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Superseding AMS 2303D

Steel Cleanliness, Aircraft Quality
Martensitic Corrosion-Resistant Steels
Magnetic Particle Inspection Procedure

1. SCOPE:

1.1 Purpose:

This specification covers steel cleanliness requirements in inch/pound units for aircraft-quality, ferro-magnetic, hardenable, corrosion-resistant steels as determined by magnetic particle inspection methods. This specification contains sampling, specimen preparation, and inspection procedures and cleanliness rating criteria.

1.1.1 MAM 2303 is the metric version of this AMS.

1.2 Application:

This procedure has been used typically for the cleanliness evaluation of blooms, billets, tube rounds, stock for forging or flash welded rings, slabs, bars, sheet, strip, plate, tubing, and extrusions used in fabricating parts subject to magnetic particle inspection, but may be used for qualification of a heat, melt, or lot of steel.

2. APPLICABLE DOCUMENTS:

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been canceled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 ASTM Publications:

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

ASTM E 10 Brinell Hardness of Metallic Materials
ASTM E 1444 Magnetic Particle Examination

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2.2 ANSI Publications:

Available from American National Standards Institute, Inc., 11 West 42nd Street, New York, NY 10036-8002.

ANSI B46.1 Surface Texture

3. TECHNICAL REQUIREMENTS:

3.1 Specimen Preparation:

- 3.1.1 Heat Qualification: Sampling shall be in accordance with 4.3.1. Samples shall be converted into test specimens in accordance with 3.1.3.
- 3.1.2 Product Qualification: Product (See 8.2) from a heat not qualified based on sampling as in 4.3.1 shall be sampled in accordance with 4.3.2. Samples shall be converted into test specimens in accordance with 3.1.3.
- 3.1.3 Working and Rough Machining:
- 3.1.3.1 Solid Product Over 36 Square Inches Cross-Sectional Area Except Flat Bars, Slabs, and Plates: A quarter-section shall be cut from the sample sufficiently oversize that the center of the original specimen will be approximately on the surface of the specimen after generating to test size. The specimen shall be converted into test size by machining, or forging and machining, to a diameter not larger than 6 inches consistent with the machining allowance specified in 3.1.4.1. As an alternate method when acceptable to purchaser, the full section may be rolled or forged to a 6 inch round or square and an oversize quarter obtained as in 3.1.3.2. The identity for specimen surface representing center of original stock shall be maintained throughout machining and testing.
- 3.1.3.2 Solid Product 16 to 36 Square Inches, Inclusive, in Cross-Sectional Area Except Flat Bars, Slabs, and Plates: A quarter-section shall be cut sufficiently oversize that the center of the original specimen will be approximately on the surface of the sample after generating to test size. The specimen shall be converted to test size by machining, or forging and machining, to the largest possible round consistent with the machining allowance specified in 3.1.4.1. The identity for specimen surface representing center of original stock shall be maintained throughout machining and testing.
- 3.1.3.3 Solid Product Under 16 Square Inches in Cross-Sectional Area Except Flat Bars, Slabs, and Plates: A quarter-section shall be cut from each sample sufficiently oversize that the center of the original sample will be approximately on the surface after generating to test size. The quarter-section shall be converted into a test specimen by machining to a "one-step" straight cylinder nominally 5 inches long. Minimum stock removal shall be consistent with the machining allowance specified in 3.1.4.
- 3.1.3.3.1 As an alternate method, a step-down specimen may be generated from the full cross-section in equal length circumferential steps as shown in Table 1, consistent with the machining allowance specified in 3.1.4.

TABLE 1 - Stepdown Specimens

Nominal Diameter or Least Distance Between Parallel Sides Inches	Step Length Inches	Step Diameter 1	Step Diameter 2	Step Diameter 3	Step Diameter 4	Step Diameter 5
0.250 to 0.500, incl	5.000	D	--	--	--	--
Over 0.500 to 0.750, incl	2.500	D	2/3D	--	--	--
Over 0.750 to 1.000, incl	1.665	D	3/4D	1/2D	--	--
Over 1.000 to 1.500, incl	1.250	D	4/5D	3/5D	2/5D	--
Over 1.500	1.000	D	4/5D	3/5D	2/5D	1/5D

D = Original diameter or distance between parallel sides minus machining stock removed.

