S9074-A4-GIB-010/AM-WIRE DED

REVISION 1

NAVSEA TECHNICAL PUBLICATION

REQUIREMENTS FOR METAL WIRE-FED DIRECTED ENERGY DEPOSITION ADDITIVE MANUFACTURING

Supersedure Notice: This revision supersedes S9074-A4-GIB-010/AM-WIRE DED dated 27 May 2021.

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08 JULY 2024

RECORD OF REVISIONS

REVISION NO.	DATE	TITLE OR BRIEF DESCRIPTION/PREPARING ACTIVITY
0	27 MAY 2021	Initial issue.
1	08 JULY 2024	This revision streamlines the qualification process for metal Directed Energy Deposition (DED) Additive Manufacturing procedures and components using wire feedstock and added allowances for additional DED technologies. The requirement for approval of the DED Procedure prior to execution of procedure qualification builds has been removed. The requirements for the DED Procedure and the procedure qualification requirements have been changed to better match commercial best practices. The requirement to perform nondestructive testing in all cases have been streamlined and clarified. Destructive testing requirements have been streamlined for procedure qualification and part verification. Electron beam and laser DED requirements have been added. Other clarifications to requirements have been made throughout the document.

FOREWORD

This document covers general requirements, provisions for quality assurance and Process Control Plans, test procedures, and instructions for preparation for delivery of directed energy deposition-produced parts.

TECHNICAL MANUAL FEEDBACKS

Ships, training activities, supply points, depots, Naval Shipyards and Supervisors of Shipbuilding are requested to arrange for the maximum practical use and evaluation of NAVSEA technical manuals. All errors, omissions, discrepancies and suggestions for improvement to NAVSEA technical manuals shall be submitted via one of the following methods:

1. The preferred method is to submit the Feedback directly into MBPS at https://mbps.navseaplm.navy.mil/Windchill/. MBPS is an unclassified system, do not include U-NNPI or Classified data as attachments to a feedback. See option 5 for classified data. To request a MBPS account submit a ticket to the National Help Desk Service Management (NHDSM) at https://nhdsm.navair.navy.mil/ (DoD PKI Certificate required).

2. Submit a ticket via NHDSM. When submitting the ticket, include a completed copy of NAVSEA 4160/1 (TMDER Form). All data submitted via NHDSM shall be unclassified only.

3. Email a completed copy of NAVSEA 4160/1 to nav_helpdesk.fct@navy.mil. All data submitted shall be unclassified only.

4. For non-Help Desk account holders, submit the feedback via the following link (CAC or ECA Cert Required): https://nhdsm.navair.navy.mil/HEAT/alp.aspx?Scope=SelfService&CommandId=NewServiceRequestByOfferingId&Tab=ServiceCatalog&Template=1DE99338DBF9480D9CD3F6EE57B08124 When submitting the ticket, include a completed copy of NAVSEA 4160/1. All data submitted shall be unclassified only.

5. For NNPI and Classified data, continue to use the paper copy of NAVSEA 4160/1 and submit using the current process.

All feedback comments shall be thoroughly investigated, and originators will be advised of action resulting therefrom. One copy of NAVSEA form 4160/1 is at the end of each separately bound technical manual 8-1/2 x 11 inches or larger.

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CHAPTER 1
SCOPE AND APPLICABILITY

1-1 SCOPE.

This document provides the minimum qualification requirements, part verification requirements, and performance requirements for fabricating metal components using directed energy deposition (DED) additive manufacturing (AM) with wire feedstock. This document also covers the general requirements, provisions for quality assurance and Process Control Plan, test procedures, and instructions in preparation for delivery of DED-produced materials. Procedure qualification, part verification, and operator qualification requirements, as well as completion of all assessments and requirements for NAVSEA's use of AM shall be met prior to any production fabrication, as specified in NAVSEA Letter 4870 Ser 05T/2018-024 or as superseded. The requirements in this document are devised to demonstrate that sound DED parts can be produced. This document does not purport to address all the safety concerns associated, if any, with the use of DED. It is the responsibility of the user of this document to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1-2 NON-APPLICABILITY.

1-2.1 NAVAL NUCLEAR PROPULSION. This document does not apply to naval nuclear propulsion plant systems, equipment, and facilities under the cognizance of the Deputy Commander, Nuclear Propulsion Directorate (SEA 08). As outlined in EO 12344, the SEA 08 Deputy Commander has responsibilities and authorities over all facilities and activities that comprise the Naval Nuclear Propulsion Program, which is a joint Department of Energy and Navy organization. These responsibilities and authorities include all technical and logistical matters related to naval nuclear propulsion. Accordingly, nothing in this document supersedes or changes those authorities, and SEA 08 shall be consulted concerning all matters related to naval nuclear propulsion.

1-2.2 STRATEGIC SYSTEMS PROGRAMS. This document does not apply to Strategic Weapons Systems, Attack Weapons Systems, and associated spares and repair parts under the cognizance of Strategic Systems Programs.

1-2.3 NON-CRITICAL APPLICATIONS. This document does not apply to applications covered by NAVSEA Letter 9070 Ser 05Z/191 or to applications with service condition level severities of level 7 and N/A, in accordance with NAVSEA's requirements on the use of AM.

1-3 REQUIREMENTS SUBJECT TO NAVSEA APPROVAL.

Any requirements contained in this document specifically requiring NAVSEA approval shall be forwarded to Naval Sea Systems Command, SEA 05T1, 1333 Isaac Hull Ave SE Stop 5142, Washington Navy Yard, DC 20376-5142 via the AM Authorized Representative. Subcontractors shall submit such items to the contracting activity in accordance with the contract or purchase order. Contracting activities and authorized representatives shall thoroughly review and make recommendations as to the acceptability of the request submitted.

1-4 REFERENCED DOCUMENTS.

1-4.1 GOVERNMENT DOCUMENTS.

1-4.1.1 Defense Standardization Program Documents.

