

PERFORMANCE SPECIFICATION  
COMMERCIAL PURE TITANIUM, WIRE ARC, DIRECTED ENERGY DEPOSITION,  
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 additively manufactured (AM) commercially pure (CP) titanium material made using the wire arc directed energy deposition (DED) process and interpass temperatures of 250 °F.

1.2. Classification. AM material is of the following grades, as specified (see 6.2):

1.2.1 Grades.

- a. Grade A – Material manufactured in compliance with S9074-A4-GIB-010/AM-WIRE DED.
- b. Grade B – Material manufactured in compliance with manufacturer or industry standards (see 6.3).

## 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 STANDARDS

MIL-STD-1684 - Control of Heat Treatment

(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.

### NAVAL SEA SYSTEMS COMMAND (NAVSEA) PUBLICATIONS

S9074-A4-GIB-010/AM-WIRE DED - Requirements for Metal Wire-Fed Directed Energy Deposition Additive Manufacturing

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 [CommandStandards@navy.mil](mailto:CommandStandards@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

AREA AMPR

Distribution Statement A. Approved for public release: distribution is unlimited.

S9074-AR-GIB-010/278

- Requirements for Fabrication Welding and Inspection, and Casting Inspection and Repair for Machinery, Piping, and Pressure Vessels

(Copies of these documents are available online via Model Based Product Support (MBPS) at <https://mbps.navseaplms.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](mailto: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.

#### AMERICAN WELDING SOCIETY (AWS)

- AWS A5.01M/A5.01 - Welding and Brazing Consumables – Procurement of Filler Metals and Fluxes
- AWS A5.16/A5.16M - Specification for Titanium and Titanium-Alloy Welding Electrodes

(Copies of these documents are available online at [www.aws.org](http://www.aws.org).)

#### ASTM INTERNATIONAL

- ASTM E8/E8M - Standard Test Methods for Tension Testing of Metallic Materials
- ASTM E23 - Standard Test Methods for Notched Bar Impact Testing of Metallic Materials
- ASTM E539 - Standard Test Method for Analysis of Titanium Alloys by Wavelength Dispersive X-Ray Fluorescence Spectrometry
- ASTM E1409 - Standard Test Method for Determination of Oxygen and Nitrogen in Titanium and Titanium Alloys by Inert Gas Fusion
- ASTM E1447 - Standard Test Method for Determination of Hydrogen in Reactive Metals and Reactive Metal Alloys by Inert Gas Fusion with Detection by Thermal Conductivity or Infrared Spectrometry
- ASTM E1941 - Standard Test Method for Determination of Carbon in Refractory and Reactive Metals and Their Alloys by Combustion Analysis
- ASTM E2371 - Standard Test Method for Analysis of Titanium and Titanium Alloys by Direct Current Plasma and Inductively Coupled Plasma Atomic Emission Spectrometry (Performance-Based Test Methodology)
- ASTM E2994 - Standard Test Method for Analysis of Titanium and Titanium Alloys by Spark Atomic Emission Spectrometry and Glow Discharge Atomic Emission Spectrometry (Performance-Based Method)

(Copies of these documents are available online at [www.astm.org](http://www.astm.org).)

#### SAE INTERNATIONAL

- SAE AMS2750 - Pyrometry
- SAE AMS-H-81200 - Heat Treatment of Titanium and Titanium Alloys

(Copies of these documents are available online at [www.sae.org](http://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 procured in the form of wire spools or drums suitable for the DED process. Wire feedstock shall meet the requirements specified in AWS A5.16/A5.16M, classification ERTi-2. Each manufacturing lot (see 4.3) shall be produced from the minimum practicable number of lots of feedstock. Unless otherwise specified (see 6.2), feedstock lots from separate heats shall not be used in the same manufacturing lot. Feedstock lots and heats are defined in accordance with AWS A5.01M/A5.01.

3.2 **Build platform.** Unless otherwise specified (see 6.2), the build platform shall not be integrated into the printed material. If a material other than S-51 or S-52 titanium, as defined in S9074-A4-GIB-010/AM-WIRE DED, is used for a non-integrated build platform, a minimum of 0.5 inch of discardable AM build material shall separate the build platform from the final component's attached dimensional surface. Methods used for removal of the build platform (e.g., band saw, water jet, or electro-discharge machining with recast layer removed) shall not affect the mechanical properties of the AM material.

3.3 **Chemical composition.** DED material shall conform to the composition specified in [table I](#). See 4.4.1 and 4.5 for composition analysis requirements.

TABLE I. Chemical composition (weight percent).

