

MIL-S-81591

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MILITARY SPECIFICATION**STEEL, INVESTMENT CASTINGS,
CARBON AND CORROSION - RESISTING**

This specification is mandatory for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 **Scope** - This specification prescribes the requirements for carbon steel castings and corrosion-resistant steel castings made by the investment casting process.

1.2 **Classification** - Castings shall be of the compositions and conditions shown in Tables I and Ia, as specified (see 6.2).

TABLE I**COMPOSITIONS AND CONDITIONS**

Composition number ^{1/}	Conditions
IC-1020	As cast or annealed
IC-1030	As cast, annealed or quenched and tempered
IC-1040	As cast, annealed or quenched and tempered
IC-1050	As cast, annealed or quenched and tempered

^{1/} Not necessarily identical to similar wrought designations.

TABLE Ia**COMPOSITIONS AND CONDITIONS**

Composition number ^{1/}	Conditions
IC-302	As cast or solution heat-treated
IC-303	As cast or solution heat-treated

FSC MECA

TABLE Ia (Continued)

COMPOSITIONS AND CONDITIONS

Composition number <u>1</u> /	Conditions
IC-304	As cast or solution heat-treated
IC-304 L	Solution heat-treated
IC-310	As cast or solution heat-treated
IC-316	As cast or solution heat-treated
IC-321	As cast or solution heat-treated
IC-347	As cast or solution heat-treated
IC-322a	Solution heat-treated or solution heat-treated and aged
IC-410	Annealed or quenched and tempered
IC-420	Annealed or quenched and tempered
IC-431	Annealed or quenched and tempered
IC-440 A	Annealed or quenched and tempered
IC-440 C	Annealed or quenched and tempered

1/ Not necessarily identical to equivalent wrought designations.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

SPECIFICATIONS

Federal

MMM-A-260	Adhesive, Water-Resistant (for Sealing Waterproofed Paper)
PPP-B-585	Boxes; Wood, Wirebound
PPP-B-601	Boxes; Wood, Cleated-Plywood
PPP-B-621	Boxes; Wood, Nailed and Lock-Corner
PPP-B-636	Box, Fiberboard
PPP-B-1055	Barrier Material, Waterproofed, Flexible

Federal (Continued)

PPP-T-76 Tape, Pressure-Sensitive Adhesive Paper, Water Resistant (for Carton Sealing)

Military

MIL-P-116 Preservation, Methods of

MIL-H-6875 Heat Treatment of Steels (Aircraft Practices, Process for)

MIL-C-7769 Cushioning Material, Uncompressed Bound Fiber for Packing

STANDARDS

Federal

Fed. Test Method Metals, Test Methods
Std. No. 151

Military

MIL-STD-105 Sampling Procedures and Tables for Inspection by Attributes

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-271 Nondestructive Testing Requirements for Metals

(Copies of specifications and standards required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications - The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the issues in effect on date of invitation for bids or request for proposal shall apply.

American Society for Testing and Materials

ASTM Designation: E 192 Standard Reference Radiographs of Investment Steel Castings For Aerospace Applications

(Application for copies of ASTM standards should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.)

United States of America Standards Institute

USAS B 46.1 Surface Texture

(Application for copies should be addressed to the United States of America Standards Institute, 10 East 40th Street, New York, New York 10016.)

Official Classification Committee

Uniform Freight Classification Rules

(Application for copies should be addressed to Official Classification Committee, 202 Chicago Union Station, 516 W. Jackson Blvd., Chicago, Illinois 60606.)

3. REQUIREMENTS

3.1 Process - Castings shall be made by any investment process producing castings complying with this specification.

3.2 Chemical composition - The chemical analyses of castings shall comply with Tables II and IIa, for the composition as specified (see 6.2).