FEDERAL SPECIFICATIONS

QQ-B-639	-	Brass, Naval: Flat Products
QQ-C-450	-	Copper-Aluminum Alloy (Aluminum Bronze) Plate, Sheet, Strip, and Bar (Copper Alloy Numbers 606, 610, 613, 614, and 630)
QQ-N-281	-	Nickel-Copper Alloy Bar, Rod, Plate, Sheet, Strip, Wire, Forgings, and Structural and Special Shaped Sections

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-T-1368	-	Tube and Pipe, Nickel-Copper Alloy, Seamless and Welded
MIL-T-15005	-	Tubes, Condenser and Heat Exchanger, Copper-Nickel Alloys (UNS C70600 & C71500)
MIL-DTL-15382	-	Bolt, Firebrick Anchor
MIL-C-15726	-	Copper-Nickel Alloy, Sheet, Plate, Strip, Bar, Rod, and Wire
MIL-T-16286	-	Tube, Steel, Seamless, Marine Boiler Application
MIL-T-16420	-	Tube, Copper-Nickel Alloy, Seamless and Welded (Copper Alloy Numbers 715 and 706)
MIL-E-19933	-	Electrodes and Rods – Welding, Bare, Chromium and Chromium-Nickel Steels
MIL-E-21562	-	Electrodes and Rods – Welding, Bare, Nickel Alloy
MIL-S-22698	-	Steel Plate, Shapes and Bars, Weldable Ordinary Strength and Higher Strength: Structural
MIL-DTL-23193	-	Steel, Corrosion Resistant, Castings (UNS J92600, J92710, J92900, and J92999)
MIL-DTL-23194	-	Steel, Forgings, Carbon and Low Alloy (UNS K13502, K12766 and K42365)
MIL-DTL-23195	-	Steel Bars and Forgings, Corrosion Resistant (UNS S30400/S30403, S31600/S31603, S34700, and S34800)
MIL-DTL-23196	-	Steel Plate, Corrosion Resistant (UNS S30400/S30403, S31600/S31603, S31703, S34700, and S34800)
MIL-DTL-23226	-	Tube and Pipe, Corrosion-Resistant Steel, Seamless (UNS S30400, S30403, S30400/S30403, S31600/S31603, S31703, S34700, and S34800)
MIL-DTL-23227	-	Tube and Pipe, Nickel-Chromium-Iron Alloy (UNS N06600)
MIL-DTL-23228	-	Nickel Chromium-Iron Alloy Plate, Sheet and Strip

MIL-DTL-23229	-	Nickel-Chromium-Iron Alloy Bars and Forgings (UNS N06600)
MIL-S-23284	-	Steel Forgings, Carbon and Alloy, for Shafts, Sleeves, Propeller Nuts, Couplings, and Stocks (Rudders and Diving Planes)
MIL-DTL-23467	-	Fittings and Flanges, Wrought, Seamless, Butt and Socket Welding, Austenitic Corrosion-Resistant Steel (UNS S30400, S30403, S30400/S30403, S31600/S31603, S31703, S34700, and S34800)
MIL-DTL-23508	-	Fittings and Flanges, Wrought, Seamless Butt and Socket Welding, Nickel-Chromium-Iron Alloy (UNS N06600)
MIL-DTL-23509	-	Fittings and Flanges, Wrought, Seamless, Butt and Socket Welding, Nickel-Copper Alloy (UNS N04400)
MIL-DTL-23520	-	Tube and Pipe, Nickel-Copper Alloy, Seamless, Air Melted (UNS N04400)
MIL-E-23765/1	-	Electrodes and Rods – Welding, Bare, Solid and Alloyed Cored, Ordinary Strength and Low Alloy Steel
MIL-E-23765/2	-	Electrodes and Rods – Welding, Bare, Solid, or Alloyed Cored; and Fluxes, Low Alloy Steel
MIL-E-23765/3	-	Electrodes and Rods – Welding, Bare, Solid Copper Alloy
MIL-S-24093	-	Steel Forgings, Carbon and Alloy Heat Treated
MIL-DTL-24106	-	Nickel-Copper Alloy Bars, Rods, and Forgings (UNS N04400)
MIL-DTL-24128	-	Low Carbon Chromium Steel Bars and Forgings
MIL-S-24238	-	Steel Plate Carbon and Low Alloy
MIL-N-24271	-	Nickel-Chromium-Iron Alloy Castings
MIL-P-24338	-	Pipe, Carbon Steel, Seamless
MIL-DTL-24339	-	Fittings and Flanges, Wrought, Seamless, Butt and Socket Welding Carbon Steel
MIL-DTL-24342	-	Fittings and Flanges, Wrought Seamless, Butt and Socket Welding, 70-30 Copper-Nickel Alloy (UNS C71500)
MIL-B-24480	-	Bronze, Nickel-Aluminum (UNS No. C95800) Castings for Seawater Service
MIL-DTL-24652	-	Extinguisher, Fire, Aqueous Film Forming Foam (AFFF), 2.5-Gallon
DOD-F-24669	-	Forgings and Forging Stock, Steel Bars, Billets and Blooms, General Specification for (Metric)
DOD-F-24669/1	-	Forgings and Forging Stock, Steel (Carbon and Alloy) Blooms, Bars, Billets and Slabs (Metric)
DOD-F-24669/2	-	Forgings and Forging Stock, Steel Bars and Billets – Chromium-Molybdenum Alloy (Metric)

DOD-F-24669/6	-	Forgings and Forging Stock, Steel Bars and Billets, Corrosion Resisting; for Reforging (Metric)
DOD-F-24669/7	-	Forgings and Forging Stock, Steel Bars and Billets, Corrosion Resisting; Naval Steam Turbine Parts Use (Metric)
MIL-P-24691/1	-	Pipe and Tube, Carbon Steel, Seamless
MIL-P-24691/2	-	Pipe and Tube, Chromium-Molybdenum Steel, Seamless
MIL-P-24691/3	-	Pipe and Tube, Corrosion-Resistant, Stainless Steel, Seamless or Welded
MIL-DTL-24707/1	-	Castings, Ferrous, for Machinery and Structural Applications
MIL-C-24707/2	-	Castings, for Pressure Containing Parts Suitable for High Temperature Service
MIL-C-24707/3	-	Castings, Ferrous, Corrosion-Resistant, Austenitic, Chromium-Nickel
MIL-C-24707/6	-	Castings, Ferrous, Chromium Steel, for Pressure-Containing Parts Suitable for High-Temperature Service
MIL-C-24723	-	Castings, Nickel-Copper Alloy
MIL-DTL-32528	-	Rod, Bar, and Billet, Titanium Alloy TI-5111 for Use in Critical Seawater Applications

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-2035	-	Nondestructive Testing Acceptance Criteria

(Copies of these documents are available online at https://quicksearch.dla.mil.)

