QQ-A-601F
March 23, 1981
SUPERSEDING
Fed. Spec QQ-A-601E
April 15, 1974

FEDERAL SPECIFICATION

ALUMINUM ALLOY SAND CASTINGS

This specification was approved by the Commissioner, Federal Supply Service, General Services Administration for the use of all Federal agencies.

1. SCOPE

1.1 Scope. This specification covers aluminum alloy sand castings for use where castings having the characteristics of the material specified herein are suitable (see 6.1).

1.1.1 Alloys and tempers. Aluminum alloy sand castings shall be furnished in the alloys and tempers shown in table 1, as specified (see 6.2).

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issues in effect on date of invitation for bids or request for proposal form a part of this specification to the extent specified herein (see 6.7):

Federal Specification:

QQ-A-371 - Aluminum Alloy Ingot (For Remelting)

Federal Standards:

Fed. Test Method Std. No. 151 - Metals; Test Methods
Fed. Test Method Std. No. 151/111 - Chemical Analysis
Fed. Test Method Std. No. 151/112 - Spectrochemical Analysis

(Activities outside the Federal Government may obtain copies of Federal specifications, standards, and commercial item descriptions as outlined under General Information in the Index of Federal Specifications, Standards and Commercial Item Descriptions. The Index, which includes cumulative bimonthly supplements as issued, is for sale on a subscription basis by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

(Single copies of this specification, other Federal specifications and commercial item descriptions required by activities outside the Federal Government for bidding purposes are available without charge from General Services Administration Business Service Centers in Boston; New York; Washington, DC; Philadelphia; Atlanta; Chicago; Kansas City, MO; Fort Worth; Houston; Denver; San Francisco; Los Angeles; and Seattle, WA.

(Federal Government activities may obtain copies of Federal specifications, standards, and commercial item descriptions, and the Index of Federal Specifications, Standards and Commercial Item Descriptions from established distribution points in their agencies.)

Military Specifications:

MIL-C-6021 - Castings, Classification and Inspection of
MIL-H-6088 - Heat Treatment of Aluminum Alloys
MIL-I-13857 - Impregnation of Metal Castings
MIL-A-21180 - Aluminum Alloy Castings, High Strength

Military Standards:

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-271 - Nondestructive Testing Requirements for Metals
MIL-STD-276 - Impregnation of Porous Nonferrous Metal Castings
MIL-STD-278 - Welding and Allied Processes for Machinery for Ships of the United States Navy
MIL-STD-453 - Inspection, Radiographic

(Copies of Military specifications and standards required by activities 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 documents form a part of this specification to the extent specified herein. Unless a specific issue is identified, the issue in effect on date of invitation for bids or request for proposal shall apply.

American Society for Testing and Materials (ASTM) Standards:

B26 - Aluminum Alloy Sand Castings
B557 - Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products

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

The Aluminum Association Standards:

Standards for Aluminum Sand and Permanent Mold Castings.

(Application for copies should be addressed to the Aluminum Association, 818 Connecticut Avenue, N.W., Washington, DC 20006.)

National Motor Freight Traffic Association, Inc., Agent:

National Motor Freight Classification.

(Application for copies should be addressed to the American Trucking Associations, Inc., Traffic Department, 1616 P Street, N.W., Washington, DC 20036.)

Uniform Classification Committee, Agent:

Uniform Freight Classification.

(Application for copies should be addressed to the Uniform Classification Committee, Room 1106, 222 South Riverside Plaza, Chicago, IL 60606.)

3. REQUIREMENTS

3.1 Material. Unless otherwise specified (see 6.2), only aluminum alloy ingots conforming to requirements of QQ-A-371 or manufacturer's foundry scrap, identified as being made from ingot conforming to QQ-A-371, shall be used in the remelting furnace from which molten metal is taken for pouring directly into castings. Remelting furnace or ladle additions of small amounts of grain refining elements or alloys will be permitted.

3.1.1 Pure materials and master alloys may be used to make alloys conforming to this specification, provided chemical analysis can be taken and adjusted to conform to table II prior to pouring any castings.

3.2 Chemical composition. The chemical composition of the castings shall be within the limits specified in table II.

3.2.1 The supplier shall furnish an analysis of each melt showing the percentage of each of the elements in table II.

3.2.2 Chemical analysis by the supplier of the individual melts may be waived at the discretion of the procuring agency, provided that the foundry's method of composition control is acceptable to the purchaser, or that all the material in the lot can be identified as being from melts previously analyzed and found to be in conformance with the chemical composition requirements of the alloy specified herein.

3.3 Mechanical properties.

3.3.1 The mechanical properties, as determined from separately cast test bars, shall conform to the requirements shown in table III.

3.3.2 Specimens cut from castings. Under any of the following conditions, conformance to the casting mechanical property requirements of 3.3.1 shall be determined by tests on specimens cut from castings.

a. When specified on the applicable drawing.
b. When authorized by the purchaser.
c. When requested by the contractor in the event that test bars fail to meet requirements and are obviously defective because of faulty molding, pouring, or other conditions not necessarily affecting the castings.
d. At the option of the contractor.

3.3.2.1 Unless otherwise specified (see 6.2), the average ultimate tensile strength and average elongation of test specimens cut from castings in accordance with section 4 shall be not less than 75 percent (to the nearest ksi (5 MPa)), and 25 percent (to the nearest 0.5 percent) respectively, of the values specified herein for separately cast test bars.

3.3.3 When alloy 222.0, 295.0, 319.0, 355.0, 356.0, and 771.0 castings are furnished, unless otherwise specified in the contract or order or when air quenching is permitted (see footnote 2 of table III), they shall be quenched in water of suitable temperature from the solution treatment temperature (see 6.2).

