



AEROSPACE MATERIAL SPECIFICATION	AMS2370™	REV. M
	Issued 1969-05 Revised 2023-01	
Superseding AMS2370L		
Quality Assurance Sampling and Testing Carbon and Low-Alloy Steel Wrought Products and Forging Stock		

RATIONALE

AMS2370M results from a Five-Year Review and update of this specification that revises heat and lot requirements (3.3.1, 3.3.2), updates composition testing and reporting (3.3.3.1.2, 3.3.3.1.4), addresses alternate test methods (3.3.3.2), clarifies reporting requirements (3.3.3.1.4), updates reporting of non-conforming tests (3.3.5.1.1, 3.3.5.3, 3.3.5.4.4), updates fracture toughness sampling (3.3.5.3), and Table 2.

1. SCOPE

This specification covers quality assurance sampling and testing procedures used to determine conformance to applicable material specification requirements of wrought carbon and low-alloy steel products and of forging stock.

1.1 Attributes included in detail herein are: composition, tensile properties, macrostructure, and micro-inclusion rating. Other requirements are included in Table 2.

1.2 Quality assurance sampling and testing procedures for forgings are covered in AMS2372.

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.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS2372 Quality Assurance Sampling and Testing Carbon and Low-Alloy Steel Forgings

AS7766 Terms Used in Aerospace Metals Specifications

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2.2 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 E8/E8M Tension Testing of Metallic Materials

ASTM E399 Linear-Elastic Plane-Strain Fracture Toughness of Metallic Materials

2.3 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.3.1 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

MIL-Q-22631 Quality Control of Metal Wrought Products Except Forgings Procured to Non-Governmental Specification

2.4 Definitions

Terms used in AMS are defined in AS7766.

3. TECHNICAL REQUIREMENTS

3.1 General

3.1.1 Omission from this specification of confirmatory tests of certain material properties or attributes controlled by the applicable material specification does not relieve the producer of responsibility for furnishing products that conform in all respects to the applicable material specification.

3.1.2 In event of conflict between requirements specified herein and requirements of a particular material specification, requirements of the material specification shall take precedence.

3.2 Responsibility for Tests

The producer of the product shall supply all samples for producer's tests and shall be responsible for the performance of all required tests. Results of such tests shall be reported to the purchaser as required by the applicable material specification.

3.3 Detailed Requirements

3.3.1 Heat

A heat shall be all steel melted in a single furnace charge. For consumable electrode remelted steel, a heat shall be all consumable electrode remelted ingots processed from steel originally melted as a single furnace charge.

3.3.2 Lot

A lot shall be a mill form of one shape, condition, and nominal cross-sectional dimensions from a single heat, processed in accordance with 3.3.2.1 or 3.3.2.2.

3.3.2.1 Sequentially heat treated during a 24-hour period in a continuous furnace with no interruption in operations and no change in furnace temperature, charge rate, or racking pattern.

- 3.3.2.1.1 The nominal cross-sectional dimension restriction may be disregarded when multiple sizes are heat treated in a single batch or during an 8-hour period in a continuous furnace operating at a constant speed. In such cases, tensile and macrostructure testing shall be performed on the size having the greatest equivalent round cross-section. The equivalent round cross-section shall be determined by multiplying wall thickness of tubing and thickness or diameter of solids by the shape factors shown in Table 1.

Table 1 - Shape factors

Product	Shape Factor
Tubing	2.0
Rounds	1.0
Hexagons	1.1
Squares	1.25
Flats	1.50

- 3.3.2.2 Sequentially heat treated during a 48-hour period in one or a series of batch-type furnace loads provided the loads are processed in the same furnace or same series of furnaces, and at the same power setting, set temperature, soak time, quench parameters, and racking pattern.

3.3.3 Sampling and Testing

Shall be in accordance with Table 2 and as follows:

3.3.3.1 Composition

- 3.3.3.1.1 The reported composition of the steel subjected to a single melting operation shall be that of a sample taken immediately before or during the pouring of a heat. Analysis results of the sample shall be within the composition limits established by the material specification, excluding any consideration of product check analysis.

- 3.3.3.1.1.1 If the sample of 3.3.3.1.1 is lost, a new sample shall be taken from the semi-finished or finished product.

