INCH-POUND

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PROJECT PECULIAR DOCUMENT

AUSTENITIC CHROMIUM-NICKEL STAINLESS STEEL, CORROSION-RESISTANT, LASER POWDER BED FUSION, ADDITIVELY MANUFACTURED

This specification is approved for use by the Naval Sea Systems Command and is available for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers material made from additively manufactured (AM) austenitic chromium-nickel stainless steel alloy using the laser powder bed fusion (LPBF) process. (see also 6.1)

1.2 Classification. Material is of the following grades and classes, as specified (see 6.2).

1.2.1 Grades. (see 4.8)

a. Grade A – Material manufactured in compliance with S9074-A2-GIB-010/AM-PBF.

b. Grade B – Material manufactured in compliance with manufacturer or industry standards.

1.2.2 Classes.

a. Class 1 – Material with chemical composition similar to UNS S31603, meeting requirements in table I.

b. Class 2 – Material with chemical composition similar to UNS S31673, meeting requirements in table II.

c. Class 3 – Material with chemical composition meeting requirements in either table I or table II.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3 and 4 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3 and 4 of this specification, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-C-24707/3 - Castings, Ferrous, Corrosion-Resistant, Austenitic, Chromium Nickel

(Copies of this document are available online at https://quicksearch.dla.mil.)

2.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

Comments, suggestions, or questions on this document should be addressed to Commander, Naval Sea Systems Command, ATTN: SEA 05S, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard, DC 20376-5160 or emailed to usn.ncr.comnavseasyscomdc.mbx.command-standards@us.navy.mil, with the subject line "Document Comment". Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.dla.mil.

AMSC N/A FSC 9630

NAVAL SEA SYSTEMS COMMAND (NAVSEA) PUBLICATIONS

S9074-A2-GIB-010/AM-PBF	-	Requirements for Metal Powder Bed Fusion Additive Manufacturing
S9074-A4-GIB-010/AM-WIRE DED	-	Requirements for Metal Directed Energy Deposition Additive Manufacturing

(Copies of these documents are available online via Model Based Product Support (MBPS) at https://mbps.navseaplm.navy.mil/Windchill/app/. To gain access to MBPS, obtain an account with National Help Desk Service Management (NHDSM) at https://nhdsm.navair.navy.mil (a valid CAC is required to access this website) and submit a SAAR-N Request. Refer questions, inquiries, or problems to (888) 292-5919. This document is available for ordering (hard copy) via the Naval Logistics Library (NLL) at https://nll.navsup.navy.mil. For questions regarding the NLL, contact the NLL Customer Service at nllhelpdesk@navy.mil, (866) 817-3130, or (215) 697-2626/DSN 442-2626.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

ASTM INTERNATIONAL

ASTM A182/A182M	-	Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
ASTM A351/A351M	-	Standard Specification for Castings, Austenitic, for Pressure-Containing Parts
ASTM A403/A403M	-	Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings
ASTM A484/A484M	-	Standard Specification for General Requirements for Stainless Steel Bars, Billets, Shapes, and Forgings
ASTM A743/A743M	-	Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application
ASTM A744/A744M	-	Standard Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
ASTM A751	-	Standard Test Methods and Practices for Chemical Analysis of Steel Products
ASTM A1080/A1080M	-	Standard Practice for Hot Isostatic Pressing of Steel, Stainless Steel, and Related Alloy Castings
ASTM E3	-	Standard Guide for Preparation of Metallographic Specimens
ASTM E8/E8M	-	Standard Test Methods for Tension Testing of Metallic Materials
ASTM E353	-	Standard Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
ASTM E562	-	Standard Test Method for Determining Volume Fraction by Systematic Manual Point Count
ASTM E1019	-	Standard 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
ASTM E1086	-	Standard Test Method for Analysis of Austenitic Stainless Steel by Spark Atomic Emission Spectrometry

ASTM E1245	-	Standard Practice for Determining the Inclusion or Second-Phase Constituent Content of Metals by Automatic Image Analysis
ASTM E1479	-	Standard Practice for Describing and Specifying Inductively Coupled Plasma Atomic Emission Spectrometers
ASTM F3184	-	Standard Specification for Additive Manufacturing Stainless Steel Alloy (UNS S31603) with Powder Bed Fusion

(Copies of these documents are available online at www.astm.org.)