	Minimum (%)	Maximum (%)
Carbon	---	0.03
Oxygen	0.08	0.16
Nitrogen	---	0.015
Hydrogen	---	0.008
Iron	---	0.12
Yttrium <sup>1/</sup>	---	0.005
Other Elements, each <sup>1/</sup>	---	0.05
Other Elements, total <sup>1/</sup>	---	0.20
Titanium	---	Remainder
NOTE: <sup>1/</sup> Residual elements need not be reported unless they exceed the individual or total composition ranges in this table. Residual elements are any elements present in small quantities inherent to sponge or scrap additions, but not intentionally added. In titanium, these elements include, among others, Al, V, Sn, Cr, Mo, Nb, Zr, Hf, Bi, Ru, Pd, Cu, Si, and Co.		

3.4 **Heat treatment.** Material shall be heat treated in accordance with SAE AMS-H-81200. Material shall be heat treated in furnaces in accordance with the pyrometry requirements of SAE AMS2750 class 5 or better. Material shall be heat treated in an inert or vacuum atmosphere at 1050±25 °F, for a minimum of 25 minutes, plus an additional 15 minutes for each additional ½ inch of section thickness or fraction thereof over ½ inch (see 6.5.1). Material shall be furnace cooled to 300 °F, then air cooled to room temperature. When specified (see 6.2), heat treatment shall be in accordance with MIL-STD-1684.

3.5 **Tensile properties.** The tensile properties of all material shall meet or exceed the minimum values specified in [table II](#).

TABLE II. Tensile property requirements.

Property	Minimum value
Ultimate tensile strength (ksi)	50
Yield strength, 0.2% offset (ksi)	40
Elongation in 2 inches (%)	20

3.6 Charpy test impact energy. Charpy notched-bar test impact energy values shall meet or exceed a minimum of 50 foot-pounds.

3.7 Weld repair. Unless otherwise specified (see 6.2), weld repair shall be in accordance with S9074-AR-GIB-010/278.

3.8 Supplemental mechanical properties. Additional mechanical properties shall be as specified (see 6.2).

3.9 Surface condition. Unless otherwise specified (see 6.2), surfaces shall be ground, machined, or otherwise finished to produce smooth surfaces that are free of alpha case.

#### 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 tests of [table III](#).

TABLE III. Conformance inspections.

Examinations and tests	Requirement	Conformance inspection
Feedstock	3.1	4.9
Build platform	3.2	4.9
Chemical composition	3.3	4.5
Heat treatment	3.4	4.9
Tensile properties	3.5	4.6
Charpy test impact energy	3.6	4.7
Weld repair	3.7	4.9
Supplemental mechanical properties	3.8	4.8 and 4.9
Surface condition	3.9	4.9

4.3 Lot size. For the purposes of inspections and tests, material produced in one build cycle, as specified in S9074-A4-GIB-010/AM-WIRE DED, and heat treated in the same furnace load shall constitute a manufacturing lot.

4.4 Sampling.

4.4.1 Chemical composition. A minimum of one sample shall be taken from each manufacturing lot for analysis, following heat treatment (see 3.4).

4.4.2 Tensile properties. A minimum of two tensile test specimens conforming to the standard round Specimen 1 geometry specified in ASTM E8/E8M, with gauge length four times the diameter, shall be taken from each manufacturing lot for testing, with at least one specimen taken with its length in the Z orientation and at least one specimen taken with its length in either the X or Y orientation (see 6.5.2). All specimens shall be taken from heat treated material (see 3.4). Specimens shall be machined from bulk deposition or near-net shape blanks.

4.4.3 Charpy test impact energy. A minimum of two Charpy V-notch specimens conforming to the standard size, as specified in ASTM E23, shall be taken from each manufacturing lot for testing, with specimen length in the X orientation (see 6.5.2). At least one specimen shall be notched on the XZ face, and at least one specimen shall be notched on the XY face. All specimens shall be taken from heat treated material (see 3.4). Specimens shall be machined from bulk deposition or near-net shape blanks.

4.4.4 Supplemental mechanical testing. Additional test types shall be conducted with specimen quantities, geometry, and orientation as specified (see 6.2).

4.4.5 Resampling and retesting. Unless otherwise specified (see 6.2), non-conforming test results may be addressed by testing of two additional samples taken from the same manufacturing lot as the original non-conforming sample. The average of all test results shall meet specified requirements for lot acceptance. If any two samples of any type of test fail to meet the acceptance criteria, then the lot shall be rejected. When specified (see 6.2), any lot may be rejected based on a single tensile test.

