



AEROSPACE MATERIAL SPECIFICATION

AMS7000™**REV. A**Issued 2018-06
Revised 2022-05

Superseding AMS7000

Laser-Powder Bed Fusion (L-PBF) Produced Parts, Nickel Alloy,
Corrosion- and Heat-Resistant, 62Ni - 21.5Cr - 9.0Mo - 3.65Nb
Stress Relieved, Hot Isostatic Pressed and Solution Annealed
(Composition similar to UNS N06625)

RATIONALE

New paragraph added to align specification requirements with AMS additive manufacturing metal powder feedstock specification.

1. SCOPE

1.1 Form

This specification covers a corrosion and heat-resistant nickel alloy in the form of parts produced by laser-powder bed fusion (L-PBF) that are subjected to post-deposition stress relief (SR), hot isostatic press (HIP) and solution anneal operations. Parts may require subsequent machining or surface finishing to meet specific application requirements.

1.2 Application

1.2.1 Typically, these parts are used for complex-shaped, statically loaded, aerospace products made to near net shape dimensions, requiring corrosion and oxidation resistance up to 1800 °F (982 °C), but usage is not limited to such applications.

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 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AMS2269	Chemical Check Analysis Limits, Nickel, Nickel Alloys, and Cobalt Alloys
AMS2774	Heat Treatment, Wrought Nickel Alloy and Cobalt Alloy Parts
AMS7001	Nickel Alloy, Corrosion- and Heat-Resistant, Powder for Additive Manufacturing, 62Ni - 21.5Cr - 9.0Mo - 3.65Nb

SAE Executive Standards Committee Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be revised, reaffirmed, stabilized, or cancelled. SAE invites your written comments and suggestions.

Copyright © 2022 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE.

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
<http://www.sae.org>

SAE WEB ADDRESS:

For more information on this standard, visit
<https://www.sae.org/standards/content/AMS7000A/>

AMS7002	Process Requirements for Production of Metal Powder Feedstock for Use in Additive Manufacturing of Aerospace Parts
AMS7003	Laser Powder Bed Fusion Process
ARP1917	Clarification of Terms Used in Aerospace Metals Specifications

2.2 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 E3	Standard Guide for Preparation of Metallographic Specimens
ASTM E8	Tension Testing of Metallic Materials
ASTM E29	Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
ASTM E112	Determining Average Grain Size
ASTM E354	Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys
ASTM E1834	Standard Test Method for Analysis of Nickel Alloys by Graphite Furnace Atomic Absorption Spectrometry
ASTM E3047	Standard Test Method for Analysis of Nickel Alloys by Spark Atomic Emission Spectrometry
ASTM 52921	Standard Terminology for Additive Manufacturing - Coordinate Systems and Test Methodologies
ISO/ASTM 52900:2015	Standard Terminology for Additive Manufacturing - General Principles - Terminology

2.3 Definitions

Terms used in AMS7000 are clarified in ARP1917 and ISO/ASTM 52900:2015 and as follows:

2.3.1 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 the supplier to decide and CEO the right to disapprove the decision.

2.3.2 AUTHORIZED BY CEO

Requires prior written approval from the CEO.

2.3.3 PRODUCER

Source that provides product manufactured and certified in accordance with this specification.

2.3.4 PROCESS CONTROL DOCUMENTATION (PCD)

A collection of procedures and requirements that are used to document and to control variation of the product.

2.3.5 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.

2.3.6 TECHNICAL DATA PACKAGE (TDP)

A technical description of an item adequate for supporting an acquisition, production, engineering, and logistics support (e.g., engineering data for provisioning, training, and technical manuals). The description defines the required design configuration or performance requirements, and procedures required to ensure adequacy of item performance. It consists of applicable technical data such as models, drawing, associated lists, specifications, standards, performance requirements, QAP, software documentation, and packaging details.

2.3.7 WITNESS SPECIMEN

A test specimen produced during the build cycle with representative feedstock materials and process parameters that is used to determine if a specific build yields similar mechanical properties compared to the original qualification build cycle.

2.3.8 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 requirements (see 3.3.2).