TABLE II

CHEMICAL REQUIREMENTS ^{1/}

Composition number	Carbon	Manganese	Silicon	Phosphorus (maximum)	Sulfur (maximum)
IC-1020	0.15-0.25	0.30-0.60	0.20-1.00	0.04	0.04
IC-1030	0.25-0.35	0.70-1.00	0.20-1.00	0.04	0.04
IC-1040	0.35-0.45	0.70-1.00	0.20-1.00	0.04	0.04
IC-1050	0.45-0.55	0.70-1.00	0.20-1.00	0.04	0.04

^{1/} Elements expressed in weight percent.

TABLE IIa
CHEMICAL REQUIREMENTS 1/

Composition number	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Copper	Other
IC-302	0.15	2.00	0.040	0.03	1.00	17.0-19.0	8.0-10.0	—	—	—
IC-303	0.12	2.00	0.17	0.15-0.35	1.00	17.0-20.0	8.0-10.0	0.60	0.50	—
IC-304	0.08	2.00	0.040	0.03	1.00	18.0-20.0	8.0-12.0	—	—	—
IC-304L	0.05	1.0-2.0	0.040	0.03	1.00	18.0-21.0	8.0-11.0	0.50	0.50	—
IC-310	0.25	2.00	0.040	0.03	1.50	24.0-26.0	19.0-22.0	—	—	—
IC-316	0.08	2.00	0.040	0.03	1.00	16.0-18.0	10.0-14.0	2.0-3.0	—	—
IC-321	0.08	2.00	0.040	0.03	1.00	17.0-19.0	9.0-12.0	—	—	Titanium: 5xc min.
IC-347	0.08	2.00	0.040	0.03	1.00	17.0-19.5	9.0-13.0	—	—	Cb + Ta 10xc-1.5
IC-17-4	0.08	1.00	0.040	0.04	1.00	15.5-17.5	3.0-5.0	—	3.0-5.0	Cb + Ta 0.45
IC-410	0.05-0.15	1.00	0.040	0.03	1.00	11.5-13.5	0.50	0.50	0.50	—
IC-420	0.15 min.	1.00	0.040	0.03	1.00	12.0-14.0	—	—	—	—
IC-4312/	0.08-0.15	1.00	0.040	0.04	1.00	15.0-17.0	1.50-2.20	—	—	Nitrogen 0.03-0.12
IC-440A	0.60-0.75	1.00	0.040	0.03	1.00	16.0-18.0	—	0.75	—	—
IC-440C	0.95-1.20	1.00	0.040	0.03	1.00	16.0-18.0	0.75	0.35-0.75	—	—

1/ Elements expressed in maximum weight percentage unless otherwise indicated.

2/ Carbon + nitrogen 0.22 max.

3.2.1 The contractor shall furnish an analysis of each master heat showing the percentages of the elements designated. A master heat shall be defined as previously refined metal of a single furnace charge or a blend thereof.

3.3 Condition - Castings shall be furnished in the condition specified in the contract or order (see 6.2). The type of heat treatment, when required, shall be at the option of the contractor unless otherwise specified by the procuring activity. For compositions IC-302, IC-304, IC-310, IC-316, and IC-347, solution heat-treated condition shall consist of heating in the range 1850 to 2150° F and quenching in water. Other steels in Table I and Table Ia shall be heat treated in accordance with MIL-H-6875.

3.4 Mechanical properties - Mechanical properties shall be as shown in Tables III and IIIa. Mechanical properties of castings required for conditions other than shown in Tables III and IIIa shall be as specified in the contract or order (see 6.2).

