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HISTORY OF REVISIONS

Rev.	Date	Description	POC	RM
0	11/01/18	Initial issue. Supersedes KSL 16-30-005.	David Bingham, *ES-EPD*	Larry Goen, *ES-DO*

Contact the Welding Standards POC for upkeep, interpretation, and variance issues.

ITM-1306-NDE-MT-101	**Welding POC and Committee**

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1.0 INTRODUCTION

1.1. Purpose

This operating procedure establishes the process and operational requirements for ferromagnetic product inspection using both stationary and portable magnetic particle testing (MT) methods and equipment. Specific requirements for each technique addressed by this procedure are in the attachments.

1.2. Scope

This operating instruction addresses safety (reference requirements only), materials and equipment, certification of personnel, technique development and procedural process information, job order system, documentation and records, process control and quality assurance measures, and maintenance. Security, part handling, interpretation, and acceptance standards are not covered by this instruction.

1.3. Description

A directional magnetic field is established in a ferromagnetic test object by means of electric current. Local flux leakage poles are created at those locations where there is a rapid change in the surface contour, or where a discontinuity exits on, or immediately below, the surface. Highly permeable ferromagnetic particles are caused to flow over the test object, and are attracted to the flux leakage poles forming a pattern of the discontinuity.

1.4. Definitions

Definitions for all terms related to magnetic particle testing are given in the latest edition of ASTM E1316.

2.0 PRECAUTIONS & LIMITATIONS

2.1. Hazards and safety

Prior to operating any MT equipment, personnel shall be indoctrinated and trained per the applicable planning and protocol governing use of electrical and pneumatic producing devices and chemicals. This will include complying with requirements of all applicable Integrated Work Documents (IWDs), Operating Procedures (OPs), Operating Instructions (OIs) and other qualifying documents covering exposure safety and security. Material Safety Data Sheets (MSDS) and appropriate personnel protective equipment (PPE) shall be available and appropriately used.

2.1.1. Tinted lenses and photochromic (e.g., Transitions™) lenses that darken with exposure to light and are not permitted when using a fluorescent medium.

2.2. In some cases, MT will be requested on parts, components, or materials that are at elevated temperatures (above 100°F). In addition to safety related reasons, certain inspections performed at high temperature may not detect flaws and defects that form as part of the cooling process (certain welds, for instance), and a maximum inspection temperature is required. The maximum allowable temperature for MT shall be 120°F, with exceptions as given in this paragraph.

2.2.1. Oil-based suspensions shall not be used at temperatures above 120°F. At temperatures above 100°F but below 120°F, additional ventilation shall be provided due to the off-gassing of the oil-based carrier.

2.2.2. Water-based suspensions shall not be used at temperatures above 120°F, due to the rapid evaporation of the water. Additionally, elevated temperatures adversely impact the fluorescence of fluorescent particles.

2.2.3. Visible dry powder inspections shall not be performed at temperatures above 600°F, due to the tendency of the particles to become sticky. Higher temperatures also risk ignition of the particles. In all cases where the part, component, or material temperature exceeds 120°F, the minimum required PPE per the appropriate IWD must be supplemented by welder's gloves to provide protection from the hot steel; care must also be taken to keep the power cord away from the hot regions of the material. Additionally, the Level III and/or appropriate SME must be consulted prior to performing MT on parts at temperatures above 120°F, since some alloys will tend to crack upon cooling.

Temperatures of hot parts (such as during a weld repair process) may be verified using a Temp Stick-type device or contact temperature measurement device. Lower temperatures must be verified using a contact temperature measurement device.

3.0 PERSONNEL QUALIFICATION AND CERTIFICATION

3.1. Certification

All personnel performing MT shall be certified to *Level I, II*, or *III* per LANL Standard WIGN 6-02, Attachment 3, *Written Practice for NDE Personnel Qualification and Certification.* Trainees and Level I personnel may perform inspections under the direct supervision and guidance of a Level II or Level III. A Level II or III shall perform all interpretation.

4.0 MATERIALS AND EQUIPMENT

4.1. Equipment Integrity

MT equipment and support tools shall be inspected and/or qualified as required under Section 8.0 of this document.

