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Additive manufacturing — Process characteristics and performance — Practice for metal powder bed fusion process to meet critical applications

Fabrication additive — Caractéristiques et performances du procédé — Pratique du procédé de fusion sur lit de poudre métallique en vue de répondre aux applications critiques

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by ASTM Committee F42, *Additive Manufacturing Technologies* (as ASTM F3303-2018), and drafted in accordance with its editorial rules. It was assigned to Technical Committee ISO/TC 261, *Additive manufacturing*, and adopted under the "fast-track procedure".

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

ISO/ASTM 52904:2019(E)

Designation: F3303 – 2018

Standard for Additive Manufacturing – Process Characteristics and Performance: Practice for Metal Powder Bed Fusion Process to Meet Critical Applications[1]

This standard is issued under the fixed designation F3303; 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.

1. Scope

1.1 This practice describes the operation and production control of metal powder bed fusion (PBF) machines and processes to meet critical applications such as commercial aerospace components and medical implants. The requirements contained herein are applicable for production components and mechanical test specimens using powder bed fusion (PBF) with both laser and electron beams.

1.2 *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.*

1.3 *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 are referred to in the text in such a way that some or all of their content constitutes requirements of this document. 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:*[2]

E8/E8M Test Methods for Tension Testing of Metallic Materials

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

E2910 Guide for Preferred Methods for Acceptance of Product

F2924 Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium with Powder Bed Fusion

F2971 Practice for Reporting Data for Test Specimens Prepared by Additive Manufacturing

F3049 Guide for Characterizing Properties of Metal Powders Used for Additive Manufacturing Processes

F3122 Guide for Evaluating Mechanical Properties of Metal Materials Made via Additive Manufacturing Processes

2.3 *ISO/ASTM Standards:*[2]

52900 Standard Terminology for Additive Manufacturing – General Principles – Terminology

52921 Terminology for Additive Manufacturing – Coordinate Systems and Test Methodologies

2.4 *ISO Standards:*[3]

4497 Metallic powders – Determination of particle size by dry sieving

D6892–1 Metallic materials – Tensile testing at ambient temperature

D6892–2 Metallic materials – Tensile testing – Part 2: Method of test at elevated temperature

8573-1 Compressed air – Part 1: Contaminants and purity classes

9001 Quality management systems – Requirements

9044 Industrial Woven Wire Cloth – Technical Requirements and Testing

13320 Particle size analysis – Laser diffraction methods

13485 Medical devices – Quality management systems – Requirements for regulatory purposes

2.5 *Other Standards:*

ANSI/ASQC C1-1996 Specification of General Requirements for a Quality Program[4]

AS9100 Quality Management Systems - Requirements for

[1] This practice 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, and is also under the jurisdiction of ISO/TC 261.

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[2] 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.

[3] 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.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

Aviation, Space, and Defense Organizations[5]

3. Terms and Definitions

3.1 For the purposes of this document, the terms and definitions given in Specification F2924, ISO/ASTM 52900, ISO/ASTM 52921, Guide E2910, and the following apply.

3.2 ISO and IEC maintain terminological databases for use in standardization at the following addresses:

– IEC Electropedia available at http://www.electropedia.org/

– ISO Online browsing platform available at https://www.iso.org/obp

3.3 *Definitions:*

3.3.1 *build programmer*—person responsible for programming a build including part orientation, part(s) nesting, and the application of critical build parameters.

3.3.2 *machine operator*—person responsible for initiating builds and turning over machines, which includes, but is not limited to, loading feedstock powder, loading build platforms, removing completed builds and routine machine cleaning and filter changes.

3.3.3 *recoater blade*—portion of the machine that comes in contact with and spreads feedstock across the build area.

3.3.3.1 *Discussion*—The recoater blade may also be called a rake, recoater, roller, or brush.

