



AEROSPACE MATERIAL SPECIFICATION

AMS7003™**REV. A**Issued 2018-06
Revised 2022-08

Superseding AMS7003

Laser Powder Bed Fusion Process

RATIONALE

Specification updated to correct and clarify intent. Key process variables and calibration requirements updated to address user inputs.

1. SCOPE

1.1 Purpose

This specification establishes process controls for the repeatable production of aerospace parts by Laser Powder Bed Fusion (L-PBF). It is intended to be used for aerospace parts manufactured using Additive Manufacturing (AM) metal alloys, but usage is not limited to such applications.

1.2 Safety - Hazardous Materials

While the materials, methods, applications, and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the responsibility of the user to ensure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

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 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 E2281 Standard Practice for Process Capability and Performance Measurement

ASTM E2587 Standard Practice for Use of Control Charts in Statistical Process Control

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For more information on this standard, visit
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Documents

Document Sharing Hub

2.2 ISO Publications

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

ISO/ASTM 52900 Additive Manufacturing - General Principles - Terminology

ISO 11146-3 Lasers and laser-related equipment - Test methods for laser beam widths, divergence angles and beam propagation ratios - Part 3: Intrinsic and geometrical laser beam classification, propagation and details of test methods

3. TECHNICAL REQUIREMENTS

3.1 Process Control Document (PCD)

The PCD shall be established by the Producer, substantiated with respect to the specified requirements, and authorized by the Cognizant Engineering Organization (CEO). Once substantiated, all aspects of the PCD are considered to be a fixed process and any changes to the PCD shall require substantiation prior to the change being implemented into production. Changes to the PCD that can affect a Key Process Variable must be authorized by the CEO. All other changes to the PCD must be acceptable to the CEO. The PCD shall address the following aspects of the L-PBF process:

3.1.1 Key Process Variables

3.1.1.1 The Producer shall establish values, tolerances, and measurement frequency for all Key Process Variables of the Laser Powder Bed Fusion process, including but not be limited to the variables defined in Appendix A. These values and tolerances shall be substantiated with respect to the specified requirements and be authorized by the CEO. Any change to a Key Process Variable shall be authorized by the CEO.

3.1.1.2 Process parameters may be omitted from the PCD when substantiated by the Producer and authorized by the CEO.

3.1.1.3 The values of any Key Process Variables considered proprietary by the Producer may be assigned a code designation and recorded by the Producer in an internal document. Each variation in such variable value shall be assigned a modified code designation.

3.1.2 Process Interruption

3.1.2.1 Process interruptions are not permitted unless previously substantiated by the Producer, incorporated in the key process variables of the PCD, and authorized by the CEO.

3.1.2.2 In order to substantiate an allowable process interruption, the Producer shall provide documentation demonstrated through testing or other suitable means that such process interruptions do not affect the quality and performance of the build. This documentation shall be provided to the Purchaser prior to acceptance.

3.1.3 Digital File and Software Configuration Control

The Producer shall establish a robust configuration control system to ensure the correct software and files are used in the production of components using L-PBF. This system shall include internal procedures to control electronic files, conversion settings, and machine parameters. All files shall be traceable through revision control and have access control.

3.1.4 Calibration and Verification Plan

3.1.4.1 Procedures for Calibration and Verification shall be established, and substantiated to measure and adjust, at a minimum, all variables required by the L-PBF machine OEM as well as those identified as required in Appendix B to meet the specified requirements. The plan shall include procedures, values, tolerances, and frequency of verification of each variable specific to the application.

3.1.4.2 All results shall be recorded via manual or electronic means and maintained for a period compliant with requirements of the ordering documents.

3.1.4.3 Calibration and Verification variables may be omitted when substantiated to have no impact on the ability for the part produced to meet the specified requirements and authorized by the CEO.

3.1.5 Maintenance Plan

3.1.5.1 Procedures for maintenance shall be established and substantiated that include a checklist of activities, instructions to perform each activity, and the frequency by which that activity shall be completed.

3.1.5.2 At a minimum, maintenance plans shall include all activities and instructions that are required by the L-PBF machine OEM.

3.1.5.3 Additional maintenance items unique to the installation, facility, or specific application shall also be documented and included in the maintenance plan.

3.1.5.4 The maintenance plan shall include all ancillary equipment required to meet the specified requirements.

3.1.5.5 The maintenance plan shall include procedures for continuous computer security on all associated devices, including those used to transfer files to and from the L-PBF machine.

3.1.5.6 All maintenance performed shall be recorded via manual or electronic means and maintained for a period compliant with requirements of the ordering documents.

3.1.6 Feedstock Handling and Storage Plan

Procedures for feedstock handling and storage shall be established and substantiated to ensure the final part meets all requirements. At a minimum, the feedstock handling plan shall include the following:

- The procedure to substantiate that the feedstock used in the L-PBF machine complies with the specified requirements including the process for sampling. This shall address virgin feedstock as well as reused feedstock, if applicable.
- The procedure to blend feedstock prior to being used in the L-PBF process. Each quantity of feedstock to be blended must independently meet the feedstock specification (i.e., no doping).
- Storage conditions for the feedstock.
- Feedstock batch control and tracking to maintain traceability compliant with the requirements of the CEO.
- Process for ensuring that used feedstock that exceeds any limitation, including maximum number of uses, is sequestered and not loaded into the L-PBF machine.
- Conveyance and transport from any storage location to the L-PBF machine.
- Process for removal of powder from the L-PBF machine that will be used in a subsequent build.