4.2. Magnetizing System/Unit

4.2.1. Items to be inspected using a stationary wet horizontal unit (Magnaflux ADH-2045) shall not exceed the weights given in the equipment manual. The maximum part length is 54"; the coil is 5-turn with ID of 12". Headstocks must have braided-copper cover pads which show minimal fraying (few broken wires) and no holes. This system includes a circulating bath pump, directional current selector, and amperage setting selection. The system may be operated with either AC or DC voltage

4.2.2. Portable equipment that may be used to inspect large objects on location will include reticulating AC or AC/DC probes and yokes.

4.2.3. Prods are not permitted.

4.2.4. A separate demagnetization coil may be used for removing residual magnetic flux from the test object.

4.3. Particle Mediums

4.3.1. Dry particle shaker bulbs may be used when conducting AC or DC dry-particle inspection techniques. The particle medium must not be contaminated, re-used, or exhibit a color which matches the test object surface. It is recommended that a penetrant developer be applied prior to dry particle inspection to provide additional contrast between the background and the particle medium. The following dry particle media are permitted for use with this procedure:

a. Black Powder: Magnflux Magnavis 3A

b. Red Powder: SirChem Dry Powder 63.

c. Yellow Powder: SirChem Dry Powder 66.

d. Gray Powder: SirChem Dry Powder 61.

4.3.2. Wet-horizontal stationary units shall be filled with a suspension of oil-based Magnaflux Carrier II fluid and Magnaglo14-A type fluorescent particles.

4.3.3. Aerosol medium shall be water-based Magnaflux Magnavis 7HF for visible inspections, or Magnaflux Magnaglo 14A.

4.4. Black-Light

Black-lights to be used for evaluation shall have a minimum intensity of 1000μW/cm^2 at 15 inches from the inspection surface. (See Section 8, *Process Control)*. Lights using filtered mercury vapor bulbs or LED technology may be used, provided the emitted UV has a wavelength between 300-400 nm.

4.4.1. The meter used to verify the black light intensity shall have been calibrated within six months before its use. Verification of the black light intensity for the mercury bulb shall be performed before inspection, and after a ten minute warmup. LED lighting systems shall be verified, at minimum, at the start of the shift after the end of the shift. There is no warmup period for LED lamps.

4.4.2. When fluorescent particles and black lights are utilized, the room where the inspection is performed must be darkened sufficiently. A white light meter which has been calibrated within six months must be used to verify that the white light level in the inspection area does not exceed 2 fc.

4.5. Magnetic Field Strength Indicator for Field Use

The magnetic field strength shall be strong enough to produce satisfactory indications, but not so strong as to mask relevant indications by nonrelevant accumulations of magnetic particles. When it is necessary to verify the adequacy of the field, one of the following two methods may be used.

4.5.1. A field-indicating pie gage shall be used to determine the relative field direction and strength at the test object surface. The gage shall be comprised of a copper-plated octagonal framework of highly permeable

steel strips which divide the gage into eight pie sections (as shown in the ASME B&PV Code, Section V, Article 7, T-764.2(a)). Place the gage on the inspection surface such that the plated copper back is facing away from the test object surface.

4.5.2. A pocket field indicator shall be kept at hand to be used in determining that adequate demagnetization of the test object is completed subsequent to the inspection. A maximum of 2 increments shall show on the indicator where the measurement is taken at a flux leakage pole. This is a relative measurement, and calibration of the field indicator is not required.

a. If a specific field strength after demagnetization is required by the requestor, a Hall Effect device or field indicator shall be used. The device used for this measurement shall be calibrated.

4.6. Centrifuge

A graduated 100-milliliter, pear-shaped centrifuge tube with graduations of 1 milliliter may be used to perform settling tests for determining particle concentrate (See section 8.1 *Process Control).*

4.7. Central Bar Conductors (CBC)

Copper, brass, or aluminum cylindrical bars having various lengths and diameters as dictated by the inspection application shall be available for use with the horizontal stationary unit for establishing circular magnetic fields

Care is to be taken in designing techniques utilizing a CBC, so as not to use one having too small of a diameter for the application. This is to prevent overheating of the CBC, which could create a fire hazard and cause distortion of the CBC. In addition, this will prolong the life of the headstock protection pads.

