# ANNEX I – Specifications

*rev. 2021-06-21*

**Content**



## I.1. Print Job

The equipment supplier is required to comply with the following print job specifications.

Sections marked by an (*) describe advisory values. The supplier is requested to communicate the actual values used.

**Number of print jobs**

Each participating supplier is invited to complete two print jobs: one mandatory for the evaluation, one optional – cf. *Powder specifications* for more details.

**Geometries**

Each print job should include **all** the following components on one platform:

(a) Part – heat shield
- IP-free design of a high criticality application: heat shield (cf. fig. 1)
- STL file is provided
- Support-free component
- Components stacking allowed
- Dimensions: 72.1 x 58 x 27.4 mm
- Number: 13
  - 6 tensile tests taken from heat shields (2 orientations and 3 tests per orientation)
  - 4 bend test specimens (3 normal + 1 corroded)
  - 3 specimens for metallographic assessment
  - *Note:* information regarding maximum number of components that can be fitted on the build tray will be requested
- Location and orientation: free, build plan and layout to be communicated to ETN (STL file of the build envelope)

(b) Charpy impact test specimen
- Specimen dimensions: 55 x 10 x10 mm (printed specimens with 60 x 12 x 12mm)
- Number: 10 (2 orientations and 5 tests per orientation)
- Location and orientation: To be agreed with ETN
- Standard reference: ISO 148-1 :2016 Metallic materials – Charpy pendulum impact test – Part 1: Test method

(c) Tensile test specimen:
- Dimensions : ø12 x 110mm
- STL file is provided
- Number: 6 (2 orientations and 3 per orientation)
- Location:
  - in overlap zones [stitching areas or multi-laser]
  - other: To be agreed with ETN
- Orientation(s): To be agreed with ETN

(d) Cubes for Archimedes relative density measurements
- Dimensions: 10 x10 x 10mm
- Number: 10
- Location: To be agreed with ETN

(e) Powder capsule for powder monitoring
- STL file is provided
- Number: 1

**Material**

Nickel Alloy 718 powder for laser powder bed fusion

**Powder specifications**

*Note*: 2-step approach - each participating supplier is invited to complete two print jobs:
<u>*Compulsory*</u>

(1) ETN powder: print job with powder batch of Oerlikon MetcoAdd 718C (*link to datasheet*), complying with ASTM F3055-14a and provided by the ETN consortium, to be used as provided.

<u>*Optional*</u>

(2) print job with powder batch selected by the supplier and complying with the ETN powder specifications below, or most suitable powder according to the supplier

*ETN powder specifications:*

- Chemical composition: ASTM F3055 - 14a
- Particle size range: Gaussian curve with max. 3%vol. <5µm
- Particle morphology: gas atomized process ensuring spherical shape (no quantitative criteria – machine dependent) without significant satellites
- Flowability: no quantitative criteria (machine dependent)
- Relative humidity level at delivery: <10%rH
- Recycling: no

**Layer thickness**

Participating suppliers may select a layer thickness parameter of either 40 µm or 60 µm.

**Post-processing**

- Heat treatment will be applied according to ASTM F3055-class F and ASTM 2774E – S1750DP (cf. fig. 2)
- No post-processing can be applied by the supplier, i.e. no part machining, heat treatment, HIPping or surface treatment.
  *Note*: if the supplier generally relies on HIPping to improve the final quality of the product, they should inform ETN.

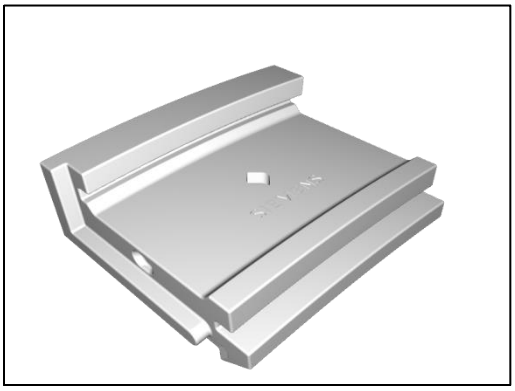

Figure 1 - Heat shield design, geometry (*a*)