3.3.4 Tensile properties of designated areas of castings. When specified on the applicable drawings or in the contract or order (see 6.2), the mechanical properties of test specimens, cut from the areas of casting designated on the applicable drawing or in the contract or order, shall meet the values on the drawing or in the contract or order. If properties are not specified, those referred to in 3.3.2.1 shall apply.

3.3.5 Simulated service tests. When the castings have critical functional requirements, special tests to simulate the stress conditions incurred in service may be required. The requirements and methods of making the test shall be as specified by the purchaser (see 6.2).

3.4 Soundness. When specified (see 6.2), castings shall be subjected to radiographic examination to determine soundness (see 4.4.3). Acceptable standard of soundness shall be established by the purchaser or, if no such standards are available, by radiographing sample castings until radiographs acceptable to the purchaser are obtained. The areas of the castings subject to soundness requirements shall be as specified (see 6.2), and the number and extent of gas-hole, porosity, and other defects in such areas shall be not greater than indicated by the standard.

3.5 Pressure tightness. When specified on the applicable drawing or in the contract or order (see 6.2), castings shall be subject to hydrostatic or aerostatic pressure as required.

3.6 Foundry control. When specified (see 6.2), castings shall be produced under foundry control approved by the purchaser. Foundry control shall consist of examination of castings by radiographic or other approved methods for determining internal defects until the gating, pouring, and other foundry practices have been established to produce castings meeting the quality standards furnished by the purchaser or agreed upon by the purchaser and the contractor. When foundry practices have been so established, the production method shall not be significantly changed without demonstrating to the satisfaction of the purchaser that the change does not adversely affect the quality of the castings. Minor changes in pouring temperature (± 50°F (± 28°C)) from the established limits are permissible.

3.7 Heat treatment.

3.7.1 When heat treatment is required (see 3.3), it shall be performed in such a manner as to produce material with the utmost uniformity which will conform to the mechanical properties specified herein. Heat treatment shall be performed on the whole casting and never on a portion only (see 6.3).

3.7.2 Unless otherwise specified herein, castings shall be heat treated in accordance with the manufacturer's recommendations and in accordance with the best commercial practices. When specified (see 6.2), castings which require heat treatment shall be heat treated in accordance with MIL-H-6088. Castings purchased for use on Naval Air Systems Command and Naval Sea Systems Command (Ordnance Systems) contracts shall be heat treated in accordance with MIL-H-6088.

3.8 Dimensions. The dimensions of the castings shall be as specified (see 6.2). Castings shall be furnished in condition ready for machining and shall not require further straightening. Unless otherwise specified (see 6.2), tolerances and draft finish allowances shall be in accordance with the sandcasting provisions of the Aluminum Association Standards for Aluminum Sand and Permanent Mold Castings.

3.9 Repairing of castings.

3.9.1 Castings shall not be repaired by welding, impregnation, peening, blending in excess of that indicated in 3.9.5, or other methods without permission of the purchaser. Such permission may be given only when the repaired defect will not adversely affect the strength or machinability or otherwise impair the suitability of the castings for the purpose intended. Soldering shall not be performed under any conditions. Repaired castings shall be re-examined in accordance with the applicable portions of the pertinent specifications, drawings, and directives (see 4.7).

3.9.2 Welding.

3.9.2.1 When welding is permitted, it shall be done by methods suitable for the particular alloy. Welding methods shall be in accordance with such specifications as are referenced on the applicable drawings, or as are required by the contract or order, or when permission to weld is granted. Periodic checks of welded castings shall be made to insure that a satisfactory procedure for welding is being adhered to by the contractor.

3.9.2.1.1 All welding shall be accomplished by welders, qualified in accordance with procedures agreed to by the purchaser and the supplier (see 6.2).

3.9.2.2 When castings are to be supplied in the heat-treated condition, they shall be heat treated to the required temper after welding, except that small arc welds may be performed without subsequent heat treatment upon approval of the purchaser.

3.9.2.3 Unless otherwise specified (see 6.2), castings which have been repaired by welding shall have the welded areas examined radiographically after all reworking and heat treatment have been completed.

3.9.2.4 All welds shall be of high quality and free from cracks, lack of fusion, and meet the same quality requirements as the parent material.

3.9.2.5 Welded castings shall be marked with a symbol of three concentric circles with a letter or number designating the welder adjacent to the symbol. The outer circle of the symbol shall not be larger than 1/4 inch (6 mm) in outside diameter. All welded areas shall be encircled with a ring of white paint prior to submission for final inspection.

3.9.2.6 Naval shipboard applications. Repair welding of castings used in Naval shipboard pressure vessels, piping systems and machinery shall be performed in accordance with requirements for repair of castings specified in MIL-STD-278.

3.9.3 Impregnation. When impregnation is permitted, it shall be to correct general seepage leaks only and shall not be used to correct poor foundry technique or significant porosity. It shall be accomplished in accordance with MIL-STD-276 or, when specified (see 6.2), MIL-I-13857. Unless otherwise authorized by the purchaser, castings which have been impregnated shall be marked "IMP."

3.9.4 Peening. When peening is permitted, it shall be to correct localized minor seepage leaks and small surface imperfections only, or to disclose subsurface voids for the purpose of inspection. Peening will not be permitted to repair cracks, cold shuts, shrinks, misruns, defects due to careless handling, or other similar major defects. Peening may be accomplished either hot or cold and shall be performed by methods which are acceptable to the purchaser. Peened castings shall be marked with a Maltese cross approximately 1/4 inch (6 mm) high.

3.9.5 Blending. Blending with suitable grinders or other tools will be permitted for the removal of surface imperfections only, and shall not result in dimensions outside the tolerances shown on the applicable drawing.

