



Designation: F3055 – 14a (Reapproved 2021)

# Standard Specification for Additive Manufacturing Nickel Alloy (UNS N07718) with Powder Bed Fusion<sup>1</sup>

This standard is issued under the fixed designation F3055; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers additively manufactured UNS N07718 components using full-melt powder bed fusion such as electron beam melting and laser melting. The components produced by these processes are used typically in applications that require mechanical properties similar to machined forgings and wrought products. Components manufactured to this specification are often, but not necessarily, post processed via machining, grinding, electrical discharge machining (EDM), polishing, and so forth to achieve desired surface finish and critical dimensions.

1.2 This specification is intended for the use of purchasers or producers, or both, of additively manufactured UNS N07718 components for defining the requirements and ensuring component properties.

1.3 Users are advised to use this specification as a basis for obtaining components that will meet the minimum acceptance requirements established and revised by consensus of the members of the committee.

1.4 User requirements considered more stringent may be met by the addition to the purchase order of one or more supplementary requirements, which may include, but are not limited to, those listed in Supplementary Requirements S1–S16.

1.5 *Units*—The values stated in SI units are to be regarded as the standard. No other units of measurement are included in this standard.

1.6 *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.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standard-*

*ization 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. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

- B213 Test Methods for Flow Rate of Metal Powders Using the Hall Flowmeter Funnel
- B214 Test Method for Sieve Analysis of Metal Powders
- B243 Terminology of Powder Metallurgy
- B311 Test Method for Density of Powder Metallurgy (PM) Materials Containing Less Than Two Percent Porosity
- B769 Test Method for Shear Testing of Aluminum Alloys
- B880 Specification for General Requirements for Chemical Check Analysis Limits for Nickel, Nickel Alloys and Cobalt Alloys
- B964 Test Methods for Flow Rate of Metal Powders Using the Carney Funnel
- D3951 Practice for Commercial Packaging
- E3 Guide for Preparation of Metallographic Specimens
- E8/E8M Test Methods for Tension Testing of Metallic Materials
- E9 Test Methods of Compression Testing of Metallic Materials at Room Temperature
- E10 Test Method for Brinell Hardness of Metallic Materials
- E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves
- E18 Test Methods for Rockwell Hardness of Metallic Materials
- E21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials
- E23 Test Methods for Notched Bar Impact Testing of Metallic Materials
- E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E238 Test Method for Pin-Type Bearing Test of Metallic Materials

<sup>1</sup> This specification 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.

Current edition approved Oct. 1, 2021. Published November 2021. Originally approved in 2014. Last previous edition approved in 2014 as F3055-14a. DOI: 10.1520/F3055-14AR21.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

**E354** Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys

**E384** Test Method for Microindentation Hardness of Materials

**E399** Test Method for Linear-Elastic Plane-Strain Fracture Toughness of Metallic Materials

**E407** Practice for Microetching Metals and Alloys

**E466** Practice for Conducting Force Controlled Constant Amplitude Axial Fatigue Tests of Metallic Materials

**E606** Test Method for Strain-Controlled Fatigue Testing

**E647** Test Method for Measurement of Fatigue Crack Growth Rates

**E1019** Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Inert Gas Fusion Techniques

**E1417** Practice for Liquid Penetrant Testing

**E1450** Test Method for Tension Testing of Structural Alloys in Liquid Helium

**E1473** Test Methods for Chemical Analysis of Nickel, Cobalt and High-Temperature Alloys

**E1820** Test Method for Measurement of Fracture Toughness

**E1941** Test Method for Determination of Carbon in Refractory and Reactive Metals and Their Alloys by Combustion Analysis

