

**Tool Steel Ring for Magnetic Particle Inspection**

**RATIONALE**

This document has been reaffirmed to comply with the SAE 5-year Review policy.

**1. SCOPE:**

**1.1 Purpose:**

This SAE Aerospace Standard (AS) establishes requirements for the manufacture and certification of tool steel rings for magnetic particle inspection.

**1.2 Application:**

These rings are used typically for determining the sensitivity of magnetic particles in accordance with AMS 3040 through 3046 and to perform magnetic particle system performance checks. Evaluations of the rings are performed using full-wave rectified alternating current through a copper conductor bar.

**2. APPLICABLE DOCUMENTS:**

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

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### 2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 3040 Magnetic Particles, Nonfluorescent, Dry Method  
AMS 3041 Magnetic Particles, Nonfluorescent, Wet Method, Oil Vehicle, Ready to Use  
AMS 3042 Magnetic Particles, Nonfluorescent, Wet Method, Dry Powder  
AMS 3043 Magnetic Particles, Nonfluorescent, Wet Method, Oil Vehicle, Aerosol Packaged  
AMS 3044 Magnetic Particles, Fluorescent, Wet Method, Dry Powder  
AMS 3045 Magnetic Particles, Fluorescent, Wet Method, Oil Vehicle, Ready to Use  
AMS 3046 Magnetic Particles, Fluorescent, Wet Method, Oil Vehicle, Aerosol Packaged  
SAE J438 Tool and Die Steels

### 2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, Conshohocken, PA 19428-2959.

ASTM E 18 Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials  
ASTM E 140 Hardness Conversion Tables for Metals (Relationship Between Superficial Hardness and Knoop Hardness)  
ASTM E 1444 Magnetic Particle Examination

## 3. TECHNICAL REQUIREMENTS:

### 3.1 Material:

The ring shall be made from normalized hot rolled 5.5-in (140-mm) minimum diameter tool steel bar stock, 01 series, conforming to SAE J438, or equivalent.

### 3.2 Configuration:

The ring configuration, dimensions, and surface finish shall be in accordance with Figure 1.

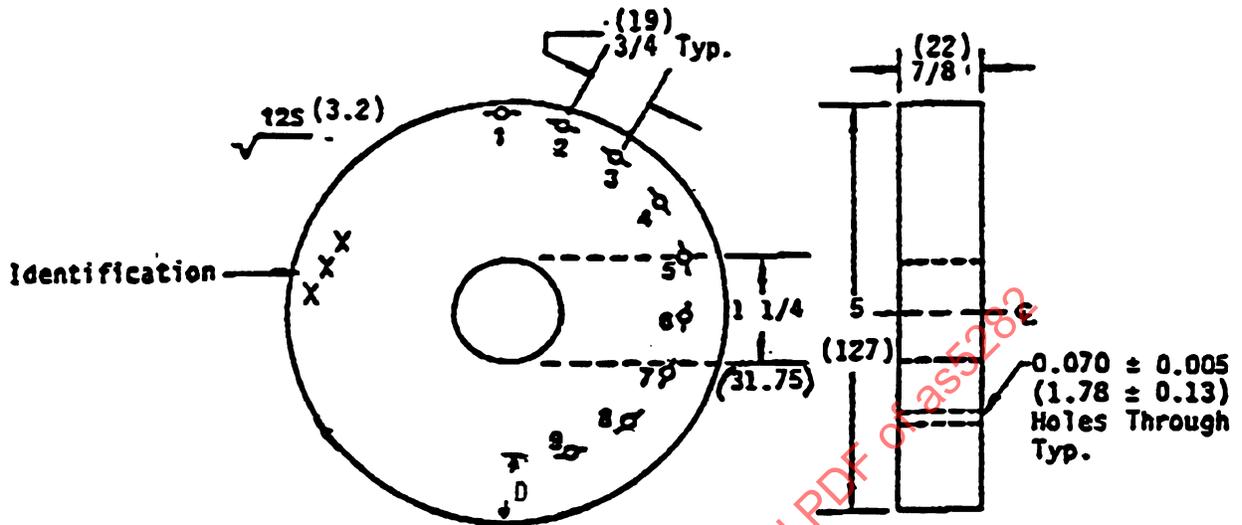
### 3.3 Normalizing:

