AEROSPACE MATERIAL SPECIFICATION

AMS5399™	REV. D

Issued 1996-03
Revised 2006-09
Reaffirmed 2023-11

Superseding AMS5399C

Nickel Alloy, Corrosion and Heat-Resistant, Investment Castings
52Ni - 19Cr - 11Co - 9.8Mo - 3.2Ti - 1.6Al - 0.006B
Vacuum-Melted, Vacuum-Cast, Solution Heat Treated
(Composition similar to UNS N07041)

RATIONALE

AMS5399D has been revised to require performance of non-destructive inspection and special processes in accordance with applicable ASTM or AMS in lieu of the previously required MIL specs, update reporting requirements and add new provisions for serialization, and is a Five Year Review and update of this specification.

AMS5399D has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE

1.1 Form

This specification covers a corrosion and heat-resistant nickel alloy in the form of investment castings.

1.2 Application

These castings have been used typically for parts requiring high strength up to 1600 °F (871 °C) and oxidation resistance up to 1800 °F (982 °C), but usage is not limited to such applications.

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 724-776-4970 (outside USA), www.sae.org.

AMS 2269	Chemical Check Analysis Limits, Nickel, Nickel Alloys, and Cobalt Alloys
AMS 2361	Elevated Temperature Tensile Properties of Castings
AMS 2362	Stress Rupture Properties of Castings
AMS 2694	Repair Welding of Aerospace Castings
AMS 2750	Pyrometry
AMS 2804	Identification, Castings
AMS 2175	Castings, Classification and Inspection of

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For more information on this standard, visit
https://www.sae.org/standards/content/AMS5399D/

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 E 18	Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
ASTM E 21	Elevated Temperature Tension Tests of Metallic Materials
ASTM E 139	Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
ASTM E 354	Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys
ASTM E 1417	Liquid Penetrant Inspection
ASTM E 1742	Radiographic Inspection

3. TECHNICAL REQUIREMENTS

3.1 Composition

Shall conform to the percentages by weight shown in Table 1, determined by wet chemical methods in accordance with ASTM E 354, by spectrochemical methods, or by other analytical methods acceptable to purchaser (See 8.2.1 and 8.2.2).

TABLE 1 - COMPOSITION

Element	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	

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3.1.1 Vendor may test for any element not listed in Table 1 and include this analysis in the report of 4.5. Limits of acceptability may be specified by purchaser (See 8.2.3).

3.1.2 Check Analysis

Composition variations shall meet the applicable requirements of AMS 2269.

3.2 Melting Practice

Castings and specimens shall be poured at casting vendor's facility either from a melt (See 8.2.4) of a master heat, or directly from a master heat (See 3.4.2 and 8.2.5).

3.2.1 Revert (gates, sprues, risers, and rejected castings) may be used only in the preparation of master heats; revert shall not be remelted directly without refining for pouring of castings. Melting of revert creates and new master heat.

3.2.1.1 The metal for castings and specimens shall be melted and poured under vacuum without loss of vacuum between melting and pouring. When authorized by purchaser (See 8.2.6), protective atmosphere may be used in lieu of vacuum for pouring of castings.

3.2.2 Portions of two or more qualified master heats (See 3.4.2) may be melted together and poured into castings using a procedure authorized by purchaser.

3.2.3 If melts (See 8.2.4) are modified by replenishment (See 8.2.7), vendor shall have a written procedure acceptable to purchaser which defines the controls, test, and traceability criteria for both castings and separately-cast specimens. Control factors of 4.4.2.2 shall apply.

3.3 Condition

Castings shall be delivered in the solution heat treated condition.

3.4 Test Specimens

Specimens shall be either separately-cast, integrally-cast (See 8.2.8), or machined from a casting, and shall conform to 3.2.

3.4.1 If specimens are separately-cast, vendor shall have a written procedure acceptable to purchaser. Control factors of 4.4.2.2 shall apply.

3.4.2 Each master heat shall be qualified by evaluation of chemical, elevated temperature tensile, and stress-rupture specimens.

3.4.2.1 If replenishments are made at remelt as in 3.2.3, the frequency of sampling and testing used by the vendor for qualification to 3.4.2 shall be acceptable to purchaser.

3.4.2.2 Tensile and stress-rupture qualification tests of 3.4.2 are not required if tests are conducted using integrally-cast specimens (4.3.3.2) or specimens machined-from-casting (4.3.3.3).

3.4.3 Chemical Analysis Specimens

Shall be of any convenient size and shape.

3.4.4 Tensile and Stress-Rupture Specimens

Shall be of standard proportions in accordance with ASTM publications referenced in 3.6.