TABLE III

MECHANICAL PROPERTIES

Composition number	Condition	Hardness of castings (Rockwell or equivalent)	Minimum properties of test bars		
			Tensile Strength psi	Yield Strength (0.2% offset) psi	Elongation (4 x D) percent
IC-1020	As cast Annealed	B80 max	—	—	—
		B75 max	60000	40000	35.0
IC-1030	As cast Annealed Quenched and tempered	B85 max	—	—	—
		B75 max	65000	45000	25.0
		C20 min	85000	60000	10.0
IC-1040	As cast Annealed Quenched and tempered	B95 max	—	—	—
		B85 max	75000	48000	25.0
		C25 min	100000	90000	10.0
IC-1050	As cast Annealed Quenched and tempered	C20 max	—	—	—
		B95 max	90000	50000	20.0
		C30 min	125000	100000	5.0

TABLE III
MECHANICAL PROPERTIES

Composition number	Condition	Hardness of castings (Rockwell or equivalent)	Minimum properties of test bar ¹			
			Yield ² Strength psi	Tensile Strength psi	Reduction of Area percent	Elong. in 4 x D percent
IC-17-4	Solution heat-treated	C36 max.	—	—	—	—
	Solution heat-treated and aged	C40 min.	150,000	180,000	15.0	6.0
IC-410	Annealed	C25 max.	—	—	—	—
	Quenched and tempered	B94-B100	75,000	95,000	20.0	8.0
IC-420	Annealed	C30 max.	—	—	—	—
	Quenched and tempered	C44 min.	150,000	180,000	—	2.0
IC-431	Annealed	C30 max.	—	—	—	—
	Quenched and tempered	C38-C49	130,000	170,000	—	2.0
IC-440A	Annealed	C28 max.	—	—	—	—
	Quenched and tempered	C50 min.	—	—	—	—
IC-440C	Annealed	C30 max.	—	—	—	—
	Quenched and tempered	C58 min.	—	—	—	—

¹ For critical applications, relation of test bar values to properties of castings should be established by actual test.

² Yield strength at 0.2 percent offset.

3.4.1 Compositions 302, 303, 304, 304L, 310, 316, 321, 347 - The hardness of castings shall be Rockwell B95 maximum or equivalent in either the as cast or solution heat-treated condition.

3.5 Soundness -

3.5.1 Surface - Castings shall be free from cold shuts, fins, laps, or other defects detrimental to fabrication or performance of parts.

3.5.2 Internal - Unless otherwise specified, castings shall conform to ASTM Standard E192.

3.6 Decarburization - Decarburization (partial plus total) shall not exceed a depth of .003 inch from the as-cast surface on as-cast condition castings. (Exception: IC-1020.)

3.6.1 Carburization - There shall be no evidence of any carburization on the as-cast surfaces of castings prior to heat treatment. (Exceptions: IC-1020, IC-440A and IC-440C.)

3.7 Repairing of defects - Castings shall not be welded, plugged, or repaired in any manner without written permission from the procuring activity. Permission to repair defective castings, when granted by the procuring activity, shall not relieve the contractor of his responsibility for meeting all requirements of the drawings or the specification.

3.8 Dimensions and surface roughness - Castings shall conform to the drawings specified in the contract or order (see 6.2) with respect to dimensions and tolerances. Unless otherwise specified, roughness of surfaces shall not exceed 125 rha (roughness height average . . . microinches). Surface roughness shall be interpreted in accordance with the provisions of USAS B 46.1.

3.9 Identification marking - Castings shall be identified with the melt or inspection lot number, and in addition, when specified on the drawing, shall be marked with the drawing or part number by any method which has no deleterious effect on serviceability.

3.10 Workmanship - Castings shall be uniform in quality and condition, free from foreign materials and other injurious defects. Castings shall be well cleaned. Unless otherwise specified, metallic shot or grit shall not be used for final cleaning.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection - The supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise

specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Sampling methods -

4.2.1 Lot description -

4.2.1.1 Lot for chemical analysis - For purposes of chemical analysis, a lot shall consist of all castings as poured from the same master heat submitted for inspection at one time.

4.2.1.2 Lot for soundness, hardness, tensile, surface roughness, workmanship and dimensional inspections - A lot shall consist of all castings of the same drawing, from the same master heat and in the same condition submitted for inspection at one time.

