01

ARTICLE 7

Figures

Mandatory Appendices

ARTICLE 7
MAGNETIC PARTICLE EXAMINATION

T-710 SCOPE

When specified by the referencing Code Section, the magnetic particle examination techniques described in this Article shall be used. In general, this Article is in conformance with SE-709, Standard Guide for Magnetic Particle Examination. This document provides details to be considered in the procedures used.

When this Article is specified by a referencing Code Section, the magnetic particle method described in this Article shall be used together with Article 1, General Requirements. Definition of terms used in this Article are in Mandatory Appendix II.

T-720 GENERAL

The magnetic particle examination method may be applied to detect cracks and other discontinuities on or near the surfaces of ferromagnetic materials. The sensitivity is greatest for surface discontinuities and diminishes rapidly with increasing depth of subsurface discontinuities below the surface. Typical types of discontinuities that can be detected by this method are cracks, laps, seams, cold shuts, and laminations.

In principle, this method involves magnetizing an area to be examined, and applying ferromagnetic particles (the examinations medium) to the surface. The particles will form patterns on the surface where cracks and other discontinuities cause distortions in the normal magnetic field. These patterns are usually characteristic of the type of discontinuity that is detected.

Whichever technique is used to produce the magnetic flux in the part, maximum sensitivity will be to linear discontinuities oriented perpendicular to the lines of flux. For optimum effectiveness in detecting all types of discontinuities, each area should be examined at least twice, with the lines of flux during one examination approximately perpendicular to the lines of flux during the other.

T-730 EQUIPMENT

A suitable and appropriate means for producing the necessary magnetic flux in the part shall be employed, using one or more of the techniques listed in T-752 and described in T-770.

T-731 Examination Medium

The finely divided ferromagnetic particles used for the examination shall meet the following requirements.

(a) Particle Types. The particles shall be treated to impart color (fluorescent pigments, nonfluorescent pigments, or both) in order to make them highly visible (contrasting) against the background of the surface being examined.

(b) Particles. Dry and wet particles, including wet particle suspension vehicles, and particle concentrations shall be in accordance with SE-709.

(c) Temperature Limitations. Particles shall be used within the temperature range limitations set by the manufacturer. Alternatively, particles may be used outside the manufacturer's recommendations providing the procedure is qualified in accordance with Article 1, T-150.

T-740 REQUIREMENTS

T-741 Surface Conditioning

T-741.1 Preparation

(a) Satisfactory results are usually obtained when the surfaces are in the as-welded, as-rolled, as-cast, or as-forged conditions. However, surface preparation by grinding or machining may be necessary where surface irregularities could mask indications due to discontinuities.

(b) Prior to magnetic particle examination, the surface to be examined and all adjacent areas within at least 1 in. (25 mm) shall be dry and free of all dirt, grease, lint, scale, welding flux and spatter, oil, or

other extraneous matter that could interfere with the examination.

(c) Cleaning may be accomplished using detergents, organic solvents, descaling solutions, paint removers, vapor degreasing, sand or grit blasting, or ultrasonic cleaning methods.

(d) If coatings are left on the part in the area being examined, it must be demonstrated that indications can be detected through the existing maximum coating thickness applied. When AC yoke technique is used, the demonstration must be in accordance with Mandatory Appendix I of this Article.

T-741.2 Surface Contrast Enhancement. When coatings are applied temporarily to uncoated surfaces only in amounts sufficient to enhance particle contrast, it must be demonstrated that indications can be detected through the enhancement coating.

NOTE: Refer to T-150(a) for guidance for the demonstration required in T-741.1(d) and T-741.2.

01 T-750 PROCEDURE REQUIREMENTS

Magnetic particle examination shall be performed in accordance with a written procedure.

Each procedure shall include at least the following information, as applicable:

(a) the materials, shapes, or sizes to be examined, and the extent of the examination;

(b) magnetization techniques to be used;

(c) equipment to be used for magnetization;

(d) surface preparation (finishing and cleaning);

(e) type of ferromagnetic particles to be used: manufacturer, color, wet or dry, etc.;

(f) maximum allowable temperature for ferromagnetic particles to be used: per manufacturer recommendation or by qualification;

(g) magnetization currents (type and amperage);

(h) demagnetization;

(i) post-examination cleaning.

T-751 Method of Examination

Examination shall be done by the continuous method; that is, the magnetizing current remains on while the examination medium is being applied and while excess of the examination medium is being removed.

T-752 Techniques and Materials

The ferromagnetic particles used as an examination medium shall be either wet or dry, and may be either fluorescent or nonfluorescent.

One or more of the following five magnetization techniques shall be used:

(a) prod technique;

(b) longitudinal magnetization technique;

(c) circular magnetization technique;

(d) yoke technique;

(e) multidirectional magnetization technique.

T-753 Magnetizing Field Adequacy and Direction

T-753.1 Magnetic Field Adequacy. The applied magnetic field shall have sufficient strength to produce satisfactory indications, but it shall not be so strong that it causes the masking of relevant indications by nonrelevant accumulations of magnetic particles. Factors that influence the required field strength include the size, shape, and material permeability of the part; the technique of magnetization; coatings; the method of particle application; and the type and location of discontinuities to be detected. When it is necessary to verify the adequacy of magnetic field strength, it shall be verified by using one or more of the following three methods.

