

AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard

SAE

MAM 5401A

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Superseding MAM 5401

(R) NICKEL ALLOY, CORROSION AND HEAT RESISTANT, INVESTMENT CASTINGS

62Ni - 21.5Cr - 9.0Mo - 3.6Cb

Vacuum Melted, Vacuum Cast

As Cast

UNS N26625

1. SCOPE:

1.1 Form:

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

1.1.1 AMS 5401 is the inch/pound version of this MAM.

1.2 Application:

These castings have been used typically for structural parts requiring moderate strength up to 870 °C and oxidation and corrosion resistance up to 980 °C, but usage is not limited to such applications.

1.3 Classification:

Castings conforming to this specification are classified as follows:

Class 1 - Trace element limits conforming to AMS 2280, Class 1 (AMS 2280-1)

Class 2 - Trace element limits conforming to AMS 2280, Class 2 (AMS 2280-2)

Class 3 - Trace element limits do not apply

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

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.

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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 2694 Repair Welding of Aerospace Castings
AMS 2804 Identification, Castings

2.2 ASTM Publications:

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

ASTM E 8M Tension Testing of Metallic Materials (Metric)
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	--	0.10
Manganese	--	0.50
Silicon	--	0.50
Phosphorus	--	0.015
Sulfur	--	0.015
Chromium	20.00	23.00
Molybdenum	8.00	10.00
Columbium (3.1.1)	3.15	4.15
Cobalt	--	1.00
Titanium (3.1.2)	--	0.40
Tantalum (3.1.1, 3.1.3)	--	0.15
Aluminum (3.1.2)	--	0.40
Iron	--	5.00
Copper	--	0.30
Other Elements (3.1.3)	--	--
Nickel	remainder	--

3.1.1 Sum of columbium plus tantalum shall not exceed 4.15%.

3.1.2 Shall be present but not in excess of maximum content specified.

3.1.3 Determination not required for routine acceptance.

3.1.4 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).

3.1.5 Trace Elements: Shall conform to AMS 2280-1 unless AMS 2280-2 or MAM 5401 Class 3 is specified by purchaser (See 1.3).

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

3.2 Melt 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 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.

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 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.

3.4 Test Specimens:

Specimens shall be either 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 and tensile 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 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 8M (See 8.3) with 6.25 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 6.25 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 8.4).

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 a casting.

3.6.1 Room Temperature Tensile Properties: Shall be as specified in 3.6.1.1, determined in accordance with 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 shown in Table 2.

TABLE 2 - Minimum Tensile Properties

Property	Value
Tensile Strength	585 MPa
Yield Strength at 0.2% Offset	310 MPa
Elongation in 4D	25%

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 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), tensile properties (3.6.1), 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 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 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 property tests shall be conducted to determine conformance with 3.6.1. 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 as-cast condition, one specimen from each master heat shall be tested to 3.6.1.

- 4.3.3.2 For integrally-cast specimens in the as-cast condition, two specimens from each lot (See 8.2.9) shall be randomly selected and tested to 3.6.1.
- 4.3.3.3 For specimens machined from a casting, one casting shall be randomly selected from each lot and tested in the as-cast condition at locations shown on the engineering drawing for conformance with 3.6.1.
- 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 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 separately-cast specimens or to alternate requirements specified by purchaser (See 8.4).
- 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 test specimens must generally represent, but need not be identical to, those factors used for castings (See 3.2.3):

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 (or protective atmosphere), and charge for melting

Mold preheat and metal pouring temperatures

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

- 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.

4.5 Reports:

- 4.5.1 The vendor of castings shall furnish with each shipment a report showing the results of tests to determine conformance to the acceptance test requirements. This report shall include the purchase order number, master heat/lot identification, MAM 5401A, part number, quantity, and source of tensile property specimens (See 4.3.3.4.1).

4.6 Resampling and Retesting:

If results of a valid test fail to meet specified 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.