Process Specification for the Heat Treatment of Aluminum Alloys

Engineering Directorate

Structural Engineering Division

August 2009

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

Process Specification for the Heat Treatment of Aluminum Alloys

Prepared by: ***Signature on file*** — ***8/10/09***
John D. Figert — Date
Materials & Processes
Branch /ES4

Approved by: ***Signature on file*** — ***8/10/09***
Brad S. Files, — Date
Chief, Materials &
Processes Branch /ES4

REVISIONS		
VERSION	CHANGES	DATE
Baseline	Original version	5/96
A	Expanded sec. 3.0, furnace chart info., tensile requirements, conductivity measurements	5/27/98
B	Changed Training Requirements, Changed Tensile Test Requirements from ASTM E8 to ASTM B557, Require Tensile Test Coupons for Solution Heat Treatment	7/21/99
C	Modified Training Requirements, Labeling Tensile Bars & Stock	2/24/00

D	Included Information on Postweld Heat Treatment, Reduced Labeling Tensile Bars & Stock Requirements, Additional Word Definitions	8/24/00
E	Update document due to reorganization from EM2 to ES4	1/20/04
F	Reviewed for accuracy and updated author.	10/04/06
G	Clarified the Usage statement	8/10/09

1.0 SCOPE

This process specification establishes the engineering requirements for the heat treatment of aluminum alloys.

2.0 APPLICABILITY

This specification shall be applicable whenever the heat treatment of aluminum alloys is invoked per section 3.0, "Usage".

3.0 USAGE

The material to be heat treated shall be listed on the drawing in the heat treat condition in which the material is to be procured. Availability of product forms and tempers may be obtained from the manufacturing production controller or from the ES4 materials engineer.

This process specification shall be called out on the engineering drawing by using an appropriate drawing note. The specific process or combination of heat treat processes shall be noted, along with the final temper. For example:

AGE HARDEN TO T7351 TEMPER PER NASA/JSC PRC-2002.

or

SOLUTION HEAT TREAT AND AGE HARDEN TO THE T6 TEMPER PER NASA/JSC PRC-2002.

If an aluminum alloy is to be formed, the age hardening process should occur after forming and should be noted on the drawing. For example:

AGE HARDEN TO T73 TEMPER PER NASA/JSC PRC-2002 AFTER FORMING.

The solution heat treatment of aluminum alloys often involves quenching parts or raw material from temperatures above 900°F into water, which can cause considerable distortion and high residual stresses. **Designers should consult with an ES4 materials engineer when considering designs that require solution heat treatment of aluminum parts. When the heat treating process includes solution heat treatment or quenching, tensile tests are required.** Sample parts must be of similar thickness and mass as the production parts or shall be parted from production parts after quenching.

Most postweld heat treat operations, if required, on aluminum alloys are generally solution heat treatments (and quenching), solution heat treatments (and quenching) plus aging, or aging. A qualified welding procedure for the specific application needs to be reviewed before making the postweld heat treat note. For example:

AFTER WELDING, SOLUTION HEAT TREAT AND AGE HARDEN TO THE T6 TEMPER PER NASA/JSC PRC-2002.

3.1 NOTATIONS RELATED TO HARDNESS AND CONDUCTIVITY TESTS

Normally, verification of aluminum heat treat is achieved by measuring hardness and conductivity. When hardness impressions are to be made on the actual part, a site is chosen by the designer and materials engineer that will not be detrimental to the function of the finished part. If no sample part is used, conductivity shall also be measured on the actual part. Special instructions must be included on the engineering drawing, such as:

HARDNESS AND CONDUCTIVITY TESTS SHALL BE PERFORMED ON ACTUAL PART IN LOCATION SPECIFIED.

Sample parts may be used to verify heat treat instead of the actual part. Sample parts shall be sketched and/or described on the engineering drawing. They may have a simplified contour and may use nominal dimensioning. Sample parts shall be made from the same raw material lot and processed before heat treatment in an identical manner as the production parts. When hardness and conductivity tests are to be performed on a sample part, the following notation should be included on the engineering drawing:

HARDNESS AND CONDUCTIVITY TESTS SHALL BE PERFORMED ON SAMPLE PART.

3.2 NOTATIONS RELATED TO TENSILE TESTS

For more critical parts, tensile testing may be warranted. Sample pieces for tensile coupons shall be machined from the same raw material lot and processed before heat treatment in an identical manner as the production parts. When tensile testing is necessary, the number of coupons, grain direction, and any special acceptance criteria shall be noted on the drawing. For example:

TENSILE TESTING IS REQUIRED AND SHALL BE PERFORMED ON SAMPLE PART(S). SAMPLE PARTS SHALL CONSIST OF THREE 6" LENGTHS OF THE SAME LOT OF MATERIAL USED FOR PRODUCTION PARTS.