3.4.4.1 Separately-cast and integrally-cast specimens may be either cast to size, or cast oversize and subsequently machined to 0.250-inch (6.35 mm) diameter.

3.4.4.2 When integrally-cast specimens and/or specimens machined-from-casting are specified, specimen size and location shall be as agreed upon by purchaser and vendor. (See 8.2.9 and 8.5.)

3.5 Heat Treatment

Castings and representative tensile and stress-rupture specimens shall be heat treated in accordance with AMS 2750 except as specified in 3.5.1 and 3.5.2.

3.5.1 Castings and Specimens

3.5.1.1 Solution Heat Treatment

Heat in a suitable protective atmosphere to 1950 °F ± 25 (1066 °C ± 14), hold at heat for not less than three hours, and rapid quench.

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3.5.2 Response to Heat Treatment

After solution heat treatment to 3.5.1, specimens shall be heat treated in accordance with the following for subsequent testing to demonstrate response to heat treatment:

3.5.2.1 Re-Solution Heat Treatment

Heat in a suitable protective atmosphere to 1950 °F ± 25 (1066 °C ± 14), hold at heat for not less than 30 minutes, and rapid cool.

3.5.2.2 Precipitation Heat Treatment

Heat to 1400 °F ± 25 (760 °C ± 14), hold at heat for not less than 16 hours, and cool in air.

3.5.3 Tensile and stress-rupture specimens used for master heat qualification may be heat treated separately from castings.

3.6 Properties

Conformance shall be based upon testing separately-cast specimens unless purchaser specifies integrally-cast specimens or specimens machined-from-casting. Properties for integrally-cast specimens and machined-from-casting specimens shall be specified by purchaser (See 8.5).

3.6.1 Room Temperature Tensile Properties

Not applicable.

3.6.2 Elevated Temperature Tensile Properties at 1200 °F (649 °C)

Shall be as specified in Table 2 on specimens heated to 1200 °F ± 10 (649 °C ± 6) and tested at 1200 °F ± 10 (649 °C ± 6) in accordance with ASTM E 21. Properties other than those listed may be defined as specified in AMS 2361.

3.6.2.1 Separately-Cast Specimens

Shall be as shown in Table 2.

TABLE 2 - MINIMUM ELEVATED TEMPERATURE TENSILE PROPERTIES

Property	Value
Tensile strength	110 ksi (758 MPa)
Yield Strength at 0.2% Offset	90 ksi (621 MPa)
Elongation in 4D	3%
Reduction of Area	5%

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3.6.3 Stress-Rupture Properties at 1650 °F (899 °C)

Shall be as follows; determined in accordance with ASTM E 139. Properties other than those listed may be defined as specified in AMS 2362.

3.6.3.1 Specimens, maintained at 1650 °F ± 3 (899 °C ± 2) while a load sufficient to produce an initial axial stress of 25.0 ksi (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.

3.6.3.2 The test of 3.6.3.1 may be conducted using a load higher than required to produce an initial axial stress of 25.0 ksi (172 MPa) but load shall not be changed while test is in progress. Time to rupture and elongation requirements shall be as specified in 3.6.3.1.

3.6.3.3 When authorized by purchaser, the test of 3.6.3.1 may be conducted using incremental loading. In such case the load required to produce an initial axial stress of 25.0 ksi (172 MPa) shall be used to rupture or for 25 hours, whichever occurs first. After the 25 hours and at intervals of 8 hours minimum, thereafter, the stress shall be increased in increments of 2.5 ksi (17.2 MPa). Time to rupture and elongation requirements shall be as specified in 3.6.3.1.

3.6.4 Hardness

Shall be as follows, determined in accordance with ASTM E 18.

3.6.4.1 Castings

Castings, in the solution heat treated condition of 3.5.1, shall have hardness not higher than 30 HRC, or equivalent (See 8.3).

3.6.4.2 Representative Specimens

Representative specimens heat treated to the solution, re-solution, and precipitation heat treated condition of 3.5.2, shall have hardness not lower then 30 HRC, or equivalent (See 8.3).

3.7 Quality

3.7.1 Castings, as received by purchaser, shall be uniform in quality and condition, sound, and free from foreign materials and from imperfections detrimental to usage of the castings. Castings shall be free of cracks, laps, hot tears, and cold shuts, and free of scale and other process-induced surface contamination which would obscure defects.

3.7.2 Castings shall be produced under radiographic control. This control shall consist of radiographic examination of each casting part number until foundry manufacturing controls in accordance with 4.4.2 have been established. Additional radiography shall be conducted in accordance with the frequency of inspection specified by purchaser, or as necessary to ensure continued maintenance of internal quality.

3.7.2.1 Radiographic inspection shall be conducted in accordance with ASTM E 1742 or other method specified by purchaser.

