AEROSPACE MATERIAL SPECIFICATION

AMS5391	REV. G

Issued 1960-06
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Superseding AMS5391F

Nickel Alloy, Corrosion and Heat-Resistant, Investment Castings
73Ni - 0.14C - 13Cr - 4.5Mo - 2.3Cb (Nb) - 0.75Ti - 6.0Al - 0.010B - 0.10Zr
Vacuum Cast, As-Cast
(Composition similar to UNS N07713)

RATIONALE

AMS5391G revises Stress Rupture Testing (3.6.2.2), Control Factors (4.4.2.2), and Reports (4.5), and is a Five Year Review and update of this specification.

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, such as turbine blade, requiring high strength up to 1800 °F (982 °C) and oxidation resistance up to 2000 °F (1093 °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 canceled 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.ams.org.

AMS2175 Castings, Classification and Inspection of

AMS2269 Chemical Check Analysis Limits, Nickel, Nickel Alloys, and Cobalt Alloys

AMS2360 Room Temperature Tensile Properties of Castings

AMS2362 Stress-Rupture Properties of Castings

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/AMS5391G

AMS2694 In-Process Welding of Castings

AMS2804 Identification, Castings

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 8/E 8M Tension Testing 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/E 1417M Liquid Penetrant Examination

ASTM E 1742/E 1742M Radiographic Examination

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	0.08	0.20
Manganese	--	0.25
Silicon	--	0.50
Phosphorus	--	0.015
Sulfur	--	0.015
Chromium	12.00	14.00
Molybdenum	3.80	5.20
Columbium (Niobium)	1.80	2.80
Titanium	0.50	1.00
Aluminum	5.50	6.50
Boron	0.005	0.015
Zirconium	0.05	0.15
Cobalt	--	1.00
Tantalum	--	0.15
Iron	--	0.50
Copper	--	0.50
Other Elements (3.1.1)	--	--
Nickel	remainder	

3.1.1 Vendor may test for any element not otherwise 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 requirements of AMS2269.

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 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 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 a new master heat.

3.2.3 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.

3.2.4 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 as-cast 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, tensile, and stress-rupture specimens.

3.4.2.1 If replenishments are made at remelt as in 3.2.4, 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 tests of 3.4.2 are not required if these 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 E 8/E 8M (See 8.3), and ASTM E 139, respectively.

3.4.4.1 Separately-cast and integrally-cast specimens may be either cast to size, and/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 agreed upon by purchaser and vendor (See 8.2.9 and 8.5).

3.5 Heat Treatment

Not applicable.

3.6 Properties

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

3.6.1 Room Temperature Tensile Properties

Shall be as specified in 3.6.1.1, determined in accordance with ASTM E 8/E 8M (See 8.3). Properties other than those listed in Table 2 may be defined as specified in AMS2360.

3.6.1.1 Separately-Cast Specimens

Shall be as shown in Table 2.

TABLE 2 - MINIMUM TENSILE PROPERTIES OF SEPARATELY-CAST SPECIMENS

Property	Value
Tensile Strength	110 ksi (758 MPa)
Yield Strength at 0.2% Offset	100 ksi (689 MPa)
Elongation in 4D	3%

3.6.2 Stress-Rupture Properties at 1800 °F (982 °C)

Shall be as follows, determined in accordance with ASTM E 139. Properties other than those listed may be defined as specified in AMS2362.

3.6.2.1 Specimens, maintained at 1800 °F ± 3 (982 °C ± 2) while a load sufficient to produce an initial axial stress of 22.0 ksi (152 MPa) or higher is applied continuously, shall not rupture in less than 30 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.

3.6.2.2 The test of 3.6.2.1 may be conducted using incremental loading. In such case, the load required to produce an initial axial stress of 22.0 ksi (152 MPa) or higher shall be used to rupture or for 30 hours, whichever occurs first. After the 30 hours and at intervals of 8 hours, minimum, thereafter, the stress shall be increased in increments of 2.0 ksi (14.0 MPa). Time to rupture and elongation requirements shall be as specified in 3.6.2.1.

3.6.3 Hardness

Not applicable.

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/E 1742M 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/E 1417M 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 (See 8.2.9). AMS2175 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 specified 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 AMS2694 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.

4.2 Classification of Tests

4.2.1 Acceptance Tests

Composition (3.1), room temperature tensile properties (3.6.1), stress rupture properties (3.6.2) 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 the vendor unless 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 (4.3.2), 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 requirements of the casting drawing and to all technical requirements.

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

4.3.3 Tensile property and stress-rupture tests shall be conducted to determine conformance with 3.6.1 and 3.6.2. Sampling and test frequency is dependent upon the type and origin of the 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 as-cast condition, two specimens from each master heat shall be tested; one for conformance to Table 2 and one for conformance to 3.6.2.

4.3.3.2 For integrally-cast specimens in the as-cast condition, two specimens shall be randomly selected from each lot and tested for conformance with properties specified by purchaser (See 3.6 and 8.5).

4.3.3.3 For specimens machined-from-casting, one casting shall be randomly selected from each lot and tested in the as-cast condition at each location shown on the engineering drawing for conformance with properties specified by purchaser (See 3.6 and 8.5).

4.3.3.3.1 When size and location of specimens are not shown, two specimens shall be tested, one from the thickest section and one 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 shall conform to the requirements of 3.6 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.

4.3.3.5 When casting size, section thickness, gating method, or other factors do not permit conformance with 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.

4.4 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 3.2.4 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, if applicable
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 molten metal is in furnace
Solidification and cooling procedures
Welding procedure, if applicable
Cleaning operations (mechanical and chemical)
Straightening
Final inspection methods
Location of specimens machined-from-casting, if applicable

4.4.2.2.1 Any of the 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.

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.