SAE INTERNATIONAL

SAE AMS2248	-	Chemical Check Analysis Limits – Corrosion- and Heat-Resistant Steels and Alloys, Maraging and Other Highly Alloyed Steels, and Iron Alloys
SAE AMS2750	-	Pyrometry

(Copies these documents are available online at www.sae.org.)

2.4 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Feedstock. Feedstock shall be metal powder characterized by size distribution, apparent density, and tap density.

3.1.1 Powder production. Unless otherwise specified (see 6.2), all melting, atomization, or spheroidization of the metal powder shall be performed using a fixed gas composition consisting primarily of argon, helium, or nitrogen. Unless otherwise specified (see 6.2), the melt chamber atmosphere shall be vacuum or a fixed gas composition.

3.1.2 Powder purity. 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 chemical composition specified in table I. No substance shall be added to the powder at any time to aid powder flowability, spreadability, or any other powder characteristics.

3.2 Build platform. Build platforms used in the production of material under this specification shall be an S-8 material, as specified in S9074-A4-GIB-010/AM-WIRE DED. For example, acceptable alloys include 304, 304L, 316, and 316L in accordance with SAE AMS-QQ-S-763 or ASTM A240.

3.3 Chemical composition. The chemical composition of class 1 builds shall conform to the percentages by weight specified in table I. Chemical composition of class 2 builds shall conform to percentages by weight specified in table II. Chemical composition of class 3 builds shall conform to percentages by weight specified in either table I or table II. Chemical check analysis limits shall conform to the ranges specified in table I or table II. Chemical check analysis tolerances do not broaden the composition requirements but cover variations between laboratories in the measurement of chemical content.

TABLE I. Chemical composition for class 1 or 3 material (weight-percent).

	Minimum (%)	Maximum (%)	Permissible variation in check analysis [1/]
Carbon	---	0.030	0.005
Manganese	---	2.00	0.04
Phosphorus	---	0.020 [2/]	0.005
Sulfur	---	0.020 [2/]	0.005
Silicon	---	1.00	0.05
Chromium	16.00	18.00	0.20
Nickel	10.00	14.00	0.15
Molybdenum	2.00	3.00	0.10
Oxygen	---	0.10	---
Nitrogen	---	0.10	0.01
Other Elements, each [3/]	---	0.10	---
Other Elements, total [3/]	---	0.50	---
Iron	---	Remainder	---

NOTES:

[1/] Values represent tolerances over the maximum limits and under the minimum limits.

[2/] Combined phosphorus and sulfur shall not exceed 0.020 weight-percent.

[3/] Other Elements: Determination not required for routine acceptance except for Al, B, Co, Cu, Mg, Ti, and Zr, which shall be measured and reported for information individually. They shall also be reported collectively, with any other measured elements, as “Other Elements, Total.”

TABLE II. Chemical composition for class 2 or 3 material (weight percent).

	Minimum (%)	Maximum (%)	Permissible variation in check analysis 1/
Carbon	---	0.030	0.005
Manganese	---	2.00	0.04
Phosphorus	---	0.020 2/	0.005
Sulfur	---	0.020 2/	0.005
Silicon	---	1.00	0.05
Chromium	17.00	19.00	0.20
Nickel	13.00	15.00	0.15
Molybdenum	2.00	3.00	0.10
Oxygen	---	0.10	---
Nitrogen	---	0.10	0.01
Other Elements, each 3/	---	0.10	---
Other Elements, total 3/	---	0.50	---
Iron	---	Remainder	---

NOTES:

1/ Values represent tolerances over the maximum limits and under the minimum limits.