Each bar shall be normalized by heating to  $1600\text{ }^{\circ}\text{F} \pm 100\text{ }^{\circ}\text{F}$  ( $871\text{ }^{\circ}\text{C} \pm 56\text{ }^{\circ}\text{C}$ ), holding at heat for  $60\text{ min/in} \pm 5\text{ min/in}$  ( $2.4\text{ min/mm} \pm 0.2\text{ min/mm}$ ) of diameter and air cool to room temperature.

### 3.4 Annealing:

Each ring shall be annealed by heating at  $1400\text{ to }1440\text{ }^{\circ}\text{F}$  ( $760\text{ to }782\text{ }^{\circ}\text{C}$ ), holding at heat for 3 h minimum, cooling at a rate of not more than  $50\text{ }^{\circ}\text{F} \pm 5\text{ }^{\circ}\text{F}$  ( $28\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$ ) per hour to  $1200\text{ }^{\circ}\text{F}$  ( $649\text{ }^{\circ}\text{C}$ ), and furnace or air cool to room temperature.

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- NOTES:**
1. All tolerances are  $\pm 0.03$  (0.8) except where shown.
  2. All dimensions are in inches and (millimeters).

HOLE	1	2	3	4	5	6	7	8	9
D, Inches $\pm 0.005$	0.07	0.14	0.21	0.28	0.35	0.42	0.49	0.56	0.63
(D) Millimeters $\pm 0.12$	1.78	3.56	5.33	7.11	8.89	10.67	12.45	14.22	16.00

FIGURE 1 - 01 Tool Steel Ring for Use in Magnetic Particle System Verification and Testing of Magnetic Particles

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3.4.1 Surface oxidation, caused by annealing, shall be removed by dry blasting using either glass beads or aluminum oxide at 25 to 40 psi (172 to 276 kPa). Following dry blasting, protect part from rust by applying a coating of oil or grease.

3.5 Hardness:

Hardness after annealing shall be 95 HRB maximum, or equivalent, as determined in accordance with ASTM E 18.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Sensitivity Test:

Each ring shall be magnetized using circular magnetization in accordance with ASTM E 1444 applied by three-phase, full-wave, rectified alternating current through a 16 to 24-in (406 to 610-mm) long and 1.0 to 1.1-in (25.4 to 30.2-mm) diameter copper internal conductor bar.

4.1.1 The rings may be qualified by recording either the residual leakage field manually with a gauss meter, or automatically by using a magnetic sensor, amplifier, and oscilloscope.

4.2 Manual Leakage Field Measurement Method:

Surface oil or grease shall be removed from each ring before magnetization. Each ring shall be magnetized at 1500 A, in accordance with 4.1. Remove the magnetized ring from the central conductor bar and place it in a fixture (Figure 2). Calibrate the gauss meter in accordance with the manufacturer's instructions. The gap between the gauss meter probe face and the ring surface shall be adjusted for a lift-off of 0.001 to 0.0015 in (0.025 to 0.038 mm). The ring shall rotate smoothly on the fixture rollers without any wobble.

NOTE: If a series of rings are to be evaluated, magnetize and evaluate the rings in a uniform orientation to avoid a reverse in polarity of the leakage field.

4.2.1 Rotate the ring or rollers so that hole #1 is centered over the gauss meter probe. Slowly rotate the ring back and forth, past the sensing probe, and record the optimum gauss meter value. Repeat this process at each hole (#2 through #9).