1-1.4.2 Other Government Publications.

NAVAL SEA SYSTEMS COMMAND (NAVSEA) LETTERS

4870 Ser 05T/2018-024	-	Guidance on the Use of Additive Manufacturing
9070 Ser 05Z/191	-	Guidance on Identification and Installation of Low Risk Additively Manufactured Metal Components
9074 Ser 05Z/223	-	Guidance for Performing Non-Destructive Testing and Non-Destructive Testing Procedure Qualification in Support of Additive Manufacturing Efforts

(Copies of these documents are available by request from Command Standards at CommandStandards@navy.mil.)

NAVAL SEA SYSTEMS COMMAND (NAVSEA) PUBLICATIONS

S9074-AQ-GIB-010/248	-	Requirements for Welding and Brazing Procedure and Performance Qualification
S9074-AR-GIB-010/278	-	Requirements for Fabrication Welding and Inspection, and Casting Inspection and Repair for Machinery, Piping, and Pressure Vessels

S9074-A1-GIB-010/1628	-	Fillet Weld and Partial Penetration Groove Tee Weld Size, Strength, and Efficiency Determination
T9074-AD-GIB-010/1688	-	Requirements for Fabrication, Welding, and Inspection of Submarine Structure
T9074-AS-GIB-010/271	-	Requirements for Nondestructive Testing Methods
T9074-BC-GIB-010/0200	-	Filler Materials for Critical Applications: Requirements for Flux-Cored Welding Electrodes Bare Welding Electrodes and Fluxes, and Covered Welding Electrodes for Low-Alloy Applications
T9074-BD-GIB-010/0300	-	Base Materials for Critical Applications: Requirements for Low Alloy Steel Plate, Forgings, Castings, Shapes, Bars, and Heads of HY-80/100/130 and HSLA-80/100

(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. These documents are 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.)

1-4.2 NON-GOVERNMENT DOCUMENTS.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME BPVC Section V	-	Nondestructive Examination

(Copies of this document are available online at www.asme.org.)

AMERICAN WELDING SOCIETY (AWS)

AWS A2.4	-	Standard Symbols for Welding, Brazing, and Nondestructive Examination
AWS A3.0M/A3.0	-	Standard Welding Terms and Definitions Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying
AWS A5.01M/A5.01	-	Welding and Brazing Consumables – Procurement of Filler Materials and Fluxes
AWS A5.7/A5.7M	-	Specification for Copper and Copper-Alloy Bare Welding Rods and Electrodes
AWS A5.9/A5.9M	-	Specification for Bare Stainless Steel Welding Electrodes and Rods
AWS A5.10/A5.10M	-	Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods
AWS A5.14/A5.14M	-	Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods

AWS A5.16/A5.16M	-	Specification for Titanium and Titanium-Alloy Welding Electrodes and Rods
AWS A5.23/5.23M	-	Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding
AWS A5.28/5.28M	-	Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding
AWS B4.0	-	Standard Methods for Mechanical Testing of Welds

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

ASTM INTERNATIONAL

ASTM A27/A27M	-	Standard Specification for Steel Castings, Carbon, for General Application
ASTM A36/A36M	-	Standard Specification for Carbon Structural Steel
ASTM A53/A53M	-	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A105/A105M	-	Standard Specification for Carbon Steel Forgings for Piping Applications
ASTM A106/A106M	-	Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service
ASTM A131/A131M	-	Standard Specification for Structural Steel for Ships
ASTM A134/A134M	-	Standard Specification for Pipe, Steel, Electric-Fusion (Arc)-Welded (Sizes NPS 16 and Over)
ASTM A178/A178M	-	Standard Specification for Electric-Resistance-Welded Carbon Steel and Carbon-Manganese Steel Boiler and Superheater Tubes
ASTM A179/A179M	-	Standard Specification for Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes
ASTM A182/A182M	-	Standard Specification for Forged or Rolled Alloy Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
ASTM A192/A192M	-	Standard Specification for Seamless Carbon Steel Boiler Tubes for High-Pressure Service
ASTM A210/A210M	-	Standard Specification for Seamless Medium-Carbon Steel Boiler and Superheater Tubes
ASTM A213/A213M	-	Standard Specification for Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes
ASTM A214/A214M	-	Standard Specification for Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes

ASTM A216/A216M	-	Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
ASTM A217/A217M	-	Standard Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service
ASTM A234/A234M	-	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
ASTM A240/A240M	-	Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
ASTM A269/A269M	-	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
ASTM A276/A276M	-	Standard Specification for Stainless Steel Bars and Shapes
ASTM A283/A283M	-	Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates
ASTM A285/A285M	-	Standard Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
ASTM A302/A302M	-	Standard Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum and Manganese-Molybdenum-Nickel
ASTM A312/A312M	-	Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
ASTM A333/A333M	-	Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service and Other Applications with Required Notch Toughness
ASTM A334/A334M	-	Standard Specification for Seamless and Welded Carbon and Alloy-Steel Tubes for Low-Temperature Service
ASTM A350/A350M	-	Standard Specification for Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping Components
ASTM A351/A351M	-	Standard Specification for Castings, Austenitic, for Pressure-Containing Parts
ASTM A352/A352M	-	Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service
ASTM A369/A369M	-	Standard Specification for Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service
ASTM A372/A372M	-	Standard Specification for Carbon and Alloy Steel Forgings for Thin-Walled Pressure Vessels
ASTM A403/A403M	-	Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings

ASTM A414/A414M	-	Standard Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy for Pressure Vessels
ASTM A420/A420M	-	Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service
ASTM A473	-	Standard Specification for Stainless Steel Forgings
ASTM A479/A479M	-	Standard Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
ASTM A487/A487M	-	Standard Specification for Steel Castings Suitable for Pressure Service
ASTM A494/A494M	-	Standard Specification for Castings, Nickel and Nickel Alloy
ASTM A500/A500M	-	Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
ASTM A501/A501M	-	Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing
ASTM A511/A511M	-	Standard Specification for Seamless Stainless Steel Mechanical Tubing and Hollow Bar
ASTM A512	-	Standard Specification for Cold-Drawn Buttweld Carbon Steel Mechanical Tubing
ASTM A513/A513M	-	Standard Specification for Electric-Resistance-Welded Carbon and Alloy Steel Mechanical Tubing
ASTM A515/A515M	-	Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service
ASTM A516/A516M	-	Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
ASTM A519/A519M	-	Standard Specification for Seamless Carbon and Alloy Steel Mechanical Tubing
ASTM A524/A524M	-	Standard Specification for Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures
ASTM A537/A537M	-	Standard Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel
ASTM A554	-	Standard Specification for Welded Stainless Steel Mechanical Tubing
ASTM A556/A556M	-	Standard Specification for Seamless Cold-Drawn Carbon Steel Feedwater Heater Tubes
ASTM A562/A562M	-	Standard Specification for Pressure Vessel Plates, Carbon Steel, Manganese-Titanium for Glass or Diffused Metallic Coatings
ASTM A572/A572M	-	Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel

ASTM A575	-	Standard Specification for Steel Bars, Carbon, Merchant Quality, M-Grades
ASTM A576	-	Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality
ASTM A587	-	Standard Specification for Electric-Resistance-Welded Low-Carbon Steel Pipe for the Chemical Industry
ASTM A606/A606M	-	Standard Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance
ASTM A659/A659M	-	Standard Specification for Commercial Steel (CS), Sheet and Strip, Carbon (0.16 Maximum to 0.25 Maximum Percent), Hot-Rolled
ASTM A660/A660M	-	Standard Specification for Centrifugally Cast Carbon Steel Pipe for High-Temperature Service
ASTM A662/A662M	-	Standard Specification for Pressure Vessel Plates, Carbon-Manganese-Silicon Steel, for Moderate and Lower Temperature Service
ASTM A666	-	Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar
ASTM A671/A671M	-	Standard Specification for Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures
ASTM A672/A672M	-	Standard Specification for Electric-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures
ASTM A709/A709M	-	Standard Specification for Structural Steel for Bridges
ASTM A727/A727M	-	Standard Specification for Carbon Steel Forgings for Piping Components with Inherent Notch Toughness
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 A765/A765M	-	Standard Specification for Carbon Steel and Low-Alloy Steel Pressure-Vessel-Component Forgings with Mandatory Toughness Requirements
ASTM A794/A794M	-	Standard Specification for Commercial Steel (CS), Sheet, Carbon (0.16% Maximum to 0.25% Maximum), Cold-Rolled
ASTM A813/A813M	-	Standard Specification for Single- or Double-Welded Austenitic Stainless Steel Pipe
ASTM A830/A830M	-	Standard Specification for Plates, Carbon Steel, Structural Quality, Furnished to Chemical Composition Requirements

ASTM A945/A945M	-	Standard Specification for High-Strength Low-Alloy Structural Steel Plate with Low Carbon and Restricted Sulfur for Improved Weldability, Formability, and Toughness
ASTM A1008/A1008M	-	Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Required Hardness, Solution Hardened, and Bake Hardenable
ASTM A1011/A1011M	-	Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength
ASTM B21/B21M	-	Standard Specification for Naval Brass Rod, Bar, and Shapes
ASTM B26/B26M	-	Standard Specification for Aluminum-Alloy Sand Castings
ASTM B98/B98M	-	Standard Specification for Copper-Silicon Alloy Rod, Bar and Shapes
ASTM B124/B124M	-	Standard Specification for Copper and Copper Alloy Forging Rod, Bar, and Shapes
ASTM B138/B138M	-	Standard Specification for Manganese Bronze Rod, Bar, and Shapes
ASTM B139/B139M	-	Standard Specification for Phosphor Bronze Rod, Bar, and Shapes
ASTM B150/B150M	-	Standard Specification for Aluminum Bronze Rod, Bar, and Shapes
ASTM B152/B152M	-	Standard Specification for Copper Sheet, Strip, Plate, and Rolled Bar
ASTM B166	-	Standard Specification for Nickel-Chromium-Aluminum Alloy, Nickel-Chromium-Iron Alloys, Nickel-Chromium-Cobalt-Molybdenum Alloy, Nickel-Iron-Chromium-Tungsten Alloy, and Nickel-Chromium-Molybdenum-Copper Alloy Rod, Bar, and Wire
ASTM B169/B169M	-	Standard Specification for Aluminum Bronze Sheet, Strip, and Rolled Bar
ASTM B209/B209M	-	Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
ASTM B210/B210M	-	Standard Specification for Aluminum and Aluminum-Alloy Drawn Seamless Tubes
ASTM B211/B211M	-	Standard Specification for Aluminum and Aluminum-Alloy Rolled or Cold Finished Bar, Rod, and Wire
ASTM B221	-	Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
ASTM B241/B241M	-	Standard Specification for Aluminum and Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube

ASTM B265	-	Standard Specification for Titanium and Titanium Alloy Strip, Sheet, and Plate
ASTM B283/B283M	-	Standard Specification for Copper and Copper-Alloy Die Forgings (Hot-Pressed)
ASTM B308/B308M	-	Standard Specification for Aluminum-Alloy 6061-T6 Standard Structural Profiles
ASTM B338	-	Standard Specification for Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers
ASTM B348/B348M	-	Standard Specification for Titanium and Titanium Alloy Bars and Billets
ASTM B361	-	Standard Specification for Factory-Made Wrought Aluminum and Aluminum-Alloy Welding Fittings
ASTM B363	-	Standard Specification for Seamless and Welded Unalloyed Titanium and Titanium Alloy Welding Fittings
ASTM B367	-	Standard Specification for Titanium and Titanium Alloy Castings
ASTM B369/B369M	-	Standard Specification for Copper-Nickel Alloy Castings
ASTM B381	-	Standard Specification for Titanium and Titanium Alloy Forgings
ASTM B443	-	Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy and Nickel-Chromium-Molybdenum-Silicon Alloy Plate, Sheet, and Strip
ASTM B444	-	Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloys (UNS N06625 and UNS N06852) and Nickel-Chromium-Molybdenum-Silicon Alloy (UNS S06219) Pipe and Tube
ASTM B446	-	Standard Specification for Nickel-Chromium-Molybdenum-Columbium Alloy (UNS N06625), Nickel-Chromium-Molybdenum-Silicon Alloy (UNS N06219), and Nickel-Chromium-Molybdenum-Tungsten Alloy (UNS N06650) Rod and Bar
ASTM B483/B483M	-	Standard Specification for Aluminum and Aluminum-Alloy Drawn Tube and Drawn Pipe for General Purpose Applications
ASTM B564	-	Standard Specification for Nickel Alloy Forgings
ASTM B574	-	Standard Specification for Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Molybdenum-Chromium-Tantalum, Low-Carbon Nickel-Chromium-Molybdenum-Copper, and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten

ASTM B575	-	Standard Specification for Low-Carbon Nickel-Chromium-Molybdenum, Low-Carbon Nickel-Chromium-Molybdenum-Copper, Low-Carbon Nickel-Chromium-Molybdenum-Tantalum, Low-Carbon Nickel-Chromium-Molybdenum-Tungsten, and Low-Carbon Nickel-Molybdenum-Chromium
ASTM B622	-	Standard Specification for Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube
ASTM B861	-	Standard Specification for Titanium and Titanium Alloy Seamless Pipe
ASTM B862	-	Standard Specification for Titanium and Titanium Alloy Welded Pipe
ASTM B928/B928M	-	Standard Specification for High Magnesium Aluminum-Alloy Products for Marine Service and Similar Environments
ASTM E3	-	Standard Guide for Preparation of Metallographic Specimens
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 E92	-	Standard Test Methods for Vickers Hardness and Knoop Hardness of Metallic Materials
ASTM E112	-	Standard Test Methods for Determining Average Grain Size
ASTM E340	-	Standard Practice for Macroetching Metals and Alloys
ASTM E407	-	Standard Practice for Microetching Metals and Alloys
ISO/ASTM 52921	-	Standard Terminology for Additive Manufacturing - Coordinate Systems and Test Methodologies

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

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION

ISO/ASTM 52900	-	Additive Manufacturing – General Principles – Fundamentals and Vocabulary

(Copies of this document are available online at www.iso.org.)

SAE INTERNATIONAL

SAE AMS2772	-	Heat Treatment of Aluminum Alloy Raw Materials
SAE AMS4056	-	Aluminum Alloy, Sheet and Plate 4.4 Mg – 0.70 Mn – 0.15 Cr (5083-0) Annealed
SAE AMS6345	-	Steel, Sheet, Strip, and Plate 0.95Cr - 0.20Mo (0.28 - 0.33C) (SAE 4130) Normalized or Otherwise Heat Treated
SAE AMS6350	-	Steel Sheet, Strip, and Plate 0.95Cr - 0.20Mo (0.28 - 0.33C) (SAE 4130)

SAE AMS6351	-	Steel, Sheet, Strip, and Plate 0.95Cr - 0.20Mo (0.28 - 0.33C) (SAE 4130) Spheroidized
SAE AMS-A-21180	-	Aluminum-Alloy Castings, High Strength
SAE AMS-H-6875	-	Heat Treatment of Steel Raw Materials
SAE AMS-H-81200	-	Heat Treatment of Titanium and Titanium Alloys
SAE AMS-QQ-A-200/4	-	Aluminum Alloy 5083, Bar, Rod, Shapes, Tube, and Wire, Extruded
SAE AMS-QQ-A-200/5	-	Aluminum Alloy 5086, Bar, Rod, Shapes, Tube, and Wire, Extruded
SAE AMS-QQ-A-200/6	-	Aluminum Alloy 5454, Bar, Rod, Shapes, Tube, and Wire, Extruded
SAE AMS-QQ-A-200/7	-	Aluminum Alloy 5456, Bar, Rod, Shapes, Tube, and Wire, Extruded
SAE AMS-QQ-A-250/8	-	Aluminum Alloy 5052, Plate and Sheet
SAE AMS-QQ-A-250/10	-	Aluminum Alloy 5454, Plate and Sheet
SAE AMS-QQ-S-763	-	Steel, Corrosion Resistant, Bars, Wire, Shapes, and Forgings
SAE AMS-WW-T-700/5	-	Tube, Aluminum Alloy, Drawn, Seamless, 5086

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

1-4.3 CANCELLED SPECIFICATIONS.

The following are cancelled or superseded specifications for materials. They are listed in this document to identify applicable requirements for welding, nondestructive testing (NDT), etc., when the materials are encountered, such as on existing ships and components.

AMERICAN BUREAU OF SHIPPING

ABS 2 P2 - Rules for Materials and Welding

(Copies of this document are available online at ww2.eagle.org.)

