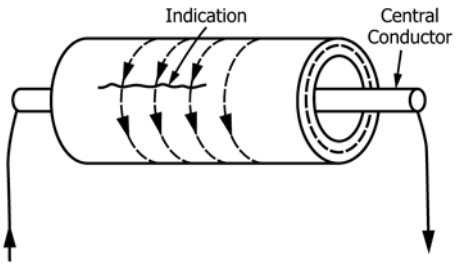

FIG. 4 Circular Magnetization, Current Through a Conductor

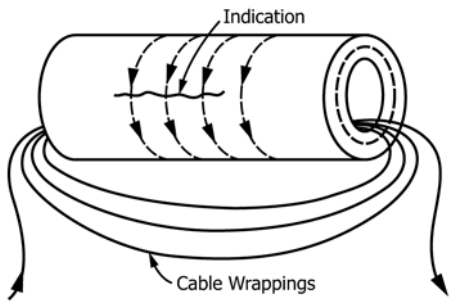

FIG. 5 Circular Magnetization, Current Through Conductors Threaded Through Forging

long parts must be magnetized in sections. If the area to be inspected extends beyond 6 in. [150 mm] on either side of the coils, the adequacy of the field shall be demonstrated by the use of field indicators (see 11.5.6).

(1) Small Forgings—Magnetizing force shall be 35 000 ampere-turns divided by the sum of 2 plus the "length over diameter" ratio of the test part. For example, a part 10 in. [250 mm] long by 2 in. [50 mm] in outside diameter has an *L/D*

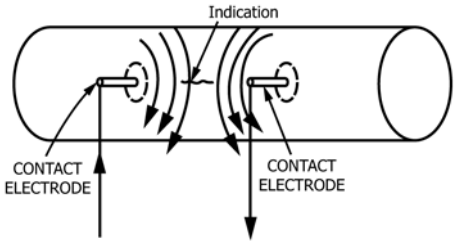

FIG. 6 Circular Magnetization with "Prod" Type Contact Electrodes

ratio of 5. Therefore, 35 000/(2 + 5) = 5000 ampere-turns; if a 5-turn coil is used, the current required is 5000/5 or 1000 A. This formula provides an adequate field strength on small parts having an *L/D* ratio of 4 or greater. For parts having a smaller *L/D* ratio, adequate field strengths shall be demonstrated by the use of a field indicator (see 11.5.6). The graph in Fig. 7 may be used to determine the ampere-turns required for each *L/D* relationship.

(2) Large Forgings—For large forgings the magnetizing force shall be in the range from 1200 to 4500 ampere-turns. A field indicator (see 11.5.6) shall be used to demonstrate the presence of an adequate field strength over the area to be inspected.

11.5.1.2 *Circular Magnetization* (Fig. 5)—For circular magnetization with through coils, use the current with amperage as specified in 11.5.2 divided by the number of turns in the coil.

11.5.2 *Direct Magnetization*—When current is passed directly through the part to be examined, the current shall be between 100 and 900 A per inch [4 and 35 A per millimetre] of diameter or cross section (per inch or millimetre of greatest width in a plane at right angles to current flow). For hollow parts this would be wall thickness when cables are clamped to the wall. Suggested current for diameters or sections up to 5 in. [125 mm] are 600 to 900 A per inch [25 to 35 A per millimetre]; for diameters or sections between 5 and 10 in. [125 to 250 mm], 400 to 600 A per inch [15 to 25 A per millimetre]; and 100 to 400 A per inch [4 to 15 A per millimetre] for outside diameters or sections over 10 in. [250 mm]. If it is not practical

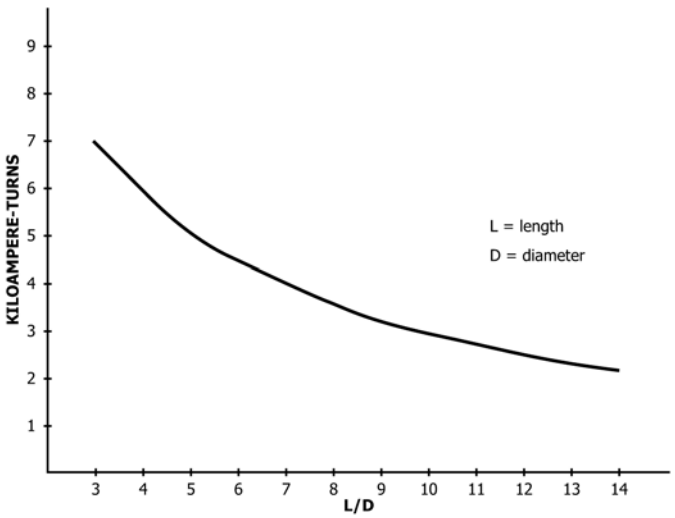

FIG. 7 Longitudinal Magnetization

to obtain these current levels for diameters over 10 in. [250 mm], the presence of an adequate field strength shall be demonstrated using a field indicator. In all other instances the adequacy of the magnetizing force shall be demonstrated by means of a field indicator (see 11.5.6). When large parts have been examined by clamping contacts to the wall thickness the adequacy of the field in the circumferential direction shall also be determined by the field indicator.

