NCAMP-DRAM

National Center for Advanced Material Performance
Defense Rapid Advanced Manufacturing

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NCAMP-DRAM Additive Material Specification

This specification is generated and maintained in accordance with NCAMP-DRAM Standard Operating Procedures

Standard Specification for Additive Manufacturing Laser Powder Bed Fusion Operational Qualification

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1. Scope

This specification defines the Operational Qualification (OQ) requirements for Laser Powder Bed Fusion.

2. Applicable Documents

The following documents are used as reference materials for this specification. The user shall use the most recent revision of these documents unless a specific document revision 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.

Document No.	Document Title
AMS7003	Laser Powder Bed Fusion Process
ASTM E8	Standard Test Methods for Tension Testing of Metallic Materials
ASTM E606	Standard Test Method for Strain-Controlled Fatigue Testing

3. Abbreviations and Acronyms

IQ	Installation Qualification
OQ	Operational Qualification
PQ	Performance Qualification
LPBF	Laser Powder Bed Fusion
SAT	Site Acceptance Test
CEA	Cognizant Engineering Authority
LCF	Low Cycle Fatigue
PCD	Process Control Document

4. Health and Safety

While the materials, methods, hardware, applications, and processes described or referenced in this specification may involve the use of hazardous materials and hazardous environments, this specification does not address the hazards which may be involved in such use. The user is solely responsible for ensuring their familiarity with the safe and proper use of any hazardous materials or processes and to take necessary precautionary measures to ensure the health and safety of all personnel involved. Only qualified personnel are authorized to handle the metallic powder and associated machinery involved in the process. All safety guidelines in the machine's safety manual and associated must be adhered to.

5. Technical Requirements

5.1. Machine Installation Qualification (IQ) and Calibration

When a new LPBF machine is installed, the site acceptance test (SAT) is typically performed by the machine OEM. The requirements of the SAT are a contractual agreement between the machine OEM and the machine purchaser.

The IQ may include a machine calibration and SAT.

5.2. Operational Qualification (OQ)

The purpose of the OQ is to demonstrate that a machine material combination is able to produce material meeting the requirements of a material specification. OQ applies only to the machine serial number on which it is performed. A single machine serial number may have multiple OQs if multiple materials are used on that machine.

A machine calibration should be performed in accordance with the calibration requirements of an applicable specification (e.g. AMS7003) prior to beginning OQ.

When industry accepted material specifications are not available, the part producer may perform OQ prior to a purchase order to demonstrate capability to the provided standard.

5.2.1. OQ Testing Requirements

OQ testing specimens will be defined with the applicable material specification.

In lieu of a material specification, the part purchaser or cognizant engineering authority (CEA) may define the OQ requirements.

The material specification defines which lot-release/witness specimens are required as well as which specimens are required for OQ. The lot-release and OQ specimens may be different as defined by the material specification. The material specification defines

the testing procedure and the minimum and maximum limits for each requirement as well as the test method (e.g. E8 & E606). The specimens quantities required for OQ testing are defined below. If any of the testing below is not listed within the material specification, it is not required for OQ.

The required specimens for OQ are:

Specimens	Total min[2]	Min per Laser	Min with stitching	Direction
Tensile[1] - Yield	9	3	3	Vertical with a minimum of 3 horizontal
Tensile[1] - Ultimate	9	3	3	Vertical with a minimum of 3 horizontal
Tensile[1] - Elongation	9	3	3	Vertical with a minimum of 3 horizontal
Microstructure	1	1	3	any
Porosity	9	3	3	vertical
Chemistry	1	na	na	any

[1]When tensile requirements are defined at multiple test temperatures within the material spec, the temperature closest to 75F shall be used for OQ testing.
[2]When possible, a single specimen may be used for all or multiple tests defined within the table (e.g. Yield, Ultimate, & Elongation)

Low cycle fatigue (LCF) Specimens with as-printed surface finish may be required. If LCF testing is required, the geometry, R-ratio, and temperature will be defined by material specification. LCF testing requirements are defined below:

Specimen	Total min	Min per stress/strain level	Min per laser	Min with stitching	Direction
LCF	9	3	1	3	Vertical with a minimum of 3 horizontal

5.2.2. OQ Build Requirements

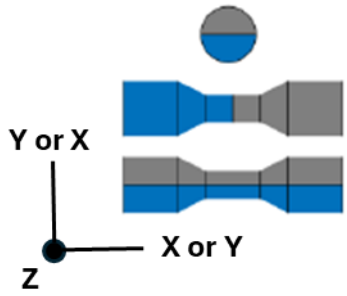
The build requirements for OQ are intended to ensure that each printer, parameter, process, powder combination shall produce material which meets a material specification requirement. Part application specific material requirements are not demonstrated during OQ, but after OQ is complete. Any part application specific testing should be performed during Performance Qualification (PQ). Z-height and specific laser stitch zones are considered part application specific and may be performed during PQ as determined by CEA or purchaser.

The qualified build area is determined by the two most extreme specimen locations. The qualified build area is 5mm outside of the furthest specimens. The maximum X-Y spacing between specimens should be no greater then 125mm. This spacing requirement does not apply to LCF specimens.

The qualified laser area is determined by 2 diagonal samples (e.g. diagonal corners of a square)

Multi-laser systems may be qualified with or without stitching. The completed OQ qualification will be defined as either “with stitching” or “without stitching”. OQ with stitching qualification is not intended to demonstrate every possible laser to laser combination. OQ with stitching is intended to demonstrate that a calibration and stitching parameter strategy is in place which meets the material specification requirements. Part specific laser to laser interaction testing may be required during PQ.

At least one stitch specimen should be produced to capture the x,y,z orthogonal orientations shown below. Whenever possible, the stitch specimens should be created with unique laser to laser combinations (e.g. laser 1+2, laser 2+3, laser 3+4)



If more than one laser is used to build a specimen it may be counted for each laser independently and also as a combined laser stitched specimen. (e.g. a specimen produced using laser 2 and laser 4 can be used as a laser 2 specimen, laser 4 specimen, and a laser 2+4 stitched specimen).

Build stops, if allowed, shall be included for the maximum allowable stop time.

OQ should be performed with the maximum reused powder.

6. OQ Requalification

After the initial machine OQ is successfully completed, a re-qualification may be required if it is determined that lot release testing and KPV monitoring are insufficient controls to maintain material quality. Typical re-qualification events are:

- Moving a machine
- New powder supplier
- Hardware change (e.g. laser, galvos)
- Software revisions (e.g. parameters)
- KPV out of control limits
- Lot release specimens out of limits
- Significant geometric changes

7. Reporting

The OQ test data should be made available to the CEA or purchaser upon request.

Appendix A: Performance Qualification (PQ)

Performance qualification contains two elements:

- CEA or purchaser part specific specimen testing
- First article inspection

It is common that there will be no additional PQ specimen required beyond the OQ testing. When additional testing is required, it may include one or more of the following:

- Part Z-height specimens
- Part specific laser stitch zone specimens
- Thin wall testing
- Part specific fatigue specimens for fatigue critical parts
- Part specific geometry specimens (e.g heat exchangers)

IMQ = Initial Material Qualification
IQ = Installation Qualification
OQ = Operational Qualification
PQ =Performance Qualification