

AEROSPACE
MATERIAL
SPECIFICATION

AMS 5355D
Superseding AMS 5355C

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STEEL CASTINGS, INVESTMENT, CORROSION RESISTANT
16Cr - 4.1Ni - 0.28 (Cb+Ta) - 3.2Cu
Solution Heat Treated

UNS J92200

1. SCOPE:

1.1 Form: This specification covers a corrosion-resistant steel in the form of investment castings.

1.2 Application: Primarily for parts requiring good corrosion resistance and strength up to 600°F (315°C). Certain processing procedures and service conditions may cause these castings to become subject to stress-corrosion cracking; ARP 1110 recommends practices to minimize such conditions on wrought products. Where stress-corrosion is considered to be a factor, precipitation heat treatment should be performed at not lower than 1000°F (540°C).

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications and Aerospace Recommended Practices shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

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2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods
AMS 2360 - Room Temperature Tensile Properties of Castings
AMS 2635 - Radiographic Inspection
AMS 2640 - Magnetic Particle Inspection
AMS 2645 - Fluorescent Penetrant Inspection
AMS 2694 - Repair Welding of Aerospace Castings
AMS 2804 - Identification, Castings

2.1.2 Aerospace Recommended Practices:

ARP 1110 - Minimizing Stress Corrosion Cracking in Heat Treatable
Wrought Low Alloy and Martensitic Corrosion Resistant
Steels

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM A370 - Mechanical Testing of Steel Products
ASTM E192 - Reference Radiographs of Investment Steel Castings for
Aerospace Applications
ASTM E353 - Chemical Analysis of Stainless, Heat-Resisting, Maraging, and
Other Similar Chromium-Nickel-Iron Alloys

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Military Specifications:

MIL-H-6875 - Heat Treatment of Steels, Process for

2.3.2 Military Standards:

MIL-STD-794 - Parts and Equipment, Procedures for Packaging and Packing of

3. TECHNICAL REQUIREMENTS:

3.1 Composition: Shall conform to the following percentages by weight,
 Ø determined by wet chemical methods in accordance with ASTM E353 or by spectrographic or other analytical methods approved by purchaser:

	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 + Tantalum	0.15 -	0.40
Aluminum	--	0.05
Copper	2.80 -	3.50
Tin	--	0.02
Nitrogen	--	0.05

3.2 Condition: Solution heat treated.

3.3 Casting: Castings shall be poured either from remelted metal from a master heat or directly from a master heat. In either case, metal for casting shall be qualified as in 3.4.

3.3.1 A master heat is refined metal of a single furnace charge or is metal blended as in 3.3.2. Gates, sprues, risers, and rejected castings shall be used only in preparation of master heats; they shall not be remelted directly, without refining, for pouring of castings.

3.3.2 Unless prohibited by purchaser, metal from two or more master heats may be blended provided that the composition of each master heat to be blended is within the limits of 3.1 and that the total weight of metal blended does not exceed 15,000 lb (6800 kg). When two or more master heats are blended, the resultant blend shall be considered a master heat.

3.4 Master Heat Qualification: Each master heat shall be qualified by evaluation of chemical analysis and tensile specimens conforming to 3.4.1 and 3.4.2, respectively. A master heat may be considered conditionally qualified if vendor's test results show conformance to all applicable requirements of this specification. However, except when purchaser waives confirmatory testing, final qualification shall be based on purchaser's test results. Conditional qualification of a master heat shall not be construed as a guarantee of acceptance of castings poured therefrom.

