Society of Automotive Engineers, Inc.
400 COMMONWEALTH DRIVE, WARRENDALE, PA. 15096

AEROSPACE MATERIAL SPECIFICATION

AMS 5399A
Superseding AMS 5399

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ALLOY CASTINGS, INVESTMENT, CORROSION AND HEAT RESISTANT
52Ni - 19Cr - 11Co - 9.8Mo - 3.2Ti - 1.6Al - 0.006B
Vacuum-Melted, Vacuum-Cast, Solution Treated

1. SCOPE:

1.1 Form: This specification covers a corrosion and heat resistant nickel alloy in the form of vacuum-melted, vacuum-cast investment castings.

1.2 Application: Primarily for small parts requiring high strength up to 1600°F (870°C) and oxidation resistance up to 1800°F (980°C).

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications (AMS) shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods
AMS 2360 - Room Temperature Tensile Properties of Castings
AMS 2361 - Elevated Temperature Tensile Properties of Castings
AMS 2362 - Stress-Rupture Properties of Castings
AMS 2635 - Radiographic Inspection
AMS 2645 - Fluorescent Penetrant Inspection

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

ASTM E8 - Tension Testing of Metallic Materials
ASTM E18 - Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E21 - Elevated Temperature Tension Tests of Metallic Materials
ASTM E139 - Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
ASTM E192 - Reference Radiographs of Investment Steel Castings for Aerospace Applications
ASTM E354 - Chemical Analysis of High Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt-Base Alloys

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

2.3.1 Federal Standards:

Federal Test Method Standard No. 151 - Metals; Test Methods

2.3.2 Military Standards:

MIL-STD-794 - Parts and Equipment, Procedures for Packaging and Packing of

3. TECHNICAL REQUIREMENTS:

3.1 Composition: Shall conform to the following percentages by weight, determined by wet chemical methods in accordance with ASTM E354, by spectrographic methods in accordance with Federal Test Method Standard No. 151, Method 112, or by other approved analytical methods:

	min	max
Carbon	0.06	0.12
Manganese	--	0.50
Silicon	--	0.50
Phosphorus	--	0.015
Sulfur	--	0.015
Chromium	18.00	20.00
Cobalt	10.00	12.00
Molybdenum	9.00	10.50
Titanium	3.00	3.30
Aluminum	1.40	1.80
Boron	0.003	0.010
Iron	--	5.00
Nickel	remainder	

3.2 Condition: Solution heat treated.

3.3 Casting:

3.3.1 The metal for castings shall be melted and poured under vacuum without loss of vacuum between melting and pouring. When permitted by purchaser, protective atmosphere may be used in lieu of vacuum for pouring of castings.

3.3.2 Castings shall be poured either from remelted metal from a master heat or directly from a master heat. In either case, metal for casting shall be qualified as in 3.4.

3.3.2.1 A master heat is refined metal of a single furnace charge or metal blended as in 3.3.2.2 melted and cast into ingot or pig under vacuum. Gates, sprues, risers, and rejected castings shall be used only in preparation of master heats; they shall not be remelted directly, without refining, for pouring of castings.

3.3.2.2 Unless prohibited by purchaser, metal from two or more master heats may be blended provided that the composition of each master heat to be blended is within the limits of 3.1 and that the total weight of metal blended does not exceed 10,000 lb (4540 kg). When two or more master heats are blended, the resultant blend shall be considered a master heat.

3.4 Master Heat Qualification: Each master heat shall be qualified by evaluation of chemical analysis and tensile test specimens conforming to 3.4.1 and 3.4.2, respectively. A master heat may be considered conditionally qualified if vendor's test results show conformance to all applicable requirements of this specification. However, except when purchaser waives confirmatory testing, final qualification shall be based on purchaser's test results. Conditional qualification of a master heat shall not be construed as a guarantee of acceptance of castings poured therefrom.

3.4.1 Chemical Analysis Specimens: Shall be of any convenient size, shape, and form for vendor's tests. When chemical analysis specimens are required by purchaser, specimens shall be cast to a size, shape, and form agreed upon by purchaser and vendor.

