



AEROSPACE MATERIAL SPECIFICATION

AMS7007™

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Electron Beam Powder Bed Fusion Process

RATIONALE

This is an initial release specification for the electron beam powder bed fusion additive manufacturing process.

AMS7007 has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE

1.1 Purpose

This specification establishes process controls for the repeatable production of aerospace parts by Electron Beam Powder Bed Fusion (EB-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 form 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 E2587 Standard Practice for Use of Control Charts in Statistical Process Control

ASTM E2281 Standard Practice for Process Capability and Performance Measurement

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

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2.3 Terminology

2.3.1 Definitions

The following definitions apply in addition to those defined in ISO/ASTM 52900 and ARP1917.

ACCEPTABLE TO CEO: Does not require prior written approval from the CEO prior to implementation into production. Any changes require notification to the CEO prior to part shipment. This allows the producer to make a decision and CEO the right to disapprove the decision.

AUTHORIZED BY CEO: Requires prior written approval from the CEO.

BUILD ENVELOPE: Largest external dimensions of the x-, y-, and z-axes with the build space where parts will be fabricated.

BUILD FILE: The electronic file that is supplied to the EB-PBF machine for manufacturing one or more parts. This includes, but is not limited to, part geometry, location, orientation, and process parameters.

EB-PBF MACHINE OEM: Company that manufactures the EB-PBF machine.

ELECTRON BEAM POWDER BED FUSION (EB-PBF): Additive manufacturing process in which thermal energy supplied by one or more electron beam(s) selectively fuses regions of a powder bed.

FEEDSTOCK MANUFACTURER: Company that manufactures the material to be used in the EB-PBF machine.

FEEDSTOCK: The metallic powder used as the input raw material for the EB-PBF machine.

INTERRUPT: To break the continuity of the build process.

KEY PROCESS VARIABLES: Aspects of the manufacturing process that may impact the capability to meet the specified requirements. These requirements include physical, chemical, metallurgical, mechanical property, or dimensional.

PROCESS CONTROL DOCUMENT (PCD): A collection of procedures and requirements that are used to document and to control variation of a product.

PRODUCER: The entity using the EB-PBF process to produce a part.

PURCHASER: Organization that issues the PO to the producer.

2.3.2 Acronyms

AM	Additive Manufacturing
CAD	Computer-Aided Design
CEO	Cognizant Engineering Organization
EB-PBF	Electron Beam Powder Bed Fusion
OEM	Original Equipment Manufacturer
PCD	Process Controls and Documentation

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 EB-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 EB-PBF 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

Process interruptions beyond the limitations (e.g., type, duration, frequency) accounted for in the build parameters authorized by the CEO are not permitted. When authorized by the CEO, parts may be accepted if all layers of the part were fully completed prior to the occurrence of a process interruption (e.g., a power outage that stops the build process and would require a re-start to complete the other parts in the build layout).

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 EB-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 EB-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 procedures performed 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.

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 EB-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 EB-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 meet the requirements defined by the finished part material. At a minimum, the feedstock handling plan shall include the following:

- The procedure to substantiate that the feedstock used in the EB-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 EB-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 EB-PBF machine.
- Conveyance and transport from any storage location to the EB-PBF machine.
- Process for removal of powder from the EB-PBF machine and ancillary equipment 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 EB-PBF process. The producer shall identify potential sources of contamination throughout all aspects of the EB-PBF process, including feedstock storage and handling, EB-PBF machine, ancillary equipment, and establish procedures to minimize the sources of such contamination.

3.1.7.1 EB-PBF Machine External Humidity

The moisture control plan (3.1.7) shall include the procedure for venting and opening the EB-PBF machine, and the maximum temperature and humidity level allowed in the room when the EB-PBF machine is opened and exposed to external conditions.

3.2 EB-PBF Machine Approval

For each individual EB-PBF machine, the producer shall demonstrate that the items fabricated in the EB-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 EB-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 quantify and reduce variation, improve, and monitor the EB-PBF process. This includes use of process capability and performance measurement per ASTM E2281 and use of control charts in SPC programs per ASTM E2587. The producer shall have reaction plan authorized by the CEO in place to respond to actions, improve the overall process, and identify special causes of variation. The key process variables identified in the SPC Required column of Appendix A shall be controlled and maintained.

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.

4.4 Process Setup Verification

Producer shall have a procedure to ensure and document that the EB-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 key process variables defined in the PCD.

- Build plate installation requirements.
- Feedstock loading requirements.

4.5 EB-PBF Process Requalification

The occurrence of any of the following events shall invalidate the qualification status of the affected EB-PBF machine(s):

- A change to any of the key process variables defined in the PCD.
- Component or witness coupon rejection attributed to the EB-PBF process.
- Change to the feedstock supplier or feedstock manufacturer.
- Change to the 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 electron beam generation and control hardware, high voltage unit, gas handling system, or powder distribution hardware.

To reobtain qualification status, the producer shall demonstrate that the items fabricated in the EB-PBF machine conform with all requirements defined by the CEO and the applicable material specification. The CEO shall define the testing 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.

4.6 Build Quality Report

4.6.1 The producer shall maintain a build tracking system that establishes a record for each build performed on the EB-PBF machine.

4.6.2 The build quality report shall include evidence that the key process variables meet the requirements of the PCD.

4.7 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.

4.8 Feedstock Base Alloy Change

Each change of base alloy feedstock requires metallographic examination of as-built samples to validate the cleanliness of the machine. For this validation, 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 inch of material in each section. Each section shall be metallographically examined with appropriate polish and etch at 200X 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.

4.9 Training Requirements

4.9.1 The producer shall establish a training program covering all elements of the specification in relation to the EB-PBF process. Recommended subject areas for a training program can be found in Appendix C.