T-753.1.1 Pie-Shaped Magnetic Particle Field Indicator. The indicator, shown in Fig. T-753.1.1, shall be positioned on the surface to be examined, such that the copper-plated side is away from the inspected surface. A suitable field strength is indicated when a clearly defined line (or lines) of magnetic particles form(s) across the copper face of the indicator when the magnetic particles are applied simultaneously with the magnetizing force. When a clearly defined line of particles is not formed, the magnetizing technique shall be changed as needed. Pie-type indicators are best used with dry particle procedures.

T-753.1.2 Artificial Flaw Shims. The shim, shown in Fig. T-753.1.2, shall be attached to the surface to be examined, such that the artificial flaw side of the shim is toward the inspected surface. A suitable field strength is indicated when a clearly defined line (or lines) of magnetic particles, representing the 30% depth flaw, appear(s) on the shim face when magnetic particles are applied simultaneously with the magnetizing force. When a clearly defined line of particles is not formed, the magnetizing technique shall be changed as needed.

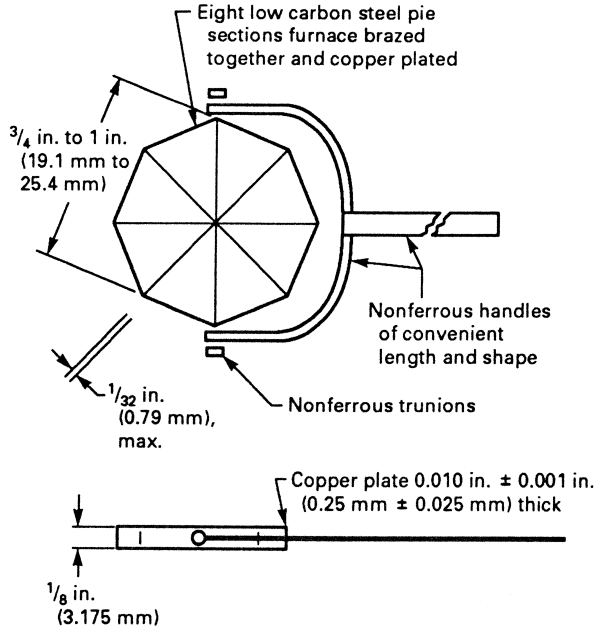
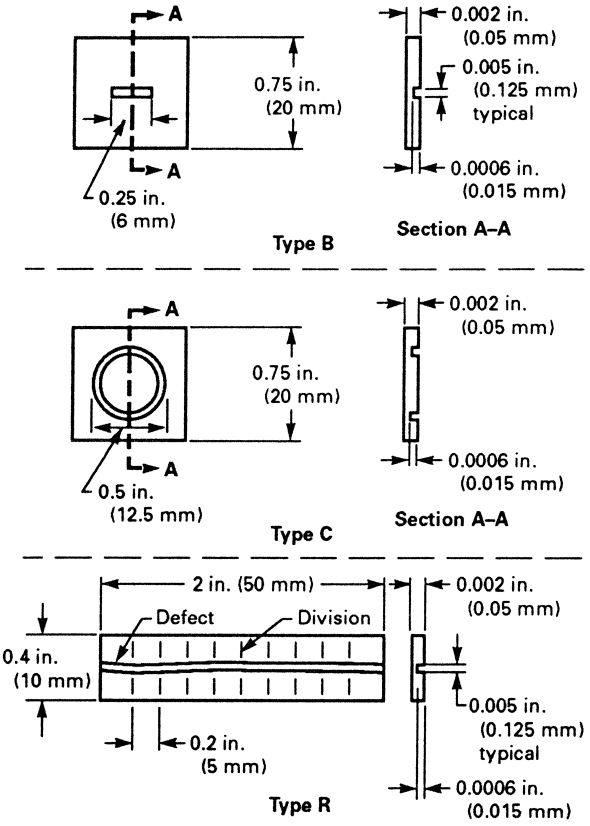


FIG. T-753.1.1 PIE-SHAPED MAGNETIC PARTICLE FIELD INDICATOR



GENERAL NOTE:
Above are examples of artificial flaw 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.

FIG. T-753.1.2 ARTIFICIAL FLAW SHIMS

Shim-type indicators are best used with wet particle procedures.

T-753.1.3 Hall-Effect Tangential-Field Probe. A gaussmeter and Hall-Effect tangential-field probe shall be used for measuring the peak value of a tangential field. The probe shall be positioned on the surface to be examined, such that the maximum field strength is determined. A suitable field strength is indicated when the measured field is within the range of 30 G to 60 G (2.4 kAm^{-1} to 4.8 kAm^{-1}) while the magnetizing force is being applied. See Article 7, Nonmandatory Appendix A.

T-753.2 Magnetic Field Direction. The direction of magnetization shall be determined by particle indications obtained using an indicator or shims as shown in Fig. T-753.1.1 or Fig. T-753.1.2. When a clearly defined line of particles is not formed in the desired direction, the magnetizing technique shall be changed as needed.

T-753.2.1 For multidirectional magnetization techniques, the orientation of the lines of flux shall be in at least two nearly perpendicular directions. When clearly defined lines of particles are not formed in at least two nearly perpendicular directions, the magnetizing technique shall be changed as needed.

T-753.3 Determination of the adequacy and direction of magnetizing fields using magnetic field indicators or artificial flaws are only permitted when specifically referenced by the magnetizing technique in T-774.2(c), T-774.2(d), T-775.1(b)(3), T-775.2(a), T-775.2(b), and T-777.2.