4.0 REFERENCES

All documents listed are assumed to be the current revision unless a specific revision is listed.

ASTM B557	American Society for Testing and Materials Specification, *Standard Test Methods of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products*
ASTM E18	American Society for Testing and Materials Specification, *Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*
MMPDS	Handbook, *Metallic Materials Properties Development and Standardization*
SAE AMS 2658	Society of Automotive Engineers Aerospace Material Specification, *Hardness and Conductivity Inspection of Wrought Aluminum Alloy Parts*
SAE AMS 2770E	Society of Automotive Engineers Aerospace Material Specification, *Heat Treatment of Wrought Aluminum Alloy Parts*
TI-2000-01	Training Instruction: Training for Heat Treat Personnel

SAE ARP 1962	Training and Approval of Heat-Treating Personnel

The following references were used in developing this process specification:

SOP-007.1	Preparation and Revision of Process Specifications
JSC 8500C	Engineering Drawing System Requirements

5.0 MATERIALS REQUIREMENTS

None identified.

6.0 PROCESS REQUIREMENTS

All heat treatment of aluminum alloys shall comply with SAE AMS 2770E and the engineering drawing requirements. Where two equivalent aging temperatures are listed for a given process, the lower aging temperature shall be used. All parts shall be heat treated before final machining, unless otherwise specified on the engineering drawing.

Sample parts (e.g. for hardness, conductivity, or tensile measurements) shall be processed before heat treatment in an identical manner as the production parts. Sample parts must be heat treated simultaneously with the production parts. If production parts have to be processed in more than one batch, each batch must have its own set of sample bars.

Tools and equipment shall be as-specified in SAE AMS 2770E. Safety precautions and warning notes shall be as-specified in SAE AMS 2770E.

7.0 PROCESS QUALIFICATION

Not required. However, work instructions shall be generated for implementing this process specification. The work instructions shall contain sufficient detail to ensure that the manufacturing process produces consistent, repeatable products that comply with this specification.

8.0 PROCESS VERIFICATION

Verification of furnace temperatures shall be accomplished by recording the furnace temperatures on strip charts or other suitable hard copy recordings.

Furnace charts for heat treatment shall be maintained with the hardware's work order router package.

Verification of aluminum heat treat is normally achieved by measuring hardness and conductivity. Hardness impressions shall be made per ASTM E18 on the actual part at the location specified on the engineering drawing or on the samples heat treated together with the part. Hardness and conductivity measurements must meet the acceptance values listed in SAE AMS-2658.

When tensile tests are required, specimens shall be machined according to ASTM B557, using full-sized coupons whenever possible. Testing shall be performed according to ASTM B557 by either the JSC Structures Test Laboratory or an accredited mechanical testing laboratory. Tensile test results for aluminum alloys shall meet the minimum values listed in MMPDS.

Labeling of stock material prior to the heat treatment shall include the material lot (certification #). Labeling of the stock material shall either be done by stenciling or by using stainless tags and stainless wire. Stainless tags shall be stenciled.

Tensile bars or tensile coupons shall be individually labeled immediately after manufacture. Label information shall always include material lot (certification #). If the tensile bars or tensile coupons are made prior to heat treating, the tensile bars or tensile coupons shall be labeled using austenitic stainless tags and austenitic stainless wire. If the tensile bars or tensile coupons are made after heat treating, cotton string and paper tags may be used instead of stainless tags and wire. Paper tags shall include material type, the material lot (certification #), and the work order router number.

9.0 TRAINING AND CERTIFICATION OF PERSONNEL

All heat treatment of aluminum alloys used on flight hardware shall be performed by qualified operators who have been certified according to the requirements in TI-2000-01, Training for Heat Treat Personnel. For vendors, a training program consistent with the recommended practices in SAE ARP 1962 shall be required.

10.0 DEFINITIONS

Age Harden	A heat treatment process, which consists of applying a relatively low temperature for sufficient time to strengthen the alloy to the desired temper.
Artificial Aging	Artificial Aging is the aging above room temperature of a metal.

Eutectic Melting	Eutectic melting is localized melting of the low melting eutectic composition in some alloys. A significant loss of ductility and a significant reduction in the resistance to fatigue cracking often results from eutectic melting.
Natural Aging	Natural Aging is the spontaneous aging at room temperature of a metal.
Precipitation Hardening	Precipitation hardening is the age hardening of an alloy by formation of precipitates.
Quenching	Quenching is a rapid cooling.
Solution Heat Treatment	A solution heat treatment is a heat treatment that places at least one phase into a solid solution and maintains that solid solution by rapid cooling.
Stress Relief	A stress relief is usually a thermal cycle to relieve residual stresses.
Tempering	Tempering is the thermal cycle performed after the quench to increase the toughness or other mechanical properties of the metal.