SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS-A-22771 | REV. C

Issued 1999-06
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Superseding AMS-A-22771B

Aluminum Alloy Forgings, Heat Treated

RATIONALE

AMS-A-22771C results from a Limited Scope Ballot to revise Mechanical Property Control of Production Parts (3.3.1.2), and to correct errors in referenced paragraphs present in revision B.

NOTICE

The initial SAE publication of this document was taken directly from U.S. Military Standard MIL-A-22771D. This SAE Standard may retain the same part numbers established by the original military document. Any requirements associated with Qualified Products Lists (QPL) may continue to be mandatory for DoD contracts. Requirements relating to QPLs have not been adopted by the SAE for this standard and are not part of this SAE document.

1. SCOPE

This specification has previously been widely used and may be required for production or processing of existing designs in the future. The Aerospace Materials Division, however, does not recommend this specification for future use in new designs (See 6.7).

1.1 Scope

This specification covers the requirements for heat treated aluminum alloy die forgings, hand forgings, and ring forgings, produced under additional mechanical property control to ensure known mechanical properties for parts used in aerospace critical applications. This specification also covers the requirements for forgings furnished in the F or 01 conditions which will ultimately be used in the heat treated condition.

1.2 Classification

The aluminum alloy forgings shall be furnished in the following alloys, tempers, and forms, as specified (See 6.2.):

1.2.1 Alloys and Tempers

2014-F, O1, T6, T652

2219-F, O1, T6, T852

2618-F, O1, T61

6061-F, O1, T6, T652

6151-F, O1, T6, T652

7049-F, O1, T73, T7352

7050-F, O1, T74, T7452

7075-F, O1, T6, T652, T73, T7352, T74, T7452

7175-F, O1, T74, T7452, T7454

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
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http://www.sae.org/technical/standards/AMSA22771C

1.2.2 Form

Forgings shall be furnished in the form of die forgings, hand forgings or ring forgings. If the form is not specified, manufacturers may use any form of forging most convenient.

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.

AMS2355 Quality Assurance Sampling and Testing of Aluminum Alloys and Magnesium Alloys, Wrought Products (Except Forging Stock), and Rolled, Forged, or Flash Welded Rings

AMS2430 Shot Peening, Automatic

AMS2644 Inspection Material, Penetrant

AMS2658 Hardness and Conductivity Inspection of Wrought Aluminum Alloy Parts

AMS2772 Heat Treatment of Aluminum Alloy Raw Materials

AMS-STD-2154 Inspection, Ultrasonic, Wrought Metals, Process for

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 B 660 Packaging/Packing of Aluminum and Magnesium Products

ASTM E 1417 Liquid Penetrant Testing

ASTM G 47 Determining Susceptibility to Stress-Corrosion Cracking of 2XXX and 7XXX Aluminum Alloy Products

2.3 Aerospace Industries Association Publications

Available from the Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3928, www.aia-aerospace.org.

NAS-410 Nondestructive Testing Personnel Qualification and Certification

2.4 Aluminum Association Publications

Available from The Aluminum Association Inc., 1525 Wilson Blvd. Suite 600, Arlington, VA 22209, www.aluminum.org.

International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys (Teal Sheets)

2.5 Order of Precedence

In the event of a conflict between the text of the specification and the references cited herein, the text of this specification shall take precedence.

3. REQUIREMENT

3.1 Chemical Composition

The chemical composition of the forgings shall be as specified in Table 1 (See 4.4.1). In case of a discrepancy in the values listed in Table 1 with those listed in the “International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys”(known as the “Teal Sheets”), the composition limits registered with the Aluminum Association and published in the “Teal Sheets” should be considered the controlling composition.

3.2 Heat Treatment

Unless otherwise specified, forgings shall be heat treated in accordance with AMS2772. Forgings of alloy 7175 shall be heat treated in a manner that the heat treated forgings shall conform to all the requirements of this specification (See 6.2.10). Discoloration due to heat treatment shall not be cause for rejection.

3.3 Mechanical Properties

3.3.1 Die Forgings

Mechanical properties of die forgings as determined in accordance with 4.4.2 shall conform to the applicable properties specified in Tables 2 and 3. When die forgings are machined before heat treatment to sizes within the maximum section thickness specified in Tables 2 and 3, the mechanical properties in these tables are applicable, provided the as-forged thickness shall be not more than twice the heat treated thickness. For as-forged thickness greater than twice the heat treated thickness, the properties shall be as agreed between the contractor and the forging supplier or between the acquiring activity and the forging supplier or contractor (See 6.3.1).

3.3.1.1 Mechanical Property Control of First Production Parts

After forging techniques have been established, a forging representative of the first production parts shall be tested. Tensile test specimens shall be taken from location both in the direction parallel to, within ±15 degrees of flow lines, and not parallel to the forging flow lines. The specimen location should be indicated on the forging enginering drawing. If the specimen locations are not indicated on the forging engineering drawing, they shall be taken from areas representative of thick and thin sections. The flow lines shall be determined as specified in 4.4.7. The mechanical properties shall be as specified in Table 2 and 3. For forgings too small to yield suitable test specimens, the tension test shall be waived or negotiated between the contractor and the forging supplier or between the acquiring activity and the forging supplier or contractor (See 6.3.1). This mechanical property control shall be repeated after any major change in the forging process, forging stock size or forging stock.

