



AEROSPACE MATERIAL SPECIFICATION

AMS2304

REV. B

Issued 1991-01
Revised 2010-08
Reaffirmed 2015-05

Superseding AMS2304A

Steel Cleanliness, Special Aircraft-Quality
Magnetic Particle Inspection Procedure

RATIONALE

AMS2304B has been reaffirmed to comply with the SAE five-year review policy.

1. SCOPE

1.1 Purpose

This specification covers steel cleanliness requirements in inch/pound units for special aircraft-quality ferromagnetic steels, including hardenable corrosion resistant steels, by magnetic particle inspection methods. This specification contains sampling, sample preparation, inspection procedures and cleanliness rating criteria (See 8.2).

1.1.1 The metric version, MAM2304, has been cancelled. The SI units have been included in this specification, but the inch/pound units are primary (See 8.7)

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, plate, tubing, and extrusions used in fabricating highly stressed parts where very strict magnetic particle inspection standards are used in final inspection of such parts, but may be used for qualification of a heat, melt or lot of steel.

1.2.1 Product qualified to this specification is not recommended for use in parts where the high transverse properties of vacuum-arc-remelted or electroslag remelted steel are required (See 8.4).

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 cancelled and no superseding document has been specified, the last published issue of that document shall apply.

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<http://www.sae.org/technical/standards/AMS2304B>

2.1 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E 10 Brinell Hardness of Metallic Materials

ASTM E 1444 Magnetic Particle Testing

2.2 ANSI Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

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 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 12 Inches (305 mm) and Over in Nominal Diameter or Distance Between Parallel Sides

A quarter section shall be cut from the sample sufficiently oversize that the center of the original sample will be approximately on the surface of the specimen after generating to test size. The quartered section shall then be forged to a 3 to 6 inch (76 to 152 mm) round or square, maintaining the axis of the forging approximately parallel to the original direction of rolling. As an alternate method, the full section may be rolled or forged to a 6-inch (152-mm) round or square and an oversize quarter obtained as in 3.1.3.3. Specimens shall be rough machined to a "one-step" straight cylinder nominally 5 inches (127 mm) long. Minimum stock removal shall be consistent with the machining allowance specified in 3.1.4.1.

3.1.3.2 Solid Product Over 6 to 12 Inches (152 to 305 mm), Exclusive, in Nominal Diameter or Distance Between Parallel Sides Except 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 of the specimen after generating to test size. The quarter section shall be converted into a test specimen by machining, or forging and machining, to a 3 to 6 inch (76 to 152 mm) round or square. Specimens shall be rough machined to a "one-step" straight cylinder nominally 5 inches (127 mm) long. Minimum stock removal shall be consistent with the machining allowance specified in 3.1.4.1.

3.1.3.3 Solid Product 6 Inches (152 mm) and Under in Nominal Diameter or Distance or Distance Between Parallel Sides 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 of the specimen 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 (127 mm) long. Minimum stock removal shall be consistent with the machining allowance specified in 3.1.4.1.

- 3.1.3.3.1 As an alternate method, a stepdown specimen may be generated from the full cross-section in equal length circumferential steps as shown in Table 1.

TABLE 1A - STEPDOWN SPECIMENS – CYLINDRICAL (INCH/POUND UNITS)

Nominal Diameter or Distance Between Parallel Sides Inches	Step Length Inches	Step 1 Diameter	Step 2 Diameter	Step 3 Diameter	Step 4 Diameter	Step 5 Diameter
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.

TABLE 1B - STEPDOWN SPECIMENS – CYLINDRICAL (SI UNITS)

Nominal Diameter or Distance Between Parallel Sides Millimeters	Step Length Millimeters	Step 1 Diameter	Step 2 Diameter	Step 3 Diameter	Step 4 Diameter	Step 5 Diameter
6.35 to 12.70, incl	127.0	D	--	--	--	--
Over 12.70 to 19.05, incl	63.50	D	2/3D	--	--	--
Over 19.05 to 25.40, incl	42.29	D	3/4D	1/2D	--	--
Over 25.40 to 38.10, incl	31.75	D	4/5D	3/5D	2/5D	--
Over 38.10	25.40	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

Specimens nominally 5 inches (127 mm) long shall be rough machined to equal-length steps across the width of the specimen, in accordance with Table 2, allowing 20% of the thickness or 0.100 inch (2.54 mm), whichever is less, for minimum stock removal. Allowance of 0.010 inch (0.25 mm) shall be made for finish machining.