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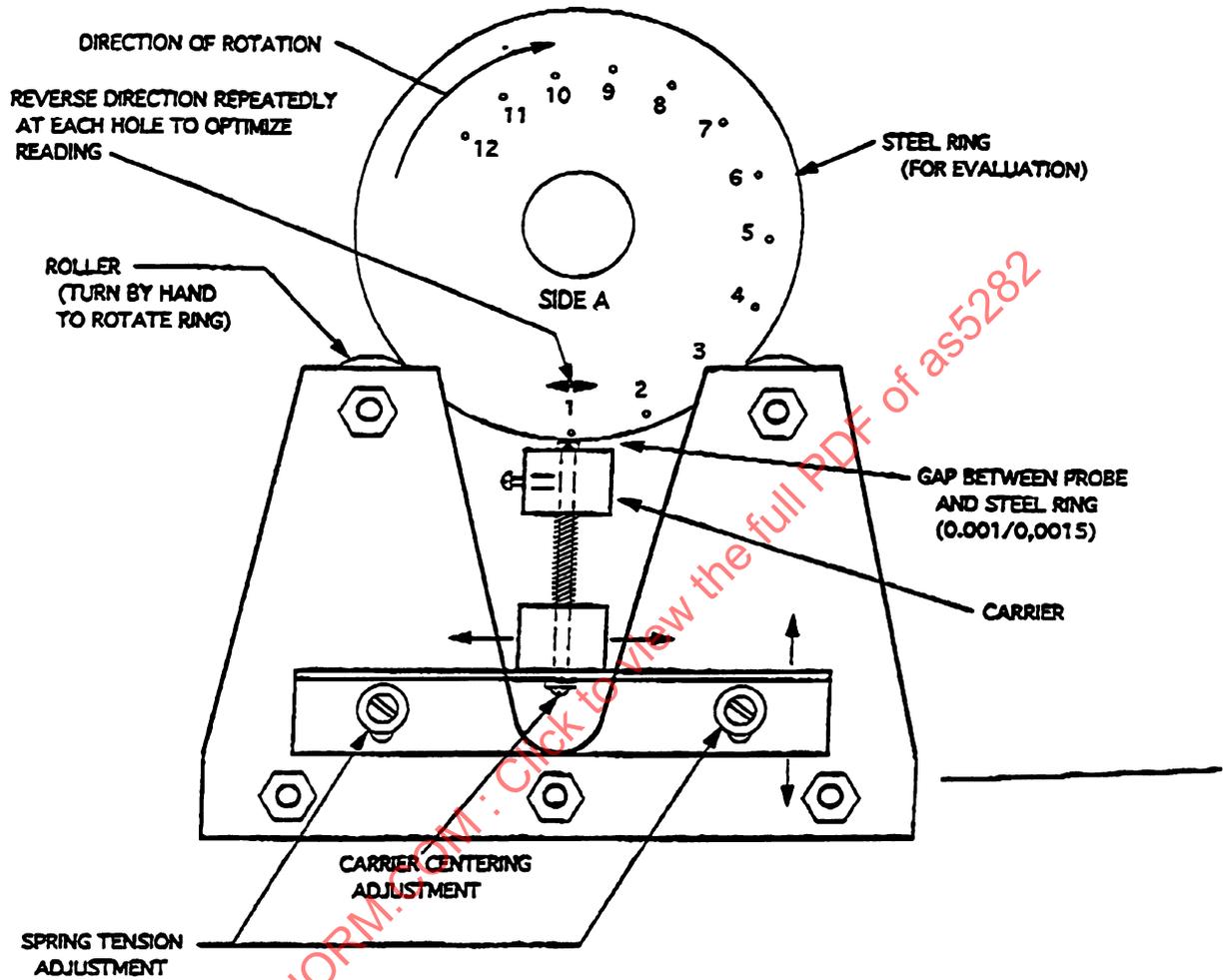


FIGURE 2 - Schematic of Fixture for Obtaining Manual Flux Leakage Readings

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4.2.2 Graph the results with the hole numbers along the abscissa (horizontal) and gauss values along the ordinate (vertical). Join each value with a line to generate a smooth curve (Figure 3). For additional rings in a lot, repeat the steps in 4.2 through 4.2.2. Upon completion of the lot measurement, calculate the average gauss value at each hole for those rings which exhibit a smooth curve (Table 1, Rings 2-4) and plot the mean average curve (Figure 4).

