Designation: A 966/A 966M – 08

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

This standard is issued under the fixed designation A 966/A 966M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers a procedure for the magnetic particle examination of steel forgings using alternating current as the power source. The procedure will produce consistent results upon which acceptance standards can be based. This practice does not contain acceptance limits or recommended quality levels.

1.2 Only alternating 50–60 cycle current shall be used as the electric power source for any of the magnetizing methods.

1.3 When subsurface indications are sought in forgings, then dc magnetization in accordance with Practice A 275/A 275M should be used.

1.4 The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Unless the order specifies the applicable "M" specification designation [SI units], the inch-pound units shall be used.

1.5 *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:* [2]

A 275/A 275M Practice for Magnetic Particle Examination of Steel Forgings

A 508/A 508M Specification for Quenched and Tempered Vacuum-Treated Carbon and Alloy Steel Forgings for Pressure Vessels

A 963/A 963M Specification for Deep Drawing Steel (DDS), Sheet, Carbon, Cold-Rolled[3]

2.2 *Other Document:*

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

3. Terminology

3.1 *Definitions:*

3.1.1 *(ac) magnetic particle method of examination*, *n*—a method for detecting discontinuities on the surface in suitably magnetized materials, which employs finely divided magnetic particles that tend to congregate in regions of leakage fields.

3.1.2 *indication*, *n*—the visual magnetic particle buildup resulting from leakage fields in the magnetic field.

3.1.3 *linear indication*, *n*—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. [1.5 mm].

3.1.4 *magnetic flux*, *n*—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.

3.1.4.1 *Discussion*—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.

3.1.5 *nonrelevant indications*, *n*—indications produced by leakage fields where the conditions causing them are present by accident or part design, or other features of the part having no relation to the damaging flaws being sought.

3.1.5.1 *Discussion*—This term signifies that such an indication has no relation to the discontinuities that might constitute defects.

4. Basis of Application

4.1 When in accordance with the requirements of the inquiry, contract, order, or specifications, forgings are to be examined by the magnetic particle method using alternating

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

[3] Withdrawn.

[4] Available from American Society for NonDestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, OH 43228-0518.

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

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current; the manufacturer and the supplier shall be in agreement concerning the following:

4.1.1 The locations on the forging that are to be subjected to magnetic particle examination.

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

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

4.1.4 Acceptance standards.

5. Significance and Use

5.1 For ferromagnetic materials, magnetic particle examination is widely specified for the detection of surface and near-surface flaws such as cracks, laps, seams, and linearly oriented nonmetallic inclusions. Such examinations are included as mandatory requirements in some forging standards such as Specifications A 508/A 508M and A 963/A 963M.

5.2 Use of alternating current as the power source for magnetic particle examination imposes a significant restriction on the detection of subsurface indications, so that the procedure is essentially limited to the finding of flaws that are open to the surface. Attention therefore is drawn to the need to have the component in the finish-machined condition before conducting the magnetic particle examination.

5.3 The presence of residual magnetic fields in a component may be undesirable, and an advantage of the use of an AC power source for magnetic particle examination is that an acceptable level of demagnetization can be readily achieved.

6. Personnel Requirements

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

7. Stage of Examination

7.1 Unless otherwise specified by the purchaser, acceptance examination shall be performed on a forging in the final machined surface condition.

8. Magnetizing Apparatus

8.1 A 50 or 60 cycle alternating current shall be used. When current is passed through the forging 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 alternating current yokes may be used as a magnetizing apparatus.

9. Magnetic Particles

9.1 The inspection medium shall consist of finely divided ferromagnetic particles (which may be coated with a fluorescent material) suspended in a suitable liquid medium or used in dry powder form.

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 examined. While defects may be satisfactorily revealed on shot-blasted or otherwise cleaned forged surfaces, without any further surface treatment, all heat treatment or forging scale must be removed. However, to reveal fine defects of ⅛ in. [3 mm] or less in length, the surfaces to be examined shall be smooth machined to at least a 250-µin. [6.35-µm] finish.

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

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, by coils, or by yoke.