11.5.3 *Prod Magnetization*—When prods are used to circularly magnetize a local area, the field strength is directly proportional to the amperage used but also varies with the prod spacing and thickness of section being inspected.

11.5.3.1 A magnetizing force of 75 to 100 A per linear inch [3 to 4 A per millimetre] of prod spacing shall be used for material under ¾ in. [20 mm] thick, and 100 to 125 A per linear inch [4 to 5 A per millimetre] of prod spacing shall be used for material ¾ in. [20 mm] and over in thickness.

11.5.3.2 Prod spacing shall be a maximum of 8 in. [200 mm]. Prod spacing less than 3 in. [75 mm] usually is not feasible due to banding of the particles around the prods. Care shall be taken to prevent local overheating or burning of the surface being examined. Steel- or aluminum-tipped prods or copper-brush-type prods rather than solid copper-tipped prods are recommended where the magnetizing voltage is over 25 V open circuit (bad contact) in order to avoid copper penetration. Permanent magnetic leeches may be used as a pair or in conjunction with a prod. Leeches should not be used in excess of 1500 A because loss of magnetization occurs.

11.5.3.3 A remote control switch, which may be built into the prod handles, shall be provided to permit the current to be turned on after the prods have been properly positioned and to turn if off before the prods are removed in order to prevent arcing.

11.5.3.4 *Examination Coverage*—Examinations shall be conducted with sufficient overlap to assure 100 % coverage at the established sensitivity.

11.5.3.5 *Direction of Magnetization*—At least two separate examinations shall be carried out on each area. The prods shall be placed so that the lines of flux during one examination are approximately perpendicular to the lines of flux during the other.

11.5.4 Indirect circular magnetization of the bores of shaft forgings (Fig. 4) shall be performed using a current of 100 to 125 A per inch [4 to 5 A per millimetre] of bore diameter.

11.5.5 A suitable instrument such as an ammeter shall be used to measure the specified or agreed upon current.

11.5.6 A magnetic particle field indicator (Fig. 8) where necessary shall be used to establish adequacy of the magnetic field. The magnetizing current shall be sufficient to develop the pattern in the indicator clearly.

11.5.6.1 The magnetic particle field indicator shall be used by positioning the indicator on the forging being examined while applying the required current and ferromagnetic particles. The production of a pattern (usually a cross) of discernible ferromagnetic particles indicates that adequate field strength has been generated in the forging being examined.

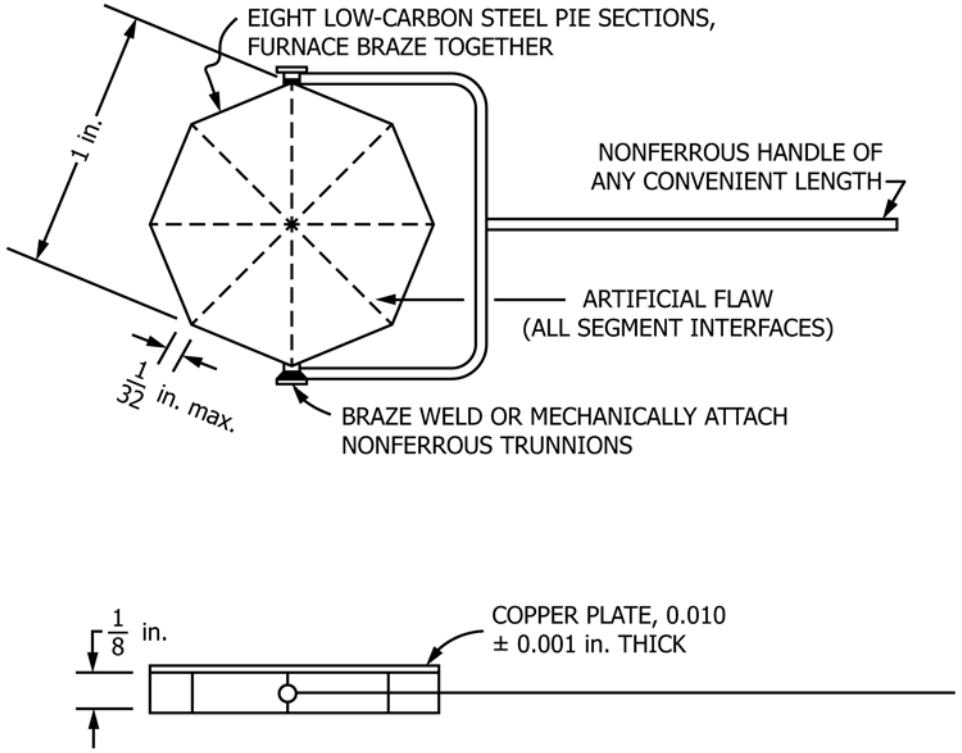

FIG. 8 Magnetic Particle Field Indicator

11.5.7 *Yoke Magnetization*—When electromagnetic yokes are used to magnetize a local area, a longitudinal field is formed between the poles.