- 3.1.3.4 Flat Bars: The type of test and the location in the section shall be as agreed upon by purchaser and vendor.
- 3.1.3.5 Slabs or Plates: A straight cylindrical or rectangular specimen shall be machined, or forged and machined, from each slab or plate tested. The specimen shall be taken essentially parallel to the direction of rolling, midway between edge and center of the slab or plate width, shall be nominally 5 inches in length, and not more than 4 inches in final diameter or thickness.
- 3.1.3.5.1 Product Up to 4 Inches, Inclusive, in Nominal Thickness: A straight cylindrical specimen shall represent the full thickness consistent with the machining allowance specified in 3.1.4.3.
- 3.1.3.5.2 Product Over 4 to 8 Inches, Inclusive, in Nominal Thickness: A straight cylindrical specimen shall represent surface to mid-thickness consistent with the machining allowance specified in 3.1.4.3.
- 3.1.3.5.3 Product Over 8 Inches in Nominal Thickness: A straight cylindrical specimen shall be taken so that the axis is approximately midway between the surface and mid-thickness, and shall have a diameter equal to one-third the nominal thickness of the section, allowing 0.010 inch per side for finish machining after heat treatment.
- 3.1.3.6 Tubing:
- 3.1.3.6.1 Up to 10 Inches, Inclusive, in Nominal OD: Specimens nominally 5 inches in length shall be machined to straight cylindrical sections in accordance with 3.1.4.2.1.
- 3.1.3.6.2 Over 10 Inches in Nominal OD with Nominal Wall Thickness Up to 2Inches, Inclusive: Specimens nominally 5 inches in length shall be machined to straight cylindrical sections in accordance with 3.1.4.2.2.
- 3.1.3.6.3 Over 10 Inches in Nominal OD with Nominal Wall Thickness Over 2 to 4Inches, Inclusive: Specimens nominally 5 inches in length representing the full cross section, less the machining allowance specified in 3.1.4.2.2, shall be machined to straight cylindrical sections.

3.1.3.6.4 Over 10 Inches in Nominal OD with Nominal Wall Thickness Over 4 Inches: Specimens nominally 5 inches in length, representing the inside surface to the mid-thickness of the wall, less the machining allowance specified in 3.1.4.2.2, shall be machined to straight cylindrical sections.

3.1.4 Machining:

3.1.4.1 Product Other Than Tubing, Flat Bars, Slab, and Plate: The converted sample shall be machined to conform to the allowance shown in Table 2 for surface removal, allowing 0.010 inch per side for finish machining after heat treatment.

TABLE 2 - Stock Removal

Nominal Diameter or Least Distance Between Parallel Sides Inches	Minimum Stock Removal Inch per Side
0.250 to 0.500, incl	0.030
Over 0.500 to 0.750, incl	0.045
Over 0.750 to 1.000, incl	0.060
Over 1.000 to 1.500, incl	0.075
Over 1.500 to 2.000, incl	0.090
Over 2.000 to 2.500, incl	0.125
Over 2.500 to 3.500, incl	0.156
Over 3.500 to 4.500, incl	0.187
Over 4.500 to 6.000, incl	0.250

3.1.4.2 Tubing:

3.1.4.2.1 Up to 10 Inches, Inclusive, in Nominal OD: Tubing with nominal wall thickness under 0.250 inch shall have 10% of the wall thickness or 0.015 inch, whichever is less, removed from the OD after heat treatment. Samples from tubing with nominal wall thickness of 0.250 inch and over shall be machined to conform to the stock removal requirement shown in Table 3.

TABLE 3 - Stock Removal, Tubing

Machined Diameter Inches	Minimum Stock Removal Inch per Side
Up to 2-1/2, incl	0.044
Over 2-1/2 to 3-1/2, incl	0.046
Over 3-1/2 to 4-1/2, incl	0.052
Over 4-1/2 to 5-1/2, incl	0.057
Over 5-1/2 to 6-1/2, incl	0.064
Over 6-1/2 to 8, incl	0.074
Over 8 to 10, incl	0.087