Example: The mean average value for Rings 2-4, at hole #1, is 21 gauss and 10% of this value is 2.1 gauss. The upper and lower acceptance limit for Rings 2-4 are plotted at  $\pm 2.1$  gauss from the mean average curve (Figure 4). Using a French curve, draw the mean curve for Ring 1 (Figure 4). The value for hole #1 (Ring 1) is 15 gauss and the upper and lower limits are 1.5 gauss. It is obvious that Ring 1 values do not generate a smooth curve and they fall outside the acceptance limits.

4.2.3 Any ring which exhibits gauss values which fall outside the limits shall be rejected (see Figure 4).

4.3 Automated Leakage Field Measurement Method:

Surface oil or grease shall be removed from each ring before magnetization. Each ring shall be magnetized at 1500 A, in accordance with 4.1. Calibrate the magnetic sensor in accordance with the manufacturer's instructions and insert it in a fixture similar to Figure 5. The gap between the sensor face and the ring surface shall be 0.001 to 0.0015 in (0.025 to 0.038 mm).

4.3.1 The automated system in Figure 5 utilizes a turntable which has a central hole through which is inserted a central conductor. Clamps and cables may be attached to the internal conductor and magnetizing source if it is desired to magnetize the ring in-place or the rings may be magnetized on a internal conductor separate from the auto fixture. A motorized drive system shall be provided to rotate the ring past the magnetic sensor. The system shall rotate freely without any wobble. In addition to the rotating fixture, the system requires a power supply, magnetic sensor, amplifier, and oscilloscope (see Figure 6).

4.3.2 The rings shall be magnetized and evaluated in a uniform orientation to avoid a reverse in polarity of the leakage field.

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TABLE 1 - Flux Leakage Results (Gauss)

Holes	Ring No. 1	Ring No. 2	Ring No. 3	Ring No. 4	Avg. 2-4
1	15.1	21.6	20.5	21.3	21.1
2	11.6	16.1	14.2	15.4	15.2
3	7.6	11.3	10.4	11.4	11.0
4	0.8	9.5	8	8.3	8.6
5	4.3	7.2	6.8	6.4	6.8
6	0.2	5.6	5.4	5.6	5.5
7	0	5.1	4.5	4.5	4.7
8	0	4.5	4.1	3.5	4.0
9	0	4.4	3.9	3.6	4.0