3.7.3 When specified, castings shall be subjected to fluorescent penetrant inspection in accordance with ASTM E 1417 or other method specified by purchaser.

3.7.4 Acceptance standards for radiographic, fluorescent penetrant, visual, and other inspection methods shall be as agreed upon by purchaser and vendor. AMS 2175 may be used to specify acceptance standards (casting grade) and frequency of inspection (casting class).

3.7.4.1 When acceptance standards are not specified, Grade C of AMS2175 as applicable to steel castings shall apply for each applicable method of inspection.

3.7.5 Castings shall not be peened, plugged, impregnated, or welded unless authorized by purchaser.

3.7.5.1 When authorized by purchaser, welding in accordance with AMS 2694 or other welding program acceptable to purchaser may be used.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The vendor of castings 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 castings conform to specified requirements.

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4.2 Classification of Tests

4.2.1 Acceptance Tests

Composition (3.1), elevated temperature tensile (3.6.2), stress-rupture (3.6.3), hardness (3.6.4), and the applicable requirements of quality (3.7) are acceptance tests and shall be performed as specified in 4.3.

4.2.2 Periodic Tests

Radiographic soundness (3.7.2) is a periodic test and shall be performed at a frequency selected by vendor unless a frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests

All technical requirements are preproduction tests and shall be performed on sample castings (4.2.3), when a change in control factors occurs (4.4.2.2), and when purchaser deems confirmatory testing to be required.

4.3 Sampling and Testing

The minimum testing performed by vendor shall be in accordance with the following:

4.3.1 One chemical analysis specimen or a casting from each master heat shall be tested for conformance with Table 1; if 3.4.2.1 applies, test frequency shall be acceptable to purchaser.

4.3.2 One preproduction casting in accordance with 4.4 shall be tested to the requirements of the casting drawing and to all technical requirements of this specification.

4.3.2.1 Dimensional inspection sample quantity shall be as specified by purchaser.

4.3.3 Elevated temperature tensile and stress-rupture tests shall be conducted to determine conformance with Table 2 and 3.6.3. Sampling and test frequency are dependent upon the type and origin of specimen specified by purchaser (See 3.4.4 and 3.6) or selected by vendor (See 4.3.3.4). When 3.4.2.1 applies, specimen source and test frequency shall be acceptable to purchaser.

4.3.3.1 For separately-cast specimens in the solution, re-solution, and precipitation heat treated condition of 3.5.2, two specimens from each master heat shall be tested for conformance; one to 3.6.2, and one to 3.6.3.

4.3.3.2 For integrally-cast specimens in the solution, re-solution, and precipitation heat treated condition of 3.5.2, four specimens from each lot (See 8.2.10) shall be randomly selected and tested for conformance to properties specified by purchaser (See 3.6 and 8.5). Two specimens shall be tested for elevated temperature tensile in accordance with 3.6.2, and two specimens tested for stress-rupture in accordance with 3.6.3.

4.3.3.3 For specimens machined-from-casting, one casting shall be randomly selected from each lot and tested after solution, re-solution, and precipitation heat treatment to 3.5.2 at each location shown on the engineering drawing for conformance to properties specified by purchaser (See 3.6 and 8.5).

4.3.3.3.1 When size and location of specimens are not shown, four specimens shall be tested, two from the thickest section and two from the thinnest section. Once established under 4.4.2.2, test locations may be changed only as agreed upon by purchaser and vendor.

4.3.3.4 When acceptable to purchaser, specimens machined-from-casting may be used in lieu of both separately-cast and integrally-cast specimens, and integrally-cast specimens may be used in lieu of separately-cast specimens. In each case, the resultant properties must conform to the requirements of 3.6 for separately-cast specimens or to alternative requirements specified by purchaser (See 8.5).

4.3.3.4.1 When specimens are selected for test as in 4.3.3.4 from an origin other than that specified by purchaser, vendor shall include in the report of 4.5 a description of the source of the specimen that was tested.

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4.3.3.5 When casting size, section thickness, gating method, or other factors do not permit conformance to 4.3.3.2 or 4.3.3.3, sampling and testing shall be agreed upon by purchaser and vendor.

4.3.4 Castings shall be inspected in accordance with 3.7 to the methods, frequency, and acceptance standards specified by purchaser.

4.3.5 Castings in the solution heat treated condition of 3.5.1 shall be tested for hardness to determine conformance with 3.6.4.1. Unless otherwise specified by purchaser, one casting per lot shall be hardness tested.

4.3.5.1 In event of failure, the entire lot shall be 100% inspected or reheat treated in accordance with 4.6.2.

4.3.6 After solution, re-solution, and precipitation heat treatment to 3.5.2, one specimen from 3.4 shall be tested for hardness to determine conformance with 3.6.4.2.