- 3.1.4.2.2 Tubing Over 10 Inches in Nominal OD: Tubing with nominal wall thickness up to 4 inches, inclusive, shall be turned to straight cylindrical sections representing the full cross section of the wall, less allowance of 0.150 inch stock removal on the OD and ID and allowing 0.010 inch per side for finish machining after heat treatment. Samples from tubing with nominal wall thickness over 4 inches shall be turned to cylindrical sections representing the cross section from the OD to mid-thickness of the wall less allowance of 0.150 inch stock removal on the OD, and allowing 0.010 inch per side for finish machining after heat treatment.
- 3.1.4.3 Flat Bars, Slabs, and Plates: Allowance of 20% of the nominal thickness or 0.100 inch whichever is less, shall be made for minimum stock removal, allowing 0.010 inch per side for finish machining after heat treatment.
- 3.1.5 Heat Treatment: Unless otherwise specified, rough machined specimens shall be hardened by suitably austenitizing, quenching, and tempering to produce hardness not lower than 200 HB, or equivalent (See 8.2), determined in accordance with ASTM E 10.
- 3.1.6 Finish Machining: The heat treated specimens shall be finished machined to a surface texture not rougher than 32 microinches AA, determined in accordance with ANSI B46.1. Rateable surface of specimens shall be nominally 5 inches in length. The ends of the specimen shall be finished to provide good electrical contact.

3.2 Inspection:

Magnetic particle inspection shall be performed in accordance with ASTM E 1444 by the circular, wet, continuous method (See 8.4) using 800 to 1200 amperes per inch of diameter. If the stepdown bar (3.1.3.3) is used, the smallest step shall be magnetized and inspected first; the larger steps shall be magnetized and inspected individually in succession of increasing size until all steps have been evaluated. If a longitudinal slice from slab or plate, as in 3.1.3.5 is used, only the longitudinal surfaces perpendicular to the two faces of the slab or plate shall be inspected.

3.2.1 Cleanliness standards presented herein govern nonmetallic inclusions only (See 8.4). Steel which, during inspection, reveals indications representing actual ruptures, such as cracks, seams, laminations, and laps, will be subject to rejection except where these defects result from sample preparation.

3.2.2 The results of magnetic particle inspection shall be appropriately recorded. All recorded results shall be identified, filed, and made available to purchaser upon request. Records shall be available for three years after shipment of the product.

3.3 Evaluation of Steel Cleanliness:

After inspection, each indication 1/16 inch and over in length shall be recorded. The frequency (number) and severity (size) of the indications shall be calculated as follows:

3.3.1 Frequency (F):

3.3.1.1 The number of indications per test specimen is totaled.

3.3.1.2 The frequency rating per specimen is determined by dividing the total number of indications for each specimen by the area of the test specimen in square inches.

3.3.1.3 The frequency ratings for all test specimens from a heat are totaled.

3.3.1.4 The average frequency (F) equals the total frequency rating for all test specimens from a heat divided by the number of test specimens.

3.3.2 Severity (S):

3.3.2.1 The length of each indication is recorded.

3.3.2.2 The product for each specimen is computed by totaling the product of the number of indications times the appropriate progression factor shown in Table 4:

TABLE 4 - Progression Factor for Severity Rating

Length of Indication Inches	Progression Factor
1/16 to 1/8, incl	0.5
Over 1/8 to 1/4, incl	1
Over 1/4 to 1/2, incl	2
Over 1/2 to 3/4, incl	4
Over 3/4 to 1, incl	8
Over 1 to 1-1/2, incl	16

- 3.3.2.2.1 Specimens which contain indications representing non-metallic inclusions over 1-1/2 inches in length shall be subject to rejection.
- 3.3.2.3 The severity rating per specimen is determined by dividing the product for each specimen by the area of the specimen in square inches.
- 3.3.2.4 The severity ratings for all test specimens from a heat are totaled.
- 3.3.2.5 The average severity (S) equals the total severity rating for all test specimens from a heat divided by the number of test specimens.

3.4 Disposition:

Product inspected in accordance with this specification shall conform to the following maximum frequency and severity ratings.