FEDERAL SPECIFICATIONS

QQ-A-200/1	-	Aluminum Alloy 3003, Bar, Rod, Shapes, Tube and Wire, Extruded
QQ-A-200/4	-	Aluminum Alloy 5083, Bar, Rod, Shapes, Structural Shapes, Tube and Wire, Extruded
QQ-A-200/5	-	Aluminum Alloy 5086, Bar, Rod, Shapes, Tube and Wire, Extruded
QQ-A-200/6	-	Aluminum Alloy 5454, Bar, Rod, Shapes, Tube and Wire, Extruded
QQ-A-225/1	-	Aluminum Alloy Bar, Rod, and Wire; Rolled, Drawn or Cold Finished, 1100
QQ-A-225/2	-	Aluminum Alloy Bar, Rod, and Wire; Rolled, Drawn or Cold Finished, 3003

QQ-A-225/7	-	Aluminum Alloy 5052, Bar, Rod and Wire; Rolled, Drawn, or Cold Finished
QQ-A-250/1	-	Aluminum 1100, Plate and Sheet
QQ-A-250/2	-	Aluminum Alloy 3003, Plate and Sheet
QQ-A-250/6	-	Aluminum Alloy 5083, Plate and Sheet
QQ-A-250/8	-	Aluminum Alloy 5052, Plate and Sheet
QQ-A-250/10	-	Aluminum Alloy 5454, Plate and Sheet
QQ-A-601	-	Aluminum Alloy Sand Castings
QQ-B-637	-	Brass, Naval: Rod, Wire, Shapes, Forgings, and Flat Products with Finished Edges (Bar, Flat Wire, and Strip)
QQ-B-728	-	Bronze Manganese; Rod, Shapes, Forgings, and Flat Products (Flat Wire, Strip, Sheet, Bar, and Plates)
QQ-B-750	-	Bronze, Phosphor; Bar, Plate, Rod, Sheet, Strip, Flat Wire, and Structural and Special Shaped Sections
QQ-C-390	-	Copper Alloy Castings (Including Cast Bar)
QQ-C-465	-	Copper-Aluminum Alloys (Aluminum Bronze) (Copper Alloy Numbers 606, 614, 630, and 642); Rod, Flat Products with Finished Edges (Flat Wire, Strip, and Bar), Shapes, and Forgings
QQ-C-576	-	Copper Flat Products with Slit, Slit and Edge-Rolled, Sheared, Sawed or Machined Edges, (Plate, Bar, Sheet, and Strip)
QQ-C-591	-	Copper-Silicon, Copper-Zinc-Silicon, and Copper-Nickel-Silicon Alloys: Rod, Wire, Shapes, Forgings, and Flat Products (Flat Wire, Strip, Sheet, Bar, and Plate)
QQ-N-288	-	Nickel-Copper Alloy and Nickel-Copper-Silicon Alloy Castings
QQ-S-763	-	Steel Bars, Wire, Shapes, and Forgings; Corrosion Resistant
QQ-S-766	-	Steel, Stainless and Heat Resisting, Alloys, Plate, Sheet and Strip
WW-P-404	-	Pipe, Steel (Seamless and Welded Black and Zinc-Coated (Galvanized))
WW-T-700/1	-	Tube, Aluminum, Drawn, Seamless, 1100
WW-T-700/2	-	Tube, Aluminum, Alloy, Drawn, Seamless, 3003
WW-T-700/5	-	Tube, Aluminum Alloy, Drawn, Seamless, 5086

(Copies of these documents are available online at https://quicksearch.dla.mil.)

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-S-860	-	Steel Forgings for Steam Turbine Rotors
MIL-S-867	-	Steel Castings, Corrosion Resisting, Austenitic

MIL-S-870	-	Steel Casting, Molybdenum Alloy
MIL-T-3595	-	Tubing, Phosphor Bronze: (CDA No. 510) Round, Seamless
MIL-T-6736	-	Tubing, Chrome-Molybdenum, 4130 Steel, Seamless and Welded, Aircraft Quality
MIL-T-8504	-	Tubing, Steel, Corrosion-Resistant (304), Aerospace Vehicle Hydraulic Systems, Annealed, Seamless and Welded
MIL-S-8699	-	Steel Bars and Forging Stock (4330) Vanadium Modified, Aircraft Quality
MIL-T-9046	-	Titanium and Titanium Alloy, Sheet, Strip, and Plate
MIL-T-9047	-	Titanium and Titanium Alloy Bars (Rolled or Forged) and Reforging Stock, Aircraft Quality
MIL-S-15083	-	Steel Castings
MIL-C-15345	-	Castings, Nonferrous, Centrifugal
MIL-S-15464	-	Steel Alloy, Chromium-Molybdenum; Castings
MIL-S-16216	-	Steel Plate, Alloy, Structural, High Yield Strength (HY-80 and HY-100)
MIL-B-16541	-	Bronze, Valve: Castings
MIL-S-16993	-	Steel Castings (12-Percent Chromium)
MIL-N-17163	-	Nickel-Copper Alloy, Wrought; (55-60 Percent Nickel) Low Permeability
MIL-S-17509	-	Steel Castings, Austenitic, Chromium-Nickel, Low Magnetic Permeability
MIL-S-18728	-	Steel Plate, Sheet, and Strip, Alloy 8630, Aircraft Quality
MIL-S-18729	-	Steel Plate, Sheet, and Strip, Alloy 4130, Aircraft Quality
MIL-T-20155	-	Tubing, Steel, Alloy, Molybdenum, Seamless
MIL-T-20157	-	Tube and Pipe, Carbon Steel, Seamless
MIL-C-20159	-	Copper-Nickel Alloy Castings (UNS No. C96200 and C96400)
MIL-F-20236	-	Fittings, Tube and Pipe, Butt-Welding, 300 P.S.I, and 775°F Maximum
MIL-F-20670	-	Flanges, Pipe, Carbon Steel, 150 P.S.I., W.S.P (For Naval Shipboard Use)
MIL-A-21180	-	Aluminum-Alloy Castings, High Strength
MIL-B-21230	-	Bronze, Nickel Aluminum and Manganese-Nickel Aluminum, Castings, Ship Propeller Application
MIL-S-21952	-	Steel (HY-80 and HY-100) Bars, Alloy
MIL-S-23008	-	Steel Castings, Alloy, High Yield Strength (HY-80 and HY-100)
MIL-S-23009	-	Steel Forgings, Alloy, High Yield Strength (HY-80 and HY-100)