4.3.6.1 In event of failure, specimens may be reheat treated in accordance with 4.6.2.

4.4 Approval

4.4.1 Sample casting(s) from new or reworked master patterns produced under the casting procedure of 4.4.2 shall be approved by purchaser before castings for production use are supplied, unless such approval be waived by purchaser.

4.4.2 For each casting part number, vendor shall establish parameters for process control factors that will consistently produce castings and test specimens meeting the requirements of the casting drawing and this specification. These parameters shall constitute the approved casting procedure and shall be used for production of subsequent castings and test specimens. If necessary to make any change to these parameters, vendor shall submit a statement of the proposed change for purchaser reapproval. When requested, vendor shall also submit test specimens, sample castings, or both to purchaser for reapproval.

4.4.2.1 Production castings produced prior to receipt of purchaser's approval shall be at vendor's risk.

4.4.2.2 Control factors for producing castings and separately-cast specimens include, but are not limited to, the following factors. Supplier's procedures shall identify tolerances, ranges, and/or control limits, as applicable. Control factors for separately-cast specimens must generally represent, but need not be identical to, those factors used for castings (See 3.2.3 and 3.4.1):

Composition of ceramic cores, if used
Arrangement and number of patterns in the mold (including integrally-cast specimens if applicable)
Size, shape, and location of gates and risers
Mold refractory formulation
Grain refinement methods
Mold back up material (weight, thickness, or number of dips)
Type of furnace, vacuum, and charge for melting
Mold preheat and metal pouring temperatures
Fluxing or deoxidation procedure
Replenishment procedure, if applicable
Time that molten metal is in the furnace
Solidification and cooling procedures
Cleaning operations (mechanical and chemical)
Heat treatment
Straightening
Final inspection methods
Location of specimens machined from casting (if applicable)

4.4.2.2.1 Any of the control factors shown above 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.

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4.4.2.2.1.1 Unless otherwise agreed upon by purchaser and vendor, purchaser shall be entitled to review proprietary control factor details and coding at vendor's facility.

4.5 Reports

The vendor of castings shall furnish with each shipment a certification document declaring that castings have been processed, tested, and inspected as specified and that the results of the inspections and tests conform to requirements.

4.5.1 Unless otherwise specified, vendor shall furnish test report(s) showing the results of tests and inspections conducted in accordance with 4.2 and 4.3.

4.5.1.1 Chemical analysis determinations, property test data, and the results of any retests conducted shall be expressed numerically to reflect actual quantitative test values.

4.5.1.2 Hardness test readings may be expressed as single values or as a range of values exhibited by results obtained from the sample size.

4.5.1.3 Inspection and preproduction results shall be reported at the frequency specified by, and in a format acceptable to purchaser.

4.5.1.4 Objective evidence of purchaser's review and acceptance of nonconforming material shall be provided with the certification document at each shipment. (See 7.)

4.5.2 The statement of conformity and test report(s) shall include or be traceable to the purchase order number, master heat identification, heat treat/lot number, AMS 5399D, part number, quantity, and when required (See 5.1.1) the list of individual serial numbers or serial number range.

4.5.2.1 If 4.3.3.4.1 applies, the mechanical property test report shall denote the source of the specimens that were tested.

4.5.3 Test reports for acceptance testing of 4.2 shall be as follows:

4.5.3.1 For each master heat

Composition (See 4.3.1)
Elevated temperature tensile properties (See 4.3.3.1 and 3.6.2)
Stress-rupture properties (See 4.3.3.1 and 3.6.3)
Response to heat treat hardness of specimens (4.3.6)

4.5.3.2 For each lot

Inspection results (See 4.3.4)
Hardness of castings (4.3.5)
Integrally-cast or machined-from-casting elevated temperature tensile and stress-rupture properties, when specified (See 3.6, 4.3.3.2 and 4.3.3.3)

4.5.4 The vendor shall retain records of processing and inspection in accordance with purchaser requirements.

4.6 Resampling and Retesting

If the results of a valid test fail to meet the requirements, two additional specimens in accordance with 4.3 from the same master heat, modified melt (See 3.2.3), or lot, as applicable, shall be tested for each nonconforming characteristic. Results of each additional test, and the average of the results of all tests (original and retests), shall meet specified requirements; otherwise, the master heat or lot shall be rejected. Results of all tests shall be reported.

4.6.1 A test may be declared invalid if failure is due to specimen mispreparation, test equipment malfunction, improper test procedure, or the presence of random process defects such as inclusions or gas holes in a tensile or stress-rupture specimen.

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