SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

AMS 5398F

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Superseding AMS 5398E

Steel, Corrosion-Resistant, Sand and Centrifugal Castings 16Cr - 4.1Ni - 0.22Cb (Nb) - 2.8Cu Solution Heat Treated

(Composition similar to UNS J92200)

RATIONALE

AMS 5398F is a Five Year Review and update of this specification.

1. SCOPE

1.1 Form

This specification covers a corrosion-resistant steel in the form of sand or centrifugal castings.

1.2 Application

These castings have been used typically for parts requiring corrosion resistance and strength up to 600 °F (316 °C), but usage is not limited to such applications. Certain processing procedures and service conditions may cause these products to become subject to stress-corrosion cracking; ARP1110 recommends practices to minimize such conditions.

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

AMS 2175	Classification and Inspection of Castings
AMS 2248	Chemical Check Analysis Limits, Corrosion and Heat-Resistant Steels and Alloys, Maraging and Other Highly-Alloyed Steels, and Iron Alloys
AMS 2633	Ultrasonic Inspection, Centrifugally-Cast, Corrosion-Resistant Steel Tubular Cylinders
AMS 2694	Repair Welding of Aerospace Castings
AMS 2750	Pyrometry
AMS 2804	Identification, Castings
ARP1110	Minimizing Stress Corrosion Cracking in Wrought Forms of Steels and Corrosion-Resistant Steels and Alloys

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

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 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 446	Reference Radiographs for Steel Castings up to 2 inches (51 mm) in Thickness
ASTM E 1417	Standard Practice for Liquid Penetrant Examination
ASTM E 1444	Standard Practice for Magnetic Particle Examination

3. TECHNICAL REQUIREMENTS

3.1 Composition

Castings shall conform to the percentages by weight shown in Table 1, determined in accordance with ASTM E 353, by spectrochemical methods, or by other analytical methods acceptable to purchaser.

TABLE 1 – COMPOSITION

Element	min	max
Carbon	--	0.06
Manganese	--	0.70
Silicon	0.50	1.00
Phosphorus	--	0.04
Sulfur	--	0.03
Chromium	15.50	16.70
Nickel	3.60	4.60
Columbium (Niobium)	0.10	0.35
Copper	2.50	3.20
Aluminum	--	0.05
Tin	--	0.02
Nitrogen	--	0.05

3.1.1 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).

3.1.2 Check Analysis

Composition variations shall meet the applicable requirements of AMS 2248.

3.2 Melting 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 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.

3.2.2 Portions of two or more qualified master heats (see 3.4.1) may be melted together and poured into castings using a procedure authorized by purchaser (see 8.2.6).

3.2.3 If modifications such as alloy additions or replenishments are made at remelt by the vendor, vendor shall have a written procedure acceptable to purchaser which defines the controls, tests, 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 solution heat treated condition.

3.4 Test Specimens

3.4.1 Each master heat shall be qualified by evaluation of chemical and tensile specimens.

3.4.1.1 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.

3.4.1.2 The tensile tests of 3.4.1 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).

3.4.2 Chemical Analysis Specimens

Shall be of any convenient size and shape.

3.4.3 Tensile Coupons

Shall be attached to castings, as prolongation or integral, if practicable, or shall be standard keel blocks conforming to ASTM A 370, unless purchaser permits use of cast-to-size specimens. Coupons shall be cast with each melt of metal for castings, shall be cast in molds made of suitable core sand, shall be poured from the same ladles as the castings, and shall be kept in the mold until black. Metal for the coupons shall be part of the melt which is used for the castings. Tensile specimens in accordance with ASTM A 370 shall be machined from the coupons after heat treatment as in 3.5.

3.4.3.1 If specimens are separately-cast, vendor shall have a written procedure acceptable to purchaser. Control factors of 4.4.2.2 shall apply.

3.5 Heat Treatment

Castings and representative tensile coupons shall be given a homogenization heat treatment prior to solution heat treatment or, when permitted by purchaser, may be given two solution heat treatments. Pyrometry shall be in accordance with AMS 2750. At least one set of tensile coupons shall, during each stage of heat treatment, be put into a batch-type furnace with each load of castings or into a continuous furnace at intervals of not longer than three hours.