4. PBF Material Identification

4.1 Material covered by this document (that is, powder and consolidated part/PBF machine input and output), shall be identified by specification callouts including, but not limited to, the following:

4.1.1 Alloy designation according to requirements; where no alloy designation exists, the chemical composition shall be listed.

4.1.2 *Powder type*—Virgin, used, blend or mix.

4.1.3 *Surface finish*—As built, media blasted, supports removed by machining or manual deburring, in accordance with specification callouts, or any combination of the latter finish types.

4.1.4 *Dimensional tolerances*—In accordance with specification callouts or PBF machine output capability.

NOTE 1—4.1.3 and 4.1.4 apply to consolidated parts only.

5. Feedstock and Powder Batches

5.1 The material supplier shall package the powder in containers capable of preventing moisture from penetrating the containers. No other materials including desiccant bags, labels, or tags shall be placed inside the containers in contact with the powder.

5.2 All feedstock shall have a certificate of conformance from the material supplier indicating that the feedstock meets the purchase specification requirements.

5.3 Metal powder shall be purchased from an approved material supplier on the QMS (Quality Management Systems (see 6.3)), an ASL (Approved Supplier List), or a customer-directed material supplier. Powder shall be verified for conformance to the material specification. Third-party certification of powder may be used. Guide F3049, ISO 4497, and ISO 13320 provide guidance on the measurement of particle size distribution.

5.4 The component manufacturer shall have a feedstock material specification against which feedstock can be ordered and tested. Feedstock used for qualification purposes may require a limited reused powder such that the powder utilized for one qualification build to another remains as consistent as practical (for example, by using virgin feedstock as the purpose of the qualification is to check the consistency of machine operation over time).

5.4.1 A feedstock material specification shall include, but not be limited to, chemical composition, particle size distribution, and manufacturing methodology.

5.5 Powder shall be stored in environmental containment to prevent contamination and moisture absorption.

5.6 Used powder is allowed (see 7.1.1.4.1 for requirement on used powder that is processed with ceramic recoater blade).The proportion of virgin to used powder shall be recorded and reported for each production run on the manufacturing plan (Section 10). Automated powder feed systems may not allow the proportion of virgin to used powder to be accurately measured and recorded on the manufacturing plan. In such systems the feedstock shall be considered used powder. The maximum number of times that used powder can be consumed as well as the number of times any portion of a powder lot can be processed in the build chamber shall be validated in accordance with 7.3. After a build cycle, any remaining used powder may be blended with virgin powder to maintain a powder quantity large enough for the next build cycle. The critical powder attributes impacting qualifications in accordance with 7.3 shall be analyzed regularly. All used powder shall be sieved with a sieve having a mesh size appropriate for removing any agglomerations. All powder sieves used to manufacture parts shall have a certificate of conformance that they were manufactured to ISO 9044 or Specification E11.

6. Personnel Requirements

6.1 Personnel competency requirements in ISO 13485 shall apply, including appropriate education, training, skills, and experience.

6.2 Manufacturing manager, machine operator, or build programmer (as defined in Section 3) shall be trained by the machine manufacturer or qualified agency for PBF machine hardware and software, where appropriate.

6.3 On machines that are qualified in accordance with 7.3, the machine manufacturer shall provide for continuing education as new hardware and software releases are purchased and implemented. Records of such training shall be maintained in employee training folders in accordance with a local Quality Management System (for example, ISO 9001, ISO 13485,

[5] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

ASQC C1, AS 9100) for reference with customers or outside regulatory agencies, or both.

6.4 Only persons trained in accordance with 6.1 and 6.2 shall be considered qualified personnel.

7. Qualification

7.1 Pre-Build Checks

7.1.1 This section describes pre-build checks applied to all builds independently of their purpose (for example, periodic preventive maintenance, machine/process qualification, scaling/calibration builds, etc.). The pre-build checks shall include, but not be limited to:

7.1.1.1 *Maintenance record*—Check the maintenance record (see 7.2.2) and qualification status of machine (see 7.3).