T-754 Rectified Current

(a) Whenever direct current is required rectified current may be used. The rectified current for magnetization shall be either three-phase (full-wave rectified) current, or single phase (half-wave rectified) current.

(b) The amperage required with three-phase, full-wave rectified current shall be verified by measuring the average current.

(c) The amperage required with single-phase (half-wave rectified) current shall be verified by measuring the average current output during the conducting half cycle only.

(d) When measuring half-wave rectified current with a direct current test meter, readings shall be multiplied by two.

T-755 Demagnetization

When residual magnetism in the part could interfere with subsequent processing or usage, the part shall be demagnetized any time after completion of the examination.

T-756 Post-examination Cleaning

When postexamination cleaning is required by the procedure, it should be conducted as soon as practical using a process that does not adversely affect the part.

T-760 CALIBRATION OF EQUIPMENT

T-761 Frequency of Calibration

(a) Frequency. Each piece of magnetizing equipment with an ammeter shall be calibrated at least once a year, or whenever the equipment has been subjected to major electric repair, periodic overhaul, or damage. If equipment has not been in use for a year or more, calibration shall be done prior to first use.

(b) Procedure. The accuracy of the unit's meter shall be verified annually by equipment traceable to a national standard. Comparative readings shall be taken for at least three different current output levels encompassing the usable range.

(c) Tolerance. The unit's meter reading shall not deviate by more than ±10% of full scale, relative to the actual current value as shown by the test meter.

T-762 Lifting Power of Yokes

(a) Prior to use, the magnetizing power of electromagnetic yokes shall have been checked within the past year. The magnetizing power of permanent magnetic yokes shall be checked daily prior to use. The magnetizing power of all yokes shall be checked whenever the yoke has been damaged or repaired.

(b) Each alternating current electromagnetic yoke shall have a lifting power of at least 10 lb (4.5 kg) at the maximum pole spacing that will be used.

(c) Each direct current or permanent magnetic yoke shall have a lifting power of at least 40 lb (18.1 kg) at the maximum pole spacing that will be used.

(d) Each weight shall be weighed with a scale from a reputable manufacturer and stenciled with the applicable nominal weight prior to first use. A weight need only be verified again if damaged in a manner that could have caused potential loss of material.

T-763 Gaussmeters

Hall-Effect probe gaussmeters used to verify magnetizing field strength in accordance with T-753 shall be calibrated at least once a year or whenever the equipment has been subjected to a major repair, periodic overhaul, or damage. If equipment has not been in use for a year or more, calibration shall be done prior to first use.

T-770 EXAMINATION

T-771 Direction of Magnetization

At least two separate examinations shall be performed on each area. During the second examination, the lines of magnetic flux shall be approximately perpendicular to those used during the first examination. A different technique for magnetization may be used for the second examination.

T-772 Examination Coverage

All examinations shall be conducted with sufficient field overlap to ensure 100% coverage at the required sensitivity (T-753).

T-773 Prod Technique

T-773.1 Magnetizing Procedure. For the prod technique, magnetization is accomplished by portable prod type electrical contacts pressed against the surface in the area to be examined. To avoid arcing, 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.

T-773.2 Magnetizing Current. Direct or rectified magnetizing current shall be used. The current shall be 100 (minimum) amp/in. (3.9 amp/mm) to 125 (maximum) amp/in. (4.9 amp/mm) of prod spacing for sections $^{3}/_{4}$ in. (19 mm) thick or greater. For sections

less than $^{3}/_{4}$ in. (19 mm) thick, the current shall be 90 amp/in. (3.5 amp/mm) to 110 amp/in. (4.3 amp/mm) of prod spacing.

T-773.3 Prod Spacing. Prod spacing shall not exceed 8 in. (203 mm). Shorter spacing may be used to accommodate the geometric limitations of the area being examined or to increase the sensitivity, but prod spacings of less than 3 in. (76 mm) are usually not practical due to banding of the particles around the prods. The prod tips shall be kept clean and dressed. If the open circuit voltage of the magnetizing current source is greater than 25 V, lead, steel, or aluminum (rather than copper) tipped prods are recommended to avoid copper deposits on the part being examined.

T-774 Longitudinal Magnetization Technique

T-774.1 Magnetizing Procedure. For this technique, magnetization is accomplished by passing current through a multi-turn fixed coil (or cables) that is wrapped around the part or section of the part to be examined. This produces a *longitudinal* magnetic field parallel to the axis of the coil.

If a fixed, prewound coil is used, the part shall be placed near the side of the coil during inspection. This is of special importance when the coil opening is more than 10 times the cross-sectional area of the part.

T-774.2 Magnetic Field Strength. Direct or rectified current shall be used to magnetize parts examined by this technique. The required field strength shall be calculated based on the length L and the diameter D of the part in accordance with (a), (b), or as established in (c), below. Long parts shall be examined in sections not to exceed 18 in. (457 mm), and 18 in. (457 mm) shall be used for the part L in calculating the required field strength. For noncylindrical parts, D shall be the maximum cross-sectional diagonal.

