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

TO PLACE A DOCUMENT ORDER: Tel: 877-606-7323 (inside USA and Canada)
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: http://www.sae.org

For more information on this standard, visit https://www.sae.org/standards/content/AMS7003A/

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.

5.5.3 The Producer shall be responsible for creating and maintaining the necessary documentation to ensure personnel continue to demonstrate competence in the required subject areas.

6. PREPARATION FOR DELIVERY

Not applicable.

7. ACKNOWLEDGMENT

Not applicable.

8. REJECTIONS

Material or parts produced in a manner not compliant with all specified requirements are subject to rejection.

9. NOTES

9.1 Revision Indicator

A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

9.2 Terminology

9.2.1 Definitions

The following definitions apply in addition to those defined in ISO/ASTM 52900 and ARP1917 Revision A:

ACCEPTABLE TO CEO: Does not require prior written approval from CEO prior to implementation into production. Any changes require notification to the CEO prior to part shipment. This allows 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 L-PBF machine for manufacturing one or more parts. This includes but is not limited to part geometry, location, orientation, and process parameters.

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

FEEDSTOCK MANUFACTURER: Company that manufactures the material to be used in the Laser Powder Bed Fusion Machine.

k: $k=1/M^2$

INTERRUPT: To break the continuity of the build process.

LASER POWDER BED FUSION (L-PBF): Additive manufacturing process in which thermal energy supplied by one or more laser(s) selectively fuses regions of a powder bed.

L-PBF MACHINE OEM: Company that manufactures the Laser Powder Bed Fusion machine.

M^2 - Beam focus-ability factor, which is the measurement of a laser beam to how closely it correlates to a pure TEM00 beam (M^2=1.00) using methods described in ISO 11146-3.

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

PURCHASER: Organization that issues the PO to the Producer.

KEY PROCESS VARIABLES: Aspects of the manufacturing process that may impact the capability to meet the specified requirements. These include physical, chemical, metallurgical, mechanical property, or dimensional (3.1.1).

PRODUCER: The entity using the Laser Powder Bed Fusion process to produce a part.

9.2.2 Acronyms

AM - Additive Manufacturing

CAD - Computer Aided Design

CEO - Cognizant Engineering Organization

L-PBF - Laser Powder Bed Fusion

OEM - Original Equipment Manufacturer

PCD - Process Controls and Documentation

9.3 Calibration of Beam Travel Speed

There are potentially many approaches to calibrating beam travel speed. An acceptable method of calibration could include verifying the time for a beam to travel a fixed distance on a surface using external measurement methods that meet the requirements of the quality system and then using that verification to calibrate the beam velocity in the part program. For example, an external time measurement device, such as a stopwatch, could be used to measure the time it takes for the laser beam to travel a measured distance. The measured time and distance are then used to calculate the average beam travel speed for that setting.

9.4 Verification versus Calibration.

In certain situations, it may be necessary to use verification methods for calibration. Three examples include laser power, beam spot size and beam travel speed, where calibration devices and methods may be used to measure/validate an output, such as laser power, spot size or scan speed, for a given input, such as laser power setting, spot size setting or scan speed setting, respectively. The results of this verification process are then used to calibrate the system by applying correction factors to the inputs to attain the desired outputs, e.g., the use of a lookup table which correlates the appropriate correction factor for a given set point to attain the desired output.

9.5 Laser Beam Spot Size and Shape Measurement

Laser beam spot size can be measured using either direct or indirect methods. Direct measurement is where the beam spot size/shape is measured directly using a device such as a beam profiler. Indirect approaches, such as the bead-on-plate method, utilize the measurement of an indirect output, such as melt pool width on a metal plate, as a proxy for the actual beam spot size and beam shape (ellipticity due to incident angle being off-vertical). The direct method is the preferred approach. Typically, the spot size and shape will change from the center of the scan region to the extremities. The intent is to capture the minimum or maximum value for the critical spot size dimension, not to characterize it fully as a function of location. An example of a critical shape dimension is when the beam is off-vertical and becomes elliptical in shape. The supplier may want to limit the maximum axis of the ellipse and so will need to develop a method for verifying the beam spot axes are within specified limits.