3.4.1 Heat Qualification (See 4.3.1):

3.4.1.1 Product Other Than Slab, Sheet, Strip, and Plate:

3.4.1.1.1 Individual Test Bar: As shown in Table 5:

TABLE 5 - Individual Test Bar

Carbon Content Percent	Ratings Frequency	Ratings Severity
Up to 0.25, excl	0.75	0.75
0.25 and over	0.67	0.55

3.4.1.1.2 Average of All Test Bars From a Heat: As shown in Table 6.

TABLE 6 - Average of All Test Bars

Carbon Content Percent	Ratings Frequency	Ratings Severity
Up to 0.25, excl	0.40	0.35
0.25 and over	0.37	0.32

3.4.1.2 Slabs and Plate: As shown in Table 7.

TABLE 7 - Slabs and Plate

Average of All Tests From a Heat Frequency	Average of All Tests From a Heat Severity
0.80	0.67

3.4.2 Production Qualification (See 4.3.2):

3.4.2.1 Product Other Than Sheet, Strip, and Plate:

3.4.2.1.1 Individual Test Bar: As shown in Table 8.

TABLE 8 - Individual Test Bars

Product Nominal Diameter Inches	Carbon Content Percent	Ratings Frequency	Ratings Severity
Up to 2.500, excl	Up to 0.25, excl	1.10	1.05
	0.25 and over	1.00	0.95
2.500 and over	Up to 0.25, excl	0.80	0.80
	0.25 and over	0.80	0.67

3.4.2.1.2 Average of All Test Bars From a Heat: As shown in Table 9.

TABLE 9 - Average of All Test Bars

Product Nominal Diameter Inches	Carbon Content Percent	Ratings Frequency	Ratings Severity
1.000 to 2.500, incl	Up to 0.25, excl	0.90	0.85
	0.25 and over	0.85	0.80
Over 2.500	Up to 0.25, excl	0.40	0.35
	0.25 and over	0.37	0.32

3.4.2.1.2.1 Product under 1.000 inch in nominal diameter or least distance between parallel sides inspected using the straight cylindrical test bars or product under 16 square inches in cross-sectional area inspected by the alternate step-down specimen (See 3.1.3.3), shall have maximum average frequency and severity ratings agreed upon by purchaser and vendor.

3.4.2.2 Sheet and Strip: Shall have maximum individual and average frequency and severity ratings agreed upon by purchaser and vendor.

3.4.3 Product inspected in accordance with this specification and having frequency, severity, or both, ratings exceeding the specified limits may be reevaluated for specific applications when permitted by purchaser. Evaluation of any one or two steps of the alternate stepdown specimen may be waived by purchaser when the area represented is not considered critical for the end product.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

The vendor of the product shall supply all samples for vendor's tests and shall be responsible for the performance of all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to specified requirements.

4.2 Classification of Tests:

All applicable requirements are acceptance tests and shall be performed as specified in 4.2.1 or 4.2.2.

4.2.1 Heat Qualification: Tests in accordance with 4.3.1 to determine conformance to "heat qualification" requirements, if acceptable, need be conducted only once per heat.

4.2.1.1 Heats which have been qualified as semi-finished product shall be considered qualified for finished product.

4.2.2 Product Qualification: Tests to determine conformance to requirements on product not "heat qualified" shall be conducted on product of each size and shape of each lot made from each heat.

4.3 Sampling and Testing:

The sampling procedure for heat qualification shall be as described in 4.3.1. No further sampling by the producer shall be required from a heat which meets the requirements of 3.4.1. The sampling procedure for product qualification shall be as described in 4.3.2.

4.3.1 Heat Qualification:

4.3.1.1 Heats of Top-Poured Ingots: Samples shall be taken from semi-finished or finished product representing the top and bottom of the first ingot and last usable ingot from heats having not more than 10 ingots or not over 30 tons or from portions of heats within these limits; and from the top and bottom of the first, middle, and last usable ingot of heats having more than 10 ingots or over 30 tons.