7.1.1.2 *Required feedstock quantity*—Verify that required quantity for build is available.

7.1.1.3 *Build platform (also known as build plate or start plate)*—Ensure that the build platform serial number matches the one specified in the manufacturing plan (Section 10). The build platform shall be free from any surface contamination (including dirt, oil, or grease), and any form of defects resulting in an inconsistent powder bed. Build platforms shall be visually inspected and rejected for any obvious damage or non-conformity. Platform shall be installed in PBF machine using the proper QMS instructions.

7.1.1.4 *Recoater blade*—Ensure material compatibility with feedstock and consolidated material, cleanliness, absence of any form of defects resulting in an inconsistent powder bed, and consistent recoater clearance to the build platform at all locations in conjunction with 10.1.2.2.

7.1.1.4.1 Before initiating a PBF machine build, the recoater blade shall be inspected. The machine operator shall visually inspect and verify that the recoater blade is free from any chips, scratches, debris or deformities and installed in accordance with the machine manufacturer's recommendations. Only qualified materials shall be used on a PBF machine in accordance with 7.3. The chemical composition of the recoater blade shall be recorded on the manufacturing plan. PBF machines with polymer recoater blade shall be validated to show the polymer does not contaminate the feedstock by analyzing and pairing the chemical composition of powder feedstock and that of consolidated part. When inspection is not possible due to installation location, polymer recoater blades should be replaced with a new one after the completion of each build. Used feedstock processed with a ceramic recoater blade shall not be further processed. This section does not apply to PBF machines that only use rollers to spread the powder.

7.1.1.5 *Auxiliary systems (for example, shield gas, filters)*—Ensure correct type, proper function, and cleanliness of auxiliary systems (grade 4.8 minimum for shielding gas).

7.1.1.6 *Chiller temperature and flow of heat transfer fluid*—Check chillier temperature and flow of heat transfer fluid (if applicable, in accordance with the machine manufacturer's recommendation). Record chiller temperature on the manufacturing plan prior to every build cycle.

7.1.1.7 *Build chamber environment*—For machines that have protective gas filters there shall be no flow restriction during machine operation.

7.1.1.8 *External gas*—Gas type and flow shall meet the machine manufacturer's recommendation for the feedstock.

7.1.1.9 *Feedstock and baseline machine and process parameters*—Ensure that feedstock and parameters (for example, beam offset, beam parameters, input energy) are correct for build.

7.1.1.10 *Beam power verification*—The instructions for checking the laser or electron beam power shall be determined by the component manufacturer and recorded in a QMS document. Laser or electron beam power shall be measured and documented in the manufacturing plan immediately prior to build initiation and following the completion of all builds.

7.1.1.11 *Part files, orientation and location*—All part files related to the digital geometry (for example, STL, AMF) shall match the intended revision, the part orientation and location on the build platform, as stated in the manufacturing plan.

7.1.1.12 *Machining stock*—Ensure that machining stock is added to part(s) in accordance with manufacturing plan.

7.1.1.13 *Parts nesting*—The build platform part nesting, as displayed by the PBF build processor software, shall be recorded (for example with a screen shot).

7.2 *Periodic Preventive Maintenance (Third Party Accreditation)*

7.2.1 PBF machines shall undergo preventive maintenance (PM) by trained technicians in accordance with the machine manufacturer's recommended frequency (for example, minimum of every six months or after a given number of build hours). PBF machines where preventive maintenance has lapsed shall not be used to meet the requirements herein. The maintenance procedure shall confirm the effective function and operations of each major machine and machine component that affects product quality. This shall include, but not be limited to:

7.2.1.1 *Laser or electron beam power*—Ensure that beam characteristics are within the machine manufacturer's recommended tolerance. Test that the laser or electron beam output matches software set point in accordance with the machine manufacturer's recommendation or specification requirements, whichever is more demanding. Users of power meters should consider the detector calibration uncertainty when measuring and monitoring laser power. More comprehensive beam quality measurements may be imposed on the machine vendor for machine acceptance, for example, switch on/off speed, power fluctuations after hours of operation, and beam profile deviations across the build platform. It is beyond the scope of this standard to specify machine acceptance criteria.