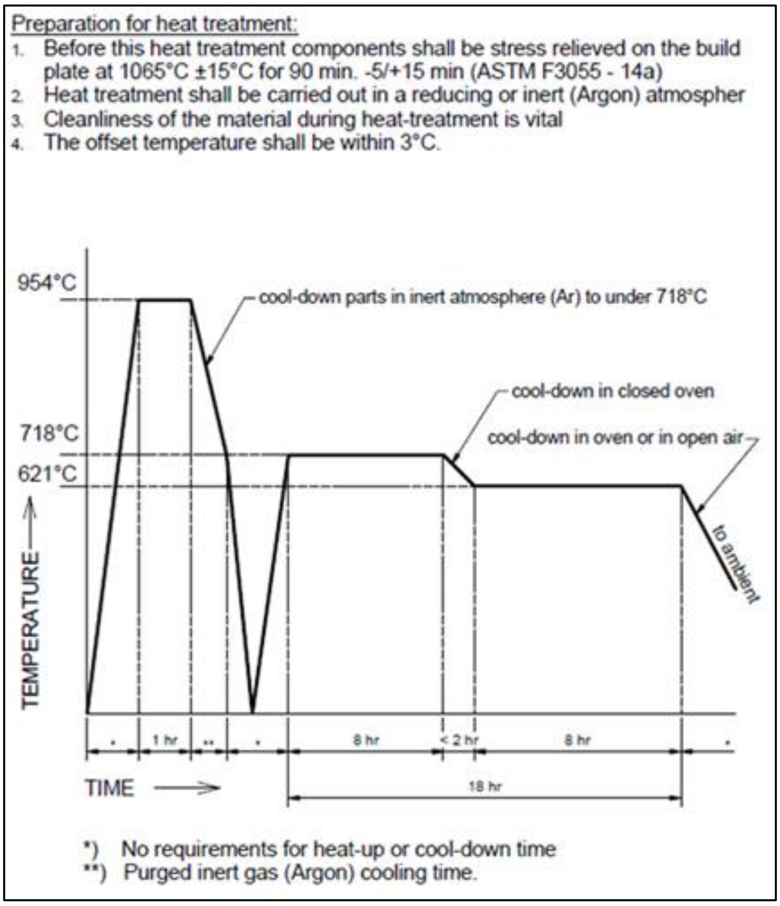


Figure 2 - Heat treatment for 3D printed Nickel Alloy 718, according to ASTM F3055-14a and AMS 2774E S1750DP

## I.2. Print job log information

The equipment supplier is required to provide the following log information relating to the print job.

**Log information**

- Log print file listing all key print events, including but not limited to:
  - error messages;
  - $O_2$ content;
  - platform temperature;
  - all quality monitoring data that could be part of a QA/QC approach (layer control system/powder bed pictures, melt pool data...);
  - location & orientation of all specimen.
- Time
  - Preparation time, broken down by preparation steps
  - Effective print time (laser on – laser off)
  - Depowdering time of the specified components (cf. above)
- Supplier to clarify: standard output information

### I.3. Equipment technical documentation

The equipment supplier is required to provide the following information:

**Equipment**

- Model
- Process basics
    - Machine handling including usability & preparation as well as change over time;
    - Ergonomics
    - Layer thickness options available
    - Re-coater times
    - Bulk parameters, contour parameters, powder utilization / losses
- Material portfolio
    - Variety of materials available for the machine
    - Availability of standard parameters sets per material
    - Allowed powder suppliers
- Build envelope
    - Dimensions
    - Maximum part size
    - Maximum number of test components – cf. Geometry (a) – that can be printed in this envelope at one print job (components stacking allowed)
    - Information regarding exclusion zones in relation to overlap of lasers
- Digital integration & data access
    - Standard interfaces & machine openness
    - List of influenceable variables
- Availability of quality monitoring system
- Number of power sources (multi-laser allowed)
- Cost range of one machine:
    - Hardware cost,
    - Maintenance cost,
    - Service costs,
    - Max running hours,
    - Guaranteed uptime.

**Powder technical documentation**

- Product Code
- Vendor's material common name
- Batch Number
- Production process and atomization gas
- Quantity (in kg)
- Chemical composition
- Particle size distribution (in vol.%, D10, D50, D90)
- Representative optical microscopy micrographs of
- Flowability (Hall Flow and static angle of repose)

### I.4. Timeline

**Timeline**

Current timeline proposal, after collaboration agreements are signed:

| *Action* | *Duration* | *Expected delivery* |
|---|---|---|
| NDA signature between all parties and ETN | 4 weeks | August 2021 |
| Parts production | 6 weeks | October 2021 |
| Testing program – carried out by independent laboratory | 4 weeks | Early December 2021 |
| Final report: results consolidation and documentation – carried out by the third-party coordinator | 3 weeks | End December 2021 |
| Communication of results | n.a. | January 2022 |

### I.5. Standards References

| | | |
|---|---|---|
| F3055 - 14a | Standard Specification for Additive Manufacturing Nickel Alloy (UNS N07718) with Powder Bed Fusion | link |
| AMS 2774E | Heat Treatment Wrought Nickel Alloy and Cobalt Alloy Parts | link |

# ANNEX II – Assessment Criteria

**Content**



## II.1. Key Performance Indicators

The equipment evaluation will be based on the following KPIs defined by ETN.