APPENDIX A - KEY PROCESS VARIABLES REQUIRED FOR LASER POWDER BED FUSION PROCESS

Variable	Description	Control Type	Impact to Process	SPC Required
Build file	The electronic file that is supplied to the L-PBF machine for manufacturing one or more parts. This includes but is not limited to part geometry, location, orientation, and process parameters.	Discrete	Contains part geometry, build layout, process parameters, sequencing, and other key process variables that if modified could affect the outcome in terms of material quality and design intent (conformity and performance/ design characteristics).	
Build plate configuration	The material, dimensions, tolerances, surface finish, and pre-build heat treat condition (including stress relief) of the build plate. [approved except for 'pre-build']	Range	Could impact geometry through distortion which would be identified in geometric inspection. Incompatible material could introduce contamination to the process.	
Build platform position	Z position of top of build plate prior to starting a build. Must be a part of the setup procedures.	Range	If the starting position is too low the first layer could have anomalies. If the starting position is too high the re-coater could crash into the plate.	
Build layout	Location and orientation of all elements to be melted within the build volume. Support structure configurations.	Discrete	The quantity, location and orientation of the part and test articles in the build is fundamental to the process.	
Manufacturer, model, and serial number of each laser	The system that generates the laser energy which transfers it to the optical train system.	Discrete	Each laser manufacturer and model can have variation and requires individual qualification to ensure compliance with performance needs.	
Laser optical train	All optics between the output of each laser and the build surface.	Discrete	The optical train can impact the beam quality, melt pool, and integrity of the material produced.	
Galvos scanner mirrors, motor, control	The optical-mechanical system which drive the beam over the build surface including mirrors, motors, and steering control system.	Range	Impacts component quality. Controls the beam location over the build surface. SPC can measure the rendering positional accuracy of the beam.	X
L-PBF machine manufacturer, model, and serial number	The overall configuration of the LPBF system.	Discrete	Hardware configuration.	
Re-coater mechanism configuration	The geometry and material of the object distributing the powder across the build plate.	Discrete	Re-coater configuration can impact powder bed density which could impact microstructure and surface condition which can impact performance.	
Integrated control system	The hardware, software, firmware, programmable control modules that allow operation and control of the system.	Discrete	Fundamental Integrated architecture operation required for process to be performed.	
Re-coater speed	The velocity at which the re-coater mechanism is distributing powder across the build plate.	Range	Depending on material PSD and spread ability, re-coater speed could impact powder bed density which impacts microstructure and surface condition.	

Feedstock specification	Material specification for the powder to be used for this application that defines the physical characteristics, and method of manufacture.	Range	Fundamental to the process. SPC can be applied against the physical characteristics defined within the feedstock specification. Method of manufacture is discrete and not required for SPC.	X
Feedstock powder particle size and distribution	The size of powder particles allowed for the process.	Range	The particle size distribution can impact the powder bed density, resulting microstructure, and the integrity of the material produced.	X
Feedstock manufacturer	The company producing the powder.	Discrete	Variation in powder between producers can impact the integrity of the material produced.	
Build platform preheat temperature	The heat source and control system used to raise the build platform temperature.	Range	Platform temperature impacts cooling rates which can impact part microstructure and performance.	X
Shielding gas composition	Chemical composition and purity of gas input into shielding gas system.	Range	Inappropriate composition can impact chemistry of the consolidated part and performance.	
Shielding gas flow rate	Flow rate of gas entering the mechanism to distribute the gas across the build plate.	Range	Flow rate can impact cooling rate as well as the ability for shielding gas to effectively manage the powder plume while melting.	X
Shielding gas flow configuration	The hardware controlling the flow of gas across the build surface.	Discrete	Fundamental to the process especially with large build volumes and higher power or multi laser systems.	
Type of filtration	The specific configuration of the filtration being applied to the shielding gas.	Discrete	Type of filtration can impact flow rate and purity which could impact chemistry of the part and the ability to manage the powder plume.	
Build chamber temperature	The temperature of the atmosphere inside the build chamber during the build.	Range	Build chamber temperature can have an impact of the thermal profile of the build and the resulting microstructure produced.	X
Build chamber moisture content	The moisture content inside the build chamber during the build.	Range	Moisture content can impact the oxygen pickup in the material and degrade the mechanical performance of the material produced.	X
Oxygen content	Oxygen content in the build chamber and the recycled atmosphere.	Range	High oxygen content can lead to oxidation of certain materials. Incoming gas as well as recycled atmosphere should be measured and monitored.	X
Layer thickness	The layer thickness of the powder deposited on the build surface for each layer before melting.	Discrete	Fundamental to the process. Impacts the material quality.	
Power of each laser	The commanded power and the delivered power at the build surface.	Range	Fundamental to the process. Impacts the material quality.	X
Contour spacing	Spacing between each contour line.	Range	Influences the density and surface finish of the built material.	
Contour overlap	Overlap between the contour scans and the hatch scans.	Range	Influences the density and surface finish of the built material.	
Hatch spacing	The distance between individual scan vectors for the hatching patterns.	Range	Influences the density of the built material.	
Hatch overlap	The amount of overlap between the hatch stripes.	Range	Influences the density of the built material.	