7.2.1.2 *Beam power at build platform*—When possible, measure laser or electron beam power at left, right, front and back of build platform (that is, build platform extremities), but at a minimum in the center of the build platform at 100% laser power or as required for electron beam. Laser or electron beam power for each energy source shall be within the machine manufacturer's recommendation or specification requirements, whichever is more demanding at all measurement locations.

NOTE 2—Beam quality and power measurements specified in 7.2.1.1 and 7.2.1.2 are for in-process control to prevent unintended changes in energy density.

7.2.1.3 *Beam positioning verification*—Ensure that software-indicated beam location and actual beam position are

within tolerances recommended by the machine manufacturer or within tolerances specified by the component manufacturer.

7.2.1.4 *Z-axis movement*—Ensure that software-controlled and actual layer movements are within the machine manufacturer's recommendation or specification requirements, whichever is more demanding.

7.2.1.5 *Recoater arm and motor*—Recoater blade alignment shall be within the machine manufacturer's recommended tolerance.

7.2.1.6 *Compressed air*—Compressed air required for the PBF machine shall be checked at each PM for any contamination in accordance with ISO 8573-1. Adjust to proper pressure and check all fittings and connections.

7.2.1.7 *Oxygen and vacuum*—Oxygen sensors shall be replaced in accordance with the machine manufacturer's recommended schedule and calibrated at a minimum of two oxygen concentration points. Vacuum shall meet the machine manufacturer's recommendation and shall have a method for calibration.

7.2.1.8 *Laser field alignment (LFA)*—The LFA on multiple-laser systems shall be calibrated according to the machine manufacturer's recommendations. Qualified machine manufacturer shall provide tolerance requirements for laser field alignment.

7.2.1.9 *Other recommended preventive maintenance*—Ensure that all other recommended preventive maintenance, as listed in the machine operation or service manual, is performed.

7.2.2 Record of maintenance activity shall be documented, dated, signed by trained technician(s) on PBF preventive maintenance document, and approved by component manufacturer quality assurance. This form shall be displayed on exterior of PBF machine showing date of service and next due date. Maintenance operations shall be monitored using a recognized procedure (for example, Guide E2910).

7.3 *Machine, Process, and Part Qualification*

7.3.1 A qualification build manufacturing plan (in accordance with Section 10) shall be created and used to build the test specimen(s) for the purpose of qualification. Once the qualification build results have been validated, the parameters used for the qualification build are recorded as PBF baseline parameters, and establish the parameters for subsequent builds (see 7.3.3).

7.3.2 *Build platform (also known as build plate or start plate)*—The component manufacturer shall have a build platform specification and all build platforms used for PBF shall conform to the specification including surface finish, flatness and parallelism requirements. Build platforms may be resurfaced. All build platforms shall be serialized, describing, at a minimum, the material. Dissimilar materials (build platform versus component) can be used provided the component meets the chemical composition engineering callouts. When a component is in direct contact with the build platform (no support structure), the cross-contaminated area on the part(s) shall be removed by appropriate processes (for example, chemical or mechanical).

7.3.3 Test specimens (consolidated material) shall be evaluated for chemical composition, microstructure, porosity and mechanical properties as specified by an appropriate standard or as agreed upon by the component manufacturer and customer. Chemical composition of the test specimens shall be verified against chemical composition requirements as indicated by the consolidated material specification. The component manufacturer shall fabricate ASTM E8, E8M, or ISO 6892 tension test blanks and additional test specimens placed, at a minimum, in five locations on the build platform as shown in Fig. 1. Additional tension test specimens built in the *Z* direction are encouraged, but not required. Guide F3122 provides guidance on evaluating mechanical properties of metal materials made using PBF. The customer may require other qualification tests. Test results shall be submitted to the customer for approval in a format conforming to Practice F2971. Once approved, all the machine parameters used to make the test specimens shall be fixed to establish machine baseline parameters. A certificate indicating the machine conforms to baseline parameters shall be posted in clear view of the machine operators, and shall remain effective on all subsequent build cycles until the PBF machine requires a new qualification.