3.5.1 Homogenization Heat Treatment

Heat to 2100 °F ± 25 (1149 °C ± 14), hold at heat for not less than 90 minutes, and cool as required to below 70 °F (21 °C).

3.5.2 Solution Heat Treatment

Heat to 1900 °F ± 25 (1038 °C ± 14), hold at heat for 60 minutes per inch (25 mm) of maximum cross-section but not less than 30 minutes, and cool as required to below 70 °F (21 °C).

3.6 Properties

Castings and representative tensile specimens produced in accordance with 3.4.3 shall conform to the following requirements; hardness and tensile testing shall be performed in accordance with ASTM A 370.

3.6.1 As Solution Heat Treated

3.6.1.1 Hardness of Castings

Shall be not higher than 363 HB, or equivalent (see 8.3).

3.6.2 After Precipitation Heat Treatment

Castings and representative tensile specimens shall have the following properties after being heated to 925 °F ± 15 (496 °C ± 8), held at heat for not less than 90 minutes, and cooled in air to room temperature. Properties after precipitation heat treatment at temperatures other than 925 °F ± 15 (496 °C ± 8) shall be as agreed upon by purchaser and vendor.

3.6.2.1 Tensile Properties of separately-cast coupons or integrally-cast coupons shall be as shown in Table 2.

TABLE 2 - MINIMUM TENSILE PROPERTIES

Property	Value
Tensile Strength	180 ksi (1241 MPa)
Yield Strength at 0.2% Offset	150 ksi (1034 MPa)
Elongation in 4D	6%
Reduction of Area	12%

3.6.2.2 Tensile Properties of Castings

When specified on the drawing or when agreed upon by purchaser and vendor, tensile specimens conforming to ASTM A 370 shall be machined from castings selected at random from each lot and heat treated in accordance with 3.6.2. Properties of such specimens shall conform to Table 2 requirements.

3.6.2.3 Hardness

Shall be not lower than 375 HB, or equivalent (see 8.3).

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, 3.7.4, and 3.7.5, or in supplemental standards specified by purchaser be free from porosity, foreign materials, cracks, and other 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.

3.7.1.1 Unless otherwise specified, castings shall have smooth surfaces and shall be sufficiently cleaned such that, after passivation by the purchaser, cast surfaces shall beet the corrosion test requirement of AMS 2700.

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, additional nondestructive testing shall be performed as follows:

3.7.3.1 Fluorescent penetrant inspection in accordance with ASTM E 1417 or another method specified by purchaser.

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

3.7.4 Acceptance standards for radiographic, fluorescent penetrant, magnetic particle, visual, and other inspection methods shall be as agreed upon by purchaser and vendor (see 8.2.8). AMS 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 2175 shall apply for each applicable method of inspection.

3.7.5 Centrifugal castings shall be ultrasonically tested in accordance with AMS 2633 and shall conform to the requirements of ultrasonic discontinuity Grade A for longitudinal and shear modes. Testing and acceptance of parts outside of the dimensional limits defined in AMS 2633 shall be as agreed upon by purchaser and vendor.

3.7.6 Castings shall not be peened, plugged, impregnated, or welded unless authorized by purchaser.

3.7.6.1 When authorized by purchaser, welding in accordance with AMS 2694 or another 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 the specified requirements.

4.2 Classification of Tests

4.2.1 Acceptance Tests

Composition (3.1), hardness after solution heat treatment (3.6.1.1), tensile properties after precipitation heat treatment (3.6.2.1), hardness after precipitation heat treatment (3.6.2.3), and applicable requirements of quality (3.7) are acceptance tests and shall be performed as specified in 4.3.

4.2.1.1 Tensile properties of specimens cut from castings shall be determined only when specified by purchaser or when separately-cast coupons or integrally-cast specimens are not available. Tensile properties of separately-cast coupons or integrally-cast specimens need not be determined when tensile properties of specimens cut from castings are determined.