3.4.2 Tensile Test Specimens: Shall be cast from remelted metal from each master heat except when castings are poured directly from a master heat, in which case the specimens shall also be poured directly from the master heat. Specimens shall be of standard proportions in accordance with ASTM E8 with 0.250 in. (6.35 mm) diameter at the reduced parallel gage section. They shall be cast to size or shall be cast oversize and subsequently machined to 0.250 in. (6.35 mm) diameter. Center gating may be used.

3.5 Heat Treatment: Castings and representative tensile test specimens shall be solution heat treated by heating in a suitable protective atmosphere to 1950°F ± 25 (1066°C ± 15), holding at heat for not less than 3 hr, and suitably quenching.

3.6 Properties: Castings and representative tensile test specimens produced in accordance with 3.4.2, solution heat treated as in 3.5, shall conform to the following requirements:

3.6.1 As Solution Heat Treated:

3.6.1.1 Hardness: Not higher than 30 HRC or equivalent, determined in accordance with ASTM E18.

3.6.2 After Re-Solution and Precipitation Heat Treatment: Castings and representative tensile test specimens, solution heat treated as in 3.5, shall meet the following requirements after being re-solution heat treated by heating in a suitable protective atmosphere to 1950°F ± 25 (1066°C ± 15), holding at heat for 30 min. ± 3, and cooling rapidly in air and precipitation heat treated by heating to 1400°F ± 25 (760°C ± 15), holding at heat for not less than 16 hr, and cooling in air.

3.6.2.1 Separately-Cast Specimens:

3.6.2.1.1 Tensile Properties at 1200°F (649°C): Shall be as follows, determined in accordance with ASTM E21 on specimens heated to 1200°F ± 10 (649°C ± 6), held at 1200°F ± 10 (649°C ± 6) for 30 min. before testing, and tested at 1200°F ± 10 (649°C ± 6) at a rate of 0.003 - 0.007 in. per in. per min. (0.003 - 0.007 mm/mm/min.) to the yield strength and at a rate of 0.03 - 0.07 in. per in. per min. (0.03 - 0.07 mm/mm/min.) above the yield strength:

Tensile Strength, min	110,000 psi (758 MPa)
Yield Strength at 0.2% Offset, min	90,000 psi (621 MPa)
Elongation in 4D, min	3%
Reduction of Area, min	5%

3.6.2.1.2 Stress-Rupture Properties at 1650°F (899°C): Specimens, maintained at 1650°F ± 3 (899°C ± 2) while a load sufficient to produce an initial axial stress of 25,000 psi (172 MPa) is applied continuously, shall not rupture in less than 25 hours. The test shall be continued to rupture without change of load. Elongation after rupture, measured at room temperature, shall be not less than 5% in 4D. Test shall be performed in accordance with ASTM E139.

3.6.2.1.2.1 The test of 3.6.2.1.2 may be conducted using a load higher than required to produce an initial axial stress of 25,000 psi (172 MPa) but load shall not be changed while test is in progress. Time to rupture and elongation requirements shall be as specified in 3.6.2.1.2.

3.6.2.1.2.2 When permitted by purchaser, the test of 3.6.2.1.2 may be conducted using incremental loading. In such case, the load required to produce an initial axial stress of 25,000 psi (172 MPa) shall be used to rupture or for 25 hr, whichever occurs first. After the 25 hr and at intervals of 8 - 16 hr, preferably 8 - 10 hr, thereafter, the stress shall be increased in increments of 2500 psi (17.2 MPa). Time to rupture and elongation requirements shall be as specified in 3.6.2.1.2.

3.6.2.2 Castings:

3.6.2.2.1 Grain Size: Shall be substantially uniform without pronounced segregation of fine and coarse grained areas. Actaul agrain size and method of measurement shall be as agreed upon by purchaser and vendor.

3.6.2.2.2 Hardness: Shall be not lower than 30 HRC or equivalent, determined in accordance with ASTM
Ø E18.

3.6.2.2.3 Tensile and Stress-Rupture Properties: When specified on the drawing or when agreed upon by
Ø purchaser and vendor, tensile test specimens conforming to ASTM E8 shall be machined from castings selected at random from each master heat. Property requirements for such specimens shall be as specified on the drawing or as agreed upon by purchaser and vendor and may be defined as specified in AMS 2360, AMS 2361, and/or AMS 2362.