7.3.3.1 If required by the customer specification, the gage section of the tension test specimen may be left in the as built condition, provided there are no support structures added to the gage section during the PBF process.

7.3.3.2 The component manufacturer and customer shall agree to the method for demonstrating consistency across the build platform for systems with multiple energy sources.

NOTE 3—Methods that tested five specimens from each build area covered by each energy source have been successfully used.

7.3.3.3 A reference part that is an indicator of build quality shall be produced and dimensionally measured as part of the qualification procedure. A reference part should be included in each production build cycle. In order for the test specimens and reference part(s) to be representative of future parts, all post-build activities, if any, on the specimens shall be consistent with the future parts (for example, thermal post-processing).

7.3.4 In instances where critical parameters such as beam power and scan speed are dynamically changed during the build (for example, based on part geometry or melt pool characteristics), using parameters that are different from what

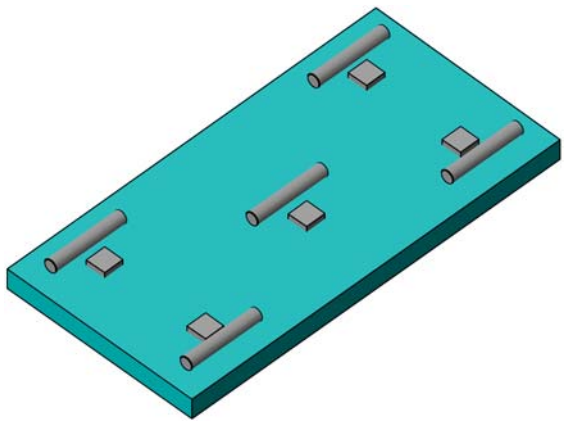


FIG. 1 Example of Tension Test Blanks and Additional Test Specimens Placed in Five Locations on a Build Platform

was used for the qualification in accordance with Section 7 is allowed. Such deviations shall be recorded in accordance with QMS. When there is a difference between the parameters used for the qualification and those parameters used in manufacturing lots, ASTM E8, E8M, or ISO 6892 test specimens that represent the component geometry shall be included and tested with each build cycle.

7.3.5 At a minimum, the manufacturer shall perform the qualification procedure once every six months or upon the occurrence of one of the following:

7.3.5.1 A machine or its sub-systems that could affect part quality is moved to a new location, including relocation within existing facility.

7.3.5.2 A machine is recalibrated or repaired and the repairs involve any machine components (for example, the laser or electron beam delivery, optics, feedstock delivery or platform positioning mechanism).

7.3.5.3 The machine software, operating system, or read-only memory is modified, changed, upgraded or reinstalled.

7.3.5.4 The machine is converted for use with a different alloy class from that of the most recent build (for example, from titanium-based alloys to aluminum-based alloys, or from nickel-based alloys to titanium-based alloys). This is to eliminate any risk of cross contamination.

7.3.6 Upon completion of the qualification procedure, a qualification certificate for the individual machine and process shall be issued and maintained in clear view of the machine operators.

7.3.7 Thermal history of a build is affected by consolidated material area at each layer and fusion time interval in the build cycle. Part qualification, which includes the number of parts per build cycle, may be required in addition to machine and process qualification in accordance with 7.3.4 and specific customer requirements.

8. Control of Machine Operating System Software

8.1 The component manufacturer shall maintain records of all software, CAD, and part nesting layouts used in the production of components, including:

8.1.1 PBF machine operation software version, as recorded on the manufacturing plan (Section 10).

8.1.2 Customer supplied or customer approved CAD files.

8.1.3 Modifications to the customer CAD files, which shall be in accordance with Section 12, and files such as AMF and STL that are converted from customer-supplied CAD files.

