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AEROSPACE MATERIAL SPECIFICATION

SAE AMS2376 | REV. D

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Superseding AMS2376C

Qualification, Approval, and Control of Premium-Quality Forgings Alloy Steels and Heat-Treatable Corrosion and Heat Resistant Steels and Alloys

RATIONALE

AMS2376D has been reaffirmed to comply with the SAE five-year review policy.

NONCURRENT NOTICE

This specification has been declared "NONCURRENT" by the Aerospace Materials Division, SAE, as of February 1998. It is recommended, therefore, that this specification not be specified for new designs.

"NONCURRENT" refers to those materials which have previously 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. Each of these "NONCURRENT" specifications is available from SAE upon request.

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http://www.sae.org/technical/standards/AMS2376D

1. SCOPE:

1.1 Purpose:

This specification covers procedures for approval of premium-quality forgings, usually serialized, the stock from which such forgings are produced, and the controls to be exercised in producing the forgings and forging stock.

1.2 Application:

This procedure has been used typically for highly-stressed parts produced from forgings which require approval of the forgings and the stock from which they are made and facets of their production to ensure that production lots of forgings are of the same metallurgical quality and are produced by the same basic procedures as the forgings and stock originally qualified, but usage is not limited to such applications.

1.2.1 This specification is applicable to parts made of steels and heat-treatable corrosion and heat resistant alloys and which are subjected to rigid inspection standards throughout manufacture from ingot to finished part.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2300	Premium Aircraft-Quality Steel Cleanliness, Magnetic Particle Inspection Procedure
MAM 2300	Premium Aircraft-Quality Steel Cleanliness, Magnetic Particle Inspection Procedure, Metric (SI) Measurement
AMS 2630	Ultrasonic Inspection, Product Over 0.5 Inch (12.5 mm) Thick
AMS 2750	Pyrometry
AMS 2759	Heat Treatment of Steel Parts, General Requirements

3. TECHNICAL REQUIREMENTS:

3.1 Ingot:

Shall be produced, by a source approved by purchaser of the forgings, under effective, documented controls of all variables of the melting processes to consistently produce uniform ingots which will yield products meeting the requirements of this specification, the applicable material specification, and applicable drawings.

3.1.1 Melting Practice: Shall be as specified in the applicable material specification. Melting parameters shall be established and shall be monitored and recorded on a continuous or periodic basis acceptable to purchaser. Deviations from established process control factors (See 4.4.2.1.1) shall be reported to purchaser of forgings and approval obtained before the ingot is considered acceptable.

3.1.2 Ingot Molds: Shall be clean and free of foreign materials. Molds used for casting leaded steels and alloys shall not be used.

3.1.3 Identification: Each ingot shall be marked with the mill heat number and pouring sequence/remelt identity such that the top and/or bottom is traceable.

3.2 Forging Stock:

Billets, bars, slabs, and tubes for forging shall be manufactured from ingot produced as in 3.1 and shall be procured only from sources approved by purchaser of the forgings. Parameters shall be established for ingot conversion procedures which will produce stock conforming to the requirements of 3.2.1, 3.2.2, 3.2.3, and 3.2.4. These parameters shall be monitored and recorded on a continuous or periodic basis acceptable to purchaser. Deviations from established process control factors (See 4.4.2.1.1) shall be reported to purchaser of forgings and approval obtained before the stock is considered acceptable.

3.2.1 Macrostructure: Shall be as specified in the applicable material specification.

3.2.2 Magnetic Particle Cleanliness: Shall be as specified in the applicable material specification. If not specified, ferromagnetic steels shall meet the requirements of AMS 2300 or MAM 2300.

3.2.3 Identification: Each piece of forging stock shall be marked with the heat number and ingot number. Forging stock, 4.0 inches (102 mm) and over in nominal diameter or distance between parallel sides, shall be identified as to its location and orientation in the remelt ingot. When specified, forging stock under the above size limit shall be identified to at least the quarter section of the remelt ingot from which it was taken. The forging stock vendor shall maintain a map or other descriptive information which correlates the identification to the remelt ingot location. Records shall be maintained of those portions of the ingots which were not acceptable, other than normal end croppage, and include the reason for rejection.

3.2.4 The forging vendor shall be responsible for ensuring that the stock conforms to the applicable material specification and will yield acceptable forgings. Tests which are characteristic of a heat and which are conducted by the forging stock vendor need not be repeated by the forging vendor. Forging vendor shall also determine that the stock is from an approved mill source.

3.2.4.1 The forging vendor shall obtain complete test reports from the mill on each heat of forging stock; the reported results shall be verified in conjunction with quality conformance testing.

3.3 Forgings:

Shall be produced from stock conforming to 3.2. Forgings shall be formed to their final rough dimensions by one or a combination of the following processes, unless a particular process is specified:

Hammer die
Press die
Hot upset
Ring roll
Mandrel forge
Extrusion
Rotary

3.3.1 Preproduction Forgings:

3.3.1.1 Vendor shall establish the forging sequence and other processing procedures, such as heat treating and cleaning, suitable for producing premium-quality forgings. These procedures shall be documented on operation sheets for the purpose of maintaining consistent practices. The operation sheets shall be submitted to purchaser for approval, unless such approval be waived by purchaser.