TABLE 2A - STEPDOWN SPECIMENS - FLAT BARS (INCH/POUND UNITS)

Nominal Thickness Inches	Step Length Inches	Step 1 Thickness	Step 2 Thickness	Step 3 Thickness	Step 4 Thickness	Step 5 Thickness
Up to 0.250, incl	5.000	T	--	--	--	--
Over 0.250 to 0.500, incl	2.500	T	2/3T	--	--	--
Over 0.500 to 1.000, incl	1.250	T	3/4T	1/2T	1/4T	--
Over 1.000	1.000	T	4/5T	3/5T	2/5T	1/5T

T = Original nominal thickness minus machining stock removed.

TABLE 2B - STEPDOWN SPECIMENS - FLAT BARS (SI UNITS)

Nominal Thickness Millimeters	Step Length Millimeters	Step 1 Thickness	Step 2 Thickness	Step 3 Thickness	Step 4 Thickness	Step 5 Thickness
Up to 6.35, incl	127.00	T	--	--	--	--
Over 6.35 to 12.70, incl	63.50	T	2/3T	--	--	--
Over 12.70 to 25.40, incl	31.75	T	3/4T	1/2T	1/4T	--
Over 25.40	25.40	T	4/5T	3/5T	2/5T	1/5T

T = Original nominal thickness minus machining stock removed.

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 at the center of the slab or plate width and thickness and shall be nominally 5 inches (127 mm) in length, and not more than 4 inches (102 mm) in final diameter or thickness.

3.1.3.5.1 Product Up to 4 Inches (102 mm), Inclusive, in Nominal Thickness

A straight cylindrical specimen shall represent the full thickness consistent with the machining allowance specified in 3.1.4.1.

3.1.3.5.2 Product Over 4 to 8 Inches (102 to 203 mm), Inclusive, in Nominal Thickness

A straight cylindrical specimen shall represent surface to mid-thickness consistent with the machining allowance specified in 3.1.4.1.

3.1.3.5.3 Product Over 8 Inches (203 mm) 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.

3.1.3.6 Tubing

3.1.3.6.1 Nominal Wall Thickness 0.250 Inch (6.35 mm) and Over

Specimens, nominally 5 inches (127 mm) long, shall be rough machined to 4 equal circumferential steps, T, 3/4T, 1/2T, and 1/4T, allowing 0.100 inch (2.54 mm) on the diameter for stock removal. Allowance of 0.010 inch (0.25 mm) on the radii for finish machining shall be made. T = nominal wall thickness minus the machining allowance.

3.1.3.6.2 Nominal Wall Thickness Under 0.250 Inch (6.35 mm)

Specimens, nominally 5 inches (127 mm) long, after heat treatment as in 3.1.5, shall have 10% of the wall thickness or 0.015 inch (3.81 mm), whichever is less, removed from the outer diameter and be tested as a straight cylinder.

3.1.4 Machining

3.1.4.1 Product Other Than Flat Bars, Slabs, and Plates Over 8 Inches (203 mm) Thick, and Tubing

The converted sample shall be machined to conform to the allowance of Table 3 for surface removal, allowing 0.010 inch (0.25 mm) per side for finish machining after heat treatment.

TABLE 3 - STOCK REMOVAL

Nominal Diameter or Distance Between Parallel Sides Inches (Millimeters)		Minimum Stock Removal Inch (Millimeters) per Side
0.250 to 0.500	(6.35 to 12.70), incl	0.030 (0.76)
Over 0.500 to 0.750	(12.70 to 19.01), incl	0.045 (1.14)
Over 0.750 to 1.000	(19.01 to 25.40), incl	0.060 (1.52)
Over 1.000 to 1.500	(25.40 to 38.10), incl	0.075 (1.91)
Over 1.500 to 2.000	(38.10 to 50.80), incl	0.090 (2.29)
Over 2.000 to 2.500	(50.80 to 63.50), incl	0.125 (3.18)
Over 2.500 to 3.500	(63.50 to 88.90), incl	0.156 (3.96)
Over 3.500 to 4.500	(88.90 to 114.30), incl	0.187 (4.75)
Over 4.500 to 6.000	(114.30 to 152.40), incl	0.250 (6.35)