3.7 Quality:

3.7.1 Castings, as received by the purchaser, shall be uniform in quality and condition, sound, and free
Ø from foreign materials and from internal and external imperfections detrimental to usage of the castings.

3.7.1.1 Castings shall have smooth surfaces and shall be well cleaned. Metallic shot or grit shall not be used for final cleaning, unless otherwise permitted.

3.7.2 Castings shall be produced under radiographic control, unless otherwise specified. This control shall
Ø consist of radiographic examination of castings in accordance with AMS 2635 until proper foundry technique, which will produce castings free from harmful internal imperfections, is established for each part number and of production castings as necessary to ensure maintenance of satisfactory quality.

3.7.3 When specified, castings shall be subject to fluorescent penetrant inspection in accordance with
Ø AMS 2645.

3.7.4 Radiographic, fluorescent penetrant, and other quality standards shall be as agreed upon by purchaser
Ø and vendor. ASTM E192 may be used to define radiographic acceptance standards.

3.7.5 Castings shall not be repaired by peening, plugging, welding, or other methods without written
Ø permission from purchaser.

3.7.5.1 When permitted in writing by purchaser, defects in castings may be removed and the castings
Ø repaired by welding provided the weld repair area has properties comparable to those of the parent metal. Repair welds shall be subjected to the same inspection procedures and acceptance standards required of the castings. Weld repair areas shall be suitably marked to facilitate inspection. Repair welding shall be performed prior to any heat treatment and nondestructive testing specified herein.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of castings shall supply all samples and shall be responsible
Ø for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.5. Purchaser reserves the right to perform such confirmatory testing as he deems necessary to ensure that the castings conform to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to composition (3.1), hardness (3.6.1.1 and 3.6.2.2.2), elevated-temperature tensile properties (3.6.2.1.1) and stress-rupture properties (3.6.2.1.2) of separately-cast test specimens, grain size (3.6.2.2.1), and quality (3.7) requirements and, when specified, tensile and stress-rupture properties of specimens cut from castings (3.6.2.2.3) are classified as acceptance tests.

4.2.2 Preproduction Tests: Tests to determine conformance to all technical requirements of this specification are classified as preproduction tests.

4.2.2.1 For direct U.S. Military procurement, substantiating test data and, when requested, preproduction test material 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 in accordance with the following:

4.3.1 Two chemical analysis specimens in accordance with 3.4.1 and/or a casting from each master heat.

4.3.2 Two preproduction castings in accordance with 4.4.1 of each part number.

4.3.3 Six tensile test specimens in accordance with 3.4.2 from each master heat.

4.3.4 One or more castings from each master heat when properties of specimens machined from castings are required. Specific size, locations, and number of specimens machined from castings shall be as specified on the drawing or as agreed upon by purchaser and vendor. When size, location, and number of test specimens are not specified, not less than four tensile test specimens, two from the thickest section and two from the thinnest section, shall be cut from a casting from each master heat.

4.4 Approval:

4.4.1 Sample castings from new or reworked master patterns and the casting procedure shall be approved by purchaser before castings for production use are supplied, unless such approval be waived.

4.4.2 Vendor shall establish separately for tensile test specimens used for master heat qualification and for production of sample castings of each part number the control factors of processing which will produce tensile test specimens meeting master heat qualification requirements and acceptable castings; these shall constitute the approved casting procedures and shall be used for producing subsequent master heat qualification specimens and production castings. If necessary to make any change in control factors of processing, vendor shall submit for reapproval a statement of the proposed changes in processing and, when requested, sample test specimens, castings, or both. Production castings incorporating the revised operations shall not be shipped prior to receipt of reapproval.

4.4.2.1 Control factors for producing test specimens and castings include, but are not limited to, the following:

Type of furnace and its capacity
Size of furnace charge
Furnace atmosphere
Fluxing or deoxidation procedure
Mold refractory formulation
Mold back-up material
Gating practices
Mold preheat and pouring temperatures (variations of ±25°F (±15°C) from established limits are permissible)
Solidification and cooling procedures
Cleaning operations
Methods of routine inspection