MIL-B-24059	-	Bronze, Nickel Aluminum; Rod, Flat Products with Finished Edges, Shapes and Forgings
MIL-E-24355	-	Electrodes, Welding, Bare, Solid, Nickel-Manganese-Chromium-Molybdenum Alloy Steel for Producing HY-130 Weldments for As-Welded Applications
MIL-S-24371	-	Steel Plate, Structural, High Yield Strength (HY-130)
MIL-S-24412	-	Steel, Special Structural Shape, Weldable, High Tensile (HT); for Submarine Hulls
MIL-S-24451	-	Steel Heat Treated Heads, Alloy Structural, High Yield Strength (HY-80 and HY-100)
MIL-S-24645	-	Steel Plate, Sheet, or Coil, Age-Hardening Alloy, Structural, High Yield Strength (HSLA-80 and HSLA-100)
MIL-F-24669/8	-	Forgings and Forging Stock, Steel for Integral Steam Turbine Rotors

(Copies of these documents are available online at https://quicksearch.dla.mil.)

AMERICAN WELDING SOCIETY (AWS)

AWS A5.27	-	Specification for Copper and Copper Alloy Rods for Oxyfuel Gas Welding

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

ASTM INTERNATIONAL

ASTM A176	-	Standard Specification for Stainless and Heat-Resisting Chromium Steel Plate, Sheet, and Strip
ASTM A441	-	Standard Specification for High-Strength Low-Alloy Structural Manganese Vanadium Steel
ASTM B337	-	Standard Specification for Seamless and Welded Titanium and Titanium Alloy Pipe
ASTM B429/B429M	-	Standard Specification for Aluminum-Alloy Extruded Structural Pipe and Tube
ASTM B547/B547M	-	Standard Specification for Aluminum and Aluminum-Alloy Formed and Arc-Welded Round Tube
ASTM A793	-	Standard Specification for Rolled Floor Plate, Stainless Steel

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

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

SAE AMS-QQ-A-225/2	-	Aluminum Alloy Bar, Rod, and Wire; Rolled, Drawn, or Cold Finished, 3003
SAE AMS6530	-	Steel Tubing, Seamless, 0.50NI – 0.55CR – 0.20MO (0.28-0.33C)

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

1-4.4 ORDER OF PRECEDENCE.

Except for fabrication documents, in the event of a conflict between the text of this document and the references cited herein, the text of this document shall take precedence.

1-5 DEFINITIONS.

1-5.1 TERMS RELATED TO ADDITIVE MANUFACTURING (AM).

1-5.1.1 General.

a. Except as noted herein, terms related to AM shall be as specified in ISO/ASTM 52900.
b. Except as noted herein, terms related to coordinate systems for AM shall be as specified in ISO/ASTM 52921.
c. Except as noted herein, NDT nomenclature and definitions shall be as specified in T9074-AS-GIB-010/271.
d. Except as noted herein, terms related to arc-based processes shall be as specified in AWS A3.0M/A3.0.

1-5.1.2 Acceptable. An item is acceptable when it complies with or conforms to the applicable standard or specification.

1-5.1.3 Active Cooling. Cooling of the deposited material, build platform, or both during the DED build processing in addition to the normal build environment, using methods such as fluid flow of gas or liquid, heat exchangers, or cooling plates.

1-5.1.4 Activity. All sites of an organization under the same quality assurance management and using the same quality assurance and Process Control Plans performing work to which this document is applicable.

1-5.1.5 Additive Manufacturing. The process of joining materials to make parts from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing and formative manufacturing methodologies (in accordance with ISO/ASTM 52900).

1-5.1.6 AM Authorized Representative. A representative specifically authorized to approve equipment, material, or procedures within the scope of this document for NAVSEA. AM Authorized Representatives are as follows:

a. The delegated representative(s) of the Commanding Officer, Naval Surface Warfare Center Carderock Division
b. Other individuals explicitly approved by NAVSEA

1-5.1.7 Approval (Approved). Approval means the item under consideration requires acceptance by NAVSEA or its AM Authorized Representative. “Approval” or “approved” as used herein shall be by the AM Authorized Representative, unless NAVSEA approval is specified.

1-5.1.8 Build. The physical items built from a single complete operation (“build cycle” in accordance with ISO/ASTM 52900) of the AM process.

1-5.1.9 Build Platform. Base that provides a surface upon which the building of the part(s) is started and supported throughout the build process (in accordance with ISO/ASTM 52900).

1-5.1.10 Digital File. All files, including dependent files, necessary to control the AM system during part fabrication. These files include file formats for communicating the surface model of the part (e.g., stereolithography [STL], IGES, or other computer-aided design [CAD] formats), slice files, build

files, etc. The set of files will be specific to the DED system software and ancillary software used for preparing the build.

1-5.1.11 Directed Energy Deposition (DED). An AM process in which focused thermal energy is used to fuse materials by melting as they are being deposited (in accordance with ISO/ASTM 52900).

1-5.1.11.1 Arc-Wire DED. DED that uses an arc as the power source and wire as the feedstock material.

1-5.1.11.2 Electron Beam Wire Directed Energy Deposition (DED). DED that uses an electron beam as the power source and wire as the feedstock material.

1-5.1.11.3 Laser Wire DED. DED that uses a laser as the power source and wire as the feedstock material.

1-5.1.12 Essential Elements. Elements, either material or process, that are important in establishing an AM procedure.

1-5.1.13 Fabrication Document. The document invoked by the contract, purchase order, or circular of requirements governing the work being accomplished.

1-5.1.14 Family of Parts. A set of parts with similar geometric features that can be made using the same procedure and qualification data.