4.2.2 Periodic Tests

Corrosion resistance (3.7.1.1) and radiographic soundness (3.7.2) 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

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 3.4.1.1 applies, test frequency shall be acceptable to purchaser.

4.3.2 One preproduction casting in accordance with 4.4.1 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 3.6.2. Sampling and test frequency is dependent upon the type and origin of the specimen specified by purchaser (see 3.6.2) or selected by vendor (see 4.3.3.4).

4.3.3.1 For separately-cast specimens (see 3.4.3.1 and 3.6.2.1), one specimen from each master heat (see 8.2.5) in the precipitation heat treated condition (see 3.6.2).

4.3.3.2 For integrally-cast specimens (see 3.4.3 and 3.6.2.1), two specimens from each lot (see 8.2.9) in the precipitation heat treated condition (see 3.6.2).

4.3.3.3 For specimens machined from castings (see 3.6.2.2), one casting from each lot (see 8.2.9) in the precipitation heat treated condition (see 3.6.2), tested at each location shown on the engineering drawing.

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 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 must conform to the requirements of 3.6 for that type of specimen.

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.

4.3.5 Each tensile specimen shall be tested for hardness to determine conformance with 3.6.2.3.

4.3.5.1 Product shall not be rejected on the basis of hardness if the tensile properties are acceptable, determined on specimens taken from the same sample as that with nonconforming hardness, or another sample with similar nonconforming hardness.

4.3.6 When an AMS 2175 Class is specified, castings shall be ultrasonically inspected in accordance with requirements of 4.3.6.1, 4.3.6.2, and Table 3. When a class is not specified, castings shall be considered as Class 1, unless otherwise approved by the cognizant engineering organization.

4.3.6.1 For Class 1 - Each casting.

4.3.6.2 For Class 4 - None required.

TABLE 3 - ULTRASONIC INSPECTION SCHEDULE

Class 2 Lot Size	Class 2 Sample Size	Class 3 Lot Size	Class 3 Sample Size
2 to 5	All	2 to 4	All
6 to 8	5	5 to 6	4
9 to 11	6	7 to 11	5
12 to 15	7	12 to 17	6
16 to 20	8	18 to 27	7
21 to 26	9	28 to 48	8
27 to 36	10	49 and Over	9
37 to 51	11		
52 to 82	12		
83 to 162	13		
163 to 971	14		
972 and Over	15		

4.4 Approval

4.4.1 Sample casting(s) from new or reworked master patterns or molds 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 the process control factors that will 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 will 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 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 3.4.1.1).

Type of melting furnace
Melting furnace atmosphere
Fluxing or deoxidation procedure
Gating and risering practices (for sand castings)
Mold set-up, reheat temperature, and rotational speed (for centrifugal castings)
Metal pouring temperature; variation of ±50 °F (±28 °C) from the established limit is permissible
Solidification and cooling procedures
Heat treatment cycles
Cleaning operations
Methods of inspection

4.4.2.2.1 Any of the control factors for which parameters are considered proprietary by the 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

The vendor of castings shall furnish with each shipment a report showing the results of tests for composition of at least one casting, or of specimens as in 3.4.1 from each melt, for tensile properties of separately-cast coupons or integrally-cast specimens representing each lot, and stating that the castings conform to the other technical requirements of this specification. When properties of specimens cut from castings are specified, the report shall include the results of tests to determine conformance to such requirements. This report shall include the purchase order number, heat and lot numbers, AMS 5398F, precipitation heat treatment temperature if other than 925 °F ± 15 (496 °C ± 8), part number, and quantity.

4.6 Resampling and Retesting

If the results of a valid test fail to meet 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. The results of each additional test, and the average of the results of all tests (original and retests) shall meet the 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.

4.6.2 Unless otherwise authorized by purchaser, castings and specimens may be subjected to not more than one reheat treatment cycle in event of hardness and/or property failure. Upon reheat treatment, castings and specimens shall be submitted for testing in accordance with 4.3.3, 4.3.4, and 4.3.5.