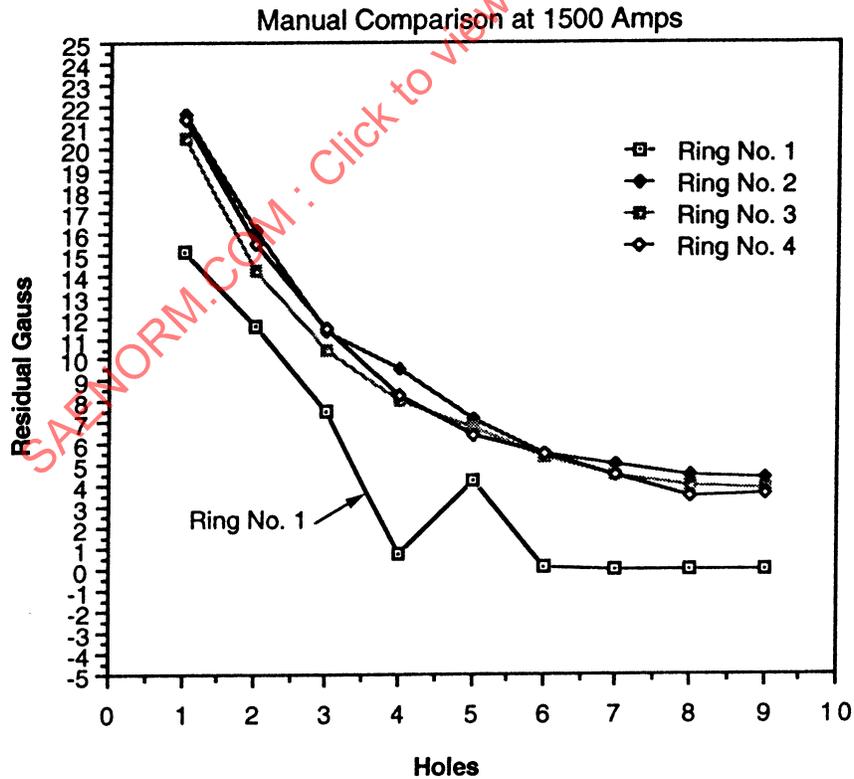


FIGURE 3 - Flux Leakage Comparison at 1500 A

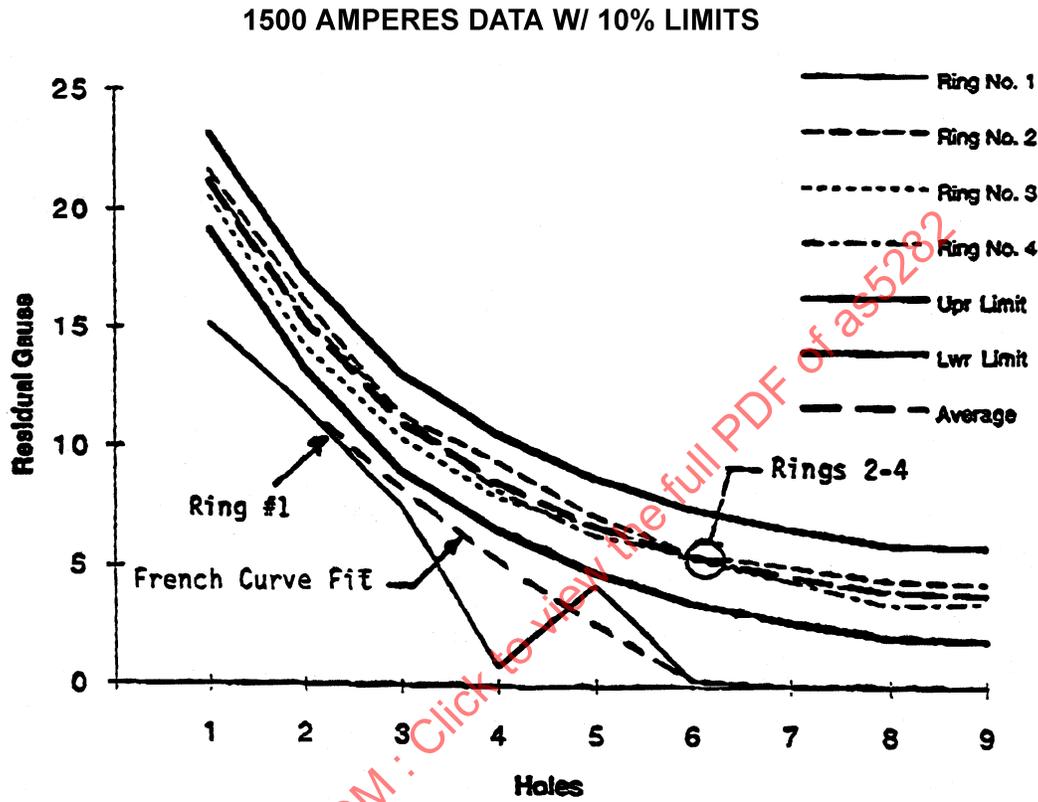