8.1.4 Slice or layer files used by the PBF machines.

8.1.5 Record of part nesting and build layout isometric view (for example, screen shots).

8.1.6 PBF machine build log file.

8.2 Any other customer-supplied electronic data, dimensional drawings, statement of work, PBF machine log file, or combination thereof, shall be maintained and saved. Multiple build cycles in a manufacturing lot shall be recorded their unique manufacturing plan number.

8.3 Manufacturing control software products that automate Section 8 are encouraged but not mandatory.

9. Auxiliary Tools and Contamination

9.1 Ancillary equipment (for example, sieves, hand tools, power tools, powder storage containers, powder transport systems and delivery mechanism to machine) shall be cleaned and maintained in a manner to prevent cross contamination from different feedstock types and from dust and foreign objects.

9.2 Particular care shall be taken with tools being used in the PBF machine build envelope to prevent contamination with feedstock. Any tool or accessories used in the build envelope like spatulas, wrenches, vacuum attachments or similar shall be non-contaminating. Virgin or used feedstock shall not be polymer brushed. Cleaning agents or degreasers containing citrus shall not be used on the machine.

10. Manufacturing Plan

10.1 The component manufacturer shall have a manufacturing plan (also known as manufacturing operation record, technical plan traveller, router, or work order) that details the sequence of steps required for the PBF process. The manufacturing plan shall contain the sequence of PBF operations and at a minimum shall contain the following:

10.1.1 Record of performance of all pre-build checks in accordance with 7.1.

10.1.1.1 Machining stock added to part(s) in accordance with manufacturing plan.

10.1.1.2 Record of build platform part nesting (for example, with a screen shot).

10.1.1.3 Reference parts used to indicate build quality or conformance to geometric tolerances.

10.1.2 PBF machine set-up including the serial number of the machine, its subsystems, and laser(s) (if any).

10.1.2.1 Ensure that laser or electron beam power measurement is acquired and the data is recorded on the manufacturing plan. Machines with laser or electron beam power not meeting requirements in 7.2.1.1 and 7.2.1.2 shall not process build cycles.

10.1.2.2 On manual loading machines, ensure that build platform is installed and leveled in accordance with the machine manufacturer's recommendation or work instruction. For automatic build platform loading, ensure no errors occurred.

10.1.2.3 No build cycle shall be started until the build chamber oxygen content or vacuum, or both, meets the requirements of the feedstock. Oxygen sensors shall be located in such a location as to most accurately measure the oxygen content at the part bed.

10.1.3 A check that the feedstock matches manufacturing plan.

10.1.4 Start of build cycle, build run time and build end time including any cool down time.

10.1.5 All thermal processing, including stress relief, hot iso-static pressing (HIP), and heat treatments.

10.1.5.1 Thermal processing can be performed before or after build supports are removed and prior to machining. Component manufacturer and customer shall agree on any additional thermal processing. Only vendors on the approved supplier list shall perform thermal processing.

10.1.5.2 When required, components shall be stress relieved while attached to the build platform in accordance with feedstock requirements and as specified on the manufacturing plan.

10.1.6 Environmental temperature and humidity (see Section 11).

10.2 Beam characteristics (including beam diameter and power) shall remain within specified tolerance throughout the build. This can be verified in the machine operating system software or by measuring those characteristics prior to and immediately at the conclusion of a build cycle. If beam characteristics do not meet specified requirements, all components in the build shall be rejected.

10.3 Unplanned build process interruptions during the PBF machine build cycle shall be designated as a failed build on the manufacturing plan. All components of failed builds shall be rejected. Material review board (see ISO 9001) may accept rejected components that were not affected by the build interruption.