3.3.1.2 Vendor shall produce one or more preproduction forgings and shall heat treat and test a forging or sections thereof to all requirements of the material specification, the drawing, and any additional requirements specified by purchaser. The preproduction forgings shall be produced by the practices to be used on production forgings in accordance with approved operation sheets and may be produced as part of the initial production run. A duplicate preproduction forging or the remaining section of such forging shall be submitted to purchaser for confirmatory testing when requested by purchaser.

3.3.1.3 The location(s) from which coupons for mechanical tests are taken and the sections for grain flow examination shall be as specified by purchaser. The vendor shall perform the required tests on specimens from these locations. If no locations are specified, vendor shall select representative areas for testing.

3.3.1.4 Grain Flow: A forging shall be sectioned through areas indicated by purchaser and the sections suitably etched to show the grain flow. Photographs showing the grain flow shall be made of each section and the photographs shall be identified to show the relationship to the corresponding sections in the forging. Except in areas of forgings which contain end grain, the grain flow shall follow the general contour of the forgings, showing no evidence of re-entrant grain flow. Standards for acceptance shall be as agreed upon by purchaser and vendor.

3.3.1.5 Heat Treatment: The preproduction forging(s) shall be heat treated to the final condition of the part by the forging vendor or by a heat treatment source approved by purchaser of the forgings. If the as-forged section size is too large to achieve proper heat treat response, the forging vendor shall, prior to heat treatment, machine the forging(s) to a configuration essentially that in which production forgings will be heat treated or shall machine sections from the forging(s) to simulate the maximum section size in the finished forging. Heat treatment of alloy steels shall be as specified in the applicable material specification. Heat treatment of maraging steels and of corrosion and heat resistant steels and alloys shall be performed in equipment meeting the requirements of, and under the controls specified in, AMS 2750, using the temperatures, times, and heating and cooling media specified in the applicable material specification, on the drawing, or in the purchaser's process specification. AMS 2759 shall apply when no heat treatment process is specified.

3.3.1.5.1 If the final heat treated condition of steel forgings requires a tensile strength of 200 ksi (1379 MPa) or higher, and the forgings are supplied in a different condition, the vendor may excise oversize test coupons from such forgings. Such coupons shall be given the final heat treatment prior to machining to specimen size for testing. Test coupons shall be representative of the maximum thickness of the forging at the time of final hardening heat treatment.

3.3.1.6 Mechanical Properties: Test specimens from representative forging(s) or forging sections shall meet the mechanical properties for the part in the final heat treated condition as specified in the applicable material specification or on the drawing. Variations from specified properties, because of section size or test specimen orientation, shall be as agreed upon by purchaser and vendor.

3.3.1.7 Hardness: Hardness surveys shall be made across the thickest sections through a test forging or forging section in the final heat treated condition. The sections prepared as in 3.3.1.4 may be used for the survey if they meet the criteria of 3.3.1.5 for forging sections.

3.3.1.8 Microstructure: Specimens shall be taken from the fully heat treated forging at the center of the thickest section and at the surface of the thickest and thinnest sections and prepared for metallographic examination. The structure shall be essentially uniform and free from imperfections and from indications of overheating and burning. Photographs of the microstructures shall be submitted to purchaser and any abnormal microstructural conditions identified. These photographs may be used to establish standards for acceptance of production forgings.

3.3.1.9 Ultrasonic Soundness: When specified by purchaser, forgings shall be subjected to ultrasonic inspection. Inspection shall be performed to the standards and at the stage of manufacture specified by purchaser. If an inspection procedure has not been specified, such inspection shall be in accordance with AMS 2630.

3.3.2 Process Control Factors: A resume of the control factors (See 4.4.2.1) established for producing forgings of each part number shall be submitted with the results of tests on the preproducion forging(s); when permitted by purchaser, the resume need not be submitted with the test results but shall be kept on file for review by purchaser.

3.3.3 Production Forgings: Shall be produced using the same operations, practices, and process control factors used on the approved preproduction forgings.

3.3.3.1 Production forgings shall not be shipped until vendor has received from purchaser written approval of the preproduction forging(s) and the processing, unless preshipment approval be waived by purchaser.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

The forging vendor shall supply all samples for vendor's tests and shall be responsible for performing all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the forgings conform to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests of forging stock and production forgings for conformance to the applicable material specification and to any additional requirements specified by purchaser are acceptance tests and shall be performed on each heat or lot as applicable. Such tests of forging stock shall be performed prior to use of a new heat or lot for production forgings.

4.2.2 Preproduction Tests: Tests of preproduction forgings for conformance to all technical requirements of the applicable material specification, to 3.3.1 of this specification, and to any additional requirements specified by purchaser are preproduction tests and shall be performed prior to or on the first-article shipment of a forging to a purchaser, when a change in material and/or processing requires reapproval as in 4.4.2, and when purchaser deems confirmatory testing to be required.