FIGURE 4 - Residual Flux Leakage (Gauss) Results With Acceptance Criteria

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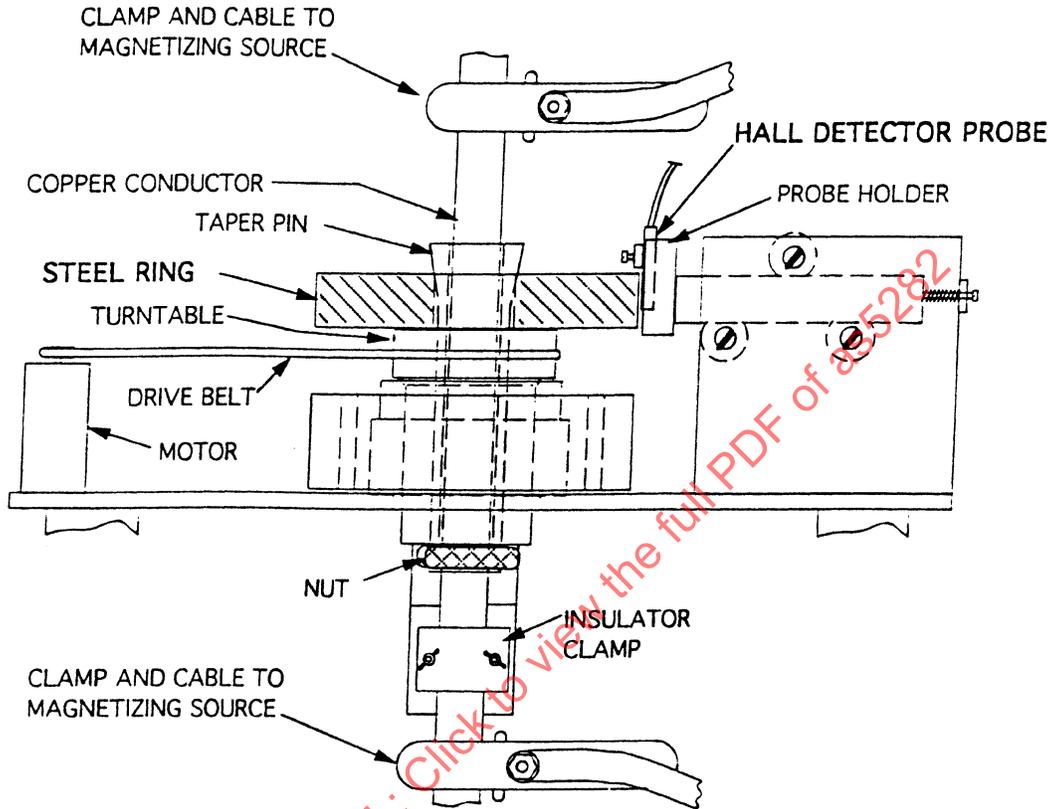


