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AEROSPACE MATERIAL SPECIFICATION

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SAE AMS 2376B

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QUALIFICATION, APPROVAL, AND CONTROL OF PREMIUM-QUALITY FORGINGS
Alloy Steels and Heat-Treatable Corrosion and Heat Resistant Steels and Alloys

1. SCOPE:

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

1.2 Application: Primarily 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. Applicable to parts made of alloy steels and heat-treatable corrosion and heat resistant steels and 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 Aerospace Material Specifications shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

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 2350 - Standards and Test Methods
AMS 2630 - Ultrasonic Inspection
AMS 2759 - Heat Treatment of Steel Parts, General Reqirements

2.1.1 (Continued):

AMS 2759/1 - Heat Treatment of Carbon and Low-Alloy Steel Parts, Minimum Tensile Strength up to 220,000 psi (1515 MPa)
AMS 2759/2 - Heat Treatment of Low-Alloy Steel Parts, Minimum Tensile Strength 220,000 psi (1515 MPa) and Higher
AMS 2759/3 - Heat Treatment of Precipitation Hardening, Corrosion Resistant and Maraging Steel Parts
AMS 2759/5 - Heat Treatment of Martensitic Corrosion Resistant Steel Parts

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM A604 - Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Military Standards:

MIL-STD-163 - Steel Mill Products, Preparation for Shipment and Storage

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 produce, consistently, 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; if not specified therein, steel or alloy shall be multiple melted using either vacuum arc consumable electrode or electroslag practice in the remelt cycle.

3.1.2 Ingot Molds: Shall be clean and free of foreign materials. Molds used for casting leaded steels and alloys shall be thoroughly cleaned before subsequent use in casting non-leaded steels and alloys.

3.1.3 Identification: Each ingot shall be marked with the mill heat number and pouring sequence in such a manner 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 as agreed upon by purchaser and vendor. Deviations from established process control factors (See 4.4.2.1.1) shall be reported to purchaser of the stock and his approval obtained before the stock may be considered acceptable. The forging purchaser shall be responsible for supplying a list of approved stock suppliers to the forging vendor.

3.2.1 Macrostructure: Visual examination of transverse sections of billets, bars, slabs, and tubes or tube rounds, etched in accordance with ASTM A604 in hot hydrochloric acid (1:1) at 160° - 180°F (70° - 80°C), or in other suitable etchant at a temperature appropriate for the alloy, for sufficient time to develop a well-defined macrostructure, shall show no pipe, cracks, laps, or folds. Except as specified in 3.2.1.1, macrostructure shall be no worse than the following macrographs of ASTM A604 unless other limits are established in the applicable material specification:

Class	Condition	Severity
1	Freckles	A
2	White Spots	B
3	Radial Segregation	B
4	Ring Pattern	C

3.2.1.1 When tubes are produced directly from ingots or large blooms, specimens for macrostructure testing may be taken from tubes rather than tube rounds. Macrostructure standards for such tubes shall be as agreed upon by purchaser and vendor.

3.2.2 Magnetic Particle Cleanliness: Alloy steels and ferromagnetic corrosion resistant steels shall meet the requirements of AMS 2300 or MAM 2300.

3.2.3 Ultrasonic Soundness: Shall meet the standards specified by purchaser at the stage of manufacture specified by purchaser. If no other method is specified, the material shall be inspected in accordance with AMS 2630.

3.2.4 Identification: Each piece of forging stock shall be marked with the heat number and ingot number.

3.2.4.1 When specified, forging stock 4.0 in. (100 mm) and over in nominal diameter or distance between parallel sides, shall be identified as to its location and orientation in the remelt ingot; 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 supply a map which correlates the identification to the remelt ingot location. The maps shall include a record of those portions of the ingots which were not acceptable, other than normal end croppage, and include the reason for rejection.

3.2.5 The forging vendor shall determine that the stock conforms to the applicable material specification and will yield acceptable forgings except that 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.

3.2.5.1 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

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 the 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 the approved operation sheets and, unless otherwise specified, 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, subject to concurrence of the purchaser.

3.3.1.4 Flow Pattern Control: Forging stock shall be of such size and dimensions that the work accomplished in forming to finished shape shall result in approximately uniform grain size throughout the forging. The techniques employed shall produce a grain flow pattern conforming to the structural shape of the part and essentially free from both re-entrant and sharply-folded flow lines.

3.3.1.4.1 Ø 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 forging, showing no evidence of re-entrant 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 by the forging vendor, or by a heat treatment source approved by purchaser of the forgings, to the final condition of the part. If the as-forged section size is too large to achieve proper heat treatment 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 performed in accordance with AMS 2760. 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 2760, 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.

3.3.1.5.1 Ø If the final heat treated condition of steel forgings requires a tensile strength of 200,000 psi (1380 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.

3.3.1.6 Mechanical Properties: Test specimens from the 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 heaviest sections through a test forging or forging section in the final heat treated condition, unless otherwise specified. The sections prepared as in 3.3.1.4.1 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 heaviest section and at the surface of the heaviest 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. Results of such tests shall be reported to the purchaser as required by 4.7. 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 to determine conformance to the applicable material specification and to any additional requirements specified by purchaser are classified as 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 to determine 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 classified as 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, processing, or both 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, the contracting officer, or the request for procurement.

4.3 Sampling: 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 heat treated in a continuous furnace or in a series of batch-type furnace operations with no change in furnace settings or interruption of power. When a batch furnace is controlled within specified limits and equipped with recording pyrometers so complete records of heat treatment are available, those batches sequentially treated in the same furnace may be considered as one heat treat lot provided there has been no power interruption and if there has been no change in the furnace settings or the time cycle.

4.3.1 For Acceptance Tests:

4.3.1.1 As specified on the drawing, applicable material specification, and quality assurance specification. 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 treat 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. Any major 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 forging stock and for forgings of each part number or configuration the 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:

Melting Method.

Melt source and conversion source shall be approved by the forging purchaser. It is the forger's responsibility to notify the melter 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 forging stock.
Type (ingot, bloom, billet, bar, tube), nominal size (cross-sectional area), shape (See 4.4.2.1.2.1) and nominal multiple-weight of forging stock.
Type of forging equipment (press, hammer, ring roll, etc, See 3.3).
Parting line location.
Sequence and number of operations, changes in 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.

4.4.2.1.2.1 For this specification, rounds and squares of the same cross sectional area are considered the same.

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.