

PROJECT PECULIAR DOCUMENT  
 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 material made from additively manufactured (AM) commercially pure (CP) titanium using the wire arc directed energy deposition (DED) process. This material will typically require machining and/or other types of surface finishing prior to inspection, assembly, and use. It is intended that material produced to this specification can be used as an alternative to ASTM B367 grade C-2 castings.

1.2. Classification. 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.

## 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 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 Directed Energy Deposition Additive Manufacturing
S9074-AQ-GIB-010/248	-	Requirements for Welding and Brazing Procedure and Performance Qualification

(Copies of this document 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

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](mailto: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>.

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 A5.16/5.16M - Specification for Titanium and Titanium-Alloy Welding Electrodes

(Copies of this document 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

(Copies of this document 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 provided in the form of CP titanium wire spools suitable for the DED process. Wire feedstock shall meet the requirements specified in AWS A5.16/A5.16M, classification ERTi-2.

#### 3.2 DED build requirements.

3.2.1 Feedstock heat. Each production lot shall be produced from a single heat of feedstock.

3.2.2 Build platform. Unless otherwise specified (see 6.2), integrated build platform material for DED AM material shall be S-51 or S-52 titanium in accordance with S9074-AQ-GIB-010/248.

3.2.3 Sacrificial build platform. If a material other than S-51 or S-52 titanium is used for the sacrificial build platform, a minimum of 1 inch of discardable AM build material shall separate the sacrificial build platform from the final component's attached dimensional surface.

3.2.4 Platform removal. Non-integrated build platform removal from the AM part shall use methods that will not affect the mechanical properties of the AM part (e.g., band saw, water jet, machining, or electro-discharge machining with recast layer removed).

3.3 Chemical composition. Feedstock and all DED material shall conform to the compositions specified in [table I](#).

TABLE I. Chemical composition (weight percent).

	Minimum (%)	Maximum (%)
Carbon	---	0.03
Oxygen	0.08	0.20
Nitrogen	---	0.02
Hydrogen	---	0.008
Iron	---	0.16
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 element 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. Unless otherwise specified (see 6.2), all 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 to 660 °F followed by furnace cooling to 500 °F, then air-cooled to room temperature. Time at temperature shall be a minimum of 1 hour plus an additional 20 minutes at temperature for each additional ½ inch or fraction thereof of section thickness greater than 1 inch (see 6.5.1).

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

TABLE II. Tensile properties.

Property	Minimum value
Ultimate tensile strength (ksi)	50
Yield strength, 0.2% offset (ksi)	40
Elongation (%)	15

3.6 Impact energy requirement. Charpy impact energy values shall be a minimum of 50 foot-pounds.

3.7 Weld repair. Weld repair shall be in accordance S9074-A4-GIB-010/AM-WIRE DED.

#### 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	4.8
DED build requirements	3.2	4.8
Chemical analysis	3.3	4.5
Tensile properties	3.4 and 3.5	4.6
Impact energy	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, 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 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 Impact energy. Unless otherwise specified (see 6.2), for each lot, a minimum of two samples shall be taken from material deposited in the X orientation.

4.5 Chemical analysis. The chemical composition of each lot shall be tested in accordance with ASTM E539, ASTM E1409, ASTM E1447, ASTM E1941, ASTM E2371, and ASTM E2994, as applicable, and shall meet the requirements of [table I](#).

4.6 Tensile properties. The tensile properties shall be tested after heat treatment in accordance with ASTM E8/E8M and shall meet the requirements of [table II](#) (see 3.5). 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 material or taken from near net shape specimens.

4.7 Impact energy properties. Charpy V-notch specimens shall be prepared and tested in accordance with ASTM E23 at 28 °F (-2.2 °C) using standard 0.394-inch x 0.394-inch specimens with the specimen length in the X orientation. Unless otherwise specified (see 6.2), Charpy V-notch specimens shall conform to the standard geometries specified in ASTM E23 and shall be machined from bulk deposition material or taken from near net shape specimens. One specimen shall have the V-notch located on the XZ face and one specimen shall have the V-notch located on the XY face.

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 DED build materials 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-A4-GIB-010/AM-WIRE DED. For grade B material, the COC shall state the manufacturer or industry standards used to determine material compliance. 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). When weld repair is performed (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 in accordance with S9074-A4-GIB-010/AM-WIRE DED 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. Wire DED CP titanium AM material is intended for replacement of ASTM B367 grade C-2 castings for new construction and repair of Navy submarines and surface platforms.

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. Requirement for build platform material that is other than S-51 or S-52 titanium (see 3.2.2).
- d. When heat treatment is not required (see 3.4).
- e. Variable lot size when required (see 4.3).
- f. Number of samples and orientation if other than specified (see 4.4.2 and 4.4.3).
- g. Tension test coupon requirements if other than specified (see 4.6).
- h. Charpy V-notch specimen requirements if other than specified (see 4.7).
- i. When a certificate of conformance is not required (see 4.8).
- j. Packaging requirements (see 5.1).

6.3 Navy technical publication. The directed energy deposition (DED) manufacturing process is sensitive to process instabilities. Material produced by this process is difficult to inspect through conventional nondestructive evaluation techniques that the process is uniquely suited to produce. Therefore, the qualification framework described in S9074-A4-GIB-010/AM-WIRE DED is recommended to ensure material of consistent quality 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. 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.

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.

6.6 Subject term (key word) listing.

3-D Printing  
Casting Substitute  
Metal Printing