



Designation: F3301 – 18a

Standard for Additive Manufacturing – Post Processing Methods – Standard Specification for Thermal Post-Processing Metal Parts Made Via Powder Bed Fusion^{1,2}

This standard is issued under the fixed designation F3301; 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.

INTRODUCTION

Parts made via metal powder bed fusion where the part bed is below the anneal temperature of the alloy in process will likely form residual stresses during processing. It is a common practice in the industry to heat treat parts while they are connected to the build platform in order to prevent geometric distortion when parts are separated from the build platform. Other post-process treatments such as hot isostatic pressing and solution annealing have been shown to reduce porosity, affect mechanical properties and modify the microstructure to the desired condition.

Applicable parts covered in this specification include, but are not limited to, the manufacture of medical implants, aerospace parts, critical parts for power generation and oil and gas production. Multiple heat treatments may be enforced on the engineering or purchase order by listing the required conditions (for example SR/HIP, for stress relief and hot isostatic pressing). PBF processes where the powder bed is maintained at a temperature in the SR Condition range shall be considered SR Condition in the as built state.

Hot isostatic pressing can be used to achieve Condition SR while the parts are attached to the build platform.

This standard should also be applied to test specimens used to generate design data for part material properties.

1. Scope

1.1 This standard specifies the requirements for thermal post-processing of parts produced via metal powder bed fusion to achieve the required material properties and microstructure to meet engineering requirements. This standard is intended to be referenced by Material Part Property specifications for powder bed fusion. Currently, this standard includes thermal post-processing for the materials including titanium alloys, cobalt 28 chromium 6 molybdenum, alloy UNS N07718, alloy UNS N06625, alloy, UNS 31603 and AlSi10Mg. This specification will be updated as new powder bed fusion material heat treatments are developed.

¹ This specification is under the jurisdiction of ASTM Committee F42 on Additive Manufacturing Technologies and is the direct responsibility of Subcommittee F42.05 on Materials and Processes.

Current edition approved July 15, 2018. Published August 2018. Originally approved in 2018. Last previous edition approved in 2018 as F3301-18. DOI: 10.1520/F3301-18A.

² This document has been prepared by ASTM F42.05 and ISO TC261 in agreement to deconvolve legacy ASTM metal powder bed fusion standards adopted within F42 only. The specifications in 4.7 are derived from work by the U.S. Army, RDECOM ARDEC and support a forthcoming material specification.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Normative References

2.1 The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

2.2 ASTM Standards:³

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A484/A484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings

A1080 Practice for Hot Isostatic Pressing of Steel, Stainless Steel, and Related Alloy Castings

2.3 AMS Standards:⁴

AMS2759 Heat Treatment of Steel Parts, General Requirements

AMS2771 Heat Treatment of Aluminum Alloy Castings

AMS2774 Heat Treatment Wrought Nickel Alloy and Cobalt Alloy Parts

AMS2801 Heat Treatment of Titanium Alloy Parts

AMS5894 Cobalt Alloys, Bars, Sheet, and Plate 60Co – 28Cr – 4.5W – 1.15C Solution Heat Treated

AMSH81200 Heat Treatment of Titanium and Titanium Alloys

2.4 ISO Standard:⁵

ISO/ASTM 52900 Standard Terminology for Additive Manufacturing – General Principles – Terminology

3. Terminology

3.1 For the purposes of this document, the terms and definitions given in ISO/ASTM 52900 shall apply.

4. Thermal Post-Processing Requirements

NOTE 1—The material specification should identify the heat treatment methodology specification, for example, AMS52801, AMS2759, and AMS2771, which includes pyrometry requirements, calibration, maintenance, furnace classification, etc. for equipment used for thermal post-processing.

4.1 Alloy titanium-6 aluminium-4 vanadium, alloy titanium-6 aluminum-4 vanadium extra low interstitial, and commercially pure titanium (CPTi):

4.1.1 *Condition SR*—Parts shall be stress relieved or annealed in accordance with SAE AMS2801 or SAE AMSH81200.