3.3.1.2 Mechanical Property Control of Production Parts

Samples for mechanical properties of production lots subsequent to the first production lot shall be taken as specified in AMS2355 and shall conform to the requirements of Table 2 and 3.

3.3.2 Hand Forgings

The mechanical properties of hand forgings as determined in accordance with 4.4.2 shall conform to the applicable properties specified in Table 4. The properties specified in Table 4 apply to hand forgings that are essentially rectangular in cross section. The requirement of long transverse and short transverse properties applies also to squares, even though transverse dimensions are equal. The forging process shall be controlled such that, the long transverse direction shall be perpendicular to the original stock axis, or both short transverse or long transverse properties shall meet the long transverse properties requirements. The direction of the long transverse properties shall be identified as specified in 3.8. For forgings too small to yield suitable test specimens, the method of tensile test shall be waived or negotiated between the contractor and forging supplier or between the acquiring activity and the forging supplier or contractor (See 6.3.1).

3.3.2.1 Large Hand Forgings

For hand forgings (1) of greater thickness or (2) heat treated in section thickness greater than covered by this specification, or (3) when the purpose of conditions under which the forging is to be used so dictates, the requirements shall be as specified in the contract, order or drawing. In such cases, the mechanical properties of test specimens taken from locations indicated on the drawing shall be as specified in the contract, order or drawing (See 6.3.1).

3.3.2.2 Machined Hand Forgings

When hand forgings are machined before heat treatment, the section thickness at time of heat treatment shall determine the minimum mechanical properties as long as the original (as forged) thickness does not exceed the maximum thickness for the alloy as shown in Table 4. When the maximum thickness in Table 4 is exceeded by not more than 3 inches, the applicable thickness to establish properties shall be not less than half the original forged thickness.

3.3.3 Special Purpose Forgings

Biscuits, octagons, mandrel rings, and contour hand forgings shall be classified as special purpose forgings. Mechanical properties of special purpose forgings shall be as negotiated between the contractor and the forging supplier or between the acquiring activity and the forging supplier or contractor (See 6.3.1). Testing to confirm mechanical properties shall be in accordance with 4.4.2.

3.3.4 Rolled Ring Forgings

The mechanical properties of rolled ring forgings shall be determined in accordance with 4.4.2 and shall conform to applicable properties specified in Table 5. For forgings too small to yield suitable test specimens, the method of tensile test shall be waived or negotiated between the contractor and the forging supplier or between the acquiring activity and the forging supplier or contractor (See 6.3.1).

3.3.5 Forging Supplied in “F” or “O1” Conditions

The mechanical properties of forgings supplied in “F” or “O1” conditions shall meet the requirements of Tables 2, 3, 4, and 5, or as required by drawing or contract order when heat treated to specified tempers in accordance with AMS2772.

3.4 Stress-Corrosion Cracking

3.4.1 Resistance to Stress-Corrosion Cracking

Forgings of alloys 7049, 7050, 7075, and 7175 supplied in the T73, T7352, T74, T7452, and T7454 tempers shall meet the following acceptance criteria, as applicable, and shall exhibit no evidence of stress-corrosion cracking when subjected to test specified in 4.4.8.

3.4.2 Acceptance Criteria for Stress-Corrosion Cracking by Conductivity Test

The capability of individual lots (See 4.3.1) to resist stress-corrosion cracking shall be determined by testing as specified in 4.4.9, and using the acceptance criteria specified as follows for the applicable aluminum alloy and temper.

3.4.2.1 7049-T73 and 7049-T7352

The acceptance criteria for the 7049-T73 and 7049-T7352 aluminum alloy forgings shall be as follows:

a. If the electrical conductivity is 40.0 percent International Annealed Copper Standards (IACS) or greater and the tensile properties meet the minimum specified value, the lot is acceptable.

b. If the electrical conductivity is 38.0 to 39.9 percent IACS, inclusive, and the longitudinal yield strength does not exceed the specified minimum by more than 9.9 ksi, the lot is acceptable.

c. If the electrical conductivity is 38.0 to 39.9 percent IACS, inclusive, and the longitudinal yield strength exceeds the specified minimum by 10.0 ksi or more, the lot is acceptable provided it passes the stress-corrosion test specified in 4.4.8.

d. If the electrical conductivity is less than 38.0 percent IACS, the lot is unacceptable.

3.4.2.2 7050-T74 and 7050-T7452

The acceptance criteria for the 7050-T74 and 7050-T7452 aluminum alloy forgings shall be as follows:

a. If the electrical conductivity is 38.0 percent IACS or greater and the longitudinal yield strength (XX.X ksi) minus the electrical conductivity (XX.X percent IACS) is equal to or less than 32.0, the lot is acceptable. For die forgings only, the maximum yield strength shall also be 72 ksi.

b. If the electrical conductivity is 38.0 percent IACS or greater and the longitudinal yield strength (XX.X ksi) minus the electrical conductivity (XX.X percent IACS) is greater than 32.0, the lot is acceptable provided it passes the stress-corrosion test specified in 4.4.8.

c. If the electrical conductivity is less than 38.0 percent IACS, the lot is unacceptable.

