SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

MAM 2301C

Issued MAR 1996
Noncurrent MAR 2003
Cancelled JUN 2007

Superseded by AMS 2301

Steel Cleanliness, Aircraft Quality Magnetic Particle Inspection Procedure Metric (SI) Measurement

RATIONALE

MAM 2301B has been designated cancelled and superseded because AMS 2301 provides equivalent technical requirements.

CANCELLATION NOTICE

This specification has been declared “CANCELLED” by the Aerospace Materials Division, SAE, as of June, 2007, and has been superseded by AMS 2301. The requirements of the latest issue of AMS 2301 shall be fulfilled whenever reference is made to the cancelled MAM 2301B. By this action, this document will remain listed in the Numerical Section of the Index of Aerospace Material Specifications noting that it is superseded by AMS 2301.

Cancelled specifications are available from SAE.

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SAE Aerospace
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AEROSPACE MATERIAL SPECIFICATION

SAE MAM 2301B

Issued MAR 1996
Revised OCT 2001
Noncurrent MAR 2003

Superseding MAM 2301A

Steel Cleanliness, Aircraft Quality Magnetic Particle Inspection Procedure Metric (SI) Measurement

NONCURRENCY NOTICE

This specification has been declared “NONCURRENT” by the Aerospace Materials Division, SAE, as of March, 2003. It is recommended, therefore, that this specification not be specified for new designs.

AMS 2301 covers the same requirements.

“NONCURRENT” refers to those materials which have been widely used and which may be required on some existing designs in the future. The Aerospace Materials Division, however, does not recommend these as standard materials for future use in new designs.

“NONCURRENT” specifications are available from SAE.

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1. SCOPE:

1.1 Purpose:

This specification covers steel cleanliness requirements in SI (metric) units for aircraft-quality ferromagnetic steels, other than hardenable corrosion-resistant steels, by magnetic particle inspection methods.

1.1.1 AMS 2301 is the inch/pound version of this MAM.

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

2.2 ANSI Publications:

Available from American National Standards Institute, Inc., 25 West 43rd 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 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 300 Millimeters and Over in Nominal Diameter or Distance Between Parallel Sides: A quarter-section shall be cut from each sample sufficiently oversized 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 then be forged to a 75 to 150 millimeters 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 150 millimeters 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 125 millimeters long. Minimum stock removal shall be consistent with the machining allowance specified in 3.1.4.

3.1.3.2 Solid Product Over 150 to 300 Millimeters, 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 75 to 150 millimeters round or square. Specimens shall be rough machined to a "one-step" straight cylinder nominally 125 millimeters long. Minimum stock removal shall be consistent with the machining allowance specified in 3.1.4.

3.1.3.3 Solid Product 150 Millimeters and Under in Nominal Diameter 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 125 millimeters 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, Cylindrical

Nominal Diameter or Distance Between Parallel Sides Millimeters	Step Length Millimeters	Step Diameter 1	Step Diameter 2	Step Diameter 3	Step Diameter 4	Step Diameter 5
6.25 to 12.50, incl	125.00	D	--	--	--	--
Over 12.50 to 18.75, incl	62.50	D	2/3D	--	--	--
Over 18.75 to 25.00, incl	41.60	D	3/4D	1/2D	--	--
Over 25.00 to 37.50, incl	31.25	D	4/5D	3/5D	2/5D	--
Over 37.50	25.00	D	4/5D	3/5D	2/5D	1/5D

See AMS 2301.
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. A step-down specimen may be generated from the full cross-section in equal length steps as shown in Table 2.

TABLE 2 - Stepdown Specimens, Flat Bar

Nominal Thickness Millimeters	Step Length Millimeters	Step Thickness 1	Step Thickness 2	Step Thickness 3	Step Thickness 4	Step Thickness 5
Up to 6.25, incl	125.00	T	--	--	--	--
Over 6.25 to 12.50, incl	62.50	T	2/3T	--	--	--
Over 12.50 to 25.00, incl	31.25	T	3/4T	1/2T	1/4T	--
Over 25.00	25.00	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, midway between edge and center of the slab or plate width, shall be nominally 125 millimeters in length, and shall be not more than 100 millimeters in final diameter or thickness.

3.1.3.5.1 Product Up to 100 Millimeters, 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 100 to 200 Millimeters, 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 200 Millimeters 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:

3.1.3.6.1 250 Millimeters and Under in Nominal OD: Specimens nominally 125 millimeters in length shall be machined to straight cylindrical sections in accordance with 3.1.4.2.1.

3.1.3.6.2 Over 250 Millimeters in Nominal OD with Nominal Wall Thickness Up to 50 Millimeters, Inclusive: Specimens nominally 125 millimeters in length shall be machined to straight cylindrical sections in accordance with 3.1.4.2.2.

3.1.3.6.3 Over 250 Millimeters in Nominal OD with Nominal Wall Thickness Over 50 to 100 Millimeters, Inclusive: Specimens nominally 125 millimeters 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 250 Millimeters in Nominal OD with Nominal Wall Thickness Over 100 Millimeters: Specimens nominally 125 millimeters 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, Slabs, and Plates Over 200 Millimeters Thick: The converted sample shall be machined to conform to the allowance shown in Table 3 for surface removal, allowing 0.25 millimeter on each side for finish machining after heat treatment.