3.1.5 Heat Treatment

Rough machined specimens shall, if necessary, be heat treated by suitably austenitizing, quenching, and tempering or by solution and precipitation heat treating to produce hardness of 248 to 352 HB or appropriate lower hardness for steel of low hardenability. Hardness testing shall be in accordance with ASTM E10. Specimens shall be austenitized in a neutral or slightly reducing atmosphere. Following heat treatment, surface scale may be removed by grit blasting or other acceptable method.

3.1.6 Finish Machining

The heat treated specimens shall be finish machined to surface roughness not greater than 32 microinches AA, determined in accordance with ANSI B46.1. The ends of the specimen shall be finished to provide good electrical contact.

3.2 Inspection

Magnetic particle testing shall be performed in accordance with ASTM E 1444 by the circular, wet, continuous method (See 8.3) using 800 to 1200 amperes per inch (32 to 48 amperes/mm) of diameter or another magnetic particle procedure acceptable to purchaser. If a stepdown bar 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 8.3). Steel that, 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. If such indications are the consequence of sample preparation, a replacement retest sample may be obtained from material adjacent to the original test location.

3.2.2 The results of the magnetic particle testing shall be appropriately recorded. All recorded results shall be identified, filed, and made available to purchaser upon request.

3.3 Evaluation of Steel Cleanliness

After inspection, each indication 1/64 inch (0.4 mm) and over shall be recorded on an inspection chart. All recorded results shall be identified, filled, and, upon request, made available to purchaser. Records shall be available for at least three years after shipment of the product. The frequency rating (F) number and the severity rating (S) length 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 per specimen is determined by dividing the total number of indications for each specimen by the test surface area of the specimen frequency in square inches (by dividing 6.45 times the total number of indications for each specimen by the test surface area of the specimen in square centimeters)..

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

3.3.1.4 The average frequency rating (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 Inch (Millimeters)	Progression Factor
1/64 to 1/32 (0.40 to 0.79), excl	2 (13)
1/32 to 1/16 (0.79 to 1.59), excl	4 (26)
1/16 to 1/8 (1.59 to 3/18), excl	16 (103)
1/8 (3.18) and over	256 (1650)

3.3.2.3 The severity rating per specimen is determined by dividing the product for each specimen by the test surface area of the specimen in square inches (square centimeters).

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 requirements:

3.4.1 Product inspected for heat qualification as in 4.3.1 and for product qualification as in 4.3.2 shall conform to a maximum average frequency rating (F) of 0.25 and a maximum average severity rating (S) of 0.50.

3.4.2 Product inspected in accordance with this specification and having frequency-severity rating exceeding the specified limits may be reevaluated for specific applications when permitted by purchaser. Evaluation of any one or two steps of stepdown specimens 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 technical requirements are acceptance tests and shall be performed as specified in 4.2.1 or 4.2.2.

4.2.1 Heat Qualification

Tests of samples taken as in 4.3.1 to determine conformance to heat qualification requirements, if acceptable, need be conducted only once per heat.

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

4.2.2 Product Qualification

Tests 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 described in 4.3.1 shall be performed by the producer. No further sampling by the producer shall be required from a heat that meets the requirements of 3.4.1. For product not heat qualified, sampling procedures 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 60 000 pounds (27 216 kgs) , 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 60 000 pounds (27 216 kgs).

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 a heat consists of two usable plates, two of the sample ingots shall be selected from the second usable plate poured. When a heat consists of a single usable plate, any three random ingots may be selected.

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 ten 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 AMS2304B frequency-severity rating for each 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 and Plates

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 where 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 those 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 and Plate

4.5.2.1 For Heat Qualification

If the average of the specimens from a heat fails to meet the requirements of 3.4 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, resampling and retesting may be repeated after as many discards as necessary to obtain acceptable results.