4.1.2 *Condition ANN*—Parts shall be annealed in accordance with SAE AMS2801 or SAE AMSH81200.

4.1.3 *Condition AGED*—Parts shall be solution heat treated and aged per AMS2801, except that components shall be inert gas back-fill cooled or air cooled during the solution heat treat process.

4.1.4 *Condition HIP*—Process parts under inert atmosphere at not less than 100 MPa within the range of 895 to 955 °C; hold at the selected temperature within ± 15 °C for 180 ± 60 min and cool under inert atmosphere to below 425 °C, unless otherwise agreed upon by the part supplier and purchaser.

4.1.5 *Condition OPT*—All thermal post processing shall be optional.

4.2 Cobalt-28 chromium-6 molybdenum:

4.2.1 *Condition SR*—Parts shall be stress relieved or solution annealed in accordance with SAE AMS2774 for SAE AMS5894 material.

4.2.2 *Condition SANN*—Parts shall be solution annealed. Process parts under inert atmosphere in the range of 1200 to 1230 °C; hold at the selected temperature within ± 15 °C for 120 ± 15 min, followed by rapid inert gas cool at a minimum cooling rate of 220 °C/min to 540 °C and 80 °C/min from 540 °C to ambient.

4.2.3 *Condition HIP*—Process parts under inert atmosphere at not less than 100 MPa within the range of 1185 to 1220 °C; hold at the selected temperature within ± 15 °C for 240 ± 60 min and cool under inert atmosphere to below 425 °C, or to parameters as agreed upon between the component supplier and purchaser. When specified by the purchaser, the component supplier shall test the material in its final condition.

NOTE 2—Additional heat treatment of Condition HIP components may be necessary to enhance mechanical properties.

4.3 Alloy UNS N07718:

4.3.1 *Condition SR*—Parts shall be stress relieved at 1065 ± 15 °C for 90 min -5 $+15$ min.

4.3.2 *Condition AGED*—Parts shall be solution treated and aged in accordance with AMS2774.

4.3.3 *Condition HIP*—Process parts under inert atmosphere at not less than 100 MPa within the range of 1120 to 1185 °C; hold at the selected temperature within ± 15 °C for 240 ± 60 min and cool under inert atmosphere to below 425 °C, or to parameters as agreed upon between the component supplier and purchaser.

4.4 Alloy UNS N06625:

4.4.1 *Condition SR*—Parts shall be stress relieved or annealed in accordance with SAE AMS2774.

4.4.2 *Condition ANN*—Parts shall be annealed in accordance with SAE AMS2774.

4.4.3 *Condition HIP*—Process components under inert atmosphere at not less than 100 MPa within the range of 1120 to 1175 °C; hold at the selected temperature within ± 15 °C for 240 ± 60 min and cool under inert atmosphere to below 425 °C, or to parameters as agreed upon between the component supplier and purchaser.

4.5 Alloy UNS S31603:

4.5.1 *Condition SR*—Parts shall be stress relieved in accordance with SAE AMS2759.

4.5.2 *Condition SANN*—Parts shall be solution annealed per AMS2759 or Specification **A484/A484M**.

4.5.3 *Condition HIP*—Process components under inert atmosphere at not less than 100 MPa within the range of 1120 to 1163 °C; hold at the selected temperature within ± 14 °C for 240 ± 60 min and cool under inert atmosphere to below 427 °C, or to parameters agreed upon by the component supplier and purchaser. Hot isostatic pressing shall, at a minimum, conform to the requirements of Practice **A1080**.

NOTE 3—Proper heat treatment of Condition HIP components may be necessary to enhance corrosion and environmental cracking resistance.

4.5.4 If testing to demonstrate the absence of detrimental phases (such as carbide precipitates)

³ 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.

⁴ Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, <http://www.sae.org>.

⁵ Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <http://www.iso.org>.