11.1.1 *Continuous Method*—In the continuous method the inspection medium is applied to the surface under examination while the current is still flowing. The alternating 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 The surge and residual methods are not applicable to this practice.

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 magnetization may be used for the second examination. Magnetizing in more than one direction cannot normally be accomplished simultaneously. 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 on the locations of the current connectors. By this technique, indications 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, frequently formed by wrapping cable around the piece (Fig. 1). For special applications, magnetic yokes can be used (Fig. 2).

11.3.2 *Circular*—Circular magnetization is obtained by passing a current through the piece (Fig. 3) or by induced by passing current through a conductor or conductors threaded through an opening in the piece (Fig. 4 or Fig. 5). By agreement with the purchaser (see 11.5.3) localized circular magnetization may be obtained by passing current through local areas by the use of prod-type contacts (Fig. 6).

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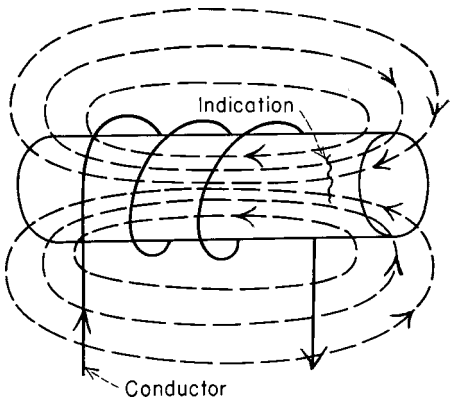

FIG. 1 Longitudinal Magnetization

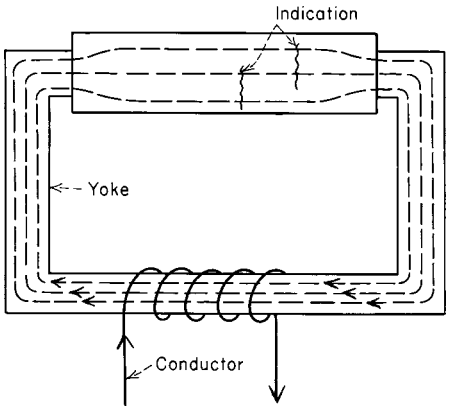

FIG. 2 Longitudinal Magnetization, with Yoke

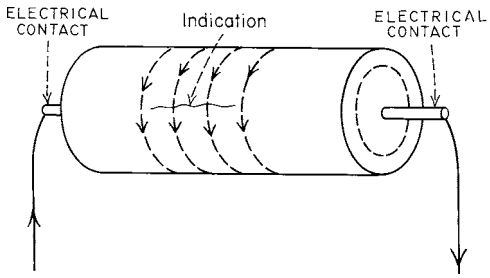

FIG. 3 Circular Magnetization, Current Directly Through Forging

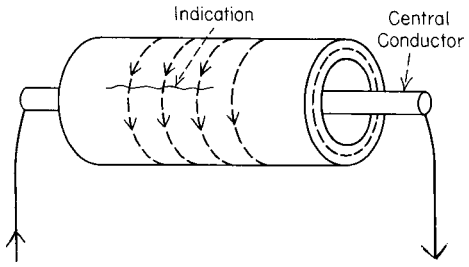

FIG. 4 Circular Magnetization, Current Through a Conductor

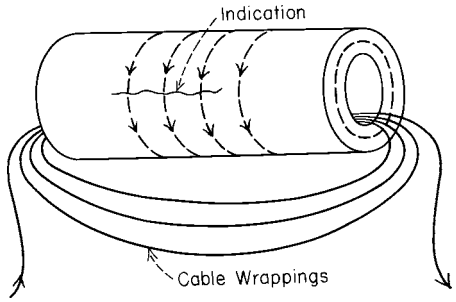

FIG. 5 Circular Magnetization, Current Through Conductors Threaded Through Forging

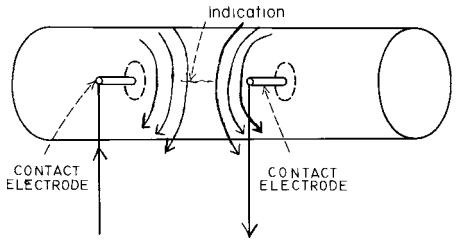

FIG. 6 Circular Magnetization with "Prod" Type Contact Electrodes

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 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 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.