3.10 Identification and repair marking.

3.10.1 Identification. Unless otherwise specified (see 6.2), each casting shall be marked with the applicable drawing or part number. The marking shall consist of raised Arabic numerals, and when applicable, upper-case letters, cast integral. The location of the identification marking shall be as specified on the applicable drawing. When the location is not specified, the manufacturer shall select the location on the basis of the following criteria:

a. The identification shall be so located that it will not be machined off when the casting is being finished to the required dimensions (see 6.3).

b. The identification shall be located to minimize deleterious effects on the static or fatigue strength of the casting.

3.10.1.1 Lot identification. When practicable, each casting shall also be marked with the melt or inspection lot number (see 4.2).

3.10.2 Repair markings. All identification markings indicating repairs as specified in 3.9.2.5, 3.9.3 and 3.9.4 shall be made with a waterproof marking fluid.

3.11 Workmanship. Before inspection, castings shall be smooth and well cleaned by a process satisfactory to the purchaser and shall be completely processed and ready for shipment. The castings shall be of uniform quality and shall be free from any defects which exceed the standards established by the purchaser.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspecton. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the contractor 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 Lot. A lot shall consist of all of the cleaned castings poured from the same heat or melt when subsequent heat treatment is not required.

4.2.1 When the castings consist of alloys which require heat treatment, the lot shall consist of all castings from the same melt or heat which have been treated in the same furnace charge, or if heat treated in a continuous furnace, all castings from the same melt or heat that are discharged from the furnace during a 4-hour period.

4.3 Sampling.

4.3.1 For chemical analysis. A sample for chemical analysis shall be taken from each melt. The sample may be taken from test coupons or from representative castings.

4.3.1.1 Wet chemical analysis. A sample for chemical analysis shall consist of not less than 2 ounces (57 g). Samples shall be obtained either by pouring a suitable sample from the same heat or melt in an iron mold at the time of pouring the castings, or directly from the castings under inspection, or from broken mechanical test specimens and shall be representative of the material. The drillings or millings shall be taken from sound metal below the surface, and shall be fine, clean, and free from oil, dirt, grit, or foreign matter.

4.3.1.2 Spectrochemical analysis. Samples shall be obtained as specified in method 112 of Fed. Test Method Std. No. 151.

4.3.1.3 Other methods of analysis. Samples for other methods of analysis shall be as agreed upon by the contractor and the purchaser.

4.3.2 For the tension test.

4.3.2.1 Test bars. At least two test bars shall be poured to represent each lot of castings (see 4.2). Test bars shall be cast to the form and dimensions shown on figure 8 of ASTM B557 or figure 1 of ASTM B26. Each test bar shall be machined to standard dimensions for test specimens conforming to the standard round specimen of ASTM B557 or they may be tested without machining. Test bars which are to be tested without machining shall be cast 0.505 inch (12.8 mm) in diameter. No test bars will be required if conformance with mechanical property requirements (see 3.3), is demonstrated by test of specimens from castings in accordance with 3.3.2 and 4.3.2.1.1. Tension tests shall be performed in accordance with ASTM B557.

4.3.2.1.1 When test specimens cut from castings are required in accordance with 3.3.2 c or 3.3.2 d, one or more castings in the temper to be furnished shall be selected from each lot and not less than two tension test specimens shall be machined therefrom, or which one shall be from the thinnest section and one from the thickest section.

4.3.2.1.2 When test specimens cut from designated areas of castings are required in accordance with 3.3.2 a and 3.3.2 b, one or more castings in the temper to be furnished shall be selected from each lot and not less than two tension test specimens shall be machined therefrom for each designated area and tested.

4.3.2.1.3 Specimens cut from castings shall be in the form of flat or round tension test specimens conforming to the standard flat or round specimens of ASTM B557. Where a standard specimen is not feasible, the largest subsize specimen practical shall be used. Unless permitted by the purchaser, the smallest round specimen used shall have dimensions not less than those of a specimen having a nominal gage diameter of 0.250 inch (6.3 mm).

4.3.2.2 Heat treatment of test bars.

4.3.2.2.1 The test bars from each lot shall be heat treated to the same temper with production castings of the same lot. When test bars are used, one of the bars representative of the particular lot shall be tested and the acceptability of the heat treatment shall be determined by the result of this test.

4.3.2.2.2 Each heat-treating furnace charge shall be represented by at least one set of test bars of the same composition range. The heat treatment of a furnace charge shall be determined by these test bars.

4.3.2.2.3 Aging of test bars. Test bars representing castings of alloy 295.0-T4 (see table III), shall be aged at room temperature for not less than 48 nor more than 96 hours after solution heat treatment before testing. At the option of the manufacturer, samples may be tested after less than 48 hours aging, and if they fail to show the properties specified here for the alloy and temper required (see 1.2.1), the tests shall be discarded without prejudice and additional tests made after 48 hours aging.

4.3.2.3 In the event the metal for castings is given any treatment such as fluxing, or cooling and re-heating, the metal for the test bars shall from a portion of the metal so treated.

4.3.3 For impregnation tests. When impregnation is permitted, sampling for testing to check the impregnation shall be as specified by the purchaser.

4.3.4 For hydrostatic or aerostatic pressure tests. Sampling for hydrostatic or aerostatic pressure tests, when required, shall be as specified by the purchaser.

4.3.5 For examination. For the purpose of examination (see 4.4), lots of castings of the same size and shape, and of the same alloy and temper may be combined up to a maximum of 10,000 lbs (4,500 kg). Unless otherwise specified by the purchaser, from this accumulated lot, a sample shall be selected at random in accordance with the tables of MIL-STD-105 at inspection level II, with lot acceptance and rejection based on acceptable quality level (AQL) equal to 1.5 percent defective. When the accumulation of lots is not practicable, the sample shall be selected from the lot sizes specified in 4.2. When MIL-STD-105 specifies an action by the Government, it shall, at the option of the purchaser, be performed either by the Government or by the contractor. The samples selected for dimensional examination may be the same as those selected for visual examination, but the determination of acceptance or rejection shall not be based on the cumulative sample for both chracteristics.