4.2.1.3 Castings shall be properly separated by lots when presented for acceptance.

4.2.2 Sampling for quality conformance inspection -

4.2.2.1 Sampling for visual and dimensional examination - Sampling of castings for dimensional, identification marking, and workmanship inspection shall be in accordance with the provisions of MIL-STD-105, Inspection Level II, and Acceptable Quality Level (AQL) 1.5 percent defective (see 6.2).

4.2.2.2 Sampling for soundness - Sampling of castings for soundness inspection shall be in accordance with the provisions of MIL-STD-105, Inspection Level II, and Acceptable Quality Level (AQL) 0.65 percent defective.

4.2.2.3 Sampling for packaging, packing, and marking - A random sample of shipping containers for the inspection of 4.3.3 shall be selected in accordance with the provisions of MIL-STD-105, Inspection Level II, Acceptable Quality Level (AQL) 4.0 percent defective.

4.2.2.4 Sampling for tests -

4.2.2.4.1 For chemical analysis - Three samples shall be taken from each master heat in accordance with either Method 111 or Method 112 of Fed. Test Method Std. No. 151 for chemical analysis.

4.2.2.4.2 For tension tests - Three test bars shall be poured to represent each lot of castings requiring a tension test. Test bars shall be separately cast from the same master heat and under the same conditions as the lot of castings to be represented. They shall be made in molds of the same material and cooled at approximately the same rate as the molds for the lot of castings to be represented. Each test bar shall have a gage section diameter of 0.250 ±0.010 inch and a gage length of not less than 1 inch. The radius of the fillet shall not be less than 1/4 inch. Each test bar shall be marked for future identification. Test bars shall be heat treated in the same furnace load with the castings they represent.

4.2.2.4.3 For surface roughness and hardness - Sampling of castings for surface roughness and hardness shall be in accordance with the provisions of MIL-STD-105, Inspection Level II, and Acceptable Quality Level (AQL) 1.5 percent defective.

4.3 Quality conformance inspection -

4.3.1 Visual and dimensional examination - Sample castings selected in accordance with 4.2.2.1 shall be inspected to determine conformance to the dimensional requirements of 3.8, the identification marking of 3.9, and the workmanship requirements of 3.10.

4.3.2 Soundness inspection - Sample castings selected in accordance with 4.2.2.2 shall be subjected to penetrant inspection or magnetic particle inspection and to radiographic inspection in accordance with MIL-STD-271, to determine conformance to the soundness requirements of 3.5.

4.3.3 Preservation, packaging, packing and marking - The inspector shall ascertain that preservation, packaging and packing of castings and marking of containers selected in accordance with 4.2.2.3 is in accordance with the requirements of this specification and the contract or order.

4.3.4 Place of inspections - Unless otherwise specified (see 4.3.5.1 and 6.2), inspection and tests shall be conducted at the place of manufacture.

4.3.5 Tests - The methods of test for chemical composition, tension tests, and hardness tests shall be in accordance with Fed. Test Method Std. No. 151.

4.3.5.1 Chemical composition - Unless otherwise specified, the metal sample selected in accordance with 4.2.2.4.1 shall be analyzed in accordance with either Method 111 or Method 112 of Fed. Test Method Std. No. 151, to determine conformance to the chemical requirements of 3.2. If any sample fails to conform to these chemical requirements, the lot represented by the sample shall be rejected.

4.3.5.2 Tension tests - Test bars prepared in accordance with 4.2.2.4.2 shall be pulled in tension in accordance with Method 211 of Fed. Test Method Std. No. 151, to determine conformance to the mechanical properties of 3.4. If a test bar fails to conform to these mechanical properties, the lot represented by the test bar shall be subject to rejection. Retests will be permitted in accordance with the provisions of Fed. Test Method Std. No. 151.

4.3.5.2.1 Method of tension test - Separately cast bars shall be tested without machining except as may be necessary to remove gates and to adapt the ends to the grips of the testing machine. Strength shall be computed from the actual measured diameter of the test bar before testing.