11.5.7.1 *Equipment*—Yokes may be of the fixed or articulated leg types.

11.5.7.2 *Yoke Qualification*—Permitted direct-current electromagnetic yokes shall have a lifting power of at least 40 lbf [175 N] at a pole spacing of 3 to 6 in. [75 to 150 mm].

11.5.7.3 *Direction of Magnetization*—At least two separate examinations shall be carried out on each area. In the second examination, the lines of magnetic flux shall be approximately perpendicular to those used for the first examination in that area.

11.5.7.4 *Pole Spacing*—Pole spacing shall be limited to 2 to 8 in. [50 to 200 mm].

11.5.7.5 *Inspection Area*—Inspection area is limited to a maximum distance of one quarter of the pole spacing on either side of a line joining the two poles. Overlapping of pole spacing shall be at least 1 in. [25 mm].

12. Application of Particles

12.1 While the forging is properly magnetized, the particles may be applied by one of the following methods:

12.1.1 *Dry Method*—In the dry method the particles shall be applied from a hand shaker (such as a shaker can), mechanical shaker, bulb blower, or mechanical blower. The use of the shaker shall be limited to flat and nearly horizontal surfaces, whereas the blowers may be used on vertical or overhead surfaces. The powder shall be applied evenly on the surface of the forging. The color of the dry powder should be chosen to provide suitable contrast. Too much powder is disadvantageous as it masks the patterns.

12.1.2 Care shall be exercised in blowing off excess powder so as not to disturb the indications.

12.2 *Wet Methods:*

12.2.1 *Oil*—The material for the wet method is usually supplied in concentrate form, and the inspection medium shall be prepared by mixing the concentrate with a suitable light oil. The liquid recommended for the inspection vehicle is a well refined, light, petroleum distillate having a relatively high flash point. The approximate characteristics of a suitable liquid are as follows:

API gravity, °	46
Viscosity, SUS	31
Flash point (Tag Open Cup), °F [°C]	155 to 175 [65 to 80]
Initial boiling point, °F [°C]	390 [200]
End point, °F [°C]	490 [255]
Color, Saybolt	25

A suspension of from 1 to 2 % solid material by volume shall generally be used. The inspection medium shall be flowed or sprayed over the area being inspected. The color of the particles should be chosen to provide suitable contrast.

12.2.2 *Water*—Magnetic particles suspended in clean water, or clean water with suitable wetting agents may be used. Suspension of from 2 to 2½ % solid material by volume shall generally be used.

12.3 *Fluorescent Method*—Fluorescent magnetic particle inspection is a variation of the wet method. A concentrate, similar to that used in the wet method, shall be used, except

that the magnetic particle shall be coated with material that fluoresces when activated by "black" light.

12.3.1 The same procedure specified when mixing the wet medium shall be followed, except that the suspension shall contain 0.1 to 0.7 % of solid material by volume when petroleum distillate or water is used.

12.3.2 The vehicle shall not be fluorescent.

12.3.3 If fluorescent particles are used, the examination shall be conducted in a darkened area using "black light," and the light intensity shall be at least 1000 μW/cm^2 at a distance of 15 in. from the lamp. The "black light" shall emit ultraviolet radiation of a wavelength within the range from 3300 to 3900 Å. The particles shall emit a brilliant fluorescence when subjected to this light. The bulb shall be allowed to warm up for a minimum of 5 min prior to its use in examination.

13. Demagnetization

13.1 When specified, parts shall be sufficiently demagnetized after inspection so that the residual field will not interfere with future welding or machining operations, magnetic instruments used in the proximity of the part, or so that leakage fields will not occur in areas of dynamic contact surfaces.

13.2 When direct current is used, demagnetizing may usually be accomplished by repeatedly reversing and progressively decreasing the magnetizing current. The initial field strength used during demagnetization shall be equal to or greater than the original magnetizing force. When the current has been reduced to the vanishing point, the part should be practically demagnetized. Direct current is recommended for demagnetizing large parts.

13.3 When alternating current is used, it is necessary merely to decrease the magnetizing current in small steps or continuously to a very low current.

13.4 Demagnetization will not be necessary if the piece is to be subject to an austenitizing treatment prior to future use or machining.

