AEROSPACE MATERIAL SPECIFICATION

AMS5337™	REV. E

Issued 1971-05
Revised 2017-09
Reaffirmed 2022-06

Superseding AMS5337D

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)

RATIONALE

AMS5337E results from a Five-Year Review and update of this specification that adds strain rate control for tensile testing (3.6.1.1), modifies radiographic acceptance criteria (3.7.4.1), reporting (4.5), and notification of exceptions to the specification requirements (4.5.5).

AMS5337E has been reaffirmed to comply with the SAE Five-Year Review policy.

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 cancelled 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 +1 724-776-4970 (outside USA), www.sae.org.

AMS2175 Castings, Classification and Inspection of

AMS2248 Chemical Check Analysis Limits Corrosion and Heat-Resistant Steels and Alloys, Maraging and Other Highly-Alloyed Steels, and Iron Alloys

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**

For more information on this standard, visit
https://www.sae.org/standards/content/AMS5337E/

AMS2360 Room Temperature Tensile Properties of Castings

AMS2694 In-Process Welding of Castings

AMS2750 Pyrometry

AMS2804 Identification Castings

ARP1917 Clarification of Terms Used in Aerospace Metals Specifications

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 A370 Mechanical Testing of Steel Products

ASTM E140 Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness

ASTM E353 Chemical Analysis of Stainless, Heat Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys

ASTM E1417 Liquid Penetrant Testing

ASTM E1444 Magnetic Particle Testing

ASTM E1742 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 E353, by spectrochemical methods, or by other analytical methods acceptable to purchaser (see 8.3.1 and 8.3.2).

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 Producer 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 8.3.3).

3.1.2 Check Analysis

Composition variations shall meet the applicable requirements of AMS2248.

3.2 Melting Practice

Castings and specimens shall be poured at casting producer's facility either from a melt (see 8.3.4) of a master heat, or directly from a master heat (see 3.4.2 and 8.3.5).

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 8.3.6), 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 8.3.6).

3.2.4 If melts are modified by replenishment (see 8.3.7), producer shall have a written procedure acceptable to purchaser that 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 separately-cast, integrally-cast (see 8.3.8), or machined from a casting, and shall conform to 3.2.

3.4.1 If specimens are separately-cast, producer 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 replenishments are made at remelt as in 3.2.4, the frequency of sampling and testing used by the producer 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-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 A370 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/or specimens machined-from-casting are specified, specimen size and location shall be as agreed upon by purchaser and producer (see 8.3.9 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 AMS2750.

3.5.1 Production Castings and Specimens

3.5.1.1 Homogenization

Heat to 2100 °F ± 25 °F (1149 °C ± 14 °C), hold at heat for 4 hours ± 0.25 hour, and cool to room temperature at a rate equivalent to air cool or faster.

3.5.1.2 Overaging

Heat to 1100 °F ± 25 °F (593 °C ± 14 °C), hold at heat for 1 to 4 hours, and cool to room temperature at a rate equivalent to air cool or faster. Alternately, heat to the solution heat treating temperature directly after overaging without cooling between steps.

3.5.1.3 Solution

Heat to 1500 °F ± 25 °F (816 °C ± 14 °C), hold at heat for 1 hour per inch (25 mm) of section thickness but in no case less than 1 hour, and cool to room temperature at a rate equivalent to 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 °F ± 15 °F (482 °C ± 8 °C), hold at heat for 3 hours ± 0.25 hour, and cool to room temperature at a rate equivalent to 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-casting. Properties of integrally-cast specimens or specimens machined-from-casting shall be as specified by purchaser (see 8.5).

3.6.1 Room Temperature Tensile Properties of Separately-Cast Specimens

Shall be as shown in Table 2, determined in accordance with ASTM A370, after heat treatment in accordance with 3.5.1 and 3.5.2. Properties other than those listed may be defined as specified in AMS2360.