**E2368** Practice for Strain Controlled Thermomechanical Fatigue Testing

**F629** Practice for Radiography of Cast Metallic Surgical Implants

**F2792** Terminology for Additive Manufacturing Technologies (Withdrawn 2015)<sup>3</sup>

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

2.2 *ISO/ASTM Standards:*<sup>2</sup>

**52915** Specification for Additive Manufacturing File Format (AMF) Version 1.1

**52921** Terminology for Additive Manufacturing—Coordinate Systems and Test Methodologies

2.3 *ASQ Standard:*<sup>4</sup>

**ASQ C1** Specification of General Requirements for a Quality Program

2.4 *ISO Standards:*<sup>5</sup>

**ISO 148-1** Metallic materials—Charpy pendulum impact test—Part 1: Test method

**ISO 1099** Metallic materials—Fatigue testing—Axial force-controlled method

**ISO 4545** Metallic materials—Knoop hardness test—Part 2: Verification and calibration of testing machines

**ISO 6506-1** Metallic materials—Brinell hardness test—Part 1: Test method

**ISO 6507-1** Metallic materials—Vickers hardness test—Part 1: Test method

**ISO 6508** Metallic materials—Rockwell hardness test—Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)

**ISO 6892-1** Metallic materials—Tensile testing at ambient temperature

**ISO 6892-2** Metallic materials—Tensile testing—Part 2: Method of test at elevated temperature

**ISO 9001** Quality management system—Requirements

**ISO 9044** Industrial woven wire cloth—Technical requirements and testing

**ISO 12108** Metallic materials—Fatigue testing—Fatigue crack growth method

**ISO 12111** Metallic materials—Fatigue testing—Strain-controlled thermomechanical fatigue testing method

**ISO 12135** Metallic materials—Unified method of test for the determination of quasistatic fracture toughness

**ISO 12737** Metallic materials—Determination of plane-strain fracture toughness (withdrawn)

**ISO 13485** Medical devices—Quality management systems—Requirements for regulatory purposes

**ISO 19819** Metallic materials—Tensile testing in liquid helium

### 2.5 *SAE Standards:*<sup>6</sup>

**AMS 2774** Heat Treatment Wrought Nickel Alloy and Cobalt Alloy Parts

**AMS 2269** Chemical Check Analysis Limits Nickel, Nickel Alloys, and Cobalt Alloys

**AMS 5596** Nickel Alloy, Corrosion and Heat Resistant, Sheet, Strip, Foil, and Plate 52.5Ni 19Cr 3.0Mo 5.1Cb 0.90Ti 0.50Al 18Fe

**AS 9100** Quality Systems—Aerospace—Model for Quality Assurance in Design, Development, Production, Installation and Servicing

### 2.6 *ASME Standard:*<sup>7</sup>

**ASME B46.1** Surface Texture

### 2.7 *NIST Standard:*<sup>8</sup>

**IR 7847** (March 2012) CODEN:NTNOEF

## 3. Terminology

### 3.1 *Definitions:*

- 3.1.1 Terminology relating to powder bed fusion in Specification **F2924** shall apply.
- 3.1.2 Terminology relating to additive manufacturing in Terminology **F2792** shall apply.
- 3.1.3 Terminology relating to coordinate systems in ISO/ASTM **52921** shall apply.
- 3.1.4 Terminology relating to powder metallurgy in Terminology **B243** shall apply.

<sup>6</sup> Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, <http://www.sae.org>.

<sup>7</sup> Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, <http://www.asme.org>.

<sup>8</sup> Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, <http://www.nist.gov>.

<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

<sup>4</sup> Available from American Society for Quality (ASQ), 600 N. Plankinton Ave., Milwaukee, WI 53203, <http://www.asq.org>.

<sup>5</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

#### 4. Classification

4.1 Unless otherwise specified herein, all classifications shall meet the requirements in each section of this standard.

4.1.1 Class A components shall be stress relieved per Section 12.

4.1.2 Class B components shall be stress relieved per Section 12 and hot isostatically pressed per Section 13.

4.1.3 Class C components shall be stress relieved per Section 12, hot isostatically pressed per Section 13, and solution treated per Section 12.

4.1.4 Class D components shall be stress relieved per Section 12, hot isostatically pressed per Section 13, solution treated and aged per Section 12.