- 3.3.3.1.2 For remelted steels, analyses shall be obtained and reported from the remelted ingot or product thereof in accordance with the following sampling.

- 3.3.3.1.2.1 Analysis shall be performed on samples from the extreme ends of each ingot involved with the order. Results from both samples shall fall within the compositional limits established by the material specification, excluding any consideration of product check analysis. The samples shall be obtained after the discards are taken.

- 3.3.3.1.3 The heat analysis may be used for reporting the analyses of those elements governed only by a maximum in the material specification if the analysis is within the compositional limits and the element routinely decreases or remains constant during remelting.

- 3.3.3.1.3.1 Analyses of samples made prior to discard need not be reported.

- 3.3.3.1.4 Producer may test for any element not listed in the material specification's composition table and include analysis in the report. Reporting of any element not listed in the composition table is not a basis for rejection, unless limits of acceptability are specified by the purchaser.

3.3.3.2 Tensile Specimen Orientation, Location, and Size

Unless otherwise specified, tensile specimens conforming to ASTM E8/E8M shall be cut from the semi-finished or finished product in the direction indicated in the following paragraphs and shall be cut from the locations and to the sizes specified. The sample shall consist of one or more sections of the product selected to represent a specific location or locations with respect to the order of pouring of the selected ingot or ingots and with respect to the location within the ingot.

3.3.3.2.1 Sheet, Strip, and Plate

3.3.3.2.1.1 Orientation

Specimens shall be taken with the axis of the specimen perpendicular to the direction of rolling from widths 9 inches (229 mm) and over and parallel to the direction of rolling from widths under 9 inches (229 mm). When short-transverse tensile properties are specified in the applicable material specification, specimens shall be taken with the axis of the specimen parallel to the thickness direction of the product.

3.3.3.2.1.2 Location and Size

3.3.3.2.1.2.1 Longitudinal and Long-Transverse Specimens

The standard 1/2 inch (12.7 mm) wide rectangular specimen or pin-loaded tensile specimen with 2 inch (50.8 mm) gage length shall be used for sheet, strip, and plate 0.625 inch (15.88 mm) and under in nominal thickness. For plate 0.625 to 0.750 inch (15.88 to 19.05 mm), inclusive, in nominal thickness, either the standard 1/2 inch (12.7 mm) wide rectangular specimen with 2 inch (50.8 mm) gage length or the standard 1/2 inch (12.7 mm) round tensile specimen with 2 inch (50.8 mm) gage length or a smaller, round specimen proportional to the standard shall be used. For plate over 0.750 inch (19.05 mm) in nominal thickness, the standard 1/2 inch (12.7 mm) round tensile specimen with 2 inch (50.8 mm) gage length or smaller, round specimen proportional to the standard shall be used. The tensile specimen shall be located midway between the faces of product 1-1/2 inches (38.1 mm) and under in nominal thickness and midway from center to surface for product over 1-1/2 inches (38.1 mm) in nominal thickness.

3.3.3.2.1.2.2 Short-Transverse Specimens

For plate 2-1/2 inches (63.5 mm) and over in nominal thickness, subsize round tensile specimens, proportional to the standard, shall be used when thickness is insufficient to accommodate standard 1/2 inch (12.7 mm) round tensile specimens with 2 inch (50.8 mm) gage length. Short-transverse testing is not applicable for plate under 2-1/2 inches (63.5 mm) in nominal thickness.

3.3.3.2.2 Bar, Rod, and Wire

3.3.3.2.2.1 Orientation

Specimens shall be taken with the axis of the specimen in the longitudinal direction except that, when long-transverse tensile properties are specified in the applicable material specification, specimens shall be taken with the axis of the specimen perpendicular to the rolling or extruding direction. When short-transverse tensile properties are specified for rectangular bar in the applicable material specification, specimens shall be taken with the axis of the specimen parallel to the thickness direction of the bar.