(a) Parts With L/D Ratios Equal to or Greater Than 4. The magnetizing current shall be within ±10% of the ampere-turns' value determined as follows:

$$\text{Ampere-turns} = \frac{35{,}000}{(L/D) + 2}$$

For example, a part 10 in. long × 2 in. diameter has an L/D ratio of 5. Therefore,

$$\frac{35{,}000}{(5 + 2)} = 5000 \text{ ampere-turns}$$

(b) Parts With L/D Ratios Less Than 4 but Not Less Than 2. The magnetizing ampere-turns shall be within ±10% of the ampere-turns' value determined as follows:

$$\text{Ampere-turns} = \frac{45{,}000}{L/D}$$

(c) If the area to be magnetized extends beyond 6 in. on either side of the coils, field adequacy shall be demonstrated using the magnetic field indicator per T-753.

(d) For large parts due to size and shape, the magnetizing current shall be 1200 ampere-turns to 4500 ampere-turns. The field adequacy shall be demonstrated using artificial flaw shims or a pie-shaped magnetic field indicator in accordance with T-753. A Hall-Effect probe gaussmeter shall not be used with encircling coil magnetization techniques.

T-774.3 Magnetizing Current. The current required to obtain the necessary magnetizing field strength shall be determined by dividing the ampere-turns obtained in steps (a) or (b) above by the number of turns in the coil as follows:

$$\text{Amperes (meter reading)} = \frac{\text{ampere-turns}}{\text{turns}}$$

For example, if a 5-turn coil is used and the ampere-turns required are 5000, use

$$\frac{5000}{5} = 1000 \text{ amperes } (\pm 10\%)$$

T-775 Circular Magnetization Technique

T-775.1 Direct Contact Technique

(a) Magnetizing Procedure. For this technique, magnetization is accomplished by passing current through the part to be examined. This produces a *circular* magnetic field that is approximately perpendicular to the direction of current flow in the part.

(b) Magnetizing Current. Direct or rectified (half-wave rectified or full-wave rectified) magnetizing current shall be used.

(1) The current shall be 300 amp/in. (12A/mm) to 800 amp/in. (31A/mm) of outer diameter.

(2) Parts with geometric shapes other than round with the greatest cross-sectional diagonal in a plane at right angles to the current flow shall determine the inches to be used in (b)(1) above.

(3) If the current levels required for (b)(1) cannot be obtained, the maximum current obtainable shall be

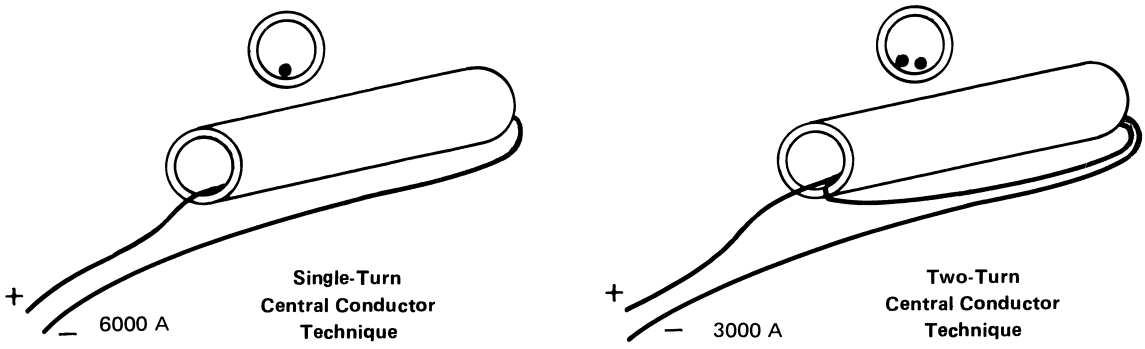


FIG. T-775.2 SINGLE-TURN AND TWO-TURN CENTRAL CONDUCTOR TECHNIQUE

used and the field adequacy shall be demonstrated in accordance with T-753.

T-775.2 Central Conductor Technique

(a) Magnetizing Procedure. For this technique, a central conductor is used to examine the internal surfaces of cylindrically or ring-shaped parts. The central conductor technique may also be used for examining the outside surfaces of these shapes. Where large diameter cylinders are to be examined, the conductor shall be positioned close to the internal surface of the cylinder. When the conductor is not centered, the circumference of the cylinder shall be examined in increments. Field strength measurements in accordance with T-753 shall be used to determine the extent of the arc that may be examined for each conductor position. Bars or cables, passed through the bore of a cylinder, may be used to induce circular magnetization.

(b) Magnetizing Current. The field strength required shall be equal to that determined in T-775.1(b) for a single-turn central conductor. The magnetic field will increase in proportion to the number of times the central conductor cable passes through a hollow part. For example, if 6000 amperes are required to examine a part using a single central conductor, then 3000 amperes are required when 2 turns of the through-cable are used, and 1200 amperes are required if 5 turns are used (see Fig. T-775.2). When the central conductor technique is used, magnetic field adequacy shall be verified using a magnetic particle field indicator in accordance with T-753.

T-776 Yoke Technique

T-776.1 Application. This method shall only be applied to detect discontinuities that are open to the surface of the part.

T-776.2 Magnetizing Procedure. For this technique alternating or direct current electromagnetic yokes, or permanent magnet yokes, shall be used.

NOTE: Except for materials $\frac{1}{4}$ in. (6 mm) or less in thickness, alternating current yokes are superior to direct or permanent magnet yokes of equal lifting power for the detection of surface discontinuities.

T-777 Multidirectional Magnetization Technique

T-777.1 Magnetizing Procedure. For this technique magnetization is accomplished by high amperage power packs operating as many as three circuits that are energized one at a time in rapid succession. The effect of these rapidly alternating magnetizing currents is to produce an overall magnetization of the part in multiple directions. Circular or longitudinal magnetic fields may be generated in any combination using the various techniques described in T-774 and T-775.