3.4.2.3 7075-T73, 7075-T7352, 7075-T74, 7075-T7452, 7175-T74, 7175-T7452, and 7175-T7454

The acceptance criteria for the 7075-T73, 7075-T7352, 7075-T74, 7075-T7452, 7175-T74, 7175-T7452, and 7175-T7454 aluminum alloy forgings shall be as follows:

a. If the conductivity is 40.0 percent IACS or higher and tensile properties meet the minimum values specified herein, the forgings shall be considered satisfactory.

b. If the electrical conductivity is 38.0 to 39.9 percent IACS, inclusive, if tensile properties meet the minimum limits specified herein, and the longitudinal yield strength does not exceed the specified minimum by more than 11.9 ksi, the forgings shall be considered satisfactory.

c. If conductivity is below 40.0 percent IACS and the longitudinal yield strength exceeds the specified minimum value by 12.00 ksi or more, the lot is unacceptable.

d. If the conductivity is below 38.0 percent IACS, the material shall be considered unsatisfactory and must be reprocessed, regardless of property level.

3.5 Indications

3.5.1 Surface Indications

Forgings shall be free of surface defects such as seams, laps, bursts and quench cracks, when inspected as specified in 4.4.4 and 4.4.5.

3.5.2 Internal Indications

Limits of acceptability for ultrasonic inspection shall be in accordance with AMS-STD-2154, Class A for hand and ring forgings and Class B for die forgings, unless limits for acceptability of finished forgings are otherwise specified. Where forging thickness or configuration will not permit ultrasonic inspection, the forging stock shall be ultrasonically inspected to Class A limits as agreed upon by the contractor and the forging supplier. When die forgings are to be used in applications requiring a quality level higher than Class B limits, or for alloys not covered herein, the requirements shall be negotiated among the contractor, forging supplier and acquisition authority (See 4.4.6 and 6.2.1).

3.6 Grain-Flow Characteristics

The grain-flow pattern shall conform to specified forging drawing approved by the acquiring activity (See 6.3.1). Precaution should be taken to avoid simultaneous occurrence of sharply re-entrant flow lines and high tensile stresses in the region of the parting line (See 4.4.7 and 6.3.1).

3.7 Tolerances

The forgings shall conform to the shape and dimensions specified in the contract or purchase order within such variations as may be shown on the drawings (See 6.3.1).

3.8 Marking of Forgings

Forgings shall be marked with the commercial alloy designation and temper, ultrasonic symbol, and the basic specification number in characters that are clearly legible and that shall not be obliterated by ordinary handling. For squares, the marking shall be on the face that is parallel to the direction of the long transverse properties but perpendicular to the direction of short transverse properties. The marking shall not be applied by the impression method, or by an electroetch or engraving method, unless it can be determined that all detrimental effects will be removed by subsequent machining. When specified (See 6.3.1), the marking of the commercial alloy designation, temper, and basic specification number shall be continuous along the forging length (See 4.4.3).

3.9 Workmanship

The forgings shall be of uniform forging quality and condition, free from blisters, fins, folds, seams, laps, cracks, segregations, spongy areas or other indications which would adversely affect their serviceability. Apparent surface defects may be removed as required, provided section thicknesses, as defined by the drawing, can be maintained. Forgings shall not be repaired by plugging or welding.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

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 purchase 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 Classification of Inspections

The inspection requirements specified herein are classified as quality conformance inspections (See 4.3.2).

4.3 Sampling

Sampling for each inspection shall be in accordance with AMS2355. Unless otherwise specified, the sample unit shall be one finished forging and for Section 5 inspection, one container ready for shipment.

4.3.1 Lot

A lot shall consist of forgings of the same shape, same size, same alloy, and heat treated and aged in the same furnace charge. If forgings are heat treated in a continuous furnace, forgings charged consecutively during continuous operation of the furnace shall be considered a furnace charge; for such forgings weighing 5 pounds or less, the maximum weight of a lot shall be 2000 pounds, and for larger forgings, it shall be 6000 pounds.

4.3.2 Examination

4.3.2.1 Surface Defects

4.3.2.1.1 Visual Inspection

Unless otherwise specified, each forging shall be 100 percent visually inspected for surface defects (See 4.4.4).

4.3.2.1.2 Penetrant Inspection

Unless otherwise specified, each forging shall be 100 percent penetrant inspected (See 4.4.5 and 6.3.1).

4.3.2.2 Internal Defects

Unless otherwise specified, all forgings shall be ultrasonically examined for internal defects (See 4.4.6 and 6.3.1).

4.3.2.3 Grain Flow

After the forging technique is established for a required size and shape, one sample from first production lot shall be selected for the grain flow structure examination. This examination shall be repeated after any major change in forging technique (See 4.4.7 and 6.3.1).

4.3.2.4 Stress-Corrosion

Sampling for stress-corrosion cracking and electrical conductivity is applicable when testing forgings of alloy temper combinations 7049-T73, 7049-T7352, 7050-T74, 7050-T7452, 7075-T73, 7075-T7352, 7075-T74, 7075-T7452, 7175-T74, 7175-T7452, and 7175-T7454 for conformance to 3.4.1.

4.3.2.4.1 Stress-Corrosion Surveillance Test

Unless otherwise specified, each month, at least one forging from each shape and thickness range, 0.750 inch and greater, produced during that month from forgings of alloys and tempers noted in 4.3.2.4, shall be sampled for stress-corrosion testing. The samples shall be taken from the forgings determined to be acceptable in accordance with the lot acceptance criteria specified in 3.4.2.