4.8. Ketos Tool Ring

The Ketos Ring tool shall be used in evaluating and comparing the overall performance and sensitivity of both dry and wet, fluorescent and visible, magnetic particle techniques using central-conductor magnetization. A standard 5-inch Ketos ring having 12 side-drilled holes and a single 1.25 inch central CBC hole shall be used for adequate current strength determination (as shown in the ASME B&PV Code, Section V, Article 7, Figure T-766.1). A 1-inch diameter, 16-inch-long-minimum CBC shall be used with the ring (see Section 8.2 *Process Control).*

4.9. Yoke

Portable yokes may be used, either AC or DC. Performance of the yoke shall be verified by the ability to lift the appropriate weight at the maximum yoke spacing to be used for inspection: 10 pounds for and AC yoke, and 40 pounds for a DC yoke. *If the yoke will be used on a painted or coated surface, this verification should be performed on a painted or coated weight.*

4.10. Demagnetization Coil

Subsequent to establishing magnetic poles within the test object by induction of a longitudinal field, all test objects shall be demagnetized by slowly passing them through a separate demagnetization coil. A field indicator shall be used to

determine that a flux level of no more than 2 scale-increments remains in the test object. If a specific field value is specified, refer to paragraph 4.5.2.a.

CAUTION

The stand-alone demagnetization coil must be energized and de-energized (using the toggle switch located on top of the coil) for each object put through it. The coil must not be left on for extended periods of time.

5.0 SURFACE PREPARATION

5.1. Prior to inspection, the area of interest and at least one inch to either side of the area of interest shall be free from any features that may inhibit the test or mask discontinuities. Such features include, but are not limited to slag, weld spatter, oil, scale, rough surface, paint, and protective coatings.

5.1.1. Paint removal is not required, unless deemed necessary in the judgment of the Level II or Level III. When a yoke is used, the appropriate 10lb or 40lb weight should be painted using the same paint at the same thickness, and the ability to lift the standard weight demonstrated prior to inspection. Paint should be removed if adequate inspection performance cannot be demonstrated.

5.2. Surface preparation by methods such as grinding, machining, washing or other methods may be necessary.

6.0 PROCESS CONTROL

6.1. Ketos Ring Check

When applying an AC current only, performing the ketos ring field strength check is optional. If performed, use a minimum ½-inch CBC to run through the central hole of ring and position between headstocks. Set selector on “contact” and 1000 amps. Position ring so shallowest hole is topside, and flow suspensoid over ring while administering 2 bursts of current. A line across the ring surface above the first side-drilled hole should appear. If not, perform an ammeter-shunt check. Ensure adequate black-light intensity is available at ring surface. Record results on FM03 “Process Control Record Log.”

6.2. Ammeter/Shunt Check

A verification check of the system current ammeter shall be made for accuracy whenever a drop in current is evidenced by the Ketos Ring or pie gage checks. Additionally, this check shall be made once each month (or prior to use, if intervals-between-use exceed one month). A calibrated shunt-meter (ammeter) shall be connected in series with the output circuit of the unit. Readings shall be taken at 1000, 2500, and 5000 amps. Deviation shall not be more than 7 percent from the current shown on the unit (system) ammeter. Record results on FM03 “Process Control Record Log.”

6.3. Pie Gage Check

After determining the appropriate current setting for the inspection, place the pie gage on surface of test object and run suspension fluid over test object and gage while energizing. Verification of acceptable flux density and direction should be

evidenced. Watch for sparse or excessive particle build-up conditions. Ensure adequate black-light intensity is available at surface of interest. Record results on FM03 "Process Control Record Log."

6.4. Black-light Intensity

Using a calibrated radiometer (light meter) attach the receptacle that reads out in units of microwatts per square centimeter (μW/cm^2). Verify the black-light intensity is no less than 1000 μW/cm^2 at the test object surface when measured from 15 inches distance. If this level of intensity is not attained, install a new bulb or bulbs. Ensure lamp is unplugged and cool to the touch (this is particularly true for mercury vapor bulbs, which can become very hot). Record results on FM03 "Process Control Record Log."

6.5. Visible Light Intensity

Visible techniques should have lighting of at least 500lx (50fc) at the examination surface. Greater intensity may be desirable. Flashlights, shop lights, and so forth may be used to provide supplemental lighting.

7.0 REFERENCES

The following references form a part of this Procedure to the extent specified herein.