Table 2 - Minimum room temperature tensile properties of separately-cast specimens

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%

3.6.1.1 The strain rate shall be set at 0.005 inch/inch/minute (0.005 mm/mm/minute) and maintained within a tolerance of ±0.002 inch/inch/minute (0.002 mm/mm/minute) through 0.2% offset yield strain. After the yield strain, the speed of the testing machine shall be set between 0.05 and 0.5 inch/inch (mm/mm) of the length of the reduced section (or distance between the grips for specimens not having a reduced section) per minute. Alternatively, an extensometer and strain rate indicator may be used to set the strain rate between 0.05 and 0.5 inch/inch/minute (mm/mm/minute).

3.6.2 Hardness

Shall be as follows, determined in accordance with ASTM A370:

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 8.2).

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 8.2).

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 that 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 E1742 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 E1417 or other process method specified by purchaser.

3.7.3.2 Magnetic particle inspection in accordance with ASTM E1444 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 producer (see 8.3.9). 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 shall apply and radiographic indications of gas holes, sand spots, and inclusions shall be cause for rejection when closer to the edge than twice their maximum dimension.

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 producer of castings shall supply all samples for producer'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 at a frequency selected by producer, unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests

All technical requirements are preproduction tests and shall be performed on specimens or 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 producer 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 tests shall be conducted to determine conformance with Table 2. Sampling and test frequency are dependent upon the type and origin of specimen specified by purchaser (see 3.4.4 and 3.6) or selected by producer (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 specimen from each master heat shall be tested for conformance to 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, two specimens from each lot (see 8.3.10) shall be randomly selected and tested for conformance to 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 homogenized, overaged, solution heat treated, and maraged condition of 3.5.2 at locations shown on the engineering drawing for conformance to the 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 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 producer.

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 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, producer 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 as agreed upon by purchaser and producer (see 8.5).

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 is waived by purchaser.

4.4.2 For each casting part number, producer 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, producer shall submit a statement of the proposed changes for purchaser reapproval. When requested, producer 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 producer's risk.

4.4.2.2 Control factors for producing castings and separately-cast test 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 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 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 for which parameters are considered proprietary by producer 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 producer, purchaser shall be entitled to review proprietary control factor details and coding at producer's facility.

4.5 Reports

The producer of castings shall furnish with each shipment a certification document declaring the producer identity, country where the metal was melted (e.g., final melt in the case of metal processed by multiple melting operations) and that castings have been processed, tested, and inspected as specified and that the results of the inspections and tests conform to requirements.

4.5.1 Unless otherwise specified, producer shall furnish test report(s) showing the results of tests and inspections conducted in accordance with 4.2 and 4.3.

4.5.1.1 Chemical analysis determinations, property test data, and the results of any retests conducted shall be expressed numerically to reflect actual quantitative test values.

4.5.1.2 Hardness test readings may be expressed as single values or as a range of values exhibited by results obtained from the sample size.

4.5.1.3 Inspection and preproduction results shall be reported at the frequency specified by, and in a format acceptable to purchaser.

4.5.1.4 Objective evidence of purchaser's review and acceptance of nonconforming material shall be provided with the certification document at each shipment (see 7).

4.5.2 The statement of conformity and test report(s) shall be traceable to the purchase order number, master heat identification, heat treat/lot number, AMS5337E, part number, quantity, and when required (see 5.1.2) the list of individual serial numbers or serial number range.

4.5.2.1 If 4.3.3.4.1 applies, the mechanical property test report shall denote the source of the specimens that were tested.

4.5.3 Test reports for acceptance testing of 4.2 shall be as follows:

4.5.3.1 For each master heat

Composition (see 4.3.1)
Tensile properties (see 4.3.3.1)
Hardness of production castings (3.6.2.1)
Response to heat treatment after hardening (3.6.2.2)

4.5.3.2 For each lot

Inspection results (see 4.3.4)
Tensile properties, when specified (see 4.3.3.2 and 4.3.3.3)

4.5.4 The producer shall retain records of processing and inspection in accordance with purchaser requirements.

4.5.5 When exceptions are taken to the technical requirements listed in Section 3, the report shall contain a statement "This material is certified as AMS5337E(EXC) because of the following exceptions:" and the specific exceptions shall be listed.

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 3.2.4), 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

4.6.1 A test may be declared invalid if failure is due to specimen mispreparation, test equipment malfunction, improper test procedure, or the presence of random process defects such as inclusions or gas holes in a tensile specimen.