4.3.2.4.2 Electrical Conductivity

Unless otherwise specified, one forging from each lot shall be selected for electrical conductivity test.

4.3.2.5 Heat Treat Capability

Unless otherwise specified, forgings in “F” and “O1” conditions shall be sampled and tested in the same manner as comparable to heat treated forgings. The sample shall be heat treated to the -T6 or -T61 temper, unless otherwise specified, or to the final temper as specified in the part drawing or other acquisition documents.

4.4 Methods of Tests and Examination

4.4.1 Chemical Analysis

Sampling for chemical analysis shall be in accordance with AMS2355. The chemical analysis of the samples shall be wet chemical method or spectro chemical method in accordance with AMS2355. In case of dispute, chemical analysis by wet chemical method shall be the basis for acceptance (See 3.1).

4.4.2 Mechanical Properties

The mechanical properties of the samples shall be determined as specified in AMS2355.

4.4.3 Examination for Marking

Unless otherwise specified, each forging shall be inspected for markings as specified in 3.8.

4.4.4 Visual Inspection of Surface Indications

Prior to visual inspection, each die or ring forging (See 4.3.2.1.1) shall be etched in an aqueous solution of sodium hydroxide containing an inhibitor to prevent intergranular attack of copper bearing alloys. A suitable solution consists of 50 grams of sodium hydroxide and 2.5 grams of sodium sulphide disolved in 1 liter of water. Etching time for this solution maintained at 155 °F ± 5 should be 1 minute. Other inhibited solutions may be used provided, they produce the same etching effect. Subsequently, the parts shall be thoroughly rinsed in water followed by a wash in nitric acid or in chromic-sulphuric acid solution or other solution that shall produce a surface of equivalent suitability for visual or penetrant inspection. After etching, each forging shall be inspected visually for surface indications such as seams, laps, bursts and quench cracks (See 3.5.1). Parts should be thoroughly dried after each etch and rinse operation to prevent fluid entrapment.

4.4.5 Penetrant Inspection

Prior to penetrant inspection, each forging shall be etched (See 4.4.4), dried (See 4.4.4), and penetrant inspected (See 4.3.2.1.2) in accordance with ASTM E 1417, using sensitivity level 2 conforming to AMS2644 to determine conformance to 3.5.1. Penetrant inspection personnel shall be certified to NDT Level 2 in accordance with NAS 410.

4.4.6 Internal Indications

Unless otherwise specified, all forgings (See 4.3.2.2) shall be ultrasonically tested for internal indications in accordance with AMS-STD-2154.

4.4.7 Grain Flow

After the forging technique is established for forging a required size and shape, a sample unit forging, selected as specified in 4.3.2.3, shall be sectioned and suitably etched to show the grain flow of structure. This sectioning shall be repeated after any change in the forging technique. Location of cross sectioning shall be such as to represent principal sections of the forging, or as agreed upon between the contractor and the forging supplier or between the acquiring activity and the forging supplier or contractor.

4.4.8 Resistance to Stress-Corrosion Cracking

Specimens of alloys and tempers specified in 4.3.2.4, selected for stress-corrosion testing, shall be prepared and tested in accordance with ASTM G 47. The stress-corrosion test stress level for each alloy temper combination shall be in accordance with 4.4.8.1.

4.4.8.1 Stress-Corrosion Test Stress Level

Unless otherwise specified, the stress level shall be 75 percent of the longitudinal yield strength as specified in Tables 2 and 4 for alloys 7049 and 7075. The stress level for 7050 alloy shall be 35 ksi. The stress level of alloy 7175 shall be 35 ksi, except for alloy 7175 hand forgings exceeding 3.000 inches, where the stress level shall be 50 percent of the longitudinal yield strength specified in Table 4.

4.4.9 Electrical Conductivity

Forgings for alloys and tempers selected for conductivity testing (See 4.3.2.4.2) shall be prepared and tested in accordance with AMS2658 to the criteria specified in 3.4.2.1 through 3.4.2.3.

4.4.10 Special Inspection Procedures

When special purpose or large forgings are specified, the inspection procedure, as related to the number and location of test samples taken from the sample forgings, shall be as agreed upon between the contractor, forging supplier and the acquiring activity.

4.5 Rejection and Retests

4.5.1 Rejection

If any individual test specimen fails to conform to this specification, the lot represented by the specimen shall be rejected.

4.5.2 Retests

If a lot of material is rejected, retests of that lot shall be permitted in accordance with the provisions of AMS2355 by:

a. Taking twice the original number of test specimens from an area in the original sample forging adjacent to the area represented by the failure.

b. Taking the original number of test specimens from an area in each of two other forgings identical to the area in the original sample forgings represented by the failure.

c. Both failing initial test data and passing retest data shall be retained with the production records.

Should any of these specimens fail to conform to this specification, the entire lot shall be rejected.

5. PACKAGING

5.1 Preservation, Packing and Marking

Preservation, packing and marking shall be in accordance with ASTM B 660. The level of preservation shall be Level A or Commercial and packing shall be Level A, B or Commercial as specified (See 6.3.1).

6. NOTES

6.1 A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

6.2 Intended Use

The aluminum alloy forgings of this specification have characteristics that are intended for use in critical aerospace applications, as follows:

6.2.1 2014

Alloy 2014 is most commonly used for general applications where high strength is essential, however, special care should be taken in the application of this alloy because of susceptibility to stress-corrosion cracking.