TABLE 3 - Stock Removal

Nominal Diameter or Distance Between Parallel Sides Millimeters	Minimum Stock Removal Millimeters per Side
6.25 to 12.50, incl	0.75
Over 12.50 to 18.75, incl	1.15
Over 18.75 to 25.00, incl	1.50
Over 25.00 to 37.50, incl	1.90
Over 37.50 to 50.00, incl	2.25
Over 50.00 to 62.50, incl	3.15
Over 62.50 to 87.50, incl	3.90
Over 87.50 to 112.50, incl	4.70
Over 112.50 to 150.00, incl	6.25

3.1.4.2 Tubing:

3.1.4.2.1 250 Millimeters and Under in Nominal OD: Tubing with nominal wall thickness under 6.25 millimeters shall have 10% of the wall thickness or 0.38 millimeters, whichever is less, removed from the OD after heat treatment. Samples from tubing with nominal wall thickness of 6.25 millimeters and over shall be machined to conform to the stock removal requirement shown in Table 4.

TABLE 4 - Stock Removal

Machined Diameter Millimeters	Minimum Stock Removal Millimeters per Side
Up to 62.5, incl	1.10
Over 62.5 to 87.5, incl	1.15
Over 87.5 to 112.5, incl	1.30
Over 112.5 to 137.5, incl	1.45
Over 137.5 to 162.5, incl	1.60
Over 162.5 to 200, incl	1.85
Over 200 to 250, incl	2.20

3.1.4.2.2 Tubing Over 250 Millimeters in Nominal OD: Tubing 100 millimeters and under in nominal wall thickness shall be turned to straight cylindrical sections representing the full cross-section of the wall, less allowance of 3.75 millimeters stock removal on the OD and ID and allowing 0.25 millimeters on each side for finish machining after heat treatment. Samples from tubing with nominal wall thickness over 100 millimeters shall be turned to cylindrical sections representing the cross section from the OD to mid-thickness of the wall less allowance of 3.75 millimeters stock removal on the OD, and allowing 0.25 millimeter on each side for finish machining after heat treatment.

3.1.4.3 Flat Bars, Slabs, and Plates: Allowance of 20% of the nominal thickness or 2.50 millimeters, whichever is less, shall be made for minimum stock removal, allowing 0.25 millimeter on each side for finish machining after heat treatment.

3.1.5 Heat Treatment: Rough machined specimens shall, if necessary, be heat treated by suitable 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 E 10. 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 finished machined to surface texture not rougher than 1.0 micrometers AA, determined in accordance with ANSI B46.1. Rateable surface of specimens shall be nominally 125 millimeters 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 8.3) using 32 to 48 amperes per millimter of diameter. If the stepdown bar (3.1.3.3.1 or 3.1.3.4) 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). Product 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 the magnetic particle inspection 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 1.6 millimeter 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 of each specimen is determined 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 (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 5:

TABLE 5 - Progression Factor for Severity Rating

Length of Indication Millimeters	Progression Factor
1.60 to 3.20, incl	3.2
3.20 to 6.35, incl	6.5
6.35 to 12.70, incl	13
12.70 to 19.00, incl	26
19.00 to 25.00, incl	52
Over 25.00 to 37.50, incl	103

3.3.2.2.1 Specimens which contain indications representing nonmetallic inclusions over 37.5 millimeters in length shall be subject to rejection.

3.3.2.3 The severity rating for specimen is determined by dividing the product for each specimen by the test surface area of the specimen in 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 maximum frequency and severity ratings:

3.4.1 Heat Qualification (Reference 4.3.1):

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

3.4.1.1.1 Individual Test Bar: Shall be as shown in Table 6.

TABLE 6 - Maximum Frequency and Severity Ratings

Carbon Content Percent	Frequency Rating (F)	Severity Rating (S)
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: Shall be as shown in Table 7.

TABLE 7 - Maximum Frequency and Severity Ratings

Carbon Content Percent		Frequency Rating	Severity Rating
Up to	0.25, excl	0.37	0.28
	0.25 and over	0.34	0.25

3.4.1.2 Slab and Plate: Shall be as shown in Table 8.

TABLE 8 - Maximum Frequency and Severity Ratings

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

3.4.2 Product Qualification (Reference 4.3.2):

3.4.2.1 Product Other Than Sheet, Strip, and Plate:

3.4.2.1.1 Individual Test Bar: Shall be as shown in Table 9.

TABLE 9 - Maximum Frequency and Severity Ratings

Product Nominal Diameter Millimeters		Carbon Content Percent		Frequency Rating	Severity Rating
Up to	62.50, excl	Up to	0.25, excl	1.10	1.05
			0.25 and over	1.00	0.95
	62.50 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: Shall be as shown in Table 10.

TABLE 10 - Maximum Frequency and Severity Ratings

Product Nominal Diameter Millimeters			Carbon Content Percent		Frequency Rating	Severity Rating
	25.00 to	62.50, incl	Up to	0.25, excl	0.90	0.85
				0.25 and over	0.85	0.80
Over	62.50 to	100.00, incl	Up to	0.25, excl	0.60	0.55
				0.25 and over	0.55	0.50
Over	100.00		Up to	0.25, excl	0.37	0.28
				0.25 and over	0.34	0.25

3.4.2.1.2.1 Product under 25.00 millimeters in nominal diameter or distance between parallel sides, inspected using the straight cylindrical test bars or product under 100 square centimeters in cross-sectional area, inspected by the alternate step-down specimen (3.1.3.3.1) shall have maximum average frequency and severity ratings agreed upon by purchaser and vendor.

3.4.2.2 Plate: Shall conform to the ratings specified in 3.4.1.2.

3.4.2.3 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 or 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 technical requirements are acceptance tests.

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 on each 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 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 as described in 4.3.1 shall be performed by the producer. No further sampling by the producer shall be required from a heat which meets the requirements of 3.4.1. Sampling procedure on product not “heat qualified” 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 27,200 kilograms, 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 27,200 kilograms.

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 MAM 2301A 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, 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 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 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 specified requirements, resampling and retesting of those locations will be permitted using the procedure specified for the original nonconforming location.