Additional recommended elements of a feedstock handling and storage plan can be found in Appendix E.

3.1.7 Moisture and Contamination Control Plan

Procedures shall be implemented to minimize the risk of moisture, foreign material, or both that would change the performance of the items produced in the L-PBF process. The Producer shall identify potential sources of contamination throughout all aspects of the L-PBF process, including feedstock storage and handling, L-PBF machine, ancillary equipment, and establish procedures to minimize the sources of such contamination.

3.2 L-PBF Machine Approval

For each individual L-PBF machine, the Producer shall demonstrate that the items fabricated in the L-PBF machine conform with all requirements of the applicable material specification. The CEO shall define the requirements (number of specimens, analysis method, and acceptance criteria) and the Producer shall meet those requirements. This substantiation shall be authorized by the CEO prior to implementation into production. Each machine shall meet the following requirements at a minimum:

- Calibration and verification plan is executed and is in compliance with the requirements of 3.1.4.
- Preventative maintenance is performed, documented, and is compliant with the requirements of 3.1.5.
- Material testing is performed using specimens built within the extents of the build envelope defined in the PCD including the extremes of the x, y, and z positions and orientations in the x-y plane and z direction.

3.3 L-PBF Process Approval

The process approval moves beyond machine approval and incorporates all key process variables of the PCD including final part geometry in the finalized build layout. The CEO shall define the requirements (i.e., how many builds, how many machines, how many feedstock lots, required testing, etc.) and the Producer shall demonstrate the capability to meet those requirements. This substantiation shall be authorized by the CEO prior to implementation of the process for production.

3.4 Statistical Process Control (SPC)

Statistical process control shall be used to demonstrate process control and be performed per the methods defined in ASTM E2587 and ASTM E2281. The key process variables identified in the SPC Required column of Appendix A shall maintain a control chart with established limits. The Producer shall have a reaction plan, authorized by the CEO, in place to respond to variations detected in process control charts.

4. QUALITY ASSURANCE PROVISIONS

4.1 Calibration and Verification

The Producer shall maintain documentation of all activities performed per the Calibration and Verification plan defined in 3.1.4.

4.2 Maintenance

The Producer shall maintain documentation of all activities performed per the Maintenance Plan defined in 3.1.5 as well as any unplanned maintenance.

4.3 Feedstock Handling and Storage

The Producer shall maintain evidence that feedstock complies with the Feedstock Handling and Storage Plan defined in 3.1.6.

5. PROCESS SETUP VERIFICATION

Producer shall have a procedure to ensure and document that the L-PBF process is executed in accordance with the PCD. At a minimum, this procedure shall include:

- Selecting the correct build file.
- Selecting the correct machine settings and parameters.

- Pre-build machine check procedure per the significant process parameters defined in the PCD.
- Build plate installation requirements.
- Feedstock loading requirements.

5.1 L-PBF Process Requalification

After initial machine and process approval, the Producer shall demonstrate capability per 3.3, and as defined by the CEO, following the occurrence of any of the following events:

- A change to any of the key process variables defined in the PCD.
- Component or witness coupon rejection.
- Feedstock manufacturer.
- Feedstock production method.
- Changing the machine location or environment.
- Feedstock material change from one specification or material type to another.
- Machine repair involving critical system components or subsystems including but not limited to the laser, optical train, positioning system and gas handling system.

5.2 Build Quality Report

- 5.2.1 The Producer shall maintain a build tracking system that establishes a record for each build performed on the L-PBF machine.
- 5.2.2 The build quality report shall include evidence that the key process variables meet the requirements of the PCD.

5.3 Digital File Traceability

The process for conversion of the data file to a build file, including conversion software and conversion settings that will affect proper file conversion, shall be controlled and documented to maintain configuration control. Recommendations for parameters that should be included in the traceability document are listed in Appendix D.

5.4 Feedstock Base Alloy Change

Each change of base alloy feedstock requires metallographic examination of multiple, as-built samples to validate the cleanliness of the machine. For this verification, at least four samples shall be built in locations including the extremes of the x-y plane of the build envelope (as defined in the PCD). Twelve metallographic sections (three from each sample) shall be cut at 1 inch intervals minimum with at least 0.2 square inches of material in each section. Each section shall be metallographically examined with appropriate polish and etch at 100X minimum, in accordance with ASTM E3. No evidence of contamination from prior feedstock is permitted. Specific test methods and acceptance criteria shall be authorized by the CEO.

5.5 Training Requirements

- 5.5.1 The Producer shall establish a training program covering all elements of the specification in relation to the laser powder bed fusion process. Recommended subject areas for a training program can be found in Appendix C.
- 5.5.2 The Producer shall be responsible for ensuring that employees demonstrate competence in operating the process. Additional training and verification of understanding of the individual PCD may be required.