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- 3.4.1 Chemical Analysis Specimens: Shall be of any convenient size, shape, and form for vendor's tests. When chemical analysis specimens are required by purchaser, specimens shall be cast to a size, shape, and form agreed upon by purchaser and vendor.
- 3.4.2 Tensile Specimens: Shall be cast from remelted metal from each master heat except when castings are poured directly from a master heat, in which case the specimens shall also be poured directly from the master heat. Specimens shall be of standard proportions in accordance with ASTM A370 with 0.250 in. (6.25 mm) diameter at the reduced parallel gage section. They shall be cast to size or shall be cast oversize and subsequently machined to 0.250 in. (6.25 mm) diameter. Center gating may be used.
- 3.5 Heat Treatment: Castings and representative tensile specimens shall be heat treated as follows; castings and tensile specimens may be given a homogenization heat treatment prior to solution treatment or may be given two solution heat treatments when permitted by purchaser, and shall be so treated when specified by purchaser; furnace surveys and calibration of temperature controllers and recorders shall be in accordance with MIL-H-6875:
- 3.5.1 Homogenization Heat Treatment: Heat to $2100^{\circ}\text{F} \pm 25$ ($1150^{\circ}\text{C} \pm 15$), hold at heat for not less than 90 min., and cool as required to below 70°F (20°C).
- 3.5.2 Solution Heat Treatment: Heat to $1900^{\circ}\text{F} \pm 25$ ($1040^{\circ}\text{C} \pm 15$), hold at heat for 1 hr per inch (25 mm) of section thickness but not less than 30 min., and cool as required to below 70°F (20°C).
- 3.6 Properties: Castings and representative tensile specimens produced in accordance with 3.4.2 shall conform to the following requirements, determined in accordance with ASTM A370:
- 3.6.1 As Solution Heat Treated:
- 3.6.1.1 Hardness: Shall be not higher than 36 HRC or equivalent.
- 3.6.2 After Precipitation Heat Treatment: Castings and representative tensile specimens, precipitation heat treated to a particular condition in accordance with the corresponding temperatures and times shown in Table I and cooled in air, shall have the following properties for that particular condition. Tensile and hardness tests shall be made in only one precipitation heat treated condition. Unless otherwise specified, the precipitation heat treated testing condition shall be H925.

TABLE I

Condition	Temperature	Time
H900	$900^{\circ}\text{F} \pm 10$ ($480^{\circ}\text{C} \pm 5$)	90 min. ± 15
H925	$925^{\circ}\text{F} \pm 10$ ($495^{\circ}\text{C} \pm 5$)	90 min. ± 15
H1000	$1000^{\circ}\text{F} \pm 10$ ($540^{\circ}\text{C} \pm 5$)	90 min. ± 15
H1100	$1100^{\circ}\text{F} \pm 10$ ($595^{\circ}\text{C} \pm 5$)	90 min. ± 15

3.6.2.1 Separately-Cast Specimens:

3.6.2.1.1 Tensile Properties: Shall be as shown in Table II.

TABLE II

Condition	Tensile Strength psi, min	Yield Strength at 0.2% Offset psi, min	Elongation in 4D %, min	Reduction of Area %, min
H900	180,000	160,000	6	15
H925	180,000	150,000	6	15
H1000	150,000	130,000	8	20
H1100	130,000	120,000	8	15

TABLE II (SI)

Condition	Tensile Strength MPa, min	Yield Strength at 0.2% Offset MPa, min	Elongation in 4D %, min	Reduction of Area %, min
H900	1240	1105	6	15
H925	1240	1035	6	15
H1000	1035	895	8	20
H1100	895	825	8	15

3.6.2.1.2 Hardness: Should be not lower than shown in Table III for the corresponding precipitation heat treated condition, but the specimens shall not be rejected on the basis of hardness if the tensile property requirements are met for the condition tested.

TABLE III

Condition	Hardness HRC, min
H900	40
H925	40
H1000	34
H1100	32

3.6.2.2 Castings:

3.6.2.2.1 Tensile Properties: When specified on the drawing or when agreed upon by purchaser and vendor, tensile specimens conforming to ASTM A370 shall be machined from locations indicated on the drawing from a casting or castings selected at random from each lot. Property requirements for such specimens shall be as specified on the drawing or as agreed upon by purchaser and vendor and may be defined as specified in AMS 2360.

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3.6.2.2.2 Hardness: Shall be as shown in Table III.

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.

3.7.1.1 Castings shall have smooth surfaces and shall be well cleaned. Metallic shot or grit shall not be used for final cleaning.

3.7.2 Castings shall be produced under radiographic control. This control shall consist of radiographic examination of castings in accordance with AMS 2635 until proper foundry technique, which will produce castings free from harmful internal imperfections, is established for each part number and of production castings as necessary to ensure maintenance of satisfactory quality.

3.7.3 When specified, castings shall be subjected to magnetic particle inspection in accordance with AMS 2640 or to fluorescent penetrant inspection in accordance with AMS 2645 or to both.

3.7.4 Radiographic, magnetic particle, fluorescent penetrant, and other quality standards shall be as agreed upon by purchaser and vendor. ASTM E192 may be used to define radiographic acceptance standards.

