SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE MAM 2303D

Issued JAN 1987
Revised OCT 2001
Noncurrent MAR 2003

Superseding MAM 2303C

Steel Cleanliness, Aircraft Quality Martensitic Corrosion-Resistant Steels 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 2303 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.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: custsvc@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

1. SCOPE:

1.1 Purpose:

This specification covers steel cleanliness requirements in SI (Metric) units for aircraft-quality, ferromagnetic, 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 AMS 2303 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., 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 230 cm^2 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 150 millimeters 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 150 millimeters 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 105 to 230 cm^2, 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 105 cm^2 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 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

Nominal Diameter or Least 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	41.62	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

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 acceptable to purchaser.

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 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, allowing 0.010 inch per side for finish machining after heat treatment.

3.1.3.6 Tubing:

3.1.3.6.1 Up to 250 Millimeters, Inclusive, 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, Slab, and Plate: The converted sample shall be machined to conform to the allowance shown in Table 2 for surface removal, allowing 0.25 millimeters per side for finish machining after heat treatment.

TABLE 2 - Stock Removal

Nominal Diameter or Least 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	3.20
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 Up to 250 Millimeters, Inclusive, in Nominal OD: Tubing with nominal wall thickness under 6.25 millimeters shall have 10% of the wall thickness or 0.40 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 3.

TABLE 3 - Stock Removal, Tubing

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 200.0, incl	1.85
Over 200.0 to 250.0, incl	2.20

3.1.4.2.2 Tubing Over 250 Millimeters in Nominal OD: Tubing with nominal wall thickness up to 100 millimeters, inclusive, 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 per 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 millimeters 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 2.50 millimeters whichever is less, shall be made for minimum stock removal, allowing 0.25 millimeters 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 0.8 µm 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 8.4) using 32 to 48 A/mm 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 1.5 millimeters 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 6.45 times the total number of indications for each specimen by the area of the test 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 4:

TABLE 4 - Progression Factor for Severity Rating

Length of Indication Millimeters	Progression Factor
1.5 to 3.0, incl	3.2
Over 3.0 to 6.0, incl	6.5
Over 6.0 to 12.5, incl	13
Over 12.5 to 19.0, incl	26
Over 19.0 to 25.0 incl	52
Over 25.0 to 37.5, incl	103

3.3.2.2.1 Specimens which contain indications representing non-metallic inclusions over 37.5 millimeters 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 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 (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 Millimeters	Carbon Content Percent	Ratings Frequency	Ratings Severity
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: As shown in Table 9.

TABLE 9 - Average of All Test Bars

Product Nominal Diameter Millimeters	Carbon Content Percent	Ratings Frequency	Ratings Severity
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	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 25.00 millimeters in nominal diameter or least distance between parallel sides inspected using the straight cylindrical test bars or product under 100 cm^2 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 27,000 kg 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 27,000 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 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 MAM 2303C 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 4.75 millimeters 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.