2/ Combined phosphorus and sulfur shall not exceed 0.020 weight-percent.

3/ Other Elements: Determination not required for routine acceptance except for Al, B, Co, Cu, Mg, Ti, and Zr, which shall be measured and reported for information individually. They shall also be reported collectively, with any other measured elements, as “Other Elements, Total.”

3.4 Heat treatment. Unless otherwise specified (see 6.2), material shall be given an annealing heat treatment. Annealing heat treatment shall be carried out under vacuum or an inert argon atmosphere in furnaces in accordance with the pyrometry requirements of SAE AMS2750 class 5 or better. Material given an annealing heat treatment shall be heated to 1875 °F, held for a minimum of 120 minutes, or 1 hour per inch of part thickness, whichever is greater, and cooled under an inert atmosphere to below 800 °F at a rate greater than or equal to 18 °F per minute.

3.4.1 Hot isostatic pressing. When specified (see 6.2), material shall undergo hot isostatic pressing instead of, or in addition to, an annealing heat treatment. Hot isostatic pressing shall be carried out under an inert argon atmosphere in accordance with ASTM A1080/A1080M. Material given a hot isostatic pressing shall be heated to 1875±25 °F and pressurized to not less than 20 ksi, held for a minimum of 120 minutes at temperature and pressure, or 1 hour per inch of part thickness, whichever is greater, and cooled under an inert atmosphere to below 800 °F at a rate greater than or equal to 18 °F per minute.

3.5 Tensile properties. The tensile properties of all material shall meet or exceed the values specified in table III.

TABLE III. Tensile properties.

Property	Minimum value
Ultimate tensile strength (ksi)	70
Yield strength, 0.2% offset (ksi)	30
Elongation (%)	30

3.6 Relative density. The relative density of the material shall be not less than 99.8 percent.

3.7 Weld repair. Unless otherwise specified (see 6.2), weld repair shall be prohibited.

4. VERIFICATION

4.1 Classification of inspections. The inspection requirements specified herein are classified as follows:

a. Conformance inspection (see 4.2).

4.2 Conformance inspection. Conformance inspection shall include the examinations and the tests of table IV.

TABLE IV. Conformance inspections.

Examinations and tests	Requirement	Conformance inspection
Feedstock	3.1	4.8
Build platform	3.2	4.8
Chemical analysis	3.3	4.5
Tensile properties	3.4 and 3.5	4.6
Relative density	3.6	4.7
Weld repair	3.7	4.8

4.3 Lot size. Unless otherwise specified (see 6.2), for the purposes of inspections and tests, when heat treatment is required, material produced in one build cycle and the same heat treatment batch shall constitute a lot. If heat treatment is not required (see 6.2), material produced in one build cycle shall constitute a lot.

4.4 Sampling.

4.4.1 Chemical composition. A minimum of one sample shall be taken from each lot for analysis.

4.4.2 Tensile property. Unless otherwise specified (see 6.2), for each lot, a minimum of one sample shall be taken that was built in the Z orientation and one sample shall be taken that was built in either the X or Y orientation.

4.4.3 Relative density. A minimum of one sample shall be taken from each lot for analysis. The sample shall be extracted in the Z orientation. The sample shall include at least one external surface in addition to interior material.

4.5 Chemical analysis. Chemical composition of builds may be tested in any condition (i.e., as-deposited or following heat treatment). Chemical analysis shall be performed in accordance with ASTM A751, ASTM E353, ASTM E1086, ASTM E1479, or ASTM E1019, or any combination thereof, as appropriate.

4.6 Tensile properties. Tension tests shall be carried out in accordance with ASTM E8/E8M on a machined gauge section. Unless otherwise specified (see 6.2), tension test coupons shall conform to the standard geometries specified in ASTM E8/E8M and shall be machined from bulk deposition, machined from bars, or taken from near net shape specimens. Tension test specimens shall be tested following final heat treatment.