- 4.3.1.2 Heats of Bottom-Poured Ingots: Samples shall be taken from semi-finished or finished product representing the top and bottom of three ingots. One ingot shall be taken at random from the first usable plate poured, one ingot at random from the usable plate poured nearest to the middle of the heat, and one ingot at random from the last usable plate poured. When less than three plates per heat are produced, samples shall be taken from the top and bottom of one random ingot per plate.
- 4.3.1.2.1 If there are less than three ingots in the heat, samples shall be taken representing the top and bottom of all ingots.
- 4.3.1.3 Strand-Cast Heats: Samples shall be taken from semi-finished or finished product having at least a 3:1 reduction in cross-section from the cast strand (or samples of the as-cast strand similarly reduced) representing the front, middle, and back of both strands when two strands are cast, or of an inside strand and an outside strand when more than two strands are cast. When a single strand is cast, six samples having at least a 3:1 reduction from the cast strand (or samples of the cast strand similarly reduced) representing both ends of the first, middle, and last usable cuts (blooms) of the strand or product shall be taken.
- 4.3.2 Product Qualification: Samples shall be taken at random from not less than 10% of the pieces of each lot. A lot shall be all product of one size from one heat in one shipment. Not less than three nor more than 10 samples shall be selected from a lot, except that if the quantity in the lot is three pieces or less, one sample shall be taken from each piece.
- 4.4 Reports:
- The vendor of the product shall include the AMS 2303E frequency-severity rating for each heat or lot in the shipment, in addition to other information required by the applicable material specification.
- 4.5 Resampling and Retesting:
- 4.5.1 Product Other Than Slabs, Plates, Sheet, and Strip: If any specimen used in the above tests fails to meet the specified requirements, disposition of the heat or lot may be based on the results of testing three additional specimens for each original nonconforming specimen; additional specimens shall be as follows:
- 4.5.1.1 Heats of Top-Poured Ingots: One of the additional specimens shall be taken from the same position from product from each of the two available ingots most immediately adjacent in pouring sequence to that from which the originally nonconforming specimen was taken. The third specimen shall be taken from product of the original nonconforming ingot after additional discard. Should the latter specimen be unacceptable, resampling and retesting of the nonconforming ingot may be repeated after as many consecutive discards as necessary to obtain acceptable results. Should any of the adjacent ingot tests fail to meet the specified requirements, resampling and retesting of these ingots will be permitted using the procedure specified for the original nonconforming ingot.

- 4.5.1.2 Heats of Bottom-Poured Ingots: One of the additional specimens shall be taken from the same position from product from each of the two available ingots most immediately adjacent to that from which the originally nonconforming specimen was taken. The third specimen shall be taken from product of the original nonconforming ingot after additional discard. Should the latter specimen be unacceptable, resampling and retesting of the nonconforming ingot may be repeated after as many consecutive discards as necessary to obtain acceptable results. Should any of the adjacent ingot tests fail to meet the specified requirements, resampling and retesting of these ingots will be permitted using the procedure specified for the original nonconforming ingot.
- 4.5.1.2.1 If there are less than three ingots in the heat, all test locations that fail shall be retested after discard is taken.
- 4.5.1.3 Strand Cast Heats: One of the additional samples shall be taken from the section adjacent to the original nonconforming specimen after sufficient discard, and the two adjacent cuts (blooms) shall be sampled at both ends and tested. Should any of the adjacent cut (bloom) test locations fail to meet the specified requirements, resampling and retesting of those locations will be permitted using the procedure specified for the original nonconforming location.
- 4.5.2 Slab, Plate, Sheet, and Strip:
- 4.5.2.1 For Heat Qualification of Slab and Plate: If the average of the specimens from a heat fails to meet the requirements of 3.4.1.2 for the average of all original specimens, disposition of the heat may be based on the results of testing three additional specimens for each original specimen to be retested. Two of the additional specimens shall be taken so as to be representative of the heat. The third specimen shall be taken from the original nonconforming slab or plate after additional discard. Should the average of the results on the original specimens not requiring retesting plus those on the additional specimens fail to meet the requirements of 3.4.1.2, resampling and retesting may be repeated after as many discards as necessary to obtain acceptable results.
- 4.5.2.2 For Product Qualification of Sheet, Strip, and Plate: If the average of all specimens from slabs or plates from a heat fails to meet the requirements of 3.4.1.2 but the slabs or plates have been rolled to less than 0.1875 inch before being resampled for retesting, or if any specimen from sheet and strip fails to meet the maximum individual or average frequency or severity ratings agreed upon by purchaser and vendor (See 3.4.2.2), or if the average of all specimens from a lot of plate not qualified as a heat fails to meet the requirements of 3.4.1.2, disposition of the product may be based on the results of testing three specimens for each original specimen which exceeds the average frequency or severity limit, or both, of 3.4.1.2 in the case of plate or which exceeds the agreed-upon individual or average limits (See 3.4.2.2) in the case of sheet and strip. The retest specimens shall be taken so as to be representative of the heat or lot. Should the average of the results on the original specimens not requiring retesting plus those on the retest specimens fail to meet the requirements of 3.4.1.2 or 3.4.2.2, as applicable, resampling and retesting may be repeated after as many discards as necessary to obtain acceptable results.