10.4 At the conclusion of the build cycle, all unmelted feedstock shall be removed from the PBF machine and stored in an appropriate container clearly labelled as used feedstock. Deviations from this practice shall require a qualification procedure to ensure part quality is not affected. Automated feedstock systems shall not be allowed to move feedstock from the build chamber directly back to the feed mechanism without previously demonstrating that such operations do not adversely affect part quality.

10.5 When available, post-build powder removal shall be performed in accordance with the machine manufacturer's recommendation. Powder shall be removed using a suitable process (for example, compressed gas under a confined compartment, brushing or vacuum). Secondary operations may be specified on the manufacturing plan to facilitate the removal of loose powder from the interior of parts. All loose powder collected outside of a confined compartment (for example, powder recovery system) shall not be reused. Ultrasonic or sonic cleaning methods specific to the part geometry may be specified on the manufacturing plan.

11. External Environmental Controls

11.1 PBF machines shall be operated in a controlled atmosphere to prevent contamination from other industrial processes and other powder manufacturing techniques.

11.2 Machine and sieve operators shall wear protective gear including smocks, gloves, hair nets, and respirators to prevent organic contaminants.

11.3 Temperature and humidity shall be controlled and recorded on the manufacturing plan (Section 10). Conditions shall conform to the machine manufacturer's recommendations.

11.4 Machine installation conditions shall be met at all times.

12. Digital Data Configuration Control

12.1 The component manufacturer shall have a manual or automated method for engineering file configuration control to ensure that the correct file designation on the purchase order is processed via PBF and, if necessary, final machining.

12.2 The component manufacturer shall perform a quality check to ensure that the received engineering files have not been altered or corrupted during transmittal, and that CAD files do not contain mathematical errors (for example, by using a third-party software package). Support structures added to aid PBF processing shall not be considered modifications to the original form.

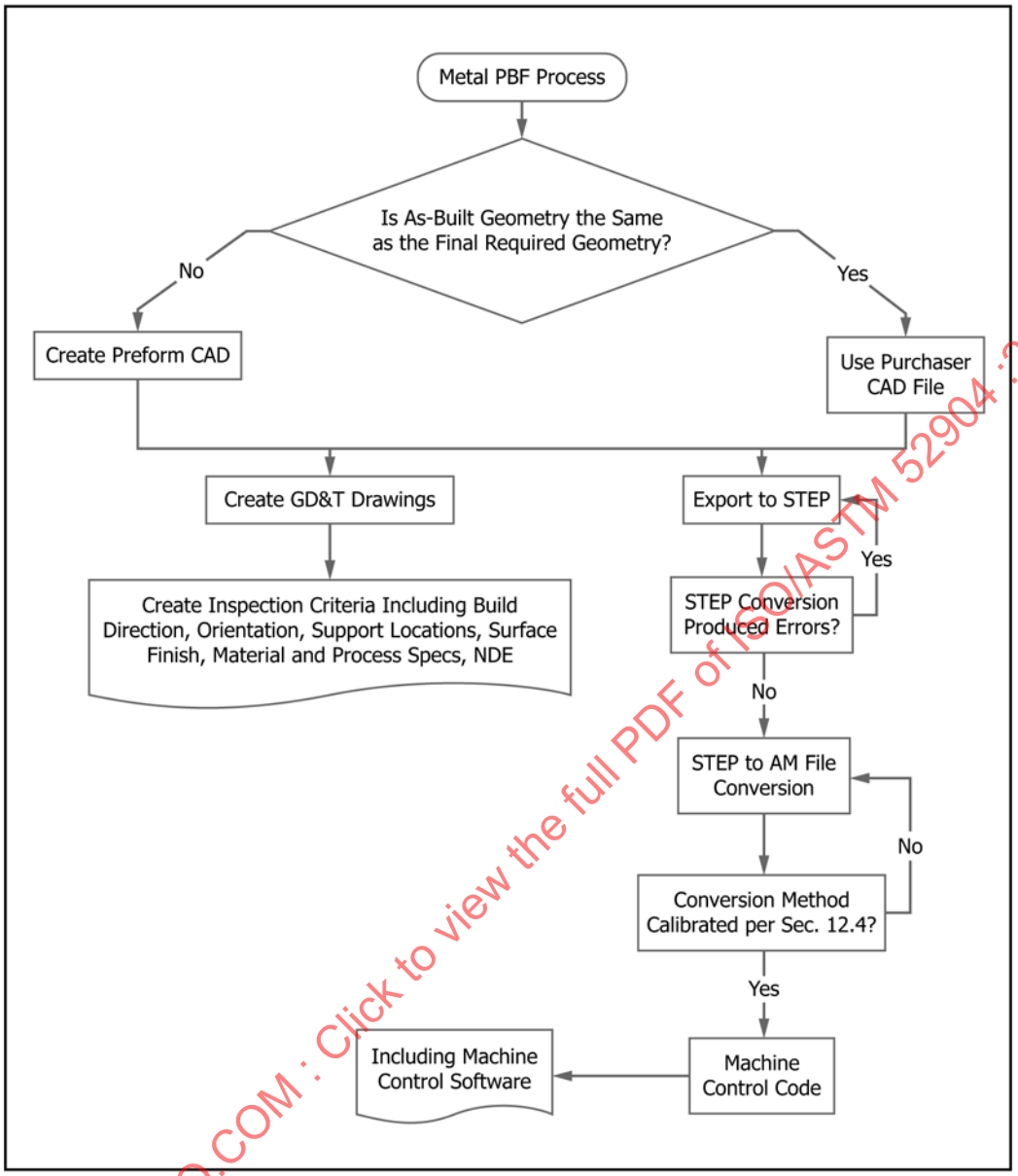
12.3 If the as-built part is modified from the original form received from the customer, the modification shall be performed in an engineering file format allowing for geometric inspection of the preform (see Fig. 2). Modified CAD files shall be verified in the same manner as 12.2.