6.2.2 2219

Alloy 2219 is used for applications which require good weldability and uniformity of strength of welds, moderate strength at room temperature and high strength in the range of 500 to 600 °F.

6.2.3 2618

Alloy 2618 is used for elevated temperature (approximately 575 °F) applications.

6.2.4 6061

Alloy 6061 is most commonly used for structural applications where strength, weldability and corrosion resistance are needed.

6.2.5 6151

Alloy 6151 is used for applications requiring good forgeability, good strength and resistance to corrosion.

6.2.6 7049-T73

Alloy 7049-T73 is recommended for applications requiring high strength and high resistance to stress-corrosion cracking.

6.2.7 7050

Alloy 7050 is recommended for applications requiring high strength and resistance to stress-corrosion.

6.2.8 7075

Alloy 7075 is used for small and medium sized forgings where maximum weight saving is essential. Special care should be taken in the application of this alloy in temper other than T73 because of susceptibility to stress-corrosion cracking.

6.2.9 7075-T73

Alloy 7075-T73 is recommended for components which are subjected to assembly stresses in transverse direction because of its stress-corrosion resistance.

6.2.10 7175

Alloy 7175 is recommended for applications requiring high strength and resistance to stress-corrosion.

6.3 Ordering Data

6.3.1 Acquisition Requirements

Acquisition documents should specify the following:

a. Title, number and date of this specification.

b. Alloy designation, temper, method of forging (See 1.2.1 and 1.2.2) and grain-flow pattern, if required (See 3.6).

c. Applicable drawings (See 3.3.2.1 and 3.6).

d. Applicable levels of preservation and packaging required (See 5.1).

e. The percent of parts to be inspected, when less than 100 percent ultrasonic inspection is required (See 4.3.2.2).

f. Ultrasonic inspection acceptance criteria, if other than required by 3.5.2.

g. The percent of parts to be inspected, when less than 100 percent penetrant inspection of die forgings is required (See 4.3.2.1.2).

h. Special markings (See 3.8).

i. For special purposes and large forgings or any other options desired (See 3.3.3 and 6.4).

j. For as-forged thickness of die forgings greater than twice the heat treated thickness, the properties shall be waived or negotiated between the contractor and forging supplier or between the acquiring activity and the forging supplier or contractor (See 3.3.1).

k. For forgings too small to yield suitable test specimens, the tension test shall be waived or negotiated between the contractor and forging supplier or between the acquiring activity and the forging supplier or contractor (See 3.3.1.1, 3.3.2, and 3.3.4).

6.4 Special Purposes and Large Forgings

Attention is called to the references herein to special purpose or large forgings, for which special mechanical properties and inspection procedures are necessary. Special attention should be given to including all special instructions on the drawings and orders so that tensile properties and grain flow will be determined at the desired areas, and to the determination of properties, particularly ductility and tensile yield strength in directions normal to the observed grain flow in critically stressed areas in the forging.

6.5 Hardness

For information, the minimum Brinell hardness (500 Kgf load, 10 mm diameter ball) usually measured on the surface of the properly heat treated forgings is shown in Table 6.

6.6 Change in Temper Designation

Tempers T736 and T73652 of alloys 7050, 7075 and 7175 have been designated as T74 and T7452, respectively. Temper T73654 of alloy 7175 has been designated as T7454.