4.3.5.1 Soundness. When soundness inspection is to be made in accordance with the requirements of 3.4, a random sample of castings shall be selected from each lot in accordance with MIL-STD-105 at inspection level II with lot acceptance and rejection based on AQL of 0.65 percent defective.

4.3.5.2 Foundry control. When specified in accordance with 3.6, radiographic or other methods of examination to establish gating, pouring, and other foundry practices shall be determined by the purchaser.

4.4 Visual and dimensional examination. Each sample selected in accordance with 4.3.5 shall be subjected to surface examination for workmanship and dimensional requirements.

4.4.1 When aircraft structural castings are specified (see 6.2), the castings shall be examined in accordance with MIL-C-6021.

4.4.2 Special examination. When the purchaser (see 6.2), advises that the presence of certain defects in any casting involves hazards to the safety of personnel, examination shall be conducted in accordance with MIL-STD-105, AQL of 0.015 percent defective, inspection level II.

4.4.3 Soundness. Castings shall be radiographed as specified by the purchaser (see 4.4.3.1 and 4.4.3.2). Each of the sample castings selected in accordance with 4.3.5.1 shall be radiographed and compared with the standard castings to determine conformance with 3.4.

4.4.3.1 When specified (see 6.2), soundness inspection tests shall be made by radiographic examination conducted in accordance with MIL-STD-453.

4.4.3.2 When specified (see 6.2), castings shall be radiographed in accordance with MIL-STD-271.

4.4.4 Examination of preparation for delivery. An examination shall be made to determine compliance with the requirements of section 5. The sample unit shall be one shipping container fully prepared for delivery. Sampling shall be in accordance with MIL-STD-105. The inspection level shall be S-2 with an AQL of 4.0 expressed in terms of percent defective.

4.5 Tests.

4.5.1 Chemical analysis. The samples selected in accordance with 4.3.1 shall be analyzed in accordance with method 111 or 112 of Fed. Test Method Std. No. 151. A single analysis of composite sample may be made. In case of dispute, referee analysis shall be by method 111. If another method of analysis is desired, it shall be as agreed upon by the contractor and the purchaser.

4.5.2 Tension tests.

4.5.2.1 Lot acceptance procedure. Tension test specimens or test bars obtained in accordance with 4.3.2 shall be pulled in tension, in accordance with the methods specified in 4.5.2.2, to determine compliance with 3.3.

4.5.2.2 Methods of tests. Tension testing shall be conducted in accordance with ASTM B557. Separately cast test bars may be tested without machining. Strength shall be computed from the actual measured diameter of the gage length.

4.5.3 Pressure tightness. If specified (see 3.5), hydrostatic or aerostatic pressure test shall be conducted in accordance with the method specified in the applicable drawing or in the contract or order.

4.5.4 Impregnation. Tests for impregnation, when permitted (see 3.9.3), shall be conducted in accordance with MIL-STD-276 or, when specified, MIL-I-13587.

4.6 Naval shipboard applications. Castings which are procured to this specification for use in Naval shipboard pressure vessels, piping systems and machinery, shall be inspected in accordance with MIL-STD-278.

4.7 Rejection.

4.7.1 Examination. Any sample unit containing one or more visual or dimensional defect shall be subject to rejection. If the number of defective units in any sample exceeds the acceptance number specified in 4.3.5 for that sample size, the entire lot represented by the sample shall be rejected.

4.7.2 Tests. A lot shall be rejected for failure to meet any of the test requirements when tested in accordance with 4.5.

4.8 Retests. Retests shall be permitted in accordance with Fed. Test Method Std. No. 151.

5. PREPARATION FOR DELIVERY

5.1 Packaging. Packaging shall be level A or commercial, as specified (see 6.2).

5.1.1 Level A. The aluminum alloy sand castings shall be packaged in accordance with the level A packaging requirements of MIL-STD-648.

5.1.2 Commercial. The aluminum alloy sand castings shall be packaged in accordance with normal commercial practice. The complete package shall be designed to protect the castings against damage during multiple shipments, handling, and storage.

5.2 Packing. Packing shall be level A or commercial, as specified (see 6.2).

5.2.1 Level A. The aluminum alloy sand castings, packaged as specified in 5.1, shall be packed in accordance with the level A packing requirements of MIL-STD-649.

5.2.2 Commercial. The aluminum alloy sand castings, packed as specified in 5.1, shall be packed in fiberboard boxes to insure delivery at destination; provide for redistribution by the initial receiving activity; and be acceptable to common carrier under the National Motor Freight Classification and Uniform Freight Classification.

5.3 Marking.

5.3.1 Civil agencies. Marking shall be as specified in the contract or order.

5.3.2 Military agencies. Marking shall be as specified in MIL-STD-129.

6. NOTES

6.1 Intended use. The intended uses of aluminum alloy castings are listed in table IV along with other pertinent data. The data shown in table IV are approximate and are supplied for general information only.