3. TECHNICAL REQUIREMENTS

3.1 Composition of Parts

Shall conform to the percentages by weight shown in Table 1, determined by chemical analysis in accordance with ASTM E2465, ASTM E1834, ASTM E2594, ASTM E2823, ASTM E3047, or by other analytical methods acceptable to the purchaser. Carbon, sulfur, oxygen, and nitrogen content shall be determined by ASTM E1019. Significant digits shall be as specified in ASTM E29.

Table 1 - Composition

Element	Min	Max
Carbon	-	0.10
Manganese	-	0.50
Silicon	-	0.50
Phosphorus	-	0.015
Sulfur	-	0.015
Chromium	20.00	23.00
Molybdenum	8.00	10.00
Niobium	3.15	4.15
Cobalt	-	1.00
Titanium	-	0.40
Aluminum	-	0.40
Iron	-	5.00
Oxygen	-	0.030
Nitrogen	-	0.025
Nickel		remainder

3.1.1 Check Analysis

Composition variations shall meet the applicable requirements of AMS2269.

3.2 Condition

Laser-powder bed fusion (L-PBF) produced parts shall be supplied in the solution annealed (SA) condition.

3.3 Processing

3.3.1 The manufacturing process shall be in accordance with AMS7003. Powder feedstock shall be per AMS7001, with composition and particle size distribution (PSD) per AMS7001 Table 1 and Class B. Following deposition, parts shall be subjected to the following additional processes, in the following sequence:

- a. Powder removed.
- b. Stress relieved (SR).
- c. Removed from build plate and support structure.
- d. Hot isostatic pressed (HIP).
- e. Solution annealed (SA).

3.3.2 Process Control Documentation (PCD)

3.3.2.1 The PCD shall be established by the producer and authorized by the cognizant engineering organization (CEO). Once established and validated, all aspects of the PCD shall be a fixed process and 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 shall not be applied until authorized by the CEO. All other changes to the PCD must be acceptable to the CEO. All sub-tier documents shall be considered part of process control documentation.

3.3.2.2 Key Process Variables

The PCD shall meet the requirements of AMS7003 and contain the following items:

- a. Manufacturing sequence.
- b. Method for removing supports.
- c. Thermal processing parameters (time, temperature, atmosphere, and/or pressure).
- d. Thermal processing tooling/fixtures, if applicable.
- e. Surface finish improvement, if applicable.
- f. Dimensional inspection plan (features, methods).
- g. Non-destructive inspection plan (features, methods).

3.3.2.3 Process variables may be omitted from the PCD when substantiated by the Producer and authorized by the CEO.

3.3.2.4 The values of significant process characteristic considered proprietary by the Producer may be assigned a code designation and recorded by the producer in an internal document. Each variation in such characteristic value shall be assigned a modified code designation.

3.3.2.5 Supplier Control Procedure

The PCD shall incorporate a revision-control procedure that defines how the producer and sub-tier material or process suppliers' control is established for the initial process approval and maintained for subsequent changes, throughout the supply chain, such that parts produced continue to conform to the approved process. The procedure shall define if the producer or a sub-tier material or process supplier is authorized to act on the behalf of the CEO and how and when any changes made by the authorized parties are documented and conveyed to the CEO. Changes to the supplier control procedure must not be applied until authorized by the CEO.

3.3.3 Thermal Processing

Thermal processing shall be performed and documented in accordance with the PCD and as specified below.

3.3.3.1 Stress Relieve

Product shall be stress relieved in accordance with AMS2774 in inert or vacuum atmosphere at 1900 °F $\pm$ 25 °F (1038 °C $\pm$ 14 °C), held at heat for 120 minutes $\pm$ 15 minutes, and cooled at a rate equal to air cool or faster.

3.3.3.2 Hot Isostatic Press

Product shall be hot isostatically pressed (HIP) under an inert atmosphere at 14500 psi (100 MPa) minimum within the range of 2100 to 2200 °F (1149 to 1204 °C), held at the selected temperature within $\pm$ 25 °F ($\pm$ 14 °C) for 3 to 5 hours, and cooled under inert atmosphere in the autoclave to below 1200 °F (649 °C). Cool from 1200 °F (649 °C) at any rate.