4.1.5 Class E components shall be stress relieved and solution treated per Section 12.

4.1.6 Class F components shall be stress relieved, solution treated and aged per Section 12.

4.1.7 For Class G components, all thermal post processing shall be optional.

#### 5. Ordering Information

5.1 Orders for components compliant with this specification shall include the following to describe the requirements adequately:

5.1.1 This specification designation,

5.1.2 Description or part number of product desired,

5.1.3 Quantity of product desired,

5.1.4 Classification,

5.1.5 SI or SAE units,

5.1.5.1 *Discussion*—The STL file format used by many powder bed fusion machines does not contain units of measurement as metadata. When only STL files are provided by the purchaser, ordering information should specify the units of the component along with the electronic data file. More information about data files can be found in ISO/ASTM 52915.

5.1.6 Dimensions and tolerances (Section 14),

5.1.7 Mechanical properties (Section 11),

5.1.8 Methods for chemical analysis (Section 9),

5.1.9 Sampling methods (Section S14),

5.1.10 Post-processing sequence of operations,

5.1.11 Thermal processing,

5.1.12 Allowable porosity (Section S8),

5.1.13 Component marking such as labeling the serial or lot number in the CAD file prior to the build cycle, or product tagging,

5.1.14 Packaging,

5.1.15 Certification,

5.1.16 Disposition of rejected material (Section 15), and

5.1.17 Other supplementary requirements.

#### 6. Manufacturing Plan

6.1 Class A, B, C, D, E, and F components manufactured to this specification shall have a manufacturing plan that includes, but is not limited to, the following:

6.1.1 A machine, manufacturing control system, and qualification procedure as agreed between component supplier and purchaser;

NOTE 1—Qualification procedures typically require qualification build

cycles in which mechanical property test specimens are prepared and measured in accordance with Section 11 or other applicable standards. Location, orientation on the build platform, number of test specimens for each machine qualification build cycle, and relationship between specimen test results and component quality shall be agreed upon between component supplier and purchaser.

6.1.2 Feedstock that meets the requirements of Section 7;

6.1.3 The machine identification, including machine software version, manufacturing control system version (if automated), build chamber environment, machine conditioning, and calibration information of the qualified machine;

6.1.4 Predetermined process as substantiated by the qualification procedure;

6.1.5 Safeguards to ensure traceability of the digital files, including design history of the components;

6.1.6 All the steps necessary to start the build process, including build platform selection, machine cleaning, and powder handling;

6.1.7 The requirements for approving machine operators;

6.1.8 Logging of machine build data files, upper and lower limits of the parameters affecting component quality and other process validation controls;

6.1.9 The number of components per build cycle, their orientation and location on the build platform, and support structures, if required;

6.1.10 Process steps including, but not limited to, Section 8;

6.1.11 Post-processing procedure, including sequence of the post-processing steps and the specifications for each step;

6.1.12 Thermal processing including stress relieve, furnace anneal, hot isostatic pressing, heat treat, and aging; and

6.1.13 Inspection requirements as agreed between the purchaser and component supplier, including any supplementary requirements.

#### 7. Feedstock

7.1 The feedstock for this specification shall be metal powder, as defined in Terminology B243, that has the powder type, size distribution, shape, tap density, and flow rate acceptable for the process as determined by the component supplier.

7.2 The metal powder shall be free from detrimental amounts of inclusions and impurities and its chemical composition shall be adequate to yield, after processing, the final material chemistry listed in Table 1.

7.3 Powder blends are allowed unless otherwise specified between the component supplier and component purchaser, as long as all powder used to create the powder blend meets the requirements in Table 1 and lot numbers are documented and maintained.

7.4 Used powder is allowed. The proportion of virgin powder to used powder shall be recorded and reported for each production run. The maximum number of times used powder can be used as well as the number of times any portion of a powder lot can be processed in the build chamber should be agreed upon between component supplier and purchaser for Classes A, through F. There are no limits on the number of build cycles for used powder for Class G components. After a

**TABLE 1 Composition (wt %)**

Element	min	max
Carbon	–	0.08
Manganese	–	0.35
Silicon	–	0.35
Phosphorus	–	0.015
Sulfur	–	0.015
Chromium	17.0	21.0
Cobalt	–	1.0
Molybdenum	2.80	3.30
Niobium + tantalum	4.75	5.50
Titanium	0.65	1.15
Aluminum	0.20	0.8
Iron	remainder	
Copper	–	0.3
Nickel	50.00	55.00
Boron	–	0.006

build cycle, any remaining used powder may be blended with virgin powder to maintain a powder quantity large enough for next build cycle. The chemical composition of used powders shall be analyzed regularly, as agreed upon between component supplier and purchaser. Powder not conforming to **Table 1** or **7.7** shall not be further processed in the machine to manufacture Class A through F components.