6.2 Ordering data. Purchasers should select the preferred options permitted herein, and include the following information in procurement documents:

a. Title, number, and date of this specification.
b. Alloy and temper required (see 1.1.1).
c. When material other than from ingots conforming to QQ-A-371 or manufacturer's identified foundry scrap is permitted (see 3.1).
d. When applicable, those designated areas from which test specimens will be taken and the minimum acceptable values of mechanical properties for these test specimens (see 3.3.2 and 3.3.2.1).
e. Heat treatment of alloy 222.0, 295.0, 319.0, 355.0, 356.0, and 771.0 castings when not as specified in 3.3.3.
f. Tensile properties of designated areas of castings, when other than as specified in 3.3.2.1 is required (see 3.3.4).
g. Requirements and methods of simulated service tests, when required (see 3.3.5).
h. When radiographic examination is required for soundness; the location of critically stressed areas and the percentage of castings to be inspected, if other than as specified (see 3.4 and 4.3.5.1).
i. When hydrostatic or aerostatic pressure tests are required (see 3.5 and 4.5.3).
j. When foundry control is applicable (see 3.6).

i. The dimensions of castings required (see 3.8).
m. Tolerances and allowances when other than standard tolerances and allowances are required (see 3.8).
n. Welder qualification procedures, when required (see 3.9.2.1.1).
o. When castings repaired by welding are to be examined radiographically (see 3.9.2.3).
p. When impregnation in accordance with MIL-I-13857 is required (see 3.9.3).
q. The location or locations which are not acceptable for raised or impression marking when the improper location of such marking could have a deleterious effect on the static or fatigue strength of the part or is important because of subsequent machining oeprations. (Impression marking improperly located may cause failure. See 3.10.)
r. Whether the special inspection of 4.4.1, 4.4.2, 4.4.3.1, or 4.4.3.2 is required.
s. Levels of packaging and packing required (see 5.1 and 5.2).
t. Quality of casting required.

6.3 General information.

6.3.1 The proper heat treatment for aluminum alloy castings varies depending upon the alloy and the service requirements. The best combination of strength and ductility, combined with freedom from room temperature aging is obtained by quenching the alloy from the solution heat-treating temperature and aging at an elevated temperature. The aging treatment can be varied to provide several combinations of mechanical properties, as well as introducing various degrees of stress relief and dimensional stability.

6.3.2 The effects of heat treatment are destroyed if the castings are subsequently used at temperatures in the annealing range for the alloy, castings to be so used should not be given such treatment but should be given other heat treatment as will substantially relieve casting stresses, or tend to stabilize the dimensions against changes at elevated temperature or both. Moreover, certain complicated castings cannot be safely quenched from the temperatures required. For these alloys, other heat treatment processes are commonly used to relieve casting stresses, or to stabilize the dimensions against changes at elevated temperatures, or both. While castings treated by these latter processes do not have as high initial properties as those quenched from the solution heat-treating temperatures, they are superior in quality for use at elevated temperatures.

6.3.3 The attention of manufacturers is specifically invited to the fact that the mechanical and chemical requirements of section 3 of this specification can be met only by a careful choice of ingredients of the melt.

6.3.4 The typical or average property values shown in table V are given for the information of designers. When the tensile strength and elongation values are in accordance with this specification, the yield strength will have the value shown within a range of plus or minus 3 ksi (20.7 MPa) except when a minimum value is required. These properties are not determined in the routine inspection of castings.

6.4 The designations used in this specification are similar to those used in ASTM B26 and are the same as commercial designations.

6.5 This specification covers the technical requirements for castings, and is not intended for the purchase of ingots. Castings for critical parts should be procured to MIL-A-21180.

6.6 The packaging, packing, and marking requirements specified herein apply to direct shipment to the Government, and are not intended to apply to contracts or orders between the manufacturer and the prime contractor.

6.7 Specifications and standards applicable to military preparation for delivery requirements. In addition to the documents listed in 2.1, the following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification for military procedures where level A packaging is specified.

Military standards:

MIL-STD-129 - Marking for Shipment and Storage
MIL-STD-649 - Aluminum and Magnesium Products; Preparation for Shipment and Storage

MILITARY CUSTODIANS:

Army - MR
Navy - SH
Air Force - 99

Review activities:

Army - AR, MD, MI
Navy - AS

User activities:

Army - ME
Navy - OS, SA

Preparing activity:

Army - MR

CIVIL AGENCY COORDINATING ACTIVITIES:

GSA - FSS
Marshall - MSF

Project No. MECA-0178

TABLE I. Alloys and tempers.

Alloy	Description	Temper designation[1/]
208.0	4 percent copper-silicon	F, T55
222.0	10 percent copper-magnesium	O, T61
242.0	4 percent copper-magnesium-nickel	T571, T77
295.0	4-1/2 percent copper-silicon	T4, T6, T62, T7
319.0	6 percent silicon-copper	F, T5, T6
328.0	8 percent silicon-copper-manganese-magnesium	F, T6
355.0	5 percent silicon-copper-magnesium	T51, T6, T7, T71
C355.0	5 percent silicon-copper-magnesium (high-purity)	T6
356.0	7 percent silicon-magnesium	T51, T6, T7
A356.0	7 percent silicon-magnesium (high-purity)	T6
B443.0	5 percent silicon	F
512.0	4 percent magnesium-silicon	F
514.0	4 percent magnesium	F
520.0	10 percent magensium	T4
535.0	7 percent magnesium-manganese	F, O
705.0	3 percent zinc-magnesium-chromium-manganese	F, T5,
707.0	4-1/2 percent zinc-magnesium-chromium-manganese	F, T5, T7
710.0	6-1/2 percent zinc-magnesium	F
712.0	5-1/2 percent zinc-magnesium-chromium	F, T5[2/]
713.0	7-1/2 percent zinc-copper-magnesium	F, T5[2/]
771.0	7 percent zinc-manganese-chromium	O, T5, T6
850.0	6-1/2 percent tin-copper-nickel	T5
851.0	6-1/2 percent tin-silicon-copper-nickel	T5
852.0	6-1/2 percent tin-copper-nickel-magnesium	T5

[1/]Temper designations:

F - As fabricated

O - Annealed

T4 - Solution heat-treated and naturally aged to a substantially stable condition.