3.3.3.3 Solution Anneal

Product shall be solution annealed in accordance with AMS2774 under an inert or vacuum atmosphere at 2150 °F $\pm$ 25 °F (1190 °C $\pm$ 14 °C) for 60 minutes $\pm$ 10 minutes and cooled at a rate equal to an air cooling or faster to 1200 °F (649 °C) and cooled from 1200 °F (649 °C) at any rate.

3.4 Additional Post Processing

Additional post processing steps such as powder and support structure removal, surface finish improvement, machining, and non-destructive inspection, along with the sequence those processes are performed, shall meet the requirements of the technical data package (see 2.3.6) and be included in the process control document (PCD).

3.5 Build Cycle Release Test Specimen Properties for Quality Control

Test specimens shall be processed concurrently with the build cycle they represent. These witness specimen blanks shall be built to a 0.5 inch thickness or diameter and oriented in the Z direction as defined by ASTM 52921. Location of specimens on the build plate shall be defined in the PCD. Sufficient blanks should be produced to allow for two retest specimens.

3.5.1 Room Temperature Tensile Properties

Room temperature tensile properties shall be as specified in Table 2, determined in accordance with ASTM E8/E8M using Figure 8, Small Size Specimen 3 (0.250 inch diameter and 1.000 inch gauge length) samples. Specimens shall be tested with the rate of strain set at 0.005 in/in/min (0.005 mm/mm/min) and maintained within a tolerance of $\pm$ 0.002 in/in/min (0.002 mm/mm/min) through the 0.2% offset yield strain. Significant digits shall be as specified in ASTM E29.

Table 2 - Minimum tensile properties of test specimen in the Z direction

Tensile Strength (ksi)	Yield Strength (ksi)	Elongation in 4D (%)
120	50.0	30

3.5.2 Grain Size

Average grain size shall be three or finer as determined in accordance with ASTM E112.

3.5.3 Microstructure

Metallography shall be performed in accordance with ASTM E3 at a magnification of 200X minimum and shall exhibit an equiaxed structure. Sample locations and any additional methods and acceptance criteria shall be as specified (see 8.5).

3.6 Quality

Parts and test specimens shall be uniform in quality and condition, and shall meet the destructive and non-destructive criteria defined in the technical data package authorized by the CEO.

3.7 Dimensions

Dimensions of the part shall comply with the technical data package requirements.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The producer of the product shall provide all samples for producer's test and shall be responsible for all required tests. CEO reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to the specified requirements of this specification.

4.2 Classification of Tests

4.2.1 Acceptance Tests (for Build Cycle Release)

Composition (3.1), room temperature tensile properties (3.5.1), grain size (3.5.2), microstructure (3.5.3), and quality (3.6) are acceptance tests and shall be performed on each build cycle.

4.3 Sampling and Testing

4.3.1 Unless otherwise noted, testing shall be performed on samples that have been subjected to stress relief, HIP, and solution anneal, along with the parts they represent.

4.3.2 Composition in accordance with Table 1 shall be determined from one sample from each build cycle. Composition may be tested in any condition (i.e., as-deposited or any heat treat condition).

4.3.3 Tensile properties shall be determined from one specimen from each build cycle.

4.3.4 Microstructure shall be assessed in the solution annealed condition on material from each build cycle (see 8.5).

4.3.5 Grain Size shall be determined from one representative sample from each build cycle.

4.3.6 Dimensional compliance shall be assessed as specified in the dimensional inspection plan.

4.4 Reports

4.4.1 Certificate of Test

Producer of the parts shall furnish with each shipment a report certifying conformance to the acceptance tests of this specification and the applicable requirements of the technical data package (TDP). The report shall show the numerical results of tests on each build cycle to determine conformance to test requirements. The report shall state that parts were made in accordance with AMS7000.

When specified, the AMS7001 reports of the powder used in the manufacture of parts certified to AMS7000 shall be provided.