7.4.1 All used powder shall be sieved with a sieve having a mesh size appropriate for removing any agglomerates or contaminants from the build cycle.

7.5 All powder sieves used to manufacture Class A through F components shall have a certificate of conformance that they were manufactured to ISO 9044 or all powder sieving shall be in conformance with Specification **E11**.

7.6 Sieve analysis of used powder or powder lots during incoming inspection or in-process inspection shall be made in accordance with Test Method **B214** or as agreed between component supplier and purchaser.

7.7 The maximum percentage of any element in **Table 1** may be increased for virgin powder, used powder and powder blends when agreed upon between component supplier and purchaser. When component supplier and purchaser agree to an increase in the maximum percentage of any element, **9.2** shall apply.

7.8 Any powder lot or powder blend containing any used powder shall be considered used powder.

## 8. Process

8.1 Processing shall be conducted per applicable standards or as agreed upon between component supplier and purchaser according to an approved manufacturing plan as described in Section **6**.

8.1.1 Test specimens for quality assurance may be required to be built and tested in accordance with Section **11** with each build cycle or before and after a production run as agreed upon between the component supplier and purchaser.

NOTE 2—In addition to tension test specimens, fatigue test specimens may be required by the purchaser to be built with the components at the beginning and end of each production run. Fatigue testing is described in Supplementary Requirement S6.

8.2 Permissible parameter, process changes and extent of external intervention during the build cycle shall be identified in the manufacturing plan. All process changes shall be continuously monitored and recorded. When agreed to by the purchaser, minor changes to the manufacturing plan are permissible without machine requalification.

8.3 Condition and finish of the components shall be agreed upon between the component supplier and purchaser.

8.4 Post-processing operations may be used to achieve the desired shape, size, surface finish, or other component properties. The post-processing operations shall be agreed upon between the component supplier and purchaser for Class A through F components.

## 9. Chemical Composition

9.1 Except for Class G, as built components shall conform to the percentages by weight shown in **Table 1**. Carbon, Sulfur, Nitrogen, and Oxygen shall be determined in accordance with Test Methods **E1019** and other elements in accordance with Test Methods **E354**. Chemical composition shall be determined by Test Methods **E1473**, **E1019**, or **E1941**, or combination thereof, as appropriate. Other analytical methods may be used if agreed upon by the component supplier and purchaser.

9.2 Chemical check analysis limits shall be in accordance to AMS 2269 or Specification **B880** and **Table 2**. Chemical check analysis tolerances do not broaden the limits in **Table 1**, but cover variations between laboratories in the measurement of chemical content. The supplier shall not ship components that are outside the limits specified in **Table 1**.

9.3 The chemical composition requirements in this specification for UNS N07718 components are the same as specification AMS 5596 for wrought alloy.

## 10. Microstructure

10.1 The microstructural requirements and frequency of examinations shall be mutually agreed upon by the supplier and purchaser. Specimen preparation shall be in accordance with Guide **E3** and Practice **E407**.

**TABLE 2 Check Analysis Tolerances**

Element	Permissible Variation in Check Analysis
Carbon	±0.01
Manganese	±0.03
Silicon	±0.03
Phosphorus	±0.005
Sulfur	±0.003
Chromium	±0.25
Cobalt	±0.03
Molybdenum	±0.15
Niobium	±0.15
Aluminum	±0.05
Titanium	±0.03
Iron	±0.07
Nickel	±0.45
Copper	
Boron	

## 11. Mechanical Properties

11.1 Build platform coordinates and build platform location for test specimens shall be used in accordance with ISO/ASTM 52921.