6.7 The following table contains recommended AMS for available combinations of alloy and temper:

ALLOY/TEMPER	APPLICABLE SAE/AMS SPECIFICATION
2014-t6	AMS4133 Aluminum alloy forgings and rolled rings 4.4Cu 0.85Si 0.80Mn 0.50Mg (2014-T6) Solution and Precipitation Heat Treated
2014-T652	AMS4314 Aluminum Alloy, Rings, Rolled or Forged 4.5Cu 0.85Si 0.80Mn 0.50Mg (2014-T651, 2014-T652) Solution Heat Treated, Mechanically Stress Relieved and Precipitation Heat Treated
2219-T6	AMS4143 Aluminum Alloy, Forgings and Rolled or Forged Rings 6.3Cu 0.3Mn 0.18Zr 0.10V 0.06Ti (2219-T6) Solution and Precipitation Heat Treated
2219-T852	AMS4144 Aluminum Alloy, Hand Forgings and Rolled Rings 6.3Cu 0.30Mn 0.18Zr 0.10V 0.06Ti (2219-T852/T851) Solution Heat Treated, Mechanically Stress Relief, and Precipitation Heat Treated
2618-T61	AMS4132 Aluminum Alloy, Die and Hand Forgings, Rolled Rings, and Forging Stock 2.3Cu 1.6Mg 1.1Fe 1.0Ni 0.18Si 0.07Ti (2618-T61) Solution and Precipitation Heat Treated
6061-T6	AMS4127 Aluminum Alloy, Forgings and Rolled or Forged Rings, (6061-T6) Solution and Precipitation Heat Treated
6061-T652	AMS4312 Aluminum Alloy, Rolled or Forged Rings 1.0Mg 0.60Si 0.28Cu 0.20Cr (6061-T651, 6061-T652) Solution Heat Treated, Mechanically Stress Relieved, and Precipitation Heat Treated AMS4248 Aluminum Alloy, Hand Forgings and Rolled Rings 1.0Mg 0.60Si 0.28Cu 0.20Cr (6061-T652) Solution Heat Treated, Stress Relief by Compression, and Precipitation Heat Treated
6151-T6	AMS4125 Aluminum Alloy Die Forgings, and Rolled or Forged Rings 0.90Si 0.62Mg 0.25Cr Solution and Precipitation Heat Treated
7049-T73	AMS4111 Aluminum Alloy, Forgings 7.7Zn 2.5Mg 1.5Cu 0.16Cr, Solution and Precipitation Heat Treated
7049-t7352	AMS4247 Aluminum Alloy, Hand Forgings 7.7Zn 2.4Mg 1.6Cu 0.16Cr (7049-T7352) Solution Heat Treated, Stress Relieved by Compression, and Precipitation Heat Treated
7050-T74	AMS4107 Aluminum Alloy Die Forgings (7050-T74) Solution Heat Treated and Overaged
7050-T7452	AMS4333 Aluminum Alloy, Die Forgings, 6.2Zn 2.3Cu 2.2Mg 0.12Zr (7050-T7452), Solution Heat Treated, Compression Stress-Relieved, and Overaged
7075-T6	AMS4122 Aluminum Alloy, Bars, Rods, and Wire Rolled or Cold Finished, and Rings, 5.6Zn 2.5Mg 1.6Cu 0.23Cr (7075-T6) Solution and Precipitation Heat Treated
7075-T652	AMS4310 Aluminum Alloy, Rolled or Forged Rings, 5.6Zn 2.5Mg 1.6Cu 0.23Cr (7075-T651, 7075-T652) Solution Heat Treated, Mechanically Stress Relieved, and Precipitation Heat Treated
7075-T73	AMS4141 Aluminum Alloy Die Forgings, 5.6Zn 2.5Mg 1.6Cu 0.23Cr (7075-T73) Solution and Precipitation Heat Treated
7075-T7352	AMS4311 Aluminum Alloy, Rolled or Forged Rings 5.6Zn 2.5Mg 1.6Cu 0.23Cr (7075-T7351, 7075-T352) Solution Heat Treated, Mechanically Stress Relieved, and Precipitation Heat Treated AMS4147 Aluminum Alloy, Forgings 5.6Zn 2.5Mg 1.6Cu 0.23Cr Solution Heat Treated, Stress Relieved by Compression, and Overaged
7075-T74	AMS4131 Aluminum Alloy, Die and Hand Forgings 5.6Zn 2.5Mg 1.6Cu 0.23Cr (7075-T-74), Solution and Precipitation Heat Treated and Aged
7075-T7452	AMS4323 Aluminum Alloy, Hand Forgings 5.6Zn 2.5Mg 1.6Cu 0.23Cr (7075-T7452) Solution Heat Treated, Stress Relieved, and Precipitation Heat Treated
7175-T74	AMS4149 Aluminum Alloy, Die and Hand Forgings 5.6Zn 2.5Mg 1.6Cu 0.23Cr (7175-T74) Solution and Precipitation Heat Treated
7175-T7452	AMS4179 Aluminum Alloy Forgings 5.6Zn 2.5Mg 1.6Cu 0.23Cr (7175-T7452) Solution Heat Treated, Stress Relieved, and Precipitation Heat Treated

TABLE 1 - CHEMICAL COMPOSITION 1/, 2/

Alloy	Copper	Silicon	Iron	Manganese	Magnesium	Zinc	Chromium	Titanium	Zirconium	Vanadium	Nickel	Other elements each	Other elements total	Aluminum
2014	3.9-5.0	0.50-1.2	0.7	0.40-1.2	0.20-0.8	0.25	0.10	0.15	---	---	---	0.05	0.15	Remainder
2219	5.8-6.8	0.20	0.30	0.20-0.40	0.02	0.10	---	0.02-0.10	0.10-0.25	0.05-0.15	---	0.05	0.15	Remainder
2618	1.9-2.7	0.10-0.25	0.9-1.3	---	1.3-1.8	0.10	---	0.04-0.10	---	---	0.9-1.2	0.05	0.15	Remainder
6061	0.15-0.40	0.40-0.8	0.7	0.15	0.8-1.2	0.25	0.04-0.35	0.15	---	---	---	0.05	0.15	Remainder
6151	0.35	0.6-1.2	1.0	0.20	0.45-0.8	0.25	0.15-0.35	0.15	---	---	---	0.05	0.15	Remainder
7049	1.2-1.9	0.25	0.35	0.20	2.0-2.9	7.2-8.2	0.10-0.22	0.10	---	---	---	0.05	0.15	Remainder
7050	2.0-2.6	0.12	0.15	0.10	1.9-2.6	5.7-6.7	0.04	0.06	0.08-0.15	---	---	0.05	0.15	Remainder
7075	1.2-2.0	0.40	0.50	0.30	2.1-2.9	5.1-6.1	0.18-0.28	0.20	---	---	---	0.05	0.15	Remainder
7175	1.2-2.0	0.15	0.20	0.10	2.1-2.9	5.1-6.1	0.18-0.28	0.10	---	---	---	0.05	0.15	Remainder

1/ Analysis shall be made only for the elements specifically mentioned in the above table. If, however, the presence of other elements are 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.