| |
|---|
| **Process basics**<br>- Machine handling incl. usability & preparation as well as change over time;<br>- Ergonomics, layer thickness, re-coater times, bulk parameters, contour parameters, powder utilization / losses |
| **Material portfolio**<br>- Variety of materials including standard parameter sets available for machine;<br>- Single source vs. multiple suppliers |
| **Build Envelope**<br>- in x/y/z determining maximal part size, that can be fitted on the build tray and productivity (maximum number of parts that can be printed in this envelope at one print job) |
| **Digital integration & data access**<br>- standard interfaces & machine openness / influenceable variables |
| **Quality**<br>- Manufactured part: observed defects, geometry, microstructure & mechanical performance |
| **Productivity**<br>- Simulation & experiment in terms of time & costs per part (e.g., maximum number of parts that can be printed in the envelope at one print job, incl. with components stacking) |
| **Transferability**<br>- of frozen build parameter sets from one machine to other of same type, same supplier, same technology |
| **Costs**<br>- Cost for printed part, CapEx & OpEx |

## II.2. Testing program

*Test methods shall comply with ASTM F3055-14a and additional references listed under II.3*

The testing scope will involve a mixed approach covering three levels of testing:

1. Build Process Qualification Testing : Machine + material + parameters
2. Production Testing : test specimens included in the print job, printed together with the test component(s)
3. Part Qualification Testing.

| **Mechanical Testing** | | |
|---|---|---|
| ***Testing*** | ***Comment*** | ***Geometry*** |
| Tensile testing at room temperature | - Longitudinal and transversal direction extracted from the component<br>- Yield strength, ultimate tensile strength, elongation and Young modulus<br>- Based on 6 tensile test specimens (2 orientations and 3 tests per orientation) and 6 tensile tests taken from heat shield (2 orientations and 3 tests per orientation) | From heat shield and tensile specimens |
| Bend testing | - Longitudinal and transversal direction extracted from the component<br>- Identification of defect or crack indication presenting a critical size of 3mm after testing<br>- Based on 3 specimens (10mm thickness) taken from a heat shield | From heat shield |
| Bend test after corrosion test | - ASTM A262 Practice B – “The Streicher Test” for corrosion test only, no bend test afterwards (one test) | From heat shield |
| Charpy impact testing at room temperature | - Spread in absorbed energies over the platform<br>- Based on 10 Charpy impact test specimens (2 orientations and 5 tests per orientation) | From Charpy impact test specimen |
| Hardness measurement at room temperature | - Measurements in bulk area and close to surface (fill contours)<br>- Spreadability along track lines (bulk and sub-surface areas)<br>- Based on 16 measurements | From heat shield |
| Archimedes relative density measurements | - Based on measurements on 10 cubes, incl. cutting of cubes from bars | From witness bars |
| Powder capsule characterisation | - Chemical composition (incl. Trace elements)<br>- Particle size distribution by laser scattering<br>- Particle morphology by image analysis via scanning electron microscopy<br>- Flowability: Hall flow, static angle of repose, dynamic angle of repose, tap density and compacity curve | From powder capsule |

| **Metallurgical analysis and NDT** | | |
|---|---|---|
| ***Testing*** | ***Comment*** | ***Geometry*** |
| Destructive examination by optical microscopy | Metallographic examination of the constitution and structure:<br>- Microstructure bulk material<br>- Microstructure sub-surface<br>- Cracking at connections points<br>- Porosity assessment (size, distribution, morphology and location): bulk and sub-surface porosities, and specific locations such as interface between part and support structures connection to platform<br>- Grain size<br>- Scanning track assessment | From heat shield |
| Destructive examination by scanning electron microscopy | - Microstructure bulk material<br>- Microstructure sub-surface<br>- Statistics on pores (morphology and location) | From heat shield |
| Surface / Volumetric NDT | - Number, location and size of surface-breaking flaws [red dye penetrant]<br>- Number, location and size of sub-surface flaws [ultrasonic & eddy current]<br>- Geometrical deviation from CAD model [CT scanning]<br>  o Thin wall features<br>  o Down-facing surface quality<br>  o Overall distortion<br>- Roughness Ra & Sa on various face orientations | From heat shield |

### II.3. Standards References

| | | |
|---|---|---|
| F3049 - 14 | Standard Guide for Characterizing Properties of Metal Powders Used for Additive Manufacturing Processes | link |
| F3055 - 14a | Standard Specification for Additive Manufacturing Nickel Alloy (UNS N07718) with Powder Bed Fusion | link |
| ISO / ASTM52904 - 19 | Additive Manufacturing – Process Characteristics and Performance: Practice for Metal Powder Bed Fusion Process to Meet Critical Applications | link |
| F2971 - 13 | Standard Practice for Reporting Data for Test Specimens Prepared by Additive Manufacturing | link |
| F3122 - 14 | Standard Guide for Evaluating Mechanical Properties of Metal Materials Made via Additive Manufacturing Processes | link |
| ISO / ASTM52907 - 19 | Additive manufacturing — Feedstock materials — Methods to characterize metallic powders | link |
| ASTM A262 - 15 | Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels | link |

*Note*

As the standard F3055 - 14a only provides the minimum tensile properties of PBF Nickel Alloy 718 at room temperature, the Special Metals datasheet for conventionally produced Inconel 718 will be referred to for guidance or information on targeted mechanical requirements not covered by F3055 - 14a. [link]