

AEROSPACE MATERIAL SPECIFICATION



AMS 5337C

Issued
Revised

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Superseding AMS 5337B

Steel, Maraging, Investment Castings
18.5Ni - 9.0Co - 5.0Mo - 0.70Ti - 0.12Al
Vacuum Melted
Homogenized, Overaged, and Solution Heat Treated
(Composition similar to UNS J93150)

1. SCOPE:

1.1 Form:

This specification covers an alloy steel in the form of investment castings.

1.2 Application:

These castings have been used typically for heat treated parts requiring ultra-high strengths up to 600 °F (316 °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, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2248	Chemical Analysis Check Limits, Corrosion and Heat Resistant Steels and Alloys, Maraging, and Other Highly-Alloyed Steels and Iron Alloys
AMS 2360	Room Temperature Tensile 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

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2.2 ASTM Publications:

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

ASTM A 370	Mechanical Testing of Steel Products
ASTM E 353	Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
ASTM E 1417	Liquid Penetrant Examination
ASTM E 1444	Magnetic Particle Examination
ASTM E 1742	Radiographic Inspection

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 353, 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	--	0.03
Manganese	--	0.10
Silicon	--	0.10
Phosphorus	--	0.010
Sulfur	--	0.010
Nickel	18.00	19.00
Cobalt	8.50	9.50
Molybdenum	4.50	5.50
Titanium	0.55	0.85
Aluminum	0.05	0.20

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 applicable requirements of AMS 2248.

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 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 (See 8.2.6).
- 3.2.4 If modifications, such as alloy additions or replenishments (See 8.2.10), 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 homogenized, overaged, and solution heat treated condition (See 3.5).
- 3.4 Test Specimens:
- Specimens shall be either separately-cast, integrally-cast (See 8.2.7), or machined from castings, 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, hardness, and tensile specimens.
- 3.4.2.1 If alloy additions or replenishments are made at remelt as in 3.2.4, 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 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 castings (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 A 370 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 castings are specified, specimen size and location shall be as agreed upon by purchaser and vendor (See 8.2.8 and 8.5).

3.4.5 Hardness Specimens for Response to Heat Treatment: May be a representative specimen or a casting.

3.5 Heat Treatment:

To produce the condition in castings for delivery, heat treat as specified in 3.5.1 to conform to hardness of 3.6.2.1. Pyrometry shall be in accordance with AMS 2750.

3.5.1 Production Castings and Specimens:

3.5.1.1 Homogenization: Heat to $2100^{\circ}\text{F} \pm 25$ ($1149^{\circ}\text{C} \pm 14$), hold at heat for four hours ± 0.25 , and cool to room temperature at a rate equivalent to an air cool or faster.

3.5.1.2 Overaging: Heat to $1100^{\circ}\text{F} \pm 25$ ($593^{\circ}\text{C} \pm 14$), hold at heat for one to four hours, and cool to room temperature at a rate equivalent to an air cool or faster. Alternately, heat to the solution heat treating temperature directly after aging without cooling between steps.

3.5.1.3 Solution: Heat to $1500^{\circ}\text{F} \pm 25$ ($816^{\circ}\text{C} \pm 14$), hold at heat for one hour per inch (25 mm) of section thickness but in no case less than one hour, and cool to room temperature at a rate equivalent to an air cool or faster.

3.5.2 Response to Heat Treatment: Castings or specimens for testing after maraging shall be heat treated as in 3.5.1 and the following:

3.5.2.1 Marage: Heat to $900^{\circ}\text{F} \pm 15$ ($482^{\circ}\text{C} \pm 8$), hold at heat for 3 hours ± 0.25 , and cool to room temperature at a rate equivalent to an air cool or faster.

3.5.3 Tensile specimens used for master heat qualification may be heat treated separately from castings.

3.6 Properties:

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

3.6.1 Room Temperature Tensile Properties: Shall be as shown in Table 2, determined in accordance with ASTM A 370, after heat treatment in accordance with 3.5.1 and 3.5.2. Properties other than those listed may be defined as specified in AMS 2360.

TABLE 2 - Minimum Tensile Properties

Property	Value
Tensile Strength	270 ksi (1862 MPa)
Yield Strength at 0.2% Offset	250 ksi (1724 MPa)
Elongation in 4D	3%
Reduction in Area	10%

3.6.2 Hardness: Shall be as follows, determined in accordance with ASTM A 370.

3.6.2.1 Production castings in the homogenized, overaged, and solution heat treated condition of 3.5.1 shall have hardness not higher than 35 HRC, or equivalent (See 8.3).

3.6.2.2 Hardness as a Response to Heat Treatment: Castings and specimens in the homogenized, overaged, solution heat treated, and maraged condition of 3.5.1 and 3.5.2 shall have hardness not lower than 50 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 process 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 ASTM E 1417 or other process method specified by purchaser.

3.7.3.2 Magnetic particle inspection in accordance with ASTM E 1444 or other method specified by purchaser.

3.7.4 Acceptance standards for radiographic, magnetic particle, fluorescent penetrant, visual, and other inspection methods shall be as 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.

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), hardness (3.6.2.1 and 3.6.2.2), 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 (3.7.3) is a periodic test and shall be performed as in 3.7.3.

4.2.3 Preproduction Tests: Tests for all technical requirements are preproduction tests and shall be performed on specimens or sample castings (4.3), 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, unless 3.4.2.1 applies, in which case frequency of testing 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 tests shall be conducted to determine conformance with Table 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 homogenized, overaged, solution heat treated, and maraged condition of 3.5.2, one or more specimens from each master heat shall be tested for conformance with 3.6.1.
- 4.3.3.2 For integrally-cast specimens in the homogenized, overaged, solution heat treated, and maraged condition of 3.5.2, at least two specimens from each lot shall be tested for conformance with 3.6.
- 4.3.3.3 For specimens machined from casting, one or more castings shall be randomly selected from each lot and tested in the homogenized, overaged, solution heat treated, and maraged condition of 3.5.2 at locations shown on the engineering drawing for conformance with 3.6.
- 4.3.3.3.1 When size and location of specimens are not shown, at least two 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 castings 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 specimen requirements 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 with 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.
- 4.3.5 Unless otherwise specified by purchaser, one casting per lot shall be tested for hardness to determine conformance to 3.6.2.1.
- 4.3.5.1 In the event of failure, the entire lot shall be 100% inspected or reheat treated in accordance with 4.6.2.
- 4.3.6 After heat treatment to 3.5.1 and 3.5.2, one casting, or a specimen representing the thickest section of the casting, from each master heat shall be tested for conformance with 3.6.2.2.
- 4.3.6.1 In the event of failure, castings and 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 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. Vendor'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 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 backup material weight, thickness, or number of dips

Type of furnace, vacuum, and charge for melting

Mold preheat and metal pouring temperatures

Fluxing or deoxidation procedures

Replenishment and alloy addition procedure, if applicable

Time that molten metal is in the furnace

Solidification and cooling procedures

Cleaning operations (mechanical and chemical)

Heat treatment

Welding procedure, if applicable

Straightening

Final inspection methods

Location of specimens machined from casting, if applicable.

4.4.2.2.1 Any of the control factors of 4.4.2.2 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.