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Standard Practice for Heat Treatment of Magnesium Alloys[1]

This standard is issued under the fixed designation B661; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This practice is intended as an aid in establishing a suitable procedure for the heat treatment of magnesium alloys to assure proper physical and mechanical properties.

1.2 Times and temperatures are typical for various forms, sizes, and manufacturing methods and may not exactly describe the optimum heat treatment for a specific item. Consequently, it is not intended that this practice be used as a substitute for a detailed production process or procedure.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

B557 Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products

E21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *aging*—Describes a time-temperature-dependent change in the properties of certain alloys. Except for strain aging and age softening, it is the result of precipitation from a solid solution of one or more compounds whose solubility decreases with decreasing temperature. For each alloy susceptible to aging, there is a unique range of time-temperature combinations to which it will respond.

3.1.2 *heat treatment*—A combination of heating and cooling operations applied to a metal or alloy in the solid state to obtain desired conditions of properties. Heating for the sole purpose of hot working is excluded from the meaning of this definition.

3.1.3 *solution heat treatment*—A treatment in which an alloy is heated to a suitable temperature and held at this temperature for a sufficient length of time to allow a desired constituent to enter into solid solution, followed by rapid cooling to hold the constituent in solution. The material is then in a supersaturated, unstable state, and may subsequently exhibit Age Hardening.

3.1.4 *quenching*—Rapid cooling. When applicable, the following more specific terms should be used: still air quenching, forced air quenching, hot water/polymer quenching.

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

3.1.6 *T5*—Artificially aged only: Applied to products which are artificially aged after an elevated-temperature rapid-cool fabrication process, such as casting or extrusion, to improve mechanical properties or dimensional stability, or both.

3.1.7 *T6*—Solution heat-treated and then artificially aged: Applies to products which are not cold worked after solution heat-treatment.

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[1] This practice is under the jurisdiction of ASTM Committee B07 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.04 on Magnesium Alloy Cast and Wrought Products.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

4. Apparatus

4.1 Furnaces used for the heat treatment of magnesium are usually of the air chamber type and may be electrically heated or oil- or gas-fired. Because of the atmospheres used for solution heat treatment, furnaces must be gas tight and contain suitable equipment for the introduction of protective atmospheres, and means for control of those atmospheres. In order to promote uniformity of temperature, furnaces should be equipped with a high-velocity fan or comparable means for circulating the atmosphere. In the design of the furnace it is desirable that there be no direct radiation from the heating elements or impingement of the flame on the magnesium.

4.2 Automatic recording and control equipment to control the temperature of the furnaces, which must be capable of maintaining temperature in the working zone to within ±10°F (±6°C) of the specified temperature.

4.3 There must be a separate manual reset safety cutout which will turn off the heat source in the event of any malfunctioning or failure of the regular control equipment. These safety cutouts shall be set as closely as practicable above the maximum temperature for the alloy being heat treated. This will be above the variation expected, but shall not be more than 10°F (6°C) above the maximum solution heat treating temperature for the alloy being heat treated. Protective devices shall also be installed to turn off the heat source in case of stoppage of circulation of air, and they shall be interconnected with a manual reset control.

4.4 The furnaces or ovens used for aging treatments may be heated by means of electricity, gas, or oil. The temperature at any point in the working zone, for any charge, shall be maintained within ±10°F (±6°C) of the desired aging temperature after the furnace has been brought up to the aging temperature.

4.5 *Quenching:*

4.5.1 Normally magnesium work loads are cooled in air. This should be by fan cooling the furnace charge after removal from the furnace in such a way that the cooling is uniform on various parts of the furnace charge.

4.5.2 Some alloys (notably EV31A, EQ21A, and QE22A) are quenched in water or other suitable media from the solution heat treating temperature. Quench facilities should be situated near the heat treatment furnaces. If required, means of heating the quench medium should be provided. Handling equipment shall be such that it is possible to quench heat treatment loads within 30 s after the opening of the furnace door.

5. Calibration and Standardization

5.1 *Calibration of Equipment:*

5.1.1 *Surveys:*

5.1.1.1 Perform a temperature survey, to ensure compliance with the applicable recommendations presented herein for each furnace.

5.1.1.2 Make a new temperature survey after any changes in the furnace that may affect operational characteristics.

5.1.2 *Furnace Calibration:*

5.1.2.1 Make the initial temperature survey at the maximum and minimum temperature of solution heat treatments and aging heat treatment for which each furnace is to be used. There shall be at least one test location for each 25 ft^3 (0.7 m^3) of air furnace volume up to a maximum of 40 test locations with a minimum of nine test locations.

5.1.2.2 After the initial survey, survey each furnace monthly, except as provided in 5.1.2.7. The monthly survey shall be at one operating temperature for solution heat treatment and one for aging heat treatment.

5.1.2.3 For the monthly surveys there shall be at least one test location for each 40 ft^3 (1.13 m^3) load volume.

5.1.2.4 For furnaces of 10 ft^3 (0.28 m^3) or less the temperature survey may be made with a minimum of three thermocouples located at front, center, and rear, or at top, center, and bottom of the furnace.

5.1.2.5 Perform the surveys in such manner as to reflect the normal operating characteristics of the furnace. If the furnace is normally charged after being stabilized at the correct operating temperature, similarly charge the temperature-sensing elements. If the furnace is normally charged cold, charge the temperature-sensing elements cold. After insertion of the temperature-sensing elements, readings should be taken frequently enough to determine when the temperature of the hottest region of the furnace approaches the bottom of the temperature range being surveyed. From that time until thermal equilibrium is reached, the temperature of all test locations should be determined at 2-min intervals in order to detect any overshooting. After thermal equilibrium is reached, readings should be taken at 5-min intervals for sufficient time to determine the recurrent temperature pattern, but for not less than 30 min. Before thermal equilibrium is reached, none of the temperature readings should exceed the maximum temperature of the range being surveyed. After thermal equilibrium is reached, the maximum temperature variation of all elements (both load and furnace thermocouples) shall not exceed 20°F (11°C) and shall not vary outside the range being surveyed.

5.1.2.6 For furnaces used only for treatments other than solution heat treatment, after the initial temperature uniformity survey as outlined in 5.1.2.5, surveys need not be made more often than at each 6-month interval, provided that (*a*) test specimens from each lot are tested and meet applicable material specifications requirements, (*b*) the furnace is equipped with a multipoint recorder, or (*c*) one or more separate load thermocouples are employed to measure and record actual metal temperatures.

5.1.2.7 Monthly surveys for batch furnaces are not necessary when the furnace is equipped with a permanent multipoint recording system with at least two sensing thermocouples in each working zone, or when one or more separate load thermocouples