4.3.5.3 Surface roughness - Sample castings selected in accordance with 4.2.2.4.3 shall be inspected to determine conformance to 3.8.

4.3.5.4 Hardness test - Each casting selected in accordance with 4.2.2.4.3 shall be subjected to a hardness test in accordance with Method 243 of Fed. Test Method Std. No. 151 to determine conformance to the requirements of 3.4. Any casting that fails to meet the hardness requirements shall be rejected and if the number of castings rejected exceeds the acceptance number for the sample, the lot represented by the sample shall be rejected.

4.3.5.5 Decarburization - Depth of the zone of decarburization below a surface shall be determined by examination of a metallographic specimen or specimens representing the entire cross-section of the item. This test shall determine conformance to the decarburization requirements of 3.6.

5. PREPARATION FOR DELIVERY

5.1 General - Castings shall be prepared for shipment in accordance with Level A, B, or C, as specified in the contract or order (see 6.2).

5.2 Preservation and packaging -

5.2.1 Level A -

5.2.1.1 Cleaning - Castings shall be cleaned in accordance with Method C-1 of MIL-P-116.

5.2.1.2 Drying - Castings shall be dried in accordance with one or more of the applicable procedures of MIL-P-116.

5.2.1.3 Preservation application - Immediately after cleaning and drying, castings shall be coated with Type P-2 preservative in accordance with MIL-P-116.

5.2.1.4 Unit packaging - Castings shall be unit packaged in accordance with Method I of MIL-P-116. Unit containers shall consist of PPP-B-636, Grade W5c fiberboard boxes and shall be lined with Type I, Grade A, Class 2 barrier material of PPP-B-1055. Unit package quantities shall be as specified in the contract or order.

5.2.1.5 Intermediate packaging - When specified in the contract or order (see 6.2), unit packages shall be further packaged in folding boxes, set-up boxes, metal-stayed boxes, or fiber boxes conforming to PPP-B-636. All seams and joints, including manufacturer's joints, shall be covered with water-resistant tape conforming to PPP-T-76.

5.2.1.6 Cushioning - When specified in the contract or order (see 6.2), castings shall be protected on all sides with sufficient thickness of cushioning material conforming to MIL-C-7769.

5.2.2 Level B - Not applicable.

5.2.3 Level C - Castings shall be packaged to the degree required to afford adequate protection from the supply source to the first receiving activity which includes shipment, handling and limited tenure of storage.

5.3 Packing -

5.3.1 Packages per pack - The number of packages per pack shall be as specified in the contract or order (see 6.2).

5.3.2 Level A - Castings that have been packaged as described in 5.2.1 shall be packed in cleated plywood boxes, nailed wood boxes, or wire bound boxes conforming to PPP-B-601 (Overseas type), PPP-B-621 (Class 2) and PPP-B-585 (Class 3), respectively. Shipping containers shall be lined with a sealed waterproof bag, or its equivalent, made of material conforming to PPP-B-1055, for case liners. The seams and closures shall be sealed with water-resistant material conforming to the requirements of MMM-A-260. The gross shipping weight shall not exceed 200 pounds.

5.3.3 Level B - Castings that have been packaged as described in 5.2.1 shall be packed in wirebound wood, wood cleated plywood, or nailed wood boxes, conforming to PPP-B-585 (Class 1), PPP-B-601 (domestic type), and PPP-B-621 (Class 1), respectively. The gross shipping weight shall not exceed 200 pounds.

5.3.4 Level C - Castings that have been packaged in accordance with 5.2.3 shall be packed or otherwise prepared for shipment to insure carrier acceptance and to insure safe delivery to destination at the lowest applicable rate. Shipping containers shall conform to the Uniform Freight Classification Rules or other carrier regulations applicable to the mode of transportation.