4.5 Chemical composition. The chemical composition shall be tested in accordance with ASTM E539, ASTM E1409, ASTM E1447, ASTM E1941, ASTM E2371, or ASTM E2994, or any combination thereof as applicable.

4.6 Tensile testing. Tensile test specimens shall be tested in accordance with ASTM E8/E8M.

4.7 Charpy testing. Charpy test specimens shall be tested in accordance with ASTM E23 at 28 °F (-2.2 °C).

4.8 Supplemental mechanical tests. Additional tests shall be conducted with specimen quantities, geometries, and orientations as specified (see 6.2).

4.9 Certificate of conformance. A certificate of conformance (COC) shall be prepared for each lot of material offered for acceptance in accordance with the lot definition specified herein (see 4.3). Unless otherwise specified (see 6.2), the COC shall be provided and shall include the following:

- a. A statement that each lot has been sampled, tested, and inspected in accordance with the requirements specified herein.
- b. For grade A material, a record of approval from the Technical Authority (see 6.5.3) or authorized representative that indicates the manufacturer is in compliance with S9074-A4-GIB-010/AM-WIRE DED.
- c. For grade B material, a statement specifying the industry standard(s) used to determine material compliance and a record of approval from the Technical Authority (see 6.5.3) or authorized representative thereof.
- d. A complete record of all heat treatments, including time, temperatures, atmosphere, and heating and cooling rates (see 3.4).
- e. A statement whether a weld repair has been performed (see 3.7), including a complete record of all repaired defects with location, weld repair inspection results, post-weld heat treatment (if any), and associated weld procedure approvals.
- f. A statement describing surface finishing method(s) used and certification that surfaces are free of alpha case (see 3.9).
- g. A complete record of testing used to demonstrate compliance with this specification, including any failed tests.

## 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. Wire DED CP titanium AM material is intended as an alternative for ASTM B367 grade C-2 castings for use in Navy applications.

6.2 Acquisition requirements. Acquisition documents should specify the following:

- a. Title, number, and date of this specification.
- b. Grade required (see 1.2).
- c. When use of feedstock lots from different heats is permissible (see 3.1).
- d. Permissible material specification and grade for integrated build platform and any additional test requirements associated with its use (see 3.2).
- e. When heat treatment in accordance with MIL-STD-1684 is required (see 3.4).
- f. Weld repair requirements or restrictions (see 3.7).
- g. Acceptance criteria for supplemental mechanical property tests (see 3.8).
- h. Requirements for surface finishing (see 3.9).
- i. Sampling criteria for supplemental mechanical property tests (see 4.4.4).
- j. Requirements for resampling and retesting (see 4.4.5).
- k. Requirements for supplemental mechanical testing (see 4.8).
- l. When a certificate of conformance is not required (see 4.9).
- m. Packaging requirements (see 5.1).

6.3 DED qualification. Grade B material requires the disclosure of a process qualification standard. Examples of appropriate commercial standards include SAE AMS7005 or AWS D20.1. These documents provide a framework to prove that the DED process is capable of producing material of consistent quality. Use of grade A material is recommended for critical applications.

6.4 Surface finish. Material produced using DED may have a rough surface finish that is associated with performance debits, particularly for corrosion resistance and fatigue life. A rough surface finish may also restrict the use of particular NDT methods (e.g., ultrasonic testing, dye penetrant testing, etc.), reducing inspectability. Material is often post-processed via machining, grinding, electrical discharge machining, polishing, and so forth to achieve the desired surface finish. To ensure good performance, prescriptive surface finishing requirements should be incorporated into acquisition requirements.

6.5 Definitions.

6.5.1 Section thickness. The section thickness is the minimum dimension of the heaviest section of the material determined by the diameter of an inscribed sphere.

6.5.2 DED build orientations. The Z orientation is perpendicular to the build direction, i.e., perpendicular to the surface of the build platform if no reorientation has occurred. The X orientation is parallel to travel direction, and the Y orientation is perpendicular to travel direction and parallel to the layer plane.

6.5.3 Technical authority. The Technical Authority has the authority, responsibility, and accountability to establish, monitor, and approve technical standards, tools, and processes in conformance to higher authority policy, requirements, architectures, and standards. NAVSEA 05S may be contacted to determine the appropriate Technical Authority for any given requirement related to equipment and systems of U.S. Navy ships and submarines.

6.6 Subject term (key word) listing.

3-D Printing  
Casting Substitute  
Metal Printing

CONCLUDING MATERIAL

Custodians:

Army – MR  
Navy – SH

Preparing activity:

Navy – SH  
(Project AMPR-2025-008)

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at <https://assist.dla.mil>.