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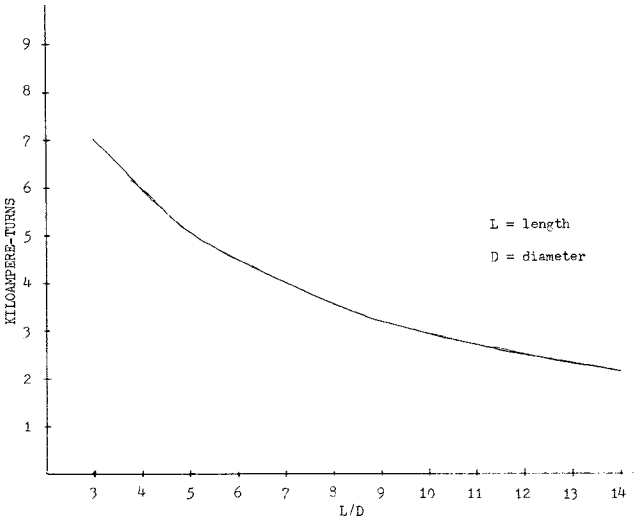

FIG. 7 Longitudinal Magnetization

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 [4 and 35 A per millimetre] per inch 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/inches [25 to 35 A per millimetre]; for diameters or sections between 5 and 10 in. [125 to 250 mm], 400 to 600 A/inches [15 to 25 A per millimetre]; and 100 to 400 A/inches [4 to 15 A per millimetre] for outside diameters or sections over 10 in. [250 mm]. If it is not practical 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*—Since this method may induce arcing or burning at the contact areas, and the inspection is intended to be performed on finished surfaces, the use of prod magnetization is not permissible without the prior approval of the purchaser. For the same reason magnetic leaches may not be used to introduce current into the part without the prior approval of the purchaser. If the use of prods or magnetic leaches should be permitted, then the following conditions shall apply:

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 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 ensure 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 forgings may be accomplished by the use of a central conductor as shown in Fig. 4. The recommended current level is 100 to 125 A per inch [4 to 5 A per millimetre] of bore diameter. Alternatively a field indicator may be used to establish the adequacy of the magnetic field (see 11.5.6).

11.5.5 An ammeter shall be used to measure the specified or agreed upon current.

11.5.6 A magnetic particle field indicator as shown in Fig. 8 shall be used to establish the 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 it copper side up on the surface of the forging being examined, while applying the magnetizing current and the particles used in the examination. Suitable magnetic field strength is indicated when the field indicator lines at 45° and 90° to the applied magnetic field are outlined by magnetic particles.

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

11.5.7.1 *Equipment*—Alternating current yokes may be of the fixed or articulated leg types.

11.5.7.2 *Yoke Qualification*—Alternating current electromagnetic yokes shall have a minimum lifting power of 10 lbf [45 N] at a pole spacing of 6 in. [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 a maximum of 6 in. [150 mm].

11.5.7.5 *Examination Area*—The examination area shall be limited to a maximum distance of ¼ of the pole spacing on either side of a line joining the two poles. Overlapping of pole spacing shall be a minimum of 1 in. [25 mm].