T5 - Cooled from an elevated temperature shaping process and then artifically aged.

T6 - Solution heat treated and then artifically aged.

T7 - Solution heat treated and stabilized.

Additional digits, the first of which shall not be zero, may be added to designations T1 through T10 to indicate a variation in treatment that signficantly alters the characteristics of the product.

[2/]Naturally aged not less than 21 days after casting for optimum mechanical properties and dimensional stability.

TABLE II. Chemical composition, percent maximum unless a range is indicated[1/]

Alloy	Silicon	Iron	Copper	Manganese	Magnesium	Chromium
208.0	2.5-3.5	1.2	3.5- 4.5	0.50	0.10	--
222.0	2.0	1.5	9.2-10.7	.50	.15-0.35	--
242.0	0.7	1.0	3.5- 4.5	.35	1.2 -1.8	0.25
295.0	0.7-1.5	1.0	4.0- 5.0	.35	0.03	--
319.0	5.5-6.5	1.0	3.0- 4.0	.50	.10	--
328.0	7.5-8.5	1.0	1.0- 2.0	.20-0.6	.20-0.5	0.35
355.0	4.5-5.5	0.6[2/]	1.0- 1.5	.50[2/]	.40-0.6	.25
C355.0	4.5-5.5	.20	1.0- 1.5	.10	.40- .6	--
356.0	6.5-7.5	.6	0.25	.35	.20- .45	--
A356.0	4.5-6.0	.20	.20	.10	.25- .45	--
B443.0	4.5-6.0	.8	.15	.35	.05	--
512.0	14.-2.2	.5	.35	.8	3.5 -4.5	0.25
514.0	0.35	.50	.15	.35	3.5 -4.5	--
520.0	.25	.30	.25	.15	9.5 -10.6	--
535.0	.15	.15	.05	.10-0.25	6.2 -7.5	--
705.0	.20	.8	.20	.40- .6	1.4 -1.8	0.20-0.40
707.0	.20	.8	.20	.40- .6	1.8 -2.4	.20- .40
710.0	.15	.50	.35- 0.65	.05	.6 -0.8	--
712.0	.30	.50	.25	.10	.50- .65	0.40-0.6
713.0	.25	1.1	.40- 1.0	.6	.20- .50	.35
771.0	.15	0.15	.10	.10	.8 -1.0	0.06-0.20
850.0	.7	.7	.7 - 1.3	.10	.10	--
851.0	2.0 -3.0	.7	.7 - 1.3	.10	.10	--
852.0	0.40	.7	1.7- 2.3	.10	.6 -0.9	--

Alloy	Nickel	Zinc	Tin	Titanium	Other Elements Each	Other Elements Total	Aluminum
208.0	0.35	1.0	--	0.25	--	0.50	Remainder
222.0	.50	0.8	--	.25	--	.35	Remainder
242.0	1.7 -2.3	.35	--	.25	0.05	.15	Remainder
295.0	--	.35	--	.25	.05	.15	Remainder
319.0	0.35	1.0	--	.25	--	.50	Remainder
328.0	.25	1.5	--	.25	--	.50	Remainder
355.0	--	0.35	--	.25	0.05	.15	Remainder
C355.0	--	.10	--	.20	.05	.15	Remainder
356.0	--	.35	--	.25	.05	.15	Remainder
A356.0	--	.10	--	.20	.05	.15	Remainder
B443.0	--	.35	--	.25	.05	.15	Remainder
512.0	--	.35	--	.25	.05	.15	Remainder
514.0	--	.15	--	.25	.05	.15	Remainder
520.0	--	.15	--	.25	.05	.15	Remainder
535.0	--	--	--	.10-0.25	.05[3/]	.15	Remainder
705.0	--	2.7-3.3	--	.25	.05	.15	Remainder
707.0	--	4.0-4.5	--	.25	.05	.15	Remainder

TABLE II. Chemical composition, percent maximum unless a range is indicated[1] (Cont'd)

Alloy	Nickel	Zinc	Tin	Titanium	Other Elements Each	Other Elements Total	Aluminum
710.0	--	6.0-7.0	--	0.25	0.05	0.15	Remainder
712.0	--	5.0-6.5	--	.15-0.25	.05	.20	Remainder
713.0	0.15	7.0-8.0	--	.25	.10	.25	Remainder
771.0	--	6.5-7.5	--	.10-0.20	.05	.15	Remainder
850.0	0.7 -1.3	--	5.5-7.0	.20	--	.30	Remainder
851.0	.30-0.7	--	5.5-7.0	.20	--	.30	Remainder
852.0	.9 -1.5	--	5.5-7.0	.20	--	.30	Remainder

1/Analysis shall regularly be made for the elements specifically mentioned in the above table. If however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that these other elements are not present in excess of the limits specified herein.

2/If iron exceeds 0.45 percent, it is desirable to have the manganese content in the amount of one-half the iron content.

3/Also 0.003-0.007 percent beryllium, boron 0.002 percent maximum.