T-777.2 Magnetic Field Strength. Only three phase, full-wave rectified current shall be used to magnetize the part. The initial magnetizing current requirements for each circuit shall be established using the previously described guidelines (see T-774 and T-775). The adequacy of the magnetic field shall be demonstrated using artificial flaw shims or a pie-shaped magnetic particle field indicator in accordance with T-753. A Hall-Effect probe gaussmeter shall not be used to measure field adequacy for the multidirectional magnetization technique. An adequate field shall be obtained in at least two nearly perpendicular directions, and the field intensities shall be balanced so that a strong field in one direction does not overwhelm the field in the other direction. For areas where adequate field strengths cannot be demonstrated, additional magnetic particle

techniques shall be used to obtain the required two-directional coverage.

T-778 Interpretation

01 **T-778.1 Nonfluorescent Particles.** With nonfluorescent particles, the examination is performed using visible light. A minimum light intensity of 100 fc (1000 Lx) is required to ensure adequate sensitivity during the examination and evaluation of indications. The light source, technique used, and light level verification is required to be demonstrated one time, documented, and maintained on file.

T-778.2 Fluorescent Particles. With fluorescent particles the examination is performed using an ultraviolet light, called *black light.* The examination shall be performed as follows:

(a) It shall be performed in a darkened area.

(b) The examiner shall be in the darkened area for at least 5 min prior to performing the examination to enable his eyes to adapt to dark viewing. If the examiner wears glasses or lenses, they shall not be photosensitive.

(c) The black light shall be allowed to warm up for a minimum of 5 min prior to use or measurement of the intensity of the ultraviolet light emitted.

(d) The black light intensity shall be measured with a black light meter. A minimum of 1000 $\mu W/cm^2$ on the surface of the part being examined shall be required. The black light intensity shall be measured at least once every 8 hr, and whenever the work station is changed.

T-780 EVALUATION

(a) All indications shall be evaluated in terms of the acceptance standards of the referencing Code Section.

(b) Discontinuities on or near the surface are indicated by retention of the examination medium. However, localized surface irregularities due to machining marks or other surface conditions may produce false indications.

(c) Broad areas of particle accumulation, which might mask indications from discontinuities, are prohibited, and such areas shall be cleaned and re-examined.

T-790 RECORDS

T-791 Multidirectional Magnetization Technique Sketch

A technique sketch shall be prepared for each different geometry examined, showing the part geometry, cable arrangement and connections, magnetizing current for each circuit, and the areas of examination where adequate field strengths are obtained. Parts with repetitive geometries, but different dimensions, may be examined using a single sketch provided that the magnetic field strength is adequate when demonstrated in accordance with T-777.2.

ARTICLE 7
MANDATORY APPENDICES

APPENDIX I — MAGNETIC PARTICLE EXAMINATION ON COATED FERRITIC MATERIALS USING THE AC YOKE TECHNIQUE

I-710 SCOPE

This Appendix provides the Magnetic Particle examination methodology and equipment requirements applicable for performing Magnetic Particle examination on coated ferritic materials.

I-720 GENERAL

I-721 Personnel Qualification

Personnel qualification requirements shall be in accordance with the referencing Code Section.

I-730 EQUIPMENT

I-730.1 The magnetizing equipment shall be in accordance with Article 7.

I-730.2 When the dry powder technique is used, a powder blower shall be utilized for powder application. Hand squeezed particle applicators shall not be used when the dry powder technique is utilized.

I-730.3 Magnetic particles shall contrast with the component background.

I-730.4 Nonconductive materials such as plastic shim stock may be used to simulate nonconductive coatings for procedure and personnel qualification.

I-750 PROCEDURE/TECHNIQUE

I-750.1 Procedure

Magnetic particle examination shall be performed in accordance with a written procedure. The procedure shall include the following:

(a) identification of surface configurations to be examined, including coating materials, maximum qualified coating thickness, and product forms (e.g., base material or welded surface)

(b) surface condition requirements and preparation methods

(c) manufacturer and model of AC yoke

(d) manufacturer and type of magnetic particles

(e) minimum and maximum yoke leg separation

(f) method of measuring coating thickness

(g) identification of the steps in performing the examination

(h) minimum lighting and AC yoke lifting power requirements (as measured in accordance with Procedure Qualification I-752)

(i) methods of identifying flaw indications and discriminating between flaw indications and nonrelevant indications (e.g., magnetic writing or particle held by surface irregularities)

(j) instructions for identification and confirmation of suspected flaw indications

(k) recording criteria

(l) personnel qualification requirements

(m) reference to the procedure qualification records

(n) method of verifying that the yoke lifting power and the illumination source used in the production examination are at least as great as specified.

I-751 Coating Thickness Measurement

The procedure demonstration and performance of examinations shall be preceded by measurement of the coating thickness in the areas to be examined. If the coating is nonconductive, an eddy current technique may be used to measure the coating thickness. If the coating is conductive, a magnetic coating thickness technique shall be used in accordance with ASTM D 1186. Coating measurement equipment shall be used in accordance with the equipment manufacturer's instructions. Coating thickness measurements shall be taken at the intersections of a 2 in. (51 mm) maximum

grid pattern over the area of examination and at least one-half the maximum yoke leg separation beyond the examination area. The thickness shall be the mean of three separate readings within $\frac{1}{4}$ in. (6 mm) of each intersection.