3.3.3.2.2.2 Location and Size

3.3.3.2.2.2.1 Longitudinal and Long-Transverse Specimens

If the product size or shape makes it impractical to use full-section specimens, the standard 1/2 inch (12.7 mm) round tensile specimen with 2 inch (50.8 mm) gage length or a smaller, round specimen proportional to the standard, shall be used, except that for rectangular bar 0.625 inch (15.88 mm) and under in nominal thickness, the standard 1/2 inch (12.7 mm) wide rectangular specimen or pin-loaded tensile specimen with 2 inch (50.8 mm) gage length may be used. The tensile specimen shall be located at the center for product 1-1/2 inches (38.1 mm) and under in nominal diameter, thickness, or distance between flats and midway from center to surface for product over 1-1/2 inches (38.1 mm) in nominal thickness.

3.3.3.2.2.2.2 Short-Transverse Specimens

For bar 2-1/2 inches (63.5 mm) and over in nominal thickness, subsize round tensile specimens, proportional to the standard, shall be used when thickness is insufficient to accommodate standard 1/2 inch (12.7 mm) round tensile specimens with 2 inch (50.8 mm) gage length. Short-transverse testing is not applicable for bar under 2-1/2 inches (63.5 mm) in nominal thickness.

3.3.3.2.3 Tubing

3.3.3.2.3.1 Orientation

Specimens shall be taken with the axis of the specimen in the longitudinal direction except that, when long-transverse tensile properties of square or rectangular tubing are required by the applicable material specification, specimens shall be taken with the axis of the specimen perpendicular to the drawing or extruding direction.

3.3.3.2.3.2 Longitudinal Specimens

Specimens from round and square tubing shall be the full section of the tubular product unless limitations of the testing machine preclude the use of such specimens. Snug-fitting metal plugs shall be inserted into the ends of tubular specimens to a sufficient depth to permit the jaws of the testing machine to grip the specimen properly without crushing. The plugs shall not extend into that portion of the specimen to be tested. Care shall be exercised to ensure that the load is applied axially. The length of full-section specimens shall be determined by the gage length specified for measuring elongation. For large-size tubing, or when it is not possible to test in full section, longitudinal specimens shall be obtained from strips cut from the tube. Either 1/2 inch (12.7 mm) wide rectangular or subsize round tensile specimens, proportional to the standard, (for thick-wall tube) shall be machined from these strips. Longitudinal strip-type tensile specimens from welded tubing shall not include weld bead. For thick-wall tubing for which subsize round tensile specimens are used, when the nominal wall thickness is under 1-1/2 inches (38.1 mm), specimens shall be taken midway between the inner and outer surface of the tubing; when the nominal wall thickness is 1-1/2 inches (38.1 mm) and over, specimens shall be taken at one-quarter wall thickness, referencing from either OD or ID.

3.3.3.2.3.3 Long-Transverse Specimens

Rectangular specimens or subsize round specimens, proportional to the standard, shall be used for square or rectangular tubing. Rectangular or round tensile specimens of the largest possible dimensions, proportional to the standard, shall be used when standard size specimens cannot be obtained. For thick-walled tubing, a round tensile specimen shall be taken midway between the inner and outer surface of the tubing when the nominal wall thickness is under 1-1/2 inches (38.1 mm); when the nominal wall thickness is 1-1/2 inches (38.1 mm) and over, specimens shall be taken at one-quarter wall thickness, referencing from either OD or ID.

3.3.3.2.4 Shapes

3.3.3.2.4.1 Orientation

Specimens shall be taken with the axis of the specimen in the longitudinal direction except that, when long-transverse tensile properties are specified in the applicable material specification, specimens shall be taken with the axis of the specimen perpendicular to the rolling or extruding direction. When short-transverse tensile properties of shapes are specified in the applicable material specification, specimens shall be taken with the axis of the specimen parallel to the thickness direction of the shape.

3.3.3.2.4.2 Location and Size

3.3.3.2.4.2.1 Longitudinal Specimens

If the product size or shape makes it impractical to use full-section specimens, the standard 1/2 inch (12.7 mm) round tensile specimen with 2 inch (50.8 mm) gage length or smaller round specimen, proportional to the standard, shall be used except that, for shapes under 1/2 inch (12.7 mm) in nominal thickness having parallel surfaces, the standard 1/2 inch (12.7 mm) wide rectangular specimen or pin-loaded tensile specimen with 2 inch (50.8 mm) gage length may be used. For shapes from which these machined specimens cannot be obtained and that cannot be tested in full section, a round or rectangular specimen of the largest possible dimensions shall be used. For shapes not tested in full section, specimens shall be taken from the center of the predominant or thickest part of the shape when that predominant nominal dimension is under 1-1/2 inches (38.1 mm); for thicker cross-sections, the specimens shall be taken from a one-quarter thickness location.