2/ Percentage figures are maximum allowed, except where a range is indicated.

TABLE 2 - MECHANICAL PROPERTIES OF DIE FORGINGS, SPECIMEN AXIS PARALLEL TO DIRECTION OF GRAIN FLOW LINES 1/

Alloy and temper 2/	Maximum heat treat section thickness, inches	Minimum tensile strength, ksi 3/	Minimum yield strength at 0.2 percent offset, ksi 3/	Minimum elongation in 2 inches or 4D 4/, percent 3/
2014-T6	Up thru 2	65.0	56.0	6
	Over 2 thru 3	65.0	55.0	6
	Over 3 thru 4	63.0	55.0	6
2219-T6	Up thru 4	58.0	38.0	8
2618-T61	Up thru 4	58.0	45.0	4
6061-T6	Up thru 4	38.0	35.0	7
6151-T6	Up thru 4	44.0	37.0	10
7049-T73	Up thru 2	72.0	62.0	7
	Over 2 thru 4	71.0	61.0	7
	Over 4 thru 5	70.0	60.0	7
7050-T74 5/	Up thru 2	72.0	62.0	7
	Over 2 thru 4	71.0	61.0	7
	Over 4 thru 5	70.0	60.0	7
	Over 5 thru 6	70.0	59.0	7
7075-T6	Up thru 1	75.0	64.0	7
	Over 1 thru 2	74.0	63.0	7
	Over 2 thru 3	74.0	63.0	7
	Over 3 thru 4	73.0	62.0	7
7075-T73	Up thru 3	66.0	56.0	7
	Over 3 thru 4	64.0	55.0	7
7075-T7352	Up thru 3	66.0	56.0	7
	Over 3 thru 4	64.0	53.0	7
7075-T74 5/	Up thru 3	76.0	66.0	7
7175-T74 5/	Up thru 3	76.0	66.0	7
7175-T7452 6/	Up thru 3	73.0	63.0	7
7175OT7454 7/	Up thru 3	75.0	65.0	7

1/ The parallel direction of specimens shall be ± 15 degrees.

2/ Die forgings in some configurations of these alloys can be purchased in the heat treated and compression stress relieved T652 temper conforming to the mechanical property requirements specified for T6 temper, respectively.

3/ Tensile property test requirements may be waived or negotiated between the contractor and the forging supplier or between the acquiring activity and the forging supplier or contractor for material in any direction in which the dimension is less than 2 inches because of the difficulty to obtain a tension test specimen suitable for routine control testing (see 6.2.1).

4/ D represents specimen diameter.

5/ Formerly designated as T736 temper.

6/ Formerly designated as T73652 temper.

7/ Formerly designated as T73654 temper.

TABLE 3 - MECHANICAL PROPERTIES OF DIE FORGINGS, SPECIMEN AXIS NOT PARALLEL TO DIRECTION OF GRAIN FLOW LINES 1/

Alloy and temper 2/	Maximum heat treat section thickness, inches	Minimum tensile strength, ksi 3/	Minimum yield strength at 0.2 percent offset, ksi 3/	Minimum elongation in 2 inches or 4D 4/, percent 3/
2014-T6	Up thru 1	64.0	55.0	3
	Over 1 thru 2	64.0	55.0	2
	Over 2 thru 3	63.0	54.0	2
	Over 3 thru 4	63.0	54.0	2
2219-T6	Up thru 4	56.0	36.0	4
2618-T61	Up thru 4	55.0	42.0	4
6061-T6	Up thru 4	38.0	35.0	5
6151-T6	Up thru 4	44.0	37.0	6
7049-T73	Up thru 1	71.0	61.0	3
	Over 1 thru 3	70.0	60.0	3
	Over 3 thru 4	70.0	60.0	2
	Over 4 thru 5	68.0	58.0	2
7050-T74 5/	Up thru 2	68.0	56.0	5
	Over 2 thru 4	67.0	55.0	4
	Over 4 thru 6	66.0	54.0	3
7075-T6	Up thru 1	71.0	61.0	3
	Over 1 thru 2	71.0	61.0	3
	Over 2 thru 3	70.0	60.0	3
	Over 3 thru 4	70.0	60.0	2
7075-T73	Up thru 3	62.0	53.0	3
	Over 3 thru 4	61.0	52.0	2
7075-T7352	Up thru 3	62.0	51.0	3
	Over 3 thru 4	61.0	49.0	2
7075-T74 5/	Up thru 3	71.0	62.0	4
7175-T74 5/	Up thru 3	71.0	62.0	4
7175-T7452 5/	Up thru 3	68.0	55.0	4
7175-T7454 7/	Up thru 3	70.0	61.0	4

1/ The parallel direction of specimens shall be ± 15 degrees.

2/ Die forgings in some configurations of these alloys can be purchased in the heat treated and compression stress relieved T652 temper conforming to the mechanical property requirements specified for T6 temper, respectively.

3/ Tensile property test requirements may be waived or negotiated between the contractor and the forging supplier or between the acquiring activity and the forging supplier or contractor for material in any direction in which the dimension is less than 2 inches because of the difficulty to obtain a tension test specimen suitable for routine control testing (see 6.2.1).

4/ D represents specimen diameter.

5/ Formerly designated as T736 temper.

6/ Formerly designated as T73652 temper.

7/ Formerly designated as T73654 temper.