TABLE III. Mechanical properties

Alloy	Temper designation	Tensile strength, ksi (MPa) minimum	Yield strength at 0.2 percent offset or at extension indicated		Elongation in 2 inches (50.8 mm) or 4 X diameter, percent, minimum
			ksi (MPa) minimum	Extension under load, inch per inch (mm/mm)	
208.0	As fabricated (F)	19 (131)	--	--	1.5
208.0	Artificially aged only (T55)	21 (145)	--	--	--
222.0	Annealed (0)	23 (159)	--	--	--
222.0	Solution heat-treated & artifically aged (T61)	30 (207)	--	--	--
242.0	Artificially aged (T571)	29 (200)	--	--	--
242.0	Solution heat-treated & stabilized (T77)	24 (166)	13 (90)	--	1.0
295.0 1/	Solution heat-treated (T4)	29 (200)	--	--	6.0
295.0	Solution heat-treated & artifically aged (T6)	32 (221)	20 (138)	0.0039	3.0
295.0	Solution heat-treated & aged (T62)	36 (248)	--	--	--
295.0	Solution heat-treated & stabilized (T7)	29 (200)	--	--	3.0
319.0	As fabricated (F)	23 (159)	--	--	--
319.0	Artificially aged (T5)	25 (172)	--	--	--
319.0	Solution heat-treated & artifically aged (T6)	31 (214)	--	--	1.5
328.0	As fabricated (F)	25 (172)	--	--	1.0
328.0	Solution heat-treated & artifically aged (T6)	34 (234)	--	--	1.0
355.0	Artificially aged only (T51)	25 (172)	--	--	--
355.0	Solution heat-treated & artifically aged (T6)	32 (221)	20 (138)	0.0039	2.0
355.0	Solution heat-treated & stabilized (T7)	35 (241) 2/	--	--	--
355.0	Solution heat-treated & stabilized (T71)	30 (207)	--	--	--
C355.0	Solution heat-treated & artifically aged (T6)	36 (248)	25 (172)	0.0039	2.5

TABLE III. Mechanical properties (cont'd)

Alloy	Temper designation	Tensile strength, ksi (MPa) minimum	Yield strength at 0.2 percent offset or at extension indicated		Elongation in 2 inches (50.8 mm) or 4 X diameter, percent, minimum
			ksi (MPa) minimum	Extension under load, inch per inch (mm/mm)	
356.0	Artificially aged (T51)	23 (159)	--	--	--
356.0	Solution heat-treated & artifically aged (T6)	30 (207)	20 (138)	0.0039	3.0
356.0	Solution heat-treated & stabilized (T7)	31 (214)	29 (200)	--	--
A356.0	Solution heat-treated & artifically aged (T6)	34 (234)	24 (166)	0.0039	3.5
B443.0	As fabricated (F)	17 (117)	--	--	3.0
512.0	As fabricated (F)	17 (117)	10 (69)	--	--
514.0	As fabricated (F)	22 (152)	--	--	6.0
520.0	Solution heat-treated (T4)	42 (290)	22 (152)	0.0041	12.0
535.0 3/	As fabricated (F)	35 (241)	18 (124)	.00375	9.0
535.0	Annealed (0)	35 (241)	18 (124)	.00375	9.0
705.0 4/	As fabricated (F) or artifically aged (T5)	30 (207)	17 (117)	--	5.0
707.0 4/	As fabricated (F) or artifically aged (T5)	33 (228)	22 (152)	--	2.0
707.0	Solution heat-treated and stabilized (T7)	37 (225)	30 (207)	--	1.0
710.0 5/	As fabricated (F)	32 (221)	20 (138)	--	2.0
712.0 6/	As fabricated (F) or artifically aged (T5)	34 (224)	25 (172)	0.0044	4.0
713.0 7/	As fabricated (F) or artifically aged (T5)	32 (221)	22 (152)	--	3.0
771.0 8/	Annealed (0)	36 (248)	27 (186)	0.0046	1.5
771.0 9/	Artificially aged (T5)	42 (290)	38 (262)	--	2.0
771.0 10/	Solution heat treated & artifically aged (T6)	42 (290)	35 (241)	0.0056	5.0
850.0	Artificially aged (T5)	16 (110)	--	--	5.0
851.0	Artificially aged (T5)	17 (117)	--	--	3.0
852.0	Artificially aged (T5)	24 (166)	18 (124)	--	--

See following page for footnotes.

TABLE III. Mechanical properties (cont'd)

FOOTNOTES:

1/These properties are obtainable when tested after 48 hours and before 96 hours of room temperature aging.

2/Applies to castings which were water quenched after heating to the solution temperature. In the case of castings which are of such complicated design that water quenching results in cracks, and quenching in an airblast is used, the minimum tensile strength shall be 32 ksi (221 MPa). Air blast quenching of casting will be permitted only when agreed upon by the contractor and the purchaser.

3/Alloy 535.0 may be furnished annealed, but no decrease in mechanical properties will be permitted.

4/These properties are obtainable after 21 days at room temperature aging or after artifically aging at 300 ± 10°F (149 ± 5°C) for 8 to 12 hours for 705.0 and 250 ± 10°F (121 ± 5.5°C) for 3 to 6 hours for 707.0.

5/These properties are obtainable after 21 days at room temperature aging.

6/The properties for alloy 712.0 are obtainable after 21 days at room temperature aging or after artificially aging at 355 ± 10°F (179 ± 5.5°C) for 10 hours.

7/These properties are obtainable after 21 days at room temperature aging or after artificially aging at 250 ± 10°F (121 ± 5.5°C) for 10 to 16 hours.

8/These properties are obtainable by holding at 775°F (413°C) for 5 hours, cooling to room temperature in still air, holding at 360 ± 10°F (182 ± 5.5°C) for 4 hours, and cooling in still air.

9/These properties are obtainable by holding at 355 ± 5°F (179 ± 3°C) for 3 to 5 hours and cooling to room temperature in still air.

10/These properties are obtainable by holding at 1080-1110°F (582-599°C) for 5 hours cooling to room temperature in still air, holding at 265 ± 10°F (129 ± 5.5°C) for 3 hours, and cooling in still air.