I-752 Procedure Demonstration

The procedure shall be demonstrated to the satisfaction of the Inspector in accordance with the requirements of the referencing Code Section.

I-753 Procedure Qualification

(a) A qualification specimen is required. The specimen shall be of similar geometry or weld profile and contain at least one surface crack no longer than the maximum flaw size allowed in the applicable acceptance criteria. The material used for the specimen shall be the same specification and heat treatment as the coated ferromagnetic material to be examined. As an alternative to the material requirement, other materials and heat treatments may be qualified provided:

(1) The measured yoke maximum lifting force on the material to be examined is equal to or greater than the maximum lifting force on the qualification specimen material. Both values shall be determined with the same or comparable equipment and shall be documented as required in paragraph (c).

(2) All the requirements of paragraphs *(b)* through *(g)* are met for the alternate material.

(b) Examine the uncoated specimen in the most unfavorable orientation expected during the performance of the production examination.

(c) Document the measured yoke maximum lifting power, illumination levels, and the results.

(d) Measure the maximum coating thickness on the item to be examined in accordance with the requirements of I-751.

(e) Coat the specimen with the same type of coating, conductive or nonconductive, to the maximum thickness measured on the production item to be examined. Alternately, nonconductive shim stock may be used to simulate nonconductive coatings.

(f) Examine the coated specimen in the most unfavorable orientation expected during the performance of the production examination. Document the measured yoke maximum lifting power, illumination level, and examination results.

(g) Compare the length of the indication resulting from the longest flaw no longer than the maximum flaw size allowed by the applicable acceptance criteria, before and after coating. The coating thickness is qualified when the length of the indication on the coated surface is at least 50% of the length of the corresponding indication prior to coating.

(h) Requalification of the procedure is required for a decrease in either the AC yoke lifting power or the illumination level, or for an increase in the coating thickness.

I-770 EXAMINATION

(a) Surfaces to be examined, and all adjacent areas within at least 1 in. (25 mm), shall be free of all dirt, grease, lint, scale, welding flux and spatter, oil, and loose, blistered, flaking, or peeling coating.

(b) Examine the coated item in accordance with the qualified procedure.

I-780 EVALUATION

If an indication greater than 50% of the maximum allowable flaw size is detected, the coating in the area of the indication shall be removed and the examination repeated.

I-790 DOCUMENTATION/RECORDS

Procedure qualification documentation shall include the following:

(a) identification of the procedure

(b) identification of the personnel performing and witnessing the qualification

(c) description and drawings or sketches of the qualification specimen, including coating thickness measurements and flaw dimensions

(d) equipment and materials used

(e) illumination level and yoke lifting power

(f) qualification results, including maximum coating thickness and flaws detected.

APPENDIX II — GLOSSARY OF TERMS FOR MAGNETIC PARTICLE EXAMINATION

II-710 SCOPE

This Mandatory Appendix is used for the purpose of establishing standard terms and definition of terms

which appear in Article 7, Magnetic Particle Examination.

II-720 GENERAL REQUIREMENTS

(a) The Standard Terminology for Nondestructive Examinations (ASTM E 1316) has been adopted by the Committee as SE-1316.

(b) SE-1316 Section 10 provides the definitions of terms listed in II-730(a).

(c) For general terms, such as *Indication, Flaw, Discontinuity, Evaluation*, etc., refer to Article 1, Mandatory Appendix I.

(d) Paragraph II-730(b) provides a list of terms and definitions, which are in addition to SE-1316 and are Code specific.

II-730 REQUIREMENTS

(a) The following SE-1316 terms are used in conjunction with this Article: ampere turns, black light, central conductor, circular magnetization, demagnetization, dry powder, full-wave direct current, half-wave current, longitudinal magnetization, magnetic field, magnetic field strength, magnetic particle examination, magnetic particle field indicator, magnetic particles, multidirectional magnetization, permanent magnet, prods, sensitivity, suspension, yoke.

(b) The following Code terms are used in conjunction with this Article:

black light intensity — a quantitative expression of ultraviolet irradiance

magnetic flux — 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. The strength of the field is defined by the number of flux lines crossing a unit area taken at right angles to the direction of the lines.

rectified magnetic current — by means of a device called a rectifier, which permits current to flow in one direction only, alternating current can be converted to unidirectional current. This differs from direct current in that the current value varies from a steady level. This variation may be extreme, as in the case of the half-wave rectified single phase AC, or slight, as in the case of three-phase rectified AC.

half-wave rectified current AC — when a single-phase alternating current is rectified in the simplest manner, the reverse of the cycle is blocked out entirely. The result is a pulsating unidirectional current with intervals when no current at all is flowing. This is often referred to as “half-wave” or pulsating direct current.

full-wave rectified current — when the reverse half of the cycle is turned around to flow in the same direction as the forward half. The result is full-wave rectified current. Three-phase alternating current when full-wave rectified is unidirectional with very little pulsation; only a ripple of varying voltage distinguishes it from straight DC single-phase, full rectified current is usually not employed for magnetic particle examination.

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ARTICLE 7 — APPENDIX III
MAGNETIC FLUX LEAKAGE (MFL) EXAMINATION

III-710 SCOPE

This Appendix describes the Magnetic Flux Leakage (MFL) examination method equipment requirements applicable for performing MFL examinations on coated and uncoated ferromagnetic materials from one surface. MFL is generally used as a post construction examination method to evaluate the condition of plate materials, such as storage tank floors and piping for corrosion or other forms of degradation. Other imperfections that may be detected are cracks, seams, dents, laps, and nonmetallic inclusions, etc.

III-711 References

When the Magnetic Flux Leakage method of Article 7, Appendix III is specified by a referencing Code Section, the MFL method shall be used together with Article 1, General Requirements.

III-720 GENERAL

III-721 Personnel Qualification Requirements

The user of this Appendix shall be responsible for documented training, qualification, and certification of personnel performing MFL examination. Personnel performing supplemental examinations, such as ultrasonic (UT) examinations, shall be qualified in accordance with the referencing Code Section.

III-722 Equipment Qualification Requirements

The equipment operation shall be demonstrated by successfully completing the unit verification and function tests outlined as follows:

(a) Reference Plate. All MFL examinations shall have a reference plate to ensure the equipment is performing in accordance with the manufacturer's specifications, prior to use. The reference plate shall consist of a plate that is made from a material of the same nomial thickness, product form, and composition as the component to be examined. The plate shall have notches, drilled holes, or other discontinuities machined into the bottom side of the plate, as shown in Figure III-722. The depths and widths of artificial discontinuities should be similar to the sizes and physical characteristics of discontinuities to be detected. If coatings or temporary coverings will be present during the examination, the reference plate shall be coated or covered with the coatings or covers representative of the maximum thickness that will be encountered during the examination.

(b) System Verification and Function Checks. The manufacturer's verification procedure shall be conducted initially to ensure that the system is functioning as designed. The functional check shall be made by scanning the reference plate over the range of scanning speeds to be utilized during the examination. Equipment settings shall be documented.

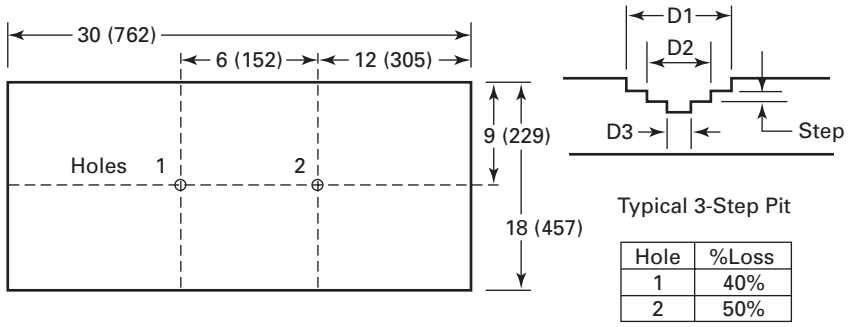
(c) Performance Confirmation. A functional check shall be conducted at the beginning and end of each examination, every eight hours, or when equipment has malfunctioned and been repaired. If it is determined that the equipment is not functioning properly, needed adjustments shall be made and all areas examined since the last performance check shall be re-inspected.

III-723 Written Procedure Requirements

III-723.1 Requirements. Magnetic Flux Leakage examination shall be performed in accordance with a written procedure that shall, as a minimum, contain the requirements listed in Table III-723. The written procedure shall establish a single value, or range of values, for each requirement.

III-723.1.1 The procedure shall address, as a minimum, the identification of imperfections, reference materials used to set up equipment, location and mapping of imperfections, and the extent of coverage. The procedure shall address the field strength of the magnets, the functioning of the sensors and the operation of the signal-processing unit. Other examination methods that will be used to supplement the MFL examination shall be identified in the procedure.

Plate Thickness	Hole Number	Number of Steps	Step Size	Diameter D1	Diameter D2	Diameter D3	Diameter D4	Diameter D5
.25 (6)	1	3	.032 (0.8)	.47 (12)	.32 (8)	.12 (3)		
	2	4	.032 (0.8)	.62 (16)	.47 (12)	.32 (8)	.12 (3)	
.31 (8)	1	4	.032 (0.8)	.62 (16)	.47 (12)	.32 (8)	.16 (4)	
	2	5	.032 (0.8)	.78 (20)	.62 (16)	.47 (12)	.32 (8)	.16 (4)
.38 (10)	1	4	.039 (1)	.78 (20)	.59 (15)	.39 (10)	.2 (5)	
	2	5	.039 (1)	.96 (24.5)	.78 (20)	.59 (15)	.39 (10)	.2 (5)



Hole	%Loss
1	40%
2	50%

GENERAL NOTE: Dimensions of references are in in. (mm).

FIG. III-722 MFL REFERENCE PLATE DIMENSIONS

III-723.2 Procedure Qualification. When procedure qualification is specified, a change of a requirement in Table III-723, identified as an essential variable from the specified value, or range of values, shall require requalification of the written procedure. A change of a requirement identified as a nonessential variable from the specified value or range of values, does not require requalification of the written procedure. All changes of essential or nonessential variables from the value or range of values specified by the written procedure shall require revision of or an addendum to the written procedure.