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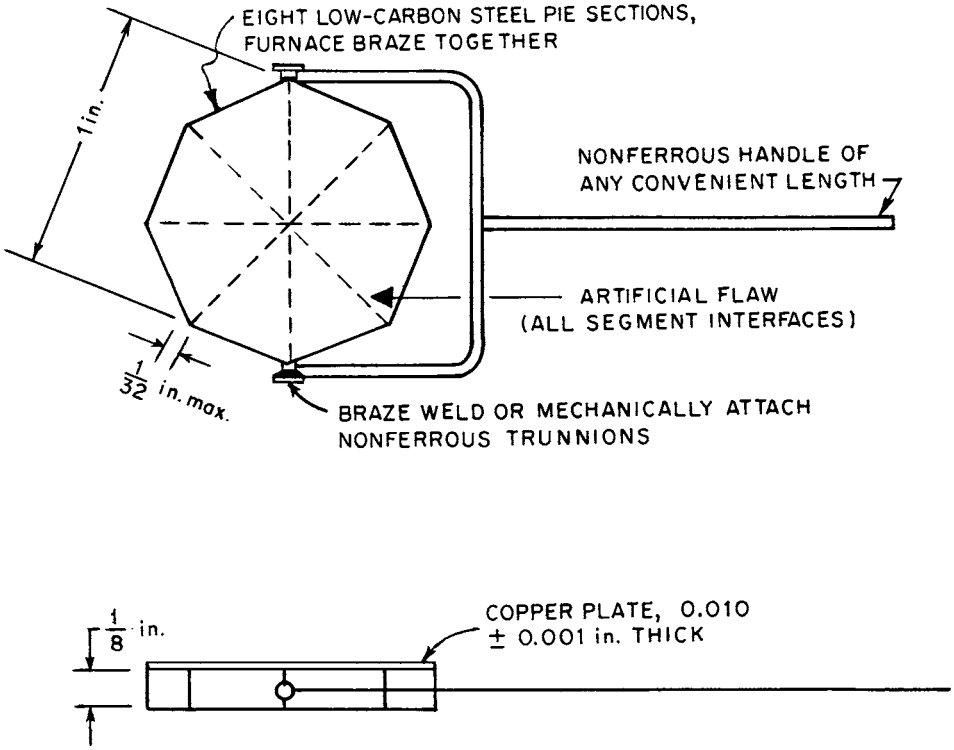

FIG. 8 Magnetic Particle Field Indicator

12. Application of Particles

12.1 *Visible Light*—Except for the fluorescent method, the intensity of the visible light at the surface of the part under examination shall be maintained at a minimum of 100 fc [1000 lux].

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

12.2.1 *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.

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

12.3 *Wet Methods*:

12.3.1 *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.

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

12.4 *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.

12.4.1 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.

12.4.2 The vehicle shall not be fluorescent.

12.4.3 When fluorescent particles are used, the examination shall be conducted in a darkened area where the maximum white light permitted shall be 2 fc. Black light shall be used, and the light intensity at the examination surface, 15 in. [375 mm] from the face of the light source lens filter shall be not less than 1000 μw/cm^2 when measured with a suitable black light meter.

12.4.4 The black light shall emit ultraviolet radiation of a wavelength within the range from 3300 to 3900 Å. The particles shall emit a bright 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.

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13. Demagnetization

13.1 Unless otherwise specified parts shall be sufficiently demagnetized after examination so that the residual field will not interfere with subsequent machining or welding operations or the intended use of the part, or that leakage fields will not occur in areas of dynamic contact surfaces.

13.2 Demagnetization may be accomplished by decreasing the magnetizing current in small steps, or continuously to a very low value. Alternatively the part may be withdrawn slowly from the magnetizing field. Demagnetization shall be verified by the use of a suitable magnetic field indicator.

14. Interpretation and Evaluation of Indications

14.1 Practice A 275/A 275M describes in some detail the interpretation and evaluation of magnetic particle indications.

15. Report of Indications

15.1 Based on the agreement between manufacturer and purchaser, or on the acceptance criteria of an applicable material specification, the size, number, and location of all ratable indications shall be recorded in the inspection report, using sketches if necessary. Methods for the permanent recording of magnetic particle indications are included in Practice A 275/A 275M.

16. Acceptance Standards

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

17. Keywords

17.1 ac magnetization; circular magnetization; dry method; ferritic steel forgings; fluorescent method; longitudinal magnetization; surface flaw detection; wet method

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A 966/A 966M – 07) that may impact the use of this standard. (Approved March 1, 2008.)

(*1*) Added Significance and Use section (Section 5).

Committee A01 has identified the location of selected changes to this standard since the last issue (A 966/A 966M – 96 (2006)) that may impact the use of this standard. (Approved May 1, 2007.)

(*1*) Changed from Test Method to Practice.

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