14. Interpretation and Evaluation of Indications

14.1 The following shall not be used as a standard for rejection or acceptance of a part, but may be used as an aid in interpreting and evaluating indications obtained. Examples of discontinuities and reference photographs of magnetic particle indications may be found in Guide E709.

14.2 Factors that must be considered in interpreting an indication as to its cause are as follows:

14.2.1 Appearance of the indication.

14.2.2 Direction and shape of the indication.

14.2.3 Type of material from which the part is made.

14.2.4 Processing history of the part, type of machining, heat treatment, etc.

14.2.5 Past experience with similar parts based on destructive tests such as sectioning, etching, fracturing, chipping, grinding, etc.

14.3 The indications may be grouped into three broad classes:

14.3.1 Surface defects that produce sharp, distinct, clear-cut, tightly adhering patterns. These may generally be interpreted from characteristic indications as follows:

14.3.1.1 *Laminar Defects* give strong indications which are parallel to the surface.

14.3.1.2 *Forging Laps and Folds* are indications that may not be very heavy, and are not straight. They follow metal flow lines.

14.3.1.3 *Flakes* (thermal ruptures caused by entrapped hydrogen) can occur in areas that have been machined away. They are characterized by irregular, scattered indications.

14.3.1.4 *Heat-Treating Crack* indications are strong and occur at corners, notches, and changes of section.

14.3.1.5 *Shrinkage Crack* indications are very strong and sharp, usually continuous with few branches, and occur at changes of section.

14.3.1.6 *Grinding Crack* indications usually occur in groups at right angles to the direction of grinding.

14.3.1.7 *Etching or Plating Cracks* produce strong indications in a direction perpendicular to residual stresses.

14.3.2 Subsurface defects produce less distinct or fuzzy patterns which are broad rather than sharp, and are less tightly held. They generally produce the following characteristic indications:

14.3.2.1 *Stringers of Nonmetallic Inclusions* often have strong indications like surface seams but are usually discontinuous or short and occur in groups. These indications follow the grain flow in forgings. The indications show only when the defects are near the surface.

14.3.2.2 *Large Nonmetallics* produce indications ranging from sharp to diffuse, which may occur anywhere in a section.

14.3.2.3 *Cracks in Underbeads of Welds* produce indications that occur in broad diffuse patterns.

14.3.2.4 *Forging Bursts* produce irregular and diffuse indications.

14.3.3 Nonrelevant or "false" indications are generally confusing but can usually be identified, as follows:

14.3.3.1 *Magnetic Writing* indications are fuzzy and will be destroyed by demagnetization. These indications are caused by contact with other steel or magnets while magnetized.

14.3.3.2 *Changes in Section* are indications that are broad and fuzzy and caused by concentration of magnetic field in gear teeth, fillets, keyways, etc.

14.3.3.3 *Edge of Weld* indications are caused by change of magnetic properties due to diffusion. These indications are not tightly adherent.

14.3.3.4 *Flow Lines* are large groups of parallel indications that occur particularly in forgings examined by means of excessive currents.

14.3.4 Any indication that is believed to be nonrelevant shall be regarded as unacceptable until the indication is either eliminated by surface conditioning or it is reexamined by the same or other nondestructive means and demonstrated to be nonrelevant.

15. Report of Indications

15.1 Record the size, number, and location of all linear indications. Use sketches to show location, direction, and

frequency of indications. The report shall indicate the type of magnetization and location of contacts.

15.1.1 *Permanent Recording of Data:*

15.1.1.1 A permanent record of the indications may be made by carefully covering the surface with transparent, adhesive-backed, cellophane tape. The tape is then removed with the particle indication adhering to it. The tape may then be placed on white paper or cardboard and photographed or otherwise reproduced.

15.1.1.2 If a more accurate reproduction of the indication is desired the following technique may be used. Once an indication has been detected using the normal examining technique, remove the accumulated powder and place a piece of white paper tape with a gloss surface and a gum adhesive backing over the area containing the indication; reapply the current and dust the tape surface with the powder. Immediately the particles will collect over the discontinuity, and with the current still passing through the test piece, spray the tape surface with a thin coating of acrylic lacquer. Terminate the current flow and remove the tape; this will leave an exact replica of the powder buildup adhering to it.

16. Acceptance Standards

16.1 The standards for acceptance of defects detected by magnetic particle examination shall be as specified in the applicable ASTM product specification, contract, or order.

17. Keywords

17.1 circular magnetization; d c magnetization; dry method; fluorescent method; longitudinal magnetization; steel forgings; surface flaw detection; wet method

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A275/A275M–08(2013)) that may impact the use of this standard. (Approved May 1, 2015.)

(1) Added definition of surface finish by reference to Specification A788/A788M in 10.1.