SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 5391D

Issued JUN 1960
Revised APR 1995

Submitted for recognition as an American National Standard

Superseding AMS 5391C

(R) NICKEL ALLOY, CORROSION AND HEAT RESISTANT, INVESTMENT CASTINGS
73Ni - 13Cr - 4.5Mo - 2.3Cb - 0.75Ti - 6.0Al - 0.010B - 0.10Zr
Vacuum Cast, As Cast

UNS N07713

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 blades, 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 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 2268 Chemical Check Analysis Limits, Cast Nickel and Nickel Alloys
AMS 2360 Room Temperature Tensile Properties of Castings
AMS 2362 Stress-Rupture Properties of Castings
AMS 2694 Repair Welding of Aerospace Castings
AMS 2804 Identification, Castings

2.2 ASTM Publications:

Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM E 8	Tension Testing of Metallic Materials
ASTM E 8M	Tension Testing of Metallic Materials (Metric)
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

2.3 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-453	Inspection, Radiographic
MIL-STD-2073-1	DOD Materiel, Procedures for Development and Application of Packaging Requirements
MIL-STD-2175	Castings, Classification and Inspection of
MIL-STD-6866	Inspection, Liquid Penetrant

3. TECHNICAL REQUIREMENTS:

3.1 Composition:

Castings 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
Sulfur	--	0.015
Chromium	12.00	14.00
Molybdenum	3.80	5.20
Columbium	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 (3.1.2)	--	1.00
Iron	--	0.50
Copper	--	0.50
Tantalum	--	0.05
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 Determination not required for routine acceptance.

3.1.3 Check Analysis: Composition variations shall meet the requirements of AMS 2268.

3.2 Melt Practice:

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

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 (See 8.2.6).

3.2.4 If modifications, such as alloy additions or replenishments, are made by the vendor at remelt, 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:

As cast.

3.4 Test Specimens:

Specimens shall be either separately-cast, integrally-cast (See 8.2.7), or machined from 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 alloy additions or replenishments are made at remelt as in 3.2.3, the frequency of sampling and testing used by the vendor for qualification 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 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 or specimens machined from casting are specified, specimen size and location shall be agreed upon by purchaser and vendor (See 8.2.8 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 or ASTM E 8M (See 8.3). Properties other than those listed may be defined as specified in AMS 2360.

3.6.1.1 Separately-Cast Specimens: Shall be as shown in Table 2.

TABLE 2 - Minimum Tensile Properties

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 AMS 2362.

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 (R) 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) shall be used to rupture or for 30 hours, whichever occurs first. After the 30 hours and at intervals of 8 to 16 hours, preferably 8 to 10 hours, 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:

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.

3.7.1 Unless otherwise specified by purchaser, the following shall apply:

3.7.1.1 Castings shall be free of cracks, laps, hot tears, and cold shuts.

3.7.1.2 Castings shall be 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 MIL-STD-453 or other method specified by purchaser.

3.7.3 When specified, additional nondestructive testing shall be performed as follows:

3.7.3.1 Fluorescent penetrant inspection in accordance with MIL-STD-6866 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 8.2.8). MIL-STD-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 MIL-STD-2175 shall apply.

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 performing all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the castings conform to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Composition (3.1), tensile properties (3.6.1), stress-rupture properties (3.6.2), and 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 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, unless 3.4.2.1 applies, in which case 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.

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

4.3.3 Tensile 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 3.6) or selected by vendor (See 4.3.3.4). When 3.4.2.1 applies, test frequency shall be acceptable to purchaser.

4.3.3.1 For separately-cast specimens in the as-cast condition one or more specimen from each master heat shall be tested for conformance to 3.6.2.

4.3.3.2 For integrally-cast specimens in the as-cast condition two or more specimens shall be randomly selected from each lot and tested for conformance to 3.6.2.

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 3.6.2.

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 origin of the specimen that was tested.

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 as 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 changes 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 test specimens include, but are not limited to, the factors shown below. 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, 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 and alloy addition procedures, if applicable
Time molten metal is in furnace
Solidification and cooling procedures
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 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.