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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 5410A

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Superseding AMS 5410

(R) Nickel Alloy, Corrosion and Heat Resistant, Investment Castings
61Ni - 16Cr - 8.5Co - 1.8Mo - 2.6W - 0.85Cb - 3.4Ti - 1.8Ta - 3.4Al - 0.010B - 0.05Zr
Vacuum Melted, Vacuum Cast
As Cast, or Solution Treated, or Solution and Precipitation Hardened

1. SCOPE:

1.1 Form:

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

1.2 Application:

These castings have been used typically for parts, such as turbine blades or vanes, requiring good strength and hot corrosion resistance up to 1800 °F (982 °C), but usage is not limited to such applications.

1.3 Classification:

Castings conforming to this specification are classified as follows:

Type A - Castings supplied in the as cast condition
Type B - Castings supplied in the solution heat treated condition
Type C - Castings supplied in the solution treated and precipitation heat treated condition

Class 1 - Trace element limits conforming to AMS 2280-1
Class 2 - Trace element limits conforming to AMS 2280-2
Class 3 - Trace element limits do not apply

1.3.1 Castings shall be supplied in the Type A condition unless Type B or Type C is specified by purchaser.

1.3.2 Castings shall conform to Class 1 unless Class 2 or Class 3 is specified by purchaser.

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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, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2269	Chemical Check Analysis Limits, Nickel, Nickel Alloys, and Cobalt Alloys
AMS 2280	Trace Element Control, Nickel Alloy Castings
AMS 2360	Room 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-STD-2175	Castings, Classification and Inspection of
AS5491	Calculation of Electron Vacancy Number in Superalloys

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

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
ASTM E 1417	Liquid Penetrant Examination
ASTM E 1742	Radiographic Examination

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 (3.1.1)	0.09	0.20
Manganese	--	0.20
Silicon	--	0.30
Phosphorus	--	0.015
Sulfur	--	0.015
Chromium	15.70	16.30
Cobalt	8.00	9.00
Molybdenum	1.50	2.00
Tungsten	2.40	2.80
Columbium	0.60	1.10
Titanium	3.20	3.70
Tantalum	1.50	2.00
Aluminum	3.20	3.70
Aluminum + Titanium	6.50	7.20
Boron	0.005	0.015
Zirconium	0.025	0.08
Iron	--	0.50
Copper	--	0.10
Other Elements (3.1.2)	--	--
Nickel	remainder	

3.1.1 The preferred range for carbon is 0.09 to 0.13.

3.1.2 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).

3.1.3 Trace Elements: Shall conform to AMS 2280 Class 1, unless AMS 5410 Class 2 or Class 3 is specified by purchaser (See 1.3 and 8.5).

3.1.4 Check Analysis: Composition variations shall meet the applicable requirements of AMS 2269.

3.1.5 Phacomp Electron Vacancy Number (N_v): For Classes 1 and 2, the phacomp electron vacancy number of the master heat (See 8.6) shall not exceed a value of 2.31 when calculated in accordance with AS5491.

3.2 Melting Practice:

3.2.1 Master Heat Preparation:

3.2.1.1 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.

3.2.1.2 Master heat metal shall be melted and poured under vacuum without loss of vacuum between melting and pouring.

3.2.1.3 The master heat source shall establish effective control procedures including parameters for the critical variables that will consistently produce material suitable for remelting of castings meeting the requirements of this specification. Control procedures shall be acceptable to purchaser and casting vendor.

3.2.2 Master Heat Qualification:

3.2.2.1 Each master heat shall conform to the Phacomp Electron Vacancy Number of 3.1.5, and shall be qualified by evaluation of chemistry, tensile, and stress rupture specimens.

3.2.3 Remelt for Casting:

3.2.3.1 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 8.2.5).

3.2.3.2 The metal for castings 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.

3.2.3.3 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.

3.2.3.4 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:

Castings shall be delivered in the as cast condition, unless Type B or Type C is specified (See 1.3 and 8.5).

3.4 Test Specimens:

Specimens shall be separately-cast, integrally-cast (See 8.2.7), 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 alloy additions or replenishments are made at remelt as in 3.2.3.4, 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 The tensile 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 a casting (4.3.3.3).

