Process Specification for the Heat Treatment of Steel Alloys

Engineering Directorate

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REVISIONS		
VERSION	CHANGES	DATE
Baseline	Original version	5/96
A	Expanded sec. 3.0, furnace chart info., tensile requirements	5/27/98
B	Changed Training Requirements, Updated to SAE AMS-H-6875A	7/21/99
C	Modified Training Requirements, Labeling Tensile Bars & Stock	2/24/00
D	Included Information on Postweld Stress Relief, Reduced Labeling Tensile Bars & Stock Requirements	8/24/00

E	Changed sec. 6.0 on aging requirements for A286. Updated document due to reorganization from EM2 to ES4.	6/06/02
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 steel and stainless steel alloys.

2.0 APPLICABILITY

This specification shall be applicable whenever the heat treatment of steel or stainless steel 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 a manufacturing production controller or from an 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:

For Class A Carbon and Low Alloy Steels:

QUENCH AND TEMPER TO 160-180 KSI PER NASA/JSC PRC-2001.

For Class B Martensitic Corrosion Resistant Steel (CRES):

QUENCH AND TEMPER AT 450°F PER NASA/JSC PRC-2001.

For Class C Austenitic CRES:

ANNEAL PER NASA/JSC PRC-2001.

For Class D Precipitation Hardening CRES and Maraging Steel

AGE HARDEN TO CONDITION H1025 PER NASA/JSC PRC-2001.

3.1 PROCESS SEQUENCE

Unless otherwise specified on the engineering drawing, all parts shall be heat treated before final machining to remove scale and decarburization, as well as to avoid changes in dimensions. Scale and decarburization, typically produced at temperatures above 1200°F, are normally detrimental to the finished part and cannot be removed by mechanical or chemical finishing techniques. After heat treating, a minimum of 0.020" will be removed from all scaled or decarburized rough machined surfaces during the final machining.

In some cases, it may be necessary to heat treat after final machining. If heat treating will result in a heat tinted surface that will not be removed by final machining, an appropriate finishing procedure to remove the heat tint shall be called out on the engineering drawing. For example:

HEAT TREAT AFTER FINAL MACHINING. REMOVE HEAT TINT BY ELECTROPOLISHING PER NASA/JSC PRC-5009.

Class A (Carbon and Low Alloy Steels) and B (Martensitic Corrosion Resistant Steel) items often require stress relief after welding operations. Postweld stress relief should be performed as soon as possible after the welding operation—typically within 2 hours. Except for rare exceptions, hardness testing and tensile testing are not required for postweld stress relief operations. A qualified welding procedure for the specific application needs to be reviewed before making the stress relief note. For example:

STRESS RELIEVE AT 1000 F FOR 2 HOURS IMMEDIATELY AFTER WELDING

3.2 NOTATIONS RELATED TO HARDNESS TESTS

Verification of heat treat of steel and stainless steel parts is typically achieved by measuring hardness. Unless otherwise specified on the engineering drawing, the hardness measurement will be made on the actual or rough machined part. For most parts, the hardness impression will be machined away during

subsequent machining. When the hardness measurements must be made on the finished part, a test location shall be chosen by the designer and the materials engineer that will not be detrimental to the function of the finished part. Special instructions must be included on the engineering drawing, such as:

HARDNESS TEST SHALL BE PERFORMED ON FINISHED 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 shall be processed before heat treatment in an identical manner as the production parts. When the heat treating process includes quenching, the samples must be of similar cross section as the production parts or shall be parted from the production part after quenching.

When a hardness test is to be performed on a sample part, special instructions shall be included on the engineering drawing, such as:

HARDNESS TEST SHALL BE PERFORMED ON SAMPLE PART. SAMPLE PART SHALL CONSIST OF ONE 1” LENGTH OF THE SAME MATERIAL LOT USED FOR PRODUCTION PARTS.

or

HARDNESS TEST SHALL BE PERFORMED ON 2” PROLONGATION OF RAW STOCK MATERIAL THAT IS PARTED AFTER HEAT TREATMENT.

3.3 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 (when applicable), and any special acceptance criteria shall be noted on the engineering 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 MATERIAL LOT USED FOR PRODUCTION PARTS.

4.0 REFERENCES

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

ASTM A370	American Society for Testing and Materials Specification, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*
SAE AMS-H-6875A	Society of Automotive Engineers, Inc., Aerospace Material Specification, *Heat Treatment of Steel Raw Materials*
MMPDS	Handbook, *Metallic Materials Properties Development and Standardization*
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 steel and stainless steel alloys shall comply with SAE AMS-H-6875A and the drawing requirements. All parts shall be heat treated before final machining, unless otherwise specified on the engineering drawing. Except for A286, specific times and temperatures for heat treatment are given in Tables

1A, 1B, 1C, and 1D of SAE AMS-H-6875A. For A286, the aging cycle required in the material specification shall be used to age harden the metal.

Sample parts (for hardness and/or tensile tests) 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 and sample bars are needed, each batch must have its own set of labeled sample bars.

Tools and equipment shall be as-specified in SAE AMS-H-6875A. Safety precautions and warning notes shall be as-specified in SAE AMS-H-6875A.

Stress relief after welding shall be done as-specified in section 3.2.4.4 in SAE AMS-H-6875A. Please note that the post stress relief cycles on austenitic stainless steel and pH stainless steel notes may not be necessary for specific cases.

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 (or equivalent documentation).

Verification of heat treat of steel and stainless steel is typically achieved by measuring hardness. Sample parts shall be used for hardness verification only if specified by the engineering drawing. When hardness tests are to be performed on the stock material or rough machined actual parts, the hardness impressions shall be placed in a location that will be machined off during machining. Hardness impressions on finished parts shall be made only at the location specified on the engineering drawing.

When tensile tests are required by the drawing, specimens shall be machined according to ASTM A370, using full-sized coupons whenever possible. Testing shall be performed according to ASTM A370 by either the JSC Structures Test Laboratory or an accredited mechanical Testing laboratory. Tensile test results for Class A steels shall meet the drawing requirements. The yield strength and

elongation shall meet the appropriate values listed in MMPDS, with maximum strengths 20 ksi above the minimums. Tensile tests are not required to verify annealed condition of Class C steels. Tensile test results for Class B and D steels shall meet the minimum values listed in MMPDS, with maximum strengths 20 ksi above the minimums.

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 steel and stainless steel 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.
Decarburization	Loss of carbon from the surface of a carbon-containing alloy from reaction with chemical substances (usually oxygen) during heat treating.
Heat Tint	A thin, tightly adhering oxide skin that forms when steels are heat-treated at low temperatures, or for a short time, in air or in a mildly oxidizing atmosphere. The color ranges from straw to light blue.

Material Lot	A single batch (bar, forging, extrusion, etc.) of material that is produced by the vendor and is documented by a certificate of compliance.
Scale	A heavy, penetrating oxide coating that forms when steels are heat treated at higher temperatures, or at longer times, in air or other oxidizing atmospheres.
Stress Relief	A thermal cycle to relieve residual stresses.