4.7 Relative density. Unless otherwise specified (see 6.2), relative density shall be evaluated by examining metallographic specimen(s). Metallography shall be performed in accordance with ASTM E3. Relative density

shall be measured by using stereographic methods in accordance with ASTM E562 or ASTM E1245. For ASTM E562 or ASTM E1245, the test procedure shall be carried out on ten 50x images from a representative cross-section of the sample. For ASTM E562, the number of fields measured and the grid size used shall attain a relative accuracy of 10 percent.

4.8 Certificate of conformance. Unless otherwise specified (see 6.2), a certificate of conformance (COC) shall be prepared for each lot of material offered for acceptance in accordance with the lot definition specified herein. The COC shall state that each lot has been sampled, tested, and inspected in accordance with the requirements specified herein. The COC shall also state that powder feedstock and build platform material are in accordance with the requirements herein. For grade A material, the COC shall also provide the date of NAVSEA approval indicating the manufacturer is in compliance with S9074-A2-GIB-010/AM-PBF. For grade B material, the COC shall state the manufacturer or industry standard used for powder and to manufacture the material. If heat treatment is required, a complete record of all heat treatments, including time, temperatures, atmosphere, and heating and cooling rates shall be included in the COC (see 3.4). If weld repair is permitted (see 3.7), a complete record of all repaired defects including their location, weld repair inspection results, post-weld heat treatments, and associated weld procedure approvals shall be included in the COC.

5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When packaging of materiel is to be performed by DoD or in-house contractor personnel, these personnel need to contact the responsible packaging activity to ascertain packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activities within the Military Service or Defense Agency, or within the military service's system commands. Packaging data retrieval is available from the managing Military Department's or Defense Agency's automated packaging files, CD-ROM products, or by contacting the responsible packaging activity.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. Laser powder bed fusion 316L AM material is intended for replacement of ASTM A351/A351M, ASTM A743/A743M, ASTM A744/A744M (Gr. CF3M, CF8M), MIL-C-24707/3 (Gr. CF8M), ASTM A182/A182M (Gr. F 304L, F 316L), and ASTM A403/A403M (Gr. WP316L, CP316L) parts for new construction and repair of Navy submarines and surface platforms. This material is intended for use in applications with a maximum operating temperature of 250 °F where general corrosion or pitting may be a problem. This material is suitable for welded applications.

6.2 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number, and date of this specification.

b. Grade and class required (see 1.2).

c. Alternative powder production methods (see 3.1.1).

d. When heat treatment is not required (see 3.4).

e. When material should undergo hot isostatic pressing instead of, or in addition to, an annealing heat treatment (see 3.4.1).

f. When weld repair is permitted (see 3.7).

g. Variable lot size when required (see 4.3).

h. Number of samples and orientation if other than specified (see 4.4.2).

i. Dimensions of non-standard tensile test specimens, when required (see 4.6).

j Acceptable methods for measuring relative density if other than specified (see 4.7).

k. When a certificate of conformance is not required (see 4.8).

l. Packaging requirements (see 5.1).

m. Surface finish requirements (see 6.4).

6.3 Navy technical publication. The LPBF manufacturing process is sensitive to process instabilities. Material produced by this process is difficult to inspect through conventional, nondestructive evaluation techniques due to finely distributed porosity and the complex, near-net shape parts that the process is uniquely suited to produce. Therefore, the qualification framework described in S9074-A2-GIB-010/AM-PBF is recommended to ensure material of consistent quality for critical applications.

6.4 Surface finish. Material produced using LPBF may have a rough surface finish that is associated with performance debits, particularly for corrosion resistance and fatigue life. Material is often post-processed via machining, grinding, electrical discharge machining, polishing, and so forth to achieve desired surface finish. This specification does not address material performance in anything but the machined condition. Surface finish requirements should be as specified (see 6.2).

6.5 Subject term (key word) listing.

316L
3-D Printing
Casting Substitute
CF8M
CRES
Metal Printing
Powdered Metal