3.4.3 Chemical Analysis Specimens: Shall be of any convenient size and shape.

3.4.4 Tensile Specimens: Shall be of standard proportions in accordance with ASTM E 8 or ASTM E 8M (See 8.3) with 0.250 inch (6.35 mm) diameter at the reduced parallel gage section.

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 specimens machined from a 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:

3.5.1 Castings: Shall be supplied to Type A, unless Type B or C is specified.

3.5.1.1 Type A, As Cast: Heat treatment is not required for castings.

3.5.1.2 Type B, Solution Treated: Heat to 2050 °F ± 25 (1121 °C ± 14) in vacuum or suitable protective atmosphere, hold at heat for 2 hours ± 15 minutes, cool to 1550 °F ± 25 (843 °C ± 14), within 15 minutes, and then cool to room temperature at any rate.

3.5.1.3 Type C, Solution Treated and Precipitation Hardened: Type B, then heat to 1550 °F ± 25 (843 °C ± 14), hold at heat for 24 hours ± 15 minutes, and cool at any rate to room temperature.

3.5.1.3.1 Type C treatment may consist of two separate cycles of 2050 °F and 1550 °F, or a single duplex cycle.

3.5.2 Representative Tensile Specimens: Shall be solution and precipitation heat treated to Type C condition as specified in 3.5.1.3.

3.6 Properties:

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

3.6.1 Room Temperature Tensile Properties: Shall be as follows, 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 Room Temperature Tensile Properties

Property	Value
Tensile strength	130 ksi (896 MPa)
Yield Strength at 0.2% Offset	115 ksi (793 MPa)
Elongation in 4D	3%
Reduction of Area	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 (151 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.

3.6.2.1.1 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 (151 Mpa) or higher 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 2.5 ksi (17.3 MPa). Time to rupture and elongation requirements shall be as specified in 3.6.2.1.

3.7 Quality:

3.7.1 Castings, as received by purchaser, shall be uniform in quality and condition. Castings shall, to the extent defined in 3.7.2, 3.7.3, and 3.7.4, or in supplemental standards specified by the purchaser, be free from porosity, foreign materials, and imperfections detrimental to their performance. Castings shall be free of cracks, laps, hot tears, and cold shuts, and free of scale and other 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 another method specified by purchaser.

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

3.7.4 Acceptance standards for radiographic, fluorescent penetrant, visual, and other inspection methods shall be agreed upon by purchaser and vendor (See 8.2.8). AMS-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 AMS-STD-2175 shall apply to each applicable inspection method.

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 another welding program acceptable to purchaser may be used.

3.7.6 When specified, grain size shall be in accordance with standards agreed upon by purchaser and vendor (See 8.5).

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), phacomp electron vacancy number (3.1.5), tensile properties (3.6.1), stress rupture properties (3.6.2), and 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) and grain size (when required, 3.7.6) are periodic tests 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 and 3.1.5; 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.

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

4.3.3 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 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 solution and precipitation heat treated condition of 3.5.2, two specimens from each master heat shall be tested, one to 3.6.1, and one to 3.6.2.

4.3.3.2 For integrally-cast specimens in the solution and precipitation heat treated condition of 3.5.2, four specimens from each lot shall be randomly selected and tested, two to 3.6.1 for properties specified by purchaser, and two to 3.6.2.

4.3.3.3 For specimens machined from a casting, one casting shall be randomly selected from each lot and tested in the solution and precipitation heat treatment condition at locations shown on the engineering drawing for conformance with 3.6.1 for properties specified by purchaser and 3.6.2.

4.3.3.3.1 When size and location of specimens are not shown, two or more test 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 a 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 that type of specimen, or to alternate 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 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 3.2.3.4):

Master heat metal source and utilization of revert materials
Composition of ceramic cores, if used
Arrangement and number of patterns in the mold (including integrally-cast specimens if applicable) and, if applicable, filter type and location
Size, shape, and location of gates and risers
Mold refractory formulation
Grain refinement methods and grain size of castings, if applicable
Mold back up material (weight, thickness, or number of dips)
Type of furnace, vacuum (or protective atmosphere), charge for melting
Mold preheat, super heat, 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 a casting, if applicable.