12.4 When engineering files such as CAD files are converted to triangulated surfaces for purposes of PBF processing, the triangulation resolution of surfaces shall be greater than the resolution of the PBF machine represented on the reference part in 7.3.3.3.

12.5 All CAD file translations necessary to support PBF processing, including those in Section 8, shall have configuration control as required in 12.1.

12.6 Fig. 2 shows a digital data configuration control diagram where the STEP file format was converted from native CAD, and an intermediate AM format was used to program builds.

NOTE 4—PBF machines with the ability to program builds from native CAD files would significantly reduce the probability of configuration control errors.



GD&T stands for Geometric Dimensioning and Tolerancing.

FIG. 2 Digital Data Configuration Control Diagram where the STEP file format is converted from native CAD, and an intermediate AM format is used to program builds

ANNEX

(informative)

A1. Example of a manufacturing plan

JOB START DATE	
JOB COMPLETION DATE	
TOTAL PBF HOURS	
PO DELIVERY DATE	

CUSTOMER INFORMATION	
PURCHASE ORDER #	
CONTACT	

		INITIALS
PLAN REVIEWED BY:		
SALES:		
OPERATIONS:		
QUALITY:		

PART NUMBER	REV	MANUFACTURING LOT QUANTITY	BUILD JOB QUANTITY

		INITIALS
BUILD FILE NAME:		
MACHINE SERIAL NUMBER		
LASER(S) SERIAL NUMBER		
FEEDSTOCK ALLOY		
MACHINE PARAMETERS		
BUILD PLATFORM SERIAL NUMBER		
FEEDSTOCK STATE (VIRGIN, USED OR MIX)		
HEAT TREATMENT	SR, ANN, HIP, STA, ETC.	
RECOATER MATERIAL TYPE		
PRE-BUILD LASER POWER		
POST-BUILD LASER POWER		
FEEDSTOCK LOT NUMBER		
VIRGIN TO USED RATIO	%	
BUILD LOG FILE NAME		

FIG. A1.1 Example of a manufacturing plan