11.2 Tension test specimens shall be prepared in accordance with Test Method E8/E8M either before or after thermal processing as agreed upon by the component supplier and purchaser.

11.3 In accordance with ISO/ASTM 52921, specimens used for tension testing shall be machined from bulk deposition, machined from bars or taken from near net shape specimens and built in X, Y, Z orientation or other orientation as agreed.

NOTE 3—Mechanical properties of the test specimens may vary because of the location of the sample on the build platform and the test specimen orientation. Whether or not the test specimens are near net shape or machined from larger blocks is a matter of preference.

11.4 Tensile properties on test specimens shall conform to Table 3, as determined in accordance with Test Methods E8/E8M at a strain rate of 0.003 to 0.007 mm/mm/min through yield and then the crosshead speed may be increased so as to produce failure in approximately one additional minute.

## 12. Thermal Processing

12.1 When required, components shall be stress relieved at 1065 °C ± 15 °C for 90 min –5/+15 min or as agreed between component supplier and purchaser.

NOTE 4—Stress relief is typically performed while the components are attached to the build platform. Some residual stress may remain depending on the stress relief processing. Components manufactured on some powder bed fusion machines may not require a stress relief procedure. Components processed to 12.1 may require further thermal processing.

12.2 Components shall be solution treated and aged per AMS 2774.

## 13. Hot Isostatic Pressing

13.1 HIP is required for Class B, C and D components and optional for Class G.

13.1.1 Process components under inert atmosphere at not less than 100 MPa within the range of 1120 to 1185 °C; hold at the selected temperature within ±15 °C for 240 min ± 60 min and cool under inert atmosphere to below 425 °C, or to parameters as agreed upon between the component supplier and purchaser.

## 14. Dimensions and Permissible Variations

14.1 Tolerances on as-built components shall be agreed upon by the component supplier and purchaser.

14.2 As-built components may be machined to meet dimensional requirements.

14.3 Component repair by welding shall be approved by the purchaser.

## 15. Retests

15.1 If the results of any chemical or mechanical property test or any inspection method, including S1–S10, on a component are not in conformance with the requirements of this specification, the component may be retested at the option of the manufacturer.

15.1.1 The frequency of the retest will be double the initial number of tests. If the results of the retest conform to the requirement, then the retest values will become the test values for certification.

15.2 All test results including the original test results and the conforming retest results shall be reported to the purchaser.

15.3 If any of the results for the retest fail to conform to this specification, the material shall be rejected in accordance with Section 17.

## 16. Inspection

16.1 Inspection criteria shall be agreed upon by the component supplier and purchaser.

## 17. Rejection

17.1 Components not conforming to this specification, or modifications to this specification that are not authorized by the purchaser, will be subject to rejection.

17.2 All rejected components shall be quarantined and reported to the component purchaser.

## 18. Certification

18.1 A certificate, including a complete test report, shall be provided by the component supplier at the time of shipment stating that the components were manufactured and tested in accordance with this specification.

18.2 If the component supplier and purchaser are one and the same, equivalent internal documentation shall be acceptable in lieu of certification.

## 19. Product Marking and Packaging

19.1 Each component shall be identified as agreed upon between the component supplier and purchaser.

**TABLE 3 Minimum Tensile Properties<sup>A</sup>**

Room Temperature Classification	Tensile Strength MPa X and Y Directions	Tensile Strength MPa Z Direction	Yield Strength at 0.2% Offset MPa X and Y Directions	Yield Strength at 0.2% Offset MPa Z Direction	Elongation in 5 cm or 4D (%) X and Y Direction	Elongation in 5 cm or 4D (%) Z Direction
A	980	920	635	600	27	27
A, B, C, E, D, F	<sup>B</sup> 1240	<sup>B</sup> 1240	940	920	12	12
G	no requirement	no requirement	no requirement	no requirement	no requirement	no requirement

<sup>A</sup> A gauge length corresponding to ISO 6892 may be used when agreed upon between supplier and purchaser (5.65 times the square root of S<sub>0</sub>, where S<sub>0</sub> is the original cross-sectional area).

<sup>B</sup> To be agreed between component supplier and purchaser.