- LANL Standard WIGN 6-02, Attachment 3, *Written Practice for NDE Personnel Qualification and Certification*
- ASME Boiler and Pressure Vessel Code, Section V, Article 7.
- ASTM E1316, *Standard Terminology for Nondestructive Examinations*

8.0 FORMS

FM01: Magnetic Particle Technique Record
FM02: MT Inspection Report
FM03: Process Control Record Log

9.0 ATTACHMENTS

Attachment I: Nominal Amperage Requirements (formulas to determine current strength)
Attachment II: Detailed Instructions for AC and DC Yoke
Attachment III: Detailed Instructions for AC Coil
Attachment IV: Detailed Instructions for Stationary Horizontal Bench

10.0 CONTACT

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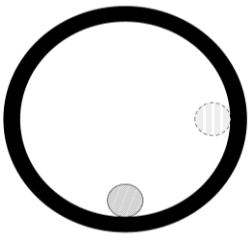
Attachment I
Nominal Amperage Requirements

These values must be determined for each configuration, and are considered essential variables.

When the Cross-sectional area of the part is less than 10% of the coil cross sectional area:

$$I = \frac{(45{,}000)\ D}{NL}$$

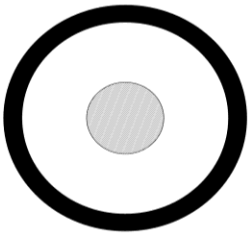
Place the object in the bottom or to the side of the coil.



When the Cross-sectional area of the part is between 10% and 50% of the coil cross-sectional area:

$$I = \frac{(43{,}000)R}{N(6L/D - 5)}$$

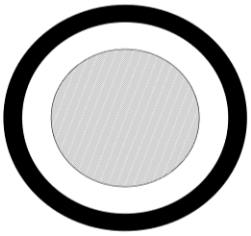
Place the object in the center of the coil.



When the coil diameter is less than twice the object diameter, or when using cable wraps,

$$I = \frac{(35{,}000)}{N(L/D + 2)}$$

The object is ideally placed at or near the center of the coil.

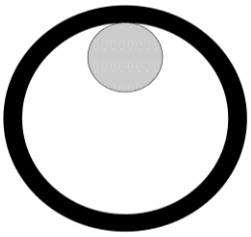


Circular Magnetization, with central bar conductor in contact with the hollow object

For the number of times S that the hollow part must be rotated in equal degrees:

$$S = \frac{H(\pi)}{0.36B}$$

Where H = diameter of the hole in the test part
B = the diameter of the central conductor



Contact circular magnetization (Head Shot)

For an object with diameter less than 5": 700 to 900 Amps per inch diameter
For an object with diameter greater than 5": 500 to 700 Amps per inch diameter

NOTE: AMPERAGE IS AN ESSENTIAL VARIABLE, THE REQUIREMENTS GIVEN ABOVE ARE NOT OPTIONAL. DIFFERING FROM THESE AMPERAGE REQUIREMENTS REQUIRES APPROVAL OF THE LEVEL III AND REVISION OF THE PROCEDURE AFTER QUALIFICATION OF THE NEW VALUES.

Attachment II
Detailed Instructions for AC and DC Yoke

1) This examination should be performed using an existing Technique as recorded on FM01 Technique Record, or a Record completed to document the specific Technique used.
2) Surface Preparation. The surface shall be suitable for the MT process.
3) Materials. Magnetic Particles shall be selected to provide suitable contrast with the surface being inspected.
4) Lighting. Adequate lighting shall be verified and documented.
5) Yoke. The magnetizing force of the yoke shall have been verified within the past 12 months.
6) Magnetizing field.
   a) The field shall be applied sequentially in two orientations approximately perpendicular to one another.
   b) A pie gage shall be used to verify the adequacy of the magnetic field.
   c) The field shall be verified for each weld geometry/orientation.
7) Sequence of operations:
   a) The continuous technique of magnetization shall be used.
8) Both legs of the yoke shall be in firm contact with the surface. Pole spacing shall be no greater than that used for the magnetic force test, and not less than 3 inches.
   a) For the wet method, apply the suspension over the area of interest, allowing the fluid to flow across the area of interest within the magnetic field.
   b) For the dry method, use a “puffer bulb” or equivalent to gently apply a light, uniform, dust-like coating to the surface. Excess powder may be GENTLY removed using an empty puffer bulb to blow the excess from the surface.
   c) Maintain the field for at least two seconds after application of the particles per c) or d).
   d) Repeat this sequence with the field oriented approximately 90 degrees to the original application.
   e) Repeat across the area of interest, ensuring a minimum of 25% overlap of the pole spacing.
9) Evaluation of indications.
   a) Any indications suspected of being nonrelevant shall be reexamined to verify nonrelevance.
   b) Relevant indications shall be evaluated against the supplied Acceptance Criteria.
   c) Indications can be larger than the discontinuity causing the indication. Indications are compared against the Acceptance Criteria, not the discontinuity size.
10) Demagnetization shall be performed if required by the Requestor. If not required by the Requestor or the Level III, demagnetization is optional.
11) Postcleaning. The part shall be cleaned after the inspection if the Requestor desires, or if required by future use or processing. Postcleaning may occur either before or after demagnetization.
12) The FM02 MT Inspection report shall be completed to document the inspection performed.