Beam spot size and shape of each laser	Diameter, roundness (ratio of major to minor radius).	Range	Fundamental to the process. Impacts the material quality.	X
Beam quality/stability of each laser	Shape of the beam (top hat, Gaussian, etc.), thermal lensing, energy density, astigmatism.	Range	Fundamental to the process. Impacts the material quality.	X
Beam pulse characteristics of each laser	If a pulsed laser is used - Pulse shape, width, frequency/period, energy.	Range	Fundamental to the process. Impacts the material quality.	
Scan speed	The speed at which the laser spot moves across the build surface.	Range	Fundamental to the process. Impacts the material quality and rendering accuracy.	
Scan strategy	Hatch pattern, stripe width, stripe overlap, rotation between layers, end of scan vector method. Scan order. Skin thickness.	Discrete	Fundamental to the process. Impacts the material quality and rendering accuracy.	
Overlap zone	Multiple Beams Fixed Locations: The scan field adjustment coupled with the build parameter settings that define the laser interaction in the space where multiple beams interact with the build surface. Single Beam Varied Locations: The scan field adjustment coupled with the build parameter settings that define the laser interaction in the space where a single laser moves within the build chamber and interacts with the build surface.	Range	Fundamental to the process. Impacts the material quality and rendering accuracy.	X
Process interruption	The allowable break in the continuity of the build process as substantiated and approved by the CEO.	Range	A delay in the build process can have an impact of the thermal profile of the build and the resulting microstructure produced.	

APPENDIX B - CALIBRATION AND VERIFICATION REQUIREMENTS

Minimum Measurement Elements
Build platform positional accuracy
Re-coater speed(s)*
Build platform preheat temperature sensor and power source
Gas flow rate(s) for shielding and/or supplementary
Shielding gas composition sensors
Recirculation filter flow rate sensor
Build chamber moisture content sensor
Chamber pressure decay verification for positive pressure Leak up for vacuum
Beam Quality 1) Laser power 2) Focus location 3) Astigmatism 4) Beam quality factor (M2, k) 5) Thermal/temporal stability (For items 1-4, consider initial condition and as a function of time.)
Laser power encompassing the entire build envelope at the build plane. The detector can be located at a safe distance above or below the work plane in order to protect the detector from damage.
Beam spot size and shape encompassing the entire build envelope at the build plane.
Beam profile at the center for each laser
Pulse characteristics of each laser if applicable
Beam travel speed (see section 9.3).
Positional accuracy of each laser on the build plane
Scan field scaling
Oxygen sensor
Dew point sensor

*Use of calibrated instruments not required.

APPENDIX C - TRAINING PROGRAM CURRICULUM RECOMMENDATIONS

1. Digital File Traceability

Personnel should have an understanding of how to maintain the integrity of the build file through the various stages of the manufacturing process.

2. Process Capability

Personnel should have a working knowledge on the complete capability and limitations of the AM equipment and process including: materials (alloys and properties), geometric features, surface finish, digital files, post-processing impacts, process parameters, and others as specified by the organization.

3. Process Monitoring (ability to detect issues while build is running)

Personnel should be trained in and demonstrate an understanding of common defects, build errors, and likely causes of failure associated with the selected process. They should also be trained in the associated mitigation techniques to ensure failures are avoided, contained, or minimized.

4. Qualification

Personnel should be trained in both industry and the organization's standards and qualification procedures and be able to demonstrate knowledge of this essential function.

5. Feedstock Handling

Personnel should be trained and demonstrate capability to execute all elements of the feedstock handling and storage plan defined by the Producer.

6. Machine Calibration and Verification

Personnel should be trained and demonstrate capability to execute all elements of the Calibration and Verification plan defined by the Supplier. Particular attention should be given to laser beam quality and power measurement instruments and methods defined in ISO 11146-3.

7. Machine Maintenance

Personnel should be trained and demonstrate capability to execute all elements of the Maintenance plan defined by the Producer.

8. Machine Setup, Operation, and Part Removal

Personnel should be trained and demonstrate capability to operate the L-PBF process in accordance with all technical requirements defined by Section 3 of this specification.

9. Documentation and Configuration Management

Personnel should be trained and demonstrate capability to maintain all documentation necessary to meet the requirements specified by the CEO.

10. EH&S

Personnel should be trained and demonstrate competency in appropriate EH&S procedures as specified by the equipment manufacturing and the organizations standards or procedures. Particular attention will be given to laser and feedstock safety as it relates to the operation of the machine.