3.3.3.2.4.2.2 Long-Transverse Specimens

The standard 1/4 inch (6.35 mm) round tensile specimen with 1 inch (25.4 mm) gage length or a smaller round specimen, proportional to the standard, shall be used for nominal thicknesses of 3/8 inch (9.5 mm) and over. For shapes under 3/8 inch (9.5 mm) in nominal thickness having parallel surfaces, the standard 1/2 inch (12.7 mm) wide rectangular specimen or pin-loaded tensile specimen with 2 inch (50.8 mm) gage length shall be used. For shapes from which these machined specimens cannot be obtained and that cannot be tested in full section, a round or rectangular specimen of the largest possible dimensions shall be used. For shapes not tested in full section, specimens shall be taken from the center of the predominant or thickest part of the shape when that predominant nominal dimension is under 1-1/2 inches (38.1 mm); for thicker cross-sections, specimens shall be taken from a one-quarter thickness location.

3.3.3.2.4.2.3 Short-Transverse Specimens

For cross-sections 2-1/2 inches (63.5 mm) and over in nominal thickness, subsize round specimens, proportional to the standard, shall be used when thickness is insufficient to accommodate standard 1/2 inch (12.7 mm) round tensile specimens with 2 inch (50.8 mm) gage length. Short-transverse testing is not applicable for cross-sections under 2-1/2 inches (63.5 mm) in nominal thickness.

3.3.3.2.4.2.4 Complicated Shapes

Size, location, and direction of tensile specimens shall be as agreed upon by purchaser and producer.

3.3.3.2.5 Flash Welded Rings

Specimens shall be taken from parent metal, not including the weld-heat-affected zone, with the axis of the specimen in the circumferential direction. Standard 1/2 inch (12.7 mm) round tensile specimens with 2 inch (50.8 mm) gage length or subsize round specimens, proportional to the standard, shall be used. The tensile specimen shall be located at the center for product 1-1/2 inches (38.1 mm) and under in nominal thickness, diameter, or distance between flats, and midway from center to surface for product over 1-1/2 inches (38.1 mm) in nominal thickness.

3.3.3.2.6 Stock for Forging

A sample of stock shall be forged to a test coupon (see 8.2) acceptable to purchaser and heat treated in accordance with the material specification. Specimens taken from the coupon shall conform to applicable requirements of the material specification. Forging stock from a heat meeting these requirements in one forged-down size need not be retested to be acceptable data for qualifying a ship size that is smaller than the forged-down coupon.

3.3.3.2.6.1 As an option, if specimens taken from the stock after heat treatment conform to the requirements of the material specification, the tests shall be accepted as equivalent to tests of a forged coupon.

3.3.3.2.7 Stock for Flash Welded Rings

Coupons shall be obtained as described in 3.3.3.2.5. Specimens taken from the coupon shall conform to applicable requirements of the material specification.

3.3.3.3 Macrostructure

Shall be as follows:

3.3.3.3.1 Aircraft Quality (Static or Strand Cast)

3.3.3.3.1.1 Heat Qualification

3.3.3.3.1.1.1 Heats of Top Poured Ingots

Full cross-sectional 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 ten ingots or not over 30 tons (27215 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 ten ingots or over 30 tons (27215 kg).

3.3.3.3.1.1.2 Heats of Bottom Poured Ingots

Full cross-sectional 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 is constituted by 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 shall be selected.

3.3.3.3.1.1.2.1 If there are less than three ingots in the heat, full cross-sectional samples shall be taken representing the top and bottom of all ingots.

3.3.3.3.1.1.3 Strand Cast Heats

Full cross-sectional 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.

3.3.3.3.1.2 Product Qualification

Full cross-sectional samples shall be taken at random from not less than 10% of the pieces of each lot. A lot for this purpose shall be further restricted to 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 less than three pieces, one sample shall be taken from each piece.