TABLE IV. Intended uses

Alloy	Casta-bility	Supplied in heat-treated condition	Principal use	Machina-bility
208.0	Good	Yes	Miscellaneous castings. Composition is such as to make it more available during periods of shortages of primary aluminum.	Good
222.0	Good	Yes	Same as alloy 242.0.	Excellent
242.0	Fair	Yes	Castings requiring strength and hardness at elevated tempratures, such as air-cooled cylinder heads and pistons.	Very Good
295.0	Good	Yes	General, where high strength ductility and resistance to shock are required.	Very Good
319.0	Excellent	Yes	General, where high strength is required.	Good
328.0	Excellent	Yes	General, where high strength is required.	Good
355.0	Excellent	Yes	General, where high strength and corrosion resistance are required. Also retains strength at elevated temperatures.	Good
C355.0	Excellent	Yes	Same as alloy 355.0.	Good
356.0	Excellent	Yes	General, where high strength and corrosion resistance are required.	Good
A356.0	Excellent	Yes	Same as alloy 356.0.	Good
B443.0	Excellent	No	General, with maximum corrosion resistance and for leakproof castings of intricate design.	Fair
512.0	Good	No	Same as alloy 514.0.	Good
514.0	Fair	No	Castings requiring superior resistance to corrosion.	Very Good
520.0	Fair	Yes	Castings requiring maximum strength, elongation and resistance to shock, require special founding practice.	Excellent

TABLE IV. Intended uses (cont'd)

Alloy	Castability	Supplied in heat-treated condition	Principal use	Machinability
535.0	Good	Yes	Applications requiring excellent shock resistance and corrosion resistance.	Excellent
705.0	Good	1/	Same as alloy 712.0.	Excellent
707.0	Good	1/	Same as alloy 712.0.	Excellent
710.0	Fair	1/	Same as alloy 712.0.	Excellent
712.0	Good	1/	General, where high strength ductility and resistance to shock are required.	Excellent
713.0	Good	1/	Same as alloy 712.0.	Excellent
771.0	Good	Yes	Applications requiring excellent dimensional stability or shock resistance combined with very high yield strength.	Excellent
850.0	Fair	Yes	Bearings.	Excellent
851.0	Fair	Yes	Bearings.	Excellent
852.0	Fair	Yes	Bearings.	Excellent

1/Alloys 705.0, 707.0, 710.0, 712.0, and 713.0 when properly cast, develop their highest strength after aging at room temperature for several weeks or after short artificial aging at slightly elevated temperatures.

TABLE V. Typical properties

Alloy	Temper	Yield Strength, ksi (MPa)	Brinell hardness (10 mm ball, 500 kilogram (kg) load)	Specific gravity[1/]	Density, lbs/in^3 (kg/m^3)
208.0	F	14 (97)	55	2.79	0.101 (2796)
208.0	T55	--	75	2.79	.101 (2796)
222.0	0	20 (138)	80	2.95	.107 (2962)
222.0	T61	40 (276)	115	2.95	.107 (2962)
242.0	0	18 (124)	70	2.81	.102 (2823)
242.0	T571	30 (207)	85	2.81	.102 (2823)
242.0	T77	23 (159)	75	2.81	.102 (2823)
295.0	T4	16 (110)	60	2.81	.102 (2823)
295.0	T6	24 (165)	75	2.81	.102 (2823)
295.0	T62	34 (234)	95	2.81	.102 (2823)
295.0	T7	19 (131)	70	2.81	.102 (2823)
319.0	F	18 (124)	70	2.79	.101 (2796)
319.0	T5	26 (179)	80	2.79	.101 (2796)
319.0	T6	24 (165)	80	2.79	.101 (2796)
328.0	F	--	60	2.73	.099 (2740)
328.0	T6	--	85	2.73	.099 (2740)
355.0	T6	25 (172)	80	2.70	.098 (2713)
355.0	T51	23 (159)	65	2.70	.098 (2713)
355.0	T7	36 (248)	85[2/]	2.70	.098 (2713)
355.0	T71	29 (200)	75	2.70	.098 (2713)
C355.0	T6	30 (207)	85	2.70	.098 (2713)
356.0	T6	24 (165)	70	2.68	.097 (2685)
356.0	T51	20 (138)	60	2.68	.097 (2685)
356.0	T7	30 (207)	75	2.68	.097 (2685)
A356.0	T6	29 (200)	75	2.68	.097 (2685)
B443.0	F	8 (55)	40	2.69	.097 (2685)
512.0	F	13 (90)	50	2.65	.096 (2657)
514.0	F	12 (83)	50	2.65	.095 (2630)
520.0	T4	25 (172)	75	2.57	.093 (2574)
535.0	F	18 (124)	70	2.62	.095 (2630)
535.0	0	18 (124)	--	2.62	.095 (2630)
705.0	T5	19 (131)	65	2.76	.100 (2768)
707.0	T5	27 (186)	85	2.77	.100 (2768)
707.0	T7	38 (262)	80	2.77	.100 (2768)
710.0	T5	25 (172)	75	2.76	.100 (2768)
712.0	T5	26 (179)	75	2.81	.102 (2823)
713.0	T5	25 (172)	75	2.81	.102 (2823)
771.0	0	30 (207)	87	2.81	.102 (2823)
771.0	T5	40 (276)	100	2.81	.102 (2823)

TABLE V. Typical properties (cont'd)

Alloy	Temper	Yield Strength, ksi (MPa)	Brinell hardness (10 mm ball, 500 kilogram (kg) load)	Specific gravity[1/]	Density, lbs/in^3 (kg/m^3)
771.0	T6	40 (276)	98	2.81	.102 (2823)
850.0	T5	11 (76)	45	2.88	.104 (2879)
851.0	T5	11 (76)	45	2.83	.103 (2851)
852.0	T5	22 (152)	65	2.88	.104 (2879)

[1/]Specific gravities of castings vary with the variation in composition permitted by operating limits and with casting conditions -- hence, there may be a point or two variation in the last decimal from one lot to another but the above are average values.

[2/]80 when quenched in air blast.

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