FIGURE 5 - Steel Ring Evaluation Fixture

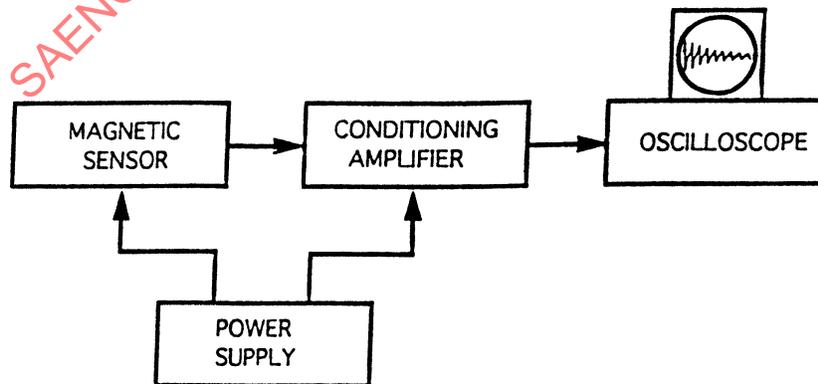


FIGURE 6 - Schematic of Automated Testing System

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- 4.3.3 After magnetizing the ring, start the rotation and set the oscilloscope gain to 10 mV/cm and adjust the oscilloscope horizontal adjustment so that the peak reading from each of the nine holes is uniformly spaced on the CRT trace (see Figure 7). Photograph or record the trace from each ring in the batch. Select the ring which gave the most uniform response from the nine holes and the one with the highest amplitude from hole #1. Using a French curve, draw a line through both the positive and negative peaks (Figure 7). Measure the total amplitude of hole #1 and calculate 5% of that value. Using the hole #1 5% value, draw duplicate lines above and below the positive and negative median lines (Figure 7).
- 4.3.4 Figure 8 shows the automated residual flux leakage results for four rings. Figures 8A and 8B results are acceptable. Figures 8C and 8D are unacceptable. Rings not yielding a uniform response and which fall outside the acceptance criteria shall be rejected.
- 4.3.5 Upon completion of all testing, each ring shall be demagnetized to a maximum level of 2 gauss, as measured at hole #1.

### 4.4 Reports:

A certification shall be supplied to the purchaser for each ring which meets the specified requirements. The certification shall include the material type (3.1), the annealing certification (3.3), the serial number of each ring (5.1), its corresponding hardness (3.5), and statements which certify that each ring conforms to the requirements of Figure 1. A leakage field plot, similar to Figure 4 for manual measurement or Figure 7 for automated measurement, shall also be provided to the purchaser.

### 4.5 Certification/Recertification:

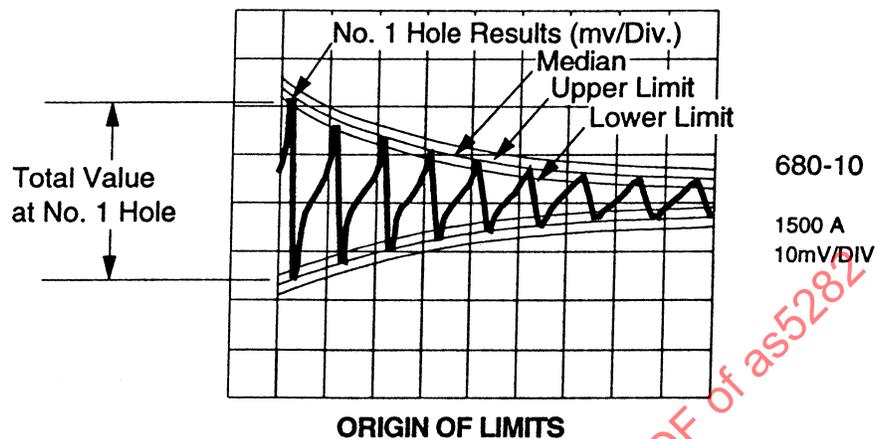
Existing rings, made prior to the release of this document, are acceptable for use provided they meet the requirements of Table 2, when tested in accordance with 4.1. Rings not meeting the requirements of Table 2 may be reannealed in accordance with 3.4 and testing in accordance with this document. New rings shall be certified in accordance with the requirements of this document. Rings which meet the requirements of this document shall be identified in accordance with 5.1.

## 5. PREPARATION FOR DELIVERY:

### 5.1 Identification:

Each ring shall be identified by electroetching or vibroetching at the location shown in Figure 1; the manufacturer's name, serial number, and AS5282. Each ring shall have a separate serial number (S/N).

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1. Draw a median line along top of positive signals.
2. Draw a duplicate line above median at 5% of total value.
3. Draw a duplicate line below median at 5% of total value.
4. Repeat Steps 1, 2 and 3 for negative signals.

The limit band widths now represent  $\pm 10\%$  of the positive or negative half of the results.

FIGURE 7 - Automated Leakage Field Results at 1500 A With Limits