3.3.3.3.2 Premium Aircraft-Quality

3.3.3.3.2.1 Heat Qualification

Full cross-sectional samples shall be taken from semi-finished or finished product representing the top and bottom of each consumable remelted ingot.

3.3.3.3.2.2 Product Qualification

Full cross-sectional samples shall be taken at random from not less than 10% of the pieces of each lot. A lot for this purpose shall be further restricted to 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 less than three pieces, one sample shall be taken from each piece.

3.3.3.4 Micro-Inclusion Rating

3.3.3.4.1 Aircraft-Quality or Aircraft-Quality for Bearing Applications

Sample shall represent the product specified for macrostructure in 3.3.3.3.1.

3.3.3.4.2 Premium Aircraft-Quality

Sampling for heat qualification shall be as described in 3.3.3.4.2.1 and 3.3.3.4.2.2. If product qualification of steel that has not been heat qualified is involved, sampling shall be as agreed upon by purchaser and producer.

3.3.3.4.2.1 Heats of Top Poured Electrodes/Ingots

Samples shall represent the top and bottom of the first and last usable remelted ingots from a heat yielding less than ten ingots. From a heat yielding ten or more ingots, samples shall represent the top and bottom of the first, middle, and last usable remelted ingots.

3.3.3.4.2.1.1 For product identified as premium aircraft-quality not vacuum arc remelted, from a heat yielding less than ten ingots, samples shall represent the top and bottom of the first and last usable remelted ingots; if the heat consists of ten or more ingots, the samples shall represent the top and the bottom of the first, middle, and last usable remelted ingots.

3.3.3.4.2.2 Heats of Bottom Poured Electrodes/Ingots

Samples shall represent the top and bottom of one electrode/ingot from each heat cluster (plate) of electrodes/ingots.

3.3.4 Test Methods

Shall be in accordance with requirements of the applicable material specification. If a test method is not specified, the method of test shall be acceptable to the purchaser.

3.3.5 Resampling and Retesting

Depending on the attributes to be evaluated, proceed as follows:

3.3.5.1 If any test fails, the test location may be considered a non-representative test location; the steel may be cut back and all properties from the new test location redetermined.

3.3.5.1.1 Reporting invalid test results is not required; however, records of the results shall be maintained.

3.3.5.2 For Composition

If an invalid specimen (see 3.3.5.2.1) is suspected, resample as in 3.3.3.1. If a non-representative sample (e.g., an end condition) is involved, cut back the test location as appropriate and resample as in 3.3.3.1.

3.3.5.2.1 A test for composition may be declared invalid if caused by a malfunction of the chemical analysis equipment or by use of an improper test procedure. Resampling and retesting results shall fulfill requirements of 3.3.3.1.

3.3.5.3 For Mechanical Properties

If the sample is not invalid (see 3.3.5.3.1), disposition may be based on the results of testing two additional specimens for each original nonconforming specimen except in the case of fracture toughness, a single retest is permitted for any invalidity except as noted in 3.3.5.3.3. Failure of any retest specimen to meet specified requirements shall be cause for rejection of the represented product.

3.3.5.3.1 Any mechanical property test may be declared invalid if the specimen was dimensionally discrepant and that discrepancy caused failure, or if the failure was caused by a malfunction of the test equipment or improper test procedure. When a test is declared invalid, the specimen may be replaced.

3.3.5.3.2 To facilitate determination of fracture toughness a tensile specimen taken immediately adjacent to the location of the fracture toughness specimen is required. Fracture planes of the tensile and K_{Ic} specimen shall be in the same orientation. If a tensile specimen cannot be excised with the fracture plane in the same orientation as that of the fracture toughness specimen, the orientation of the tensile specimen shall be as approved by the purchaser.

3.3.5.3.3 Invalid test results in accordance with ASTM E399 shall be considered meaningful and the material shall be accepted to K_{Ic} requirements if the thickest possible standard compact specimen was used and the calculated K_Q equals or exceeds the required K_{Ic} , and the invalidity is due to one or both of the following conditions:

a. $W - a < 2.5 (K_Q / \sigma_{YS})^2$

b. $P_{max} / P_Q > 1.10$