3.7.5 Castings shall not be repaired by peening, plugging, welding, or other methods without written permission from purchaser.

3.7.5.1 When permitted in writing by purchaser, defects in castings may be removed and the castings repaired by welding in accordance with AMS 2694.

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 performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.5. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the castings conform to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Tests to determine conformance to the following requirements are classified as acceptance tests and shall be performed on each heat or lot as applicable:

4.2.1.1 Composition (3.1) of each master heat.

4.2.1.2 Hardness (3.6.1.1) of each lot of castings as solution heat treated.

- 4.2.1.3 Tensile properties (3.6.2.1.1) and hardness (3.6.2.1.2) of separately-cast specimens after precipitation heat treatment to the H925 condition except as specified in 4.2.1.3.1.
- 4.2.1.3.1 Tensile properties of specimens cut from castings shall be determined only when specified by purchaser or when separately-cast specimens are not available. Tensile properties of separately-cast specimens need not be determined when tensile properties of specimens cut from castings are determined.
- 4.2.1.4 Hardness (3.6.2.2.2) of each lot of castings after precipitation heat treatment.
- 4.2.1.5 Quality (3.7) of each lot of castings.
- 4.2.2 Periodic Tests: Tests to determine conformance to requirements for
Ø tensile properties (3.6.2.1.1) and hardness (3.6.2.1.2) after precipitation heat treatment at temperatures other than 925°F (495°C) are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.
- 4.2.3 Preproduction Tests: Tests to determine conformance to all technical
Ø requirements of this specification are classified as preproduction tests and shall be performed prior to or on the first-article shipment of a casting to a purchaser, when a change in material, processing, or both requires reapproval as in 4.4.2, and when purchaser deems confirmatory testing to be required.
- 4.2.3.1 For direct U.S. Military procurement, substantiating test data and, when requested, preproduction test material shall be submitted to the cognizant agency as directed by the procuring activity, the contracting officer, or the request for procurement.
- 4.3 Sampling: Shall be in accordance with the following; a lot shall be all
Ø castings of the same part number poured from a single master heat, solution heat treated as a batch, and presented for vendor's inspection at one time.
- 4.3.1 At least one chemical analysis specimen in accordance with 3.4.1 from each
Ø master heat or a casting from each lot.
- 4.3.2 Three tensile specimens in accordance with 3.4.2 from each lot.
- 4.3.3 Two preproduction castings in accordance with 4.4.1 of each part number.

4.3.4 One or more castings from each lot when properties of specimens machined from castings are required. Size, location, and number of specimens machined from castings shall be as specified on the drawing or as agreed upon by purchaser and vendor. When size, location, and number of specimens are not specified, not less than two tensile specimens, one from the thickest section and one from the thinnest section, shall be cut from a casting or castings from each lot.

4.4 Approval:

4.4.1 Sample castings from new or reworked master patterns and the casting procedure shall be approved by purchaser before castings for production use are supplied, unless such approval be waived by purchaser.

4.4.2 Vendor shall establish, separately for tensile specimens used for master heat qualification and for production of sample castings of each part number, parameters for the process control factors which will produce tensile specimens meeting master heat qualification requirements and acceptable castings; these shall constitute the approved casting procedures and shall be used for producing subsequent master heat qualification specimens and production castings. If necessary to make any change in parameters for the process control factors, vendor shall submit for reapproval a statement of the proposed changes in processing and, when requested, tensile specimens, sample castings, or both. Production castings incorporating the revised operations shall not be shipped prior to receipt of reapproval.

4.4.2.1 Control factors for producing tensile specimens and castings include, but are not limited to, the following:

- Type of furnace and its capacity
- Type and size of furnace charge
- Time molten metal is in furnace
- Furnace atmosphere
- Fluxing or deoxidation procedure
- Number of ladles used in pour
- Mold refractory formulation
- Mold back-up material
- Gating practices
- Mold preheat and metal pouring temperatures; variations of $\pm 25^{\circ}\text{F}$ ($\pm 15^{\circ}\text{C}$) from established limits are permissible
- Solidification and cooling procedures
- Homogenization and solution heat treatment cycles
- Cleaning operations
- Methods of inspection

4.4.2.1.1 Any of the above process 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.