TABLE 4 - MECHANICAL PROPERTIES OF HAND FORGINGS 1/, 7/

Alloy and temper	Maximum heat treat section thickness, inches 4/	Axis of test specimen	Minimum tensile strength, ksi 2/	Minimum yield strength at 0.2 percent offset, ksi 2/	Minimum elongation in 2 inches or 4D 3/, percent 2/
2014-T6	Up thru 2	Longitudinal	65.0	56.0	8
		Long trvs.	65.0	56.0	3
	Over 2 thru 3	Longitudinal	64.0	56.0	8
		Long trvs.	64.0	55.0	3
		Short trvs.	62.0	55.0	2
	Over 3 thru 4	Longitudinal	63.0	55.0	8
		Long trvs.	63.0	55.0	3
		Short trvs.	61.0	54.0	2
	Over 4 thru 5	Longitudinal	62.0	54.0	7
		Long trvs.	62.0	54.0	2
		Short trvs.	60.0	53.0	1
	Over 5 thru 6	Longitudinal	61.0	53.0	7
		Long trvs.	61.0	53.0	2
		Short trvs.	59.0	53.0	1
	Over 6 thru 7	Longitudinal	60.0	52.0	6
		Long trvs.	60.0	52.0	2
		Short trvs.	58.0	52.0	1
	Over 7 thru 8	Longitudinal	59.0	51.0	6
		Long trvs.	59.0	51.0	2
		Short trvs.	57.0	51.0	1
2014-T652	Up thru 2	Longitudinal	65.0	56.0	8
		Long trvs.	65.0	56.0	3
	Over 2 thru 3	Longitudinal	64.0	56.0	8
		Long trvs.	64.0	55.0	3
		Short trvs.	62.0	52.0	2
	Over 3 thru 4	Longitudinal	63.0	55.0	8
		Long trvs.	63.0	55.0	3
		Short trvs.	61.0	51.0	2
	Over 4 thru 5	Longitudinal	62.0	54.0	7
		Long trvs.	62.0	54.0	2
		Short trvs.	60.0	50.0	1
	Over 5 thru 6	Longitudinal	61.0	53.0	7
		Long trvs.	61.0	53.0	2
		Short trvs.	59.0	50.0	1
	Over 6 thru 7	Longitudinal	60.0	52.0	6
		Long trvs.	60.0	52.0	2
		Short trvs.	58.0	49.0	1
	Over 7 thru 8	Longitudinal	59.0	51.0	6
		Long trvs.	59.0	51.0	2
		Short trvs.	57.0	48.0	1
2219-T6	Up thru 4	Longitudinal	58.0	40.0	6
		Long trvs.	55.0	37.0	4
		Short trvs.	53.0	35.0	2

TABLE 4 - MECHANICAL PROPERTIES OF HAND FORGINGS 1/, 7/ (CONTINUED)

Alloy and temper	Maximum heat treat section thickness, inches 4/	Axis of test specimen	Minimum tensile strength, ksi 2/	Minimum yield strength at 0.2 percent offset, ksi 2/	Minimum elongation in 2 inches or 4D 3/, percent 2/
2219-T852	Up thru 4	Longitudinal	62.0	50.0	6
		Long trvs.	62.0	49.0	4
		Short trvs.	60.0	46.0	3
2618-T61	Up thru 2	Longitudinal	58.0	47.0	7
		Long trvs.	55.0	42.0	5
		Short trvs.	52.0	42.0	4
	Over 2 thru 3	Longitudinal	57.0	46.0	7
		Long trvs.	55.0	42.0	5
		Short trvs.	52.0	42.0	4
	Over 3 thru 4	Longitudinal	56.0	45.0	7
		Long trvs.	53.0	40.0	5
		Short trvs.	51.0	39.0	4
6061-T6	Up thru 4	Longitudinal	38.0	35.0	10
		Long trvs.	38.0	35.0	8
		Short trvs.	37.0	33.0	5
	Over 4 thru 8	Longitudinal	37.0	34.0	8
		Long trvs.	37.0	34.0	6
		Short trvs.	35.0	32.0	4
7049-T73	Over 2 thru 3	Longitudinal	71.0	61.0	9
		Long trvs.	71.0	59.0	4
		Short trvs.	69.0	58.0	3
	Over 3 thru 4	Longitudinal	69.0	59.0	8
		Long trvs.	69.0	57.0	3
		Short trvs.	67.0	56.0	2
	Over 4 thru 5	Longitudinal	67.0	56.0	7
		Long trvs.	67.0	56.0	3
		Short trvs.	66.0	55.0	2
7049-T7352	Over 1 thru 3	Longitudinal	71.0	59.0	9
		Long trvs.	71.0	57.0	4
		Short trvs.	69.0	56.0	3
	Over 3 thru 4	Longitudinal	69.0	57.0	8
		Long trvs.	69.0	54.0	3
		Short trvs.	67.0	53.0	2
	Over 4 thru 5	Longitudinal	67.0	54.0	7
		Long trvs.	67.0	53.0	3
		Short trvs.	66.0	51.0	2
7050-T452	Up thru 2	Longitudinal	72.0	63.0	9
		Long trvs.	71.0	61.0	5
	Over 2 thru 3	Longitudinal	72.0	62.0	9
		Long trvs.	70.0	60.0	5
		Short trvs.	67.0	55.0	4