5.4 **Marking** - In addition to any special marking required by the contract or order (see 6.2), packages and shipping containers shall be marked in accordance with MIL-STD-129.

6. NOTES

6.1 **Intended use** - Castings purchased under this specification are intended primarily for use in manufacture and assembly of aerospace and weapons equipment which requires small, sound, high quality, and intricate precision castings weighing from approximately 1 ounce to 6 pounds.

6.1.1 Composition numbers IC-302, IC-304, IC-304L, IC-310, IC-316, IC-321, and IC-347 are austenitic stainless steels of the chromium nickel type. As a group they are generally more corrosion resistant than ferritic and martensitic stainless steels and have better elevated temperature oxidation resistance and strength. Maximum corrosion resistance for these materials is obtained in the solution heat-treated condition. Selection for design purposes will be governed primarily by the type of corrosive media involved since these alloys exhibit similar mechanical properties and castability.

6.1.2 Composition numbers IC-410, IC-420, IC-431, IC-440A, and IC-440C are martensitic stainless steels hardenable by heat treatment. Resistance to corrosion is generally increased by the greater percentages of chromium and decreasing percentages of carbon. Composition IC-410 is intended for structural parts where corrosive conditions are not severe. This alloy is subject to rusting and pitting when exposed to sea water and will rust in salt air. Composition IC-420 will exhibit greater hardness and strength than IC-410 and is used for bearing surfaces, cutlery, gages, valve parts, etc. Composition IC-431 possesses greater corrosion resistance than other steels in this group. Reheating quenched composition IC-431 material in the range 850-1000° F should be avoided to prevent loss of impact strength. Composition numbers IC-440A and IC-440C offer maximum hardness in this group. All alloys in this group possess good casting fluidity. Composition numbers IC-410, IC-440A, and IC-440C tend to form surface pits when cast and may require finishing operations.

6.1.3 Composition number IC-17-4 is a precipitation hardening stainless steel which can be heat-treated to high strength and with corrosion resistance superior to the IC-400 series.

6.2 **Ordering data** - Procurement documents should specify the following:

- a. Title, date, and number of this specification.

- b. The composition and condition of castings required (see 1.2, 3.2, and 3.3).
- c. Mechanical properties when required (see 3.4).
- d. Applicable drawings or dimensions of castings (see 3.8).
- e. Place of inspection and test, if different from 4.3.4.
- f. Whether Level A or Level C packaging is required (see 5.2).
- g. Intermediate packaging and cushioning material when required (see 5.2.1.5 and 5.2.1.6).
- h. Whether Level A, Level B, or Level C packing is required (see 5.3).
- i. Number of packages per pack required (see 5.3.1).
- j. Additional marking, if required (see 5.4).

Custodians:

Army - MR
Navy - AS
Air Force - 84

Preparing Activity
Navy - AS

Project No. MECA-0021

Review activities:

Army - AV, GL, ME, MU, WC
Navy - AS, MC

Civilian Agencies
Interest

User activities:

Navy - OS

NSA

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER	2. DOCUMENT TITLE
3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION <i>(Mark one)</i> <input type="checkbox"/> VENDOR <input type="checkbox"/> USER <input type="checkbox"/> MANUFACTURER <input type="checkbox"/> OTHER <i>(Specify):</i> _____
b. ADDRESS <i>(Street, City, State, ZIP Code)</i>	
5. PROBLEM AREAS	
a. Paragraph Number and Wording:	
b. Recommended Wording:	
c. Reason/Rationale for Recommendation:	
6. REMARKS	
7a. NAME OF SUBMITTER <i>(Last, First, MI)</i> – Optional	b. WORK TELEPHONE NUMBER <i>(Include Area Code)</i> – Optional
c. MAILING ADDRESS <i>(Street, City, State, ZIP Code)</i> – Optional	8. DATE OF SUBMISSION (YYMMDD)

(TO DETACH THIS FORM, CUT ALONG THIS LINE.)