1-5.1.15 Flat Position. The position where deposition is performed from the upper side of the build platform in which the weld axis, at the point and time of deposition, is approximately horizontal, and the weld face lies in an approximately horizontal plane (adapted from AWS A3.0M/A3.0).

1-5.1.16 Heat Treatment. A post-processing procedure that shall be defined as any of the following processes: homogenization/normalization, annealing, solution treating, precipitation hardening, austenitizing, tempering, quenching (in any medium), stress relieving, hydrogen soaking, or hot isostatic pressing (HIP).

1-5.1.17 Integrated Build. A build where DED will be performed on an existing component, assembly, or subassembly or any plate or other raw product form that will not be removed from the build prior to use.

1-5.1.18 Interpass. Frequency of an action that is performed between subsequent deposition passes.

1-5.1.19 Interlayer. Frequency of an action that is performed between layers.

1-5.1.20 Layer Height. The height of a single surface of material created when material is fused by the power source.

1-5.1.21 Machine. The section of the system including hardware, machine control software, required setup software, and peripheral accessories necessary to produce a build.

1-5.1.22 Non-Integrated Build. A build that will be removed from the build platform prior to use.

1-5.1.23 Operator. User of an AM machine.

1-5.1.24 Oscillation. Defining characteristics of oscillation include the following:

a. Amplitude: The distance normal to the direction of welding between the outermost positions that the electrode tip reaches while oscillating.

b. Dwell: The time during which the electrode rests at any point in each oscillating swing or traverse.

c. Frequency: The number of complete cycles made by the oscillating head in 1 minute, or other specified time increment.

1-5.1.25 Part. Final physical product fabricated using AM after all post-processing.

1-5.1.26 Part Verification Build. Preproduction build fabricated using final production procedures that serves as a model for preproduction testing and approval.

1-5.1.27 Position. The relationship between the weld pool, build platform, and heat source during deposition (adapted from AWS A3.0M/A3.0).

1-5.1.28 Power Source. Source of thermal energy delivered by a DED machine used for deposition.

1-5.1.29 Procedure. A written fabrication instruction that contains all the applicable essential elements listed in this document.

1-5.1.30 Procedure Qualification. An action by which test assemblies are prepared in accordance with a proposed procedure and evaluated by destructive or nondestructive tests, or both. Also included are requirements for qualification record keeping.

1-5.1.31 Procedure Qualification Build. Build consisting of the specimens for procedure qualification.

1-5.1.32 Review for Adequacy. A review determining that a submission contains all relevant controls and procedures defined in the applicable standard or specification that is actionable but does not require approval.

1-5.1.33 Special DED Applications/Parts. Parts or applications that require additional testing and approvals outside of the requirements of this document in accordance with NAVSEA requirements for AM. This shall include, but not be limited to, DED repair, parts in the Submarine Safety Program (SUBSAFE), Critical Ship Systems parts, Pressure Hull Boundaries parts, and Material Identification and Control level I parts.

1-5.1.34 System. AM equipment, machine, and auxiliary equipment used for producing DED parts.

1-5.1.35 TP 248 Authorized Representative. The authorized representative as defined by S9074-AQ-GIB-010/248.

1-5.1.36 Waiver. A document submitted for approval that allows for deviation from some or all the requirements in the procedure qualification.

1-5.1.37 Witness Coupon. Material built along with a part verification build or production build for reference or testing purposes from which test specimens can be obtained.

1-6 CLASSIFICATION.

1-6.1 INCLUDED CLASSIFICATION. The following classifications are contained in this document:

a. Machinery, class M-DED. S9074-AR-GIB-010/278 shall be the governing document for any requirements for this class outside of those listed in this document.

(1) Class M-DED-1. Class M-DED-1 machinery includes moving parts, such as gears, rotors, impellers, and shafting (excluding propulsion shafting and rudder stocks) that transmit torque or thrust.

(2) Class M-DED-2. Class M-DED-2 machinery includes stationary non-pressurized parts or structures, such as sub-bases for turbines, engines, motors, and pumps. Stationary pressurized components (other than turbines) that cannot be classified as pressure vessels or piping may be

classified as M-DED-2, if approved. Structures governed by T9074-AD-GIB-010/1688 and MIL-STD-1689 shall not be classified as M-DED-2.

Each of these sub-classes shall be further categorized as to criticality in accordance with the following:

(a) Category A. Safety and mission of the ship.

1 Safety. Includes machinery forming part of, or directly supporting, watertight integrity or machinery whose failure would cause loss of ship control, propulsion, or weight handling equipment.

2 Mission. Machinery essential to the mission of the ship, such as weapon and fire control systems, navigation communication systems, and major auxiliary support systems.

(b) Category B. Normal operation of the ship. Machinery essential to the normal operation of the ship.

(c) Category C. Non-essential items. Includes parts of components in categories A and B that do not transmit the principal operating load or support any type of pressure boundary.

b. Piping, class P-DED. Class P-DED piping includes all piping, tubing, and fittings for conveying fluids. S9074-AR-GIB-010/278 shall be the governing document for any requirements for this class outside of those listed in this document.

(1) Class P-DED-1. Class P-DED-1 includes production builds for design pressures exceeding 300 pounds per square inch (lb/in^2) or design temperatures exceeding 650 degrees Fahrenheit (°F), or both, such as steam lines, hydraulic systems, boiler generating tubes, superheater and economizer elements, other pressure retaining tubes and piping (excluding nozzles to pressure vessels, which are covered under the appropriate classification), and all piping systems for conveying oxygen, gasoline, and lethal gases or liquids regardless of pressure and temperature. This class also includes production builds in piping systems that transmit oxygen, helium, mixed gases, air, water, and exhaust of diving life support systems. Specifically excluded are pipe joints meeting the classification criteria of class P-DED-LT.

(2) Class P-DED-2. Class P-DED-2 includes production builds for design pressures not exceeding 300 lb/in^2 or 650 °F. Also included are fabrication builds of all open-ended vent, drain, and steam escape piping that has no isolation capability from