Attachment III
Detailed Instructions for AC Coil

1) This examination should be performed using an existing Technique as recorded on the FM01 Technique Record, or a Record completed to document the specific Technique used.
2) Surface Preparation. The surface shall be suitable for the MT process.
3) Materials. Magnetic Particles shall be selected to provide suitable contrast with the surface being inspected.
4) Lighting. Adequate lighting shall be verified and documented.
5) Coil. The coil may bed either a fixed coil or a coil made of wraps of cable from a fixed or mobile unit.
6) Magnetizing field.
   a) The amperage to be applied shall be determined using the formulae in Attachment 2.
   b) If possible, the field shall be applied sequentially in two orientations approximately perpendicular to one another.
   c) A pie gage shall be used to verify the adequacy of the magnetic field.
   d) The field shall be verified for each weld geometry/orientation.
7) Sequence of operations:
   a) The continuous technique of magnetization shall be used.
   b) For the wet method, apply the suspension over the area of interest, allowing the fluid to flow across the area of interest within the magnetic field.
   c) For the dry method, use a “puffer bulb” to gently apply a light, uniform, dust-like coating to the surface. Excess powder may be GENTLY removed using an empty puffer bulb to blow the excess from the surface.
   d) Maintain the field for at least two seconds after application of the particles per c) or d).
   e) Repeat this sequence with the field oriented approximately 90 degrees to the original application.
8) Evaluation of indications.
   a) Any indications suspected of being nonrelevant shall be reexamined to verify nonrelevance.
   b) Relevant indications shall be evaluated against the supplied Acceptance Criteria.
   c) Indications can be larger than the discontinuity causing the indication. Indications are compared against the Acceptance Criteria, not the discontinuity size.
9) Demagnetization shall be performed if required by the Requestor. If not required by the Requestor or the Level III, demagnetization is optional.
10) Postcleaning. The part shall be cleaned after the inspection if the Requestor desires, or if required by future use or processing. Postcleaning may occur either before or after demagnetization.
11) The FM02 MT Inspection report shall be completed to document the inspection performed.

Attachment IV
Detailed Instructions for Stationary Horizontal Bench

This attachment is applicable to use of a Horizontal AC/DC bench unit. This unit is used with wet-continuous techniques whereby the suspensoid is applied to the test object while the current is flowing. Residual techniques shall not be used.

1) This examination should be performed using an existing Technique as recorded on the FM01 Technique Record, or a Record completed to document the specific Technique used.
2) Surface Preparation. The surface shall be suitable for the MT process.
3) Materials. Magnaglo 14A particles and Magnaflux Carrier II are approved for use with this procedure. Other materials may be used only after Level III approval and revision of this procedure.
4) Lighting. Adequate lighting (both UV and visible) shall be verified and documented.
5) Current direction. Both circular and longitudinal fields are to be used.
   a) A minimum of two successive magnetic flux fields shall be established within the test object oriented 90-degrees from each other.
   b) The first step is to induce a circular field in the part, done by securing the test object between the headstocks and passing current through the test part (or CBC) to create a circular magnetic field.
   c) Upon completion of evaluating the test object after circular magnetization, a coil shall be used to establish a longitudinal field in the test part.