4.2.2.1 For direct U.S. Military procurement of forgings, substantiating test data and preproduction forgings shall be submitted to the cognizant agency as directed by the procuring activity, contracting officer, or request for procurement.

4.3 Sampling and Testing:

Shall be as follows: a lot shall be all forgings of the same part number or configuration, opposite hands being considered one configuration, produced from the same heat or lot of forging stock, heated and forged in the same manner, and processed by either of the following methods:

a. Sequentially heat treated during an eight-hour period in a continuous furnace.

b. Sequentially heat treated during an 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 there is no change in power, set temperature, soak time, quench parameters, or racking pattern.

4.3.1 For Acceptance Tests:

4.3.1.1 Unless otherwise specified on the drawing, applicable material specification, or purchaser quality assurance specification, the following shall apply: For forgings supplied in the fully heat treated condition, a forging from each lot shall be subjected to destructive testing; on forgings which contain a test prolongation, each prolongation shall be tested unless a sampling plan is agreed upon by purchaser and vendor. Each prolongation and the forging it represents shall be given an identical serial number.

4.3.1.1.1 When specified by purchaser, forgings which are supplied in a condition not representing the final heat treated condition shall be destructively tested. One forging from each heat shall be fully heat treated as in 3.3.1.5 and 3.3.1.5.1 and subjected to such destructive testing as purchaser directs.

4.3.1.2 Samples shall be taken from the first shipment of forging stock from each heat to determine ability of stock from that heat to yield acceptable forgings.

4.3.2 For Preproduction Tests: As specified in Section 3, tests shall be conducted the first time a forging is produced by a vendor. Significant change in the configuration of the forging shall be cause for retesting. It is the prerogative of the forging purchaser to determine if a change is of sufficient magnitude to require retesting.

4.4 Approval:

4.4.1 Preproduction forgings and the forging procedure shall be approved by purchaser before production forgings are shipped, unless preshipment approval be waived by purchaser. The approval of preproduction forgings and procedures or the waiver of preproduction approval shall not relieve the forging vendor of responsibility for continued conformance to all requirements.

4.4.2 The respective vendors shall establish, for ingot and forging stock and for forgings of each part number or configuration, parameters for the process control factors which will yield products meeting the respective requirements of this specification and the applicable material specification. These shall constitute the approved manufacturing procedures for each product and shall be used for subsequent production of the product. If necessary to make any change in process control factors, vendor shall submit for reapproval a statement of the proposed changes in processing and, when requested, sample product. Production products made by the revised procedure shall not be shipped prior to receipt of reapproval without permission of purchaser.

4.4.2.1 Process control factors for producing the respective products include, but are not limited to, the following:

4.4.2.1.1 Forging Stock and Ingot:

Melting Method.

Melt source and conversion source shall be approved by the forging purchaser. It is the forger's responsibility to notify the melter and conversion source as to whose approval is required.

Stock to be melted in accordance with 3.1.

Stock to meet requirements of 3.2 and base material specification.

4.4.2.1.2 Forgings:

Source of Ingot and forging stock.
Die pre-heating, if used.
Type (ingot, bloom, billet, bar, tube), nominal size (cross-sectional area), shape and nominal multiple-weight of forging stock.
Type of forging equipment (press, hammer, ring roll, etc, See 3.3).
Die Identification
Parting line location.
Sequence and number of operations, changes which would result in a different cross-sectional structure, grain flow, or working of the metal.
Protective atmosphere, coatings, or both.
Thermal cycling, including preheating temperature, forging temperature range, and heat treatment temperatures, times, and methods of cooling.
Cleaning operations (e.g., chemical descaling, abrasive blasting, etc).
Inspection procedures.

4.4.2.1.3 Any of the above process control factors for which parameters are considered proprietary by the vendor may be assigned a code designation. Each variation in such parameters shall be assigned a modified code designation. Proprietary process parameters shall be available for audit by the purchaser as in 4.6.

4.5 Documentation:

4.5.1 Maintenance of Facilities: Each vendor shall keep records demonstrating that the facilities used to produce, control, measure, and test forging stock and forgings during manufacture and inspection are properly maintained and are checked for accuracy at stated intervals against recognized standards.

4.5.2 Process Sheets: Each vendor shall prepare and maintain documented instructions defining the processing methods and routing in the manufacturing cycle for producing the respective products. Separate process sheets shall be prepared and maintained for each forging configuration, opposite hands being considered a single configuration.

4.5.3 Traceability: Forgings shall be traceable to the heat of steel or alloy from which they were made.

4.5.3.1 When traceability of a forging to its location in the remelt ingot is required, the vendor shall serialize each forging. A record shall be maintained which correlates the serial number and the ingot location from which the forging multiple was taken. Forgings made from stock under 4.0 inches (102 mm) in nominal diameter or distance between parallel sides need only be identified to the quarter ingot section from which the forging multiple was taken. Record shall be maintained seven years, unless otherwise specified by purchaser.