TABLE III-723
REQUIREMENTS OF AN MFL EXAMINATION PROCEDURE

Requirement	Essential Variable	Non-Essential Variable
Equipment Manufacturer/Model	X	
Sensor Type; Manufacturer and Model	X	
Scanning Speed/Speed Range	X	
Scanning Technique (Remote Control/Manual)		X
Overlap	X	
Lift-off	X	
Material examined	X	
Material Thickness Range and Dimensions	X	
Reference Plate and Calibration Materials	X	
Scanning Equipment/Fixtures		X
Data Recording Equipment		X
Software	X	
Evaluation of Indications	X	
Surface Conditioning	X	
Coating/Sheet	X	

III-730 EQUIPMENT

The equipment shall consist of magnets, sensor or sensor array, and related electronic circuitry. A reference indicator, such as a ruled scale or linear array of illuminated light emitting diodes, should be used to provide a means for identifying the approximate lateral position of indications. The equipment may be designed for manual scanning or may be motor driven. Software may be incorporated to assist in detection and characterization of discontinuities.

III-740 REQUIREMENTS

(a) The surface shall be cleaned of all loose scale and debris that could interfere with the examination and movement of the scanner. The surface should be sufficiently flat to minimize excessive changes in lift-off and vibration. Alternate techniques will be required to handle variables exceeding those specified in the procedure.

(b) Cleaning may be accomplished using high-pressure water blast or by sandblasting. If the material is coated and the coating is not removed, it shall be demonstrated that the MFL equipment can detect the specified imperfections through the maximum thickness of the coating.

(c) If a temporary sheet or coating is applied between the scanner and plate to provide a smooth surface, for example, on a heavily pitted surface, it must be demonstrated that the equipment can find the specified imperfections through the maximum thickness of the temporary sheet or coating.

III-760 CALIBRATION

The MFL equipment shall be recalibrated annually and whenever the equipment is subjected to major damage following required repairs. If equipment has not been in use for a year or more, calibration shall be done prior to first use.

III-770 EXAMINATION

(a) Areas to be examined shall be scanned in accordance with the written procedure. Each pass of the sensing unit shall be overlapped in accordance with the written procedure.

(b) The unit shall be scanned manually or by a motor driven system. Other examination methods may be used to provide coverage in areas not accessible to MFL examinations, in accordance with the written procedure. Typical examples of inaccessible areas in storage tanks are lap welds and corner welds adjacent to the shell or other obstructions, such as roof columns and sumps.

(c) Imperfections detected with MFL during this procedure shall be confirmed by supplemental examination. Supplemental examinations shall be performed in accordance with written procedures.

(d) Where detection of linear imperfections is required, an additional scan shall be performed in a direction approximately perpendicular to the initial scanning direction.

III-780 EVALUATION

All indications shall be evaluated in accordance with the referencing Code Section.

III-790 DOCUMENTATION

A report of the examination shall contain the following information:

(a) plate material specification, nominal wall thickness, pipe diameter, as applicable;

(b) description, such as drawing/sketches, documenting areas examined, and/or areas inaccessible;

(c) identification of the procedure used for the examination;

(d) system detection sensitivity (minimum size of imperfections detectable);

(e) location, depth, and type of all imperfections that meet or exceed the reporting criteria;

(f) examination personnel identity, and, when required by referencing Code Section, qualification level;

(g) model and serial number of equipment utilized for the examination, including supplemental equipment;

(h) date and time of examination;

(i) date and time of performance verification checks;

(j) supplemental methods utilized and referenced to associated reports.

ARTICLE 7
NONMANDATORY APPENDIX

APPENDIX A — MEASUREMENT OF TANGENTIAL FIELD STRENGTH WITH GAUSSMETERS

A-710 SCOPE

This Nonmandatory Appendix is used for the purpose of establishing procedures and equipment specifications for measuring the tangential applied magnetic field strength.

A-720 GENERAL REQUIREMENTS

Personnel qualification requirements shall be in accordance with Article 1.

Gaussmeters and related equipment shall be calibrated in accordance with T-763 of Article 7.

Definitions: standard terminology for magnetic particle examinations is presented in SE-1316.

A-730 EQUIPMENT

Gaussmeter having the capability of being set to read peak values of field intensity. The frequency response of the gaussmeter shall be at least 0 Hz to 300 Hz.

The Hall-Effect tangential field probe should be no larger than 0.2 in. (5 mm) by 0.2 in. (5 mm) and should have a maximum center location 0.2 in. (5 mm) from the part surface. Probe leads shall be shielded or twisted to prevent reading errors due to voltage induced during the large field changes encountered during magnetic particle examinations.

A-750 PROCEDURE

Care must be exercised when measuring the tangential applied field strengths specified in T-753.1.3. The plane of the probe must be perpendicular to the surface of the part at the location of measurement to within 5 deg. This may be difficult to accomplish by hand orientation. A jig or fixture may be used to ensure this orientation is achieved and maintained.

The direction and magnitude of the tangential field on the part surface can be determined by placing the Hall-Effect tangential field probe on the part surface in the area of interest. The direction of the field can be determined during the application of the magnetizing field by rotating the tangential field probe while in contact with the part until the highest field reading is obtained on the Gaussmeter. The orientation of the probe, when the highest field is obtained, will indicate the field direction at that point. Gaussmeters cannot be used to determine the adequacy of magnetizing fields for multidirectional and coil magnetization techniques.

Once adequate field strength has been demonstrated with artificial flaw shims, Gaussmeter readings may be used at the location of shim attachment on identical parts or similar configurations to verify field intensity and direction.

A-790 DOCUMENTATION/RECORDS

Documentation should include the following:

(a) equipment model and probe description;

(b) sketch or drawing showing where measurements are made; and

(c) field intensity and direction of measurement.