      NOTE: THE LONGITUDINAL FIELD INSPECTION SHALL ALWAYS FOLLOW A CIRCULAR FIELD INSPECTION.
6) A test object not having the dimensions to satisfy the length-to-width (L/D) ratio described in Attachment II (current strength formulas), may be examined solely with longitudinal induction by placing the test object on the inside ID surface of the coil. The test object shall be rotated sequentially to establish a minimum of two directional flux fields (normal to each other), being evaluated in each position.
7) Current strength
   a) The amount of current applied to establish an adequate magnetic flux field within the test object is to be calculated based on the formulas given in Attachment II. Additionally, a pie gage shall be used to verify sufficient flux and field direction on at least the first test object tested, and all cases where the test object does not fit into the L/D ratio criteria.

      NOTE: TOO MUCH CURRENT CAN MASK EXISTING DISCONTINUITIES BY CREATING EXCESSIVE PARTICLE BUILDUP. THE PIE GAGE CAN BE USED TO ASCERTAIN AN APPROPRIATE CURRENT STRENGTH TO BE USED IN PREVENTING THIS CONDITION.
8) Preparation for use and maintenance
   a) Sump Screen. Before each use, locate the copper mesh filter at the bottom right end of the bath tank. This screen needs to be kept clean of debris. Verify there is enough suspensoid in tank to cover sump screen.
   b) Tank Racks. The tank racks need to be wetted with running suspensoid, and brushed to release particle buildup, prior to each use.

c) Suspension Bath. The suspension bath should be discarded and the tank cleaned annually, with a new 10 gallon batch of suspensoid being mixed. When mixing, make a slurry paste with the particles before pouring into the tank adjacent to the sump screen (pump intake). If system use has been low, and the suspensoid is free of contamination, discarding of the suspensoid can be done at intervals greater than one year.

d) Black-Light. The black-light filter on all mercury-vapor UV lamps shall be checked before each use to assure the lens is not damaged or dirty. The minimum intensity for all UV lighting shall be 1000 $\mu W/cm^2$ at the part surface.

e) White-Light. The white or visible light intensity shall not exceed 2 fc for all fluorescent particle inspections.

9) Operation

a) The horizontal bench unit has a main disconnect at the wall. After closing the main disconnect, turn on the circulation pump using the switch located at the front panel.

b) Turn on the black light and allow a minimum 10 minute warmup (warmup not required for LED black lights).

c) Allow the suspensoid to flow through the application hose for 15-30 minutes.

d) Fill the 100mL centrifuge tube to the 100mL level. Holding it upright, slowly pass it through the demagnetization coil and place it in its holding stand, or utilize the centrifuge.

i) Let sit for a minimum of one hour. If all of the particles don't settle out of suspension, hold a magnet to the bottom of the tube. Check that the level of accumulated particles is not less than 0.3mL, and not more than 0.5mL.

ii) If the level is less than 0.3mL, mix a new slurry of particles and suspension fluid and add to tank adjacent to the sump screen (pump intake). If the level is greater than 0.5mL, add suspension fluid to bring the concentration down.

iii) While assessing the particle concentration, look for contamination. Contaminants will generally show up in the suspension just above the particles, and have a translucent lavender color. Floating fluorescent particles in the suspensoid may be an indication of pigment separation from the particles. If there is evidence of separation, discard the bath and mix a new one. Record on Form 03 "Process Control Record Log."

e) Select the current strength (amps) and direction field type (coil or contact) at the front of the unit panel.

f) There is a foot pedal located on the floor to pneumatically actuate the opening and closing of the headstock ends. When utilizing this implement to conduct circular field magnetization, rotate the tailstock component to within approximately one half inch of the test object end (or CBC) and lock down. Use the foot switch to establish a tight hold of the test object between the head and tailstock assemblies.

g) Position the black-light such that adequate flow and distribution of the suspensoid can be assured.

h) Using the lever bar located out and across the front of the unit, energize the system by pushing the bar in momentarily and releasing. Administer two "shots" whether the test object is positioned in the coil or headstocks.

i) Examine for the presence of indications using the black light. Report the presence (or lack thereof) of indications on the MT Report (FM 02).

10) Demagnetization. Demagnetize the part if required by the Requestor. Demagnetization is optional if not specifically requested. Demagnetization with the ADH-2045 bench utilizes decaying AC.
11) Postcleaning. The part shall be cleaned after the inspection if the Requestor desires, or if required by future use or processing. Postcleaning may occur either before or after demagnetization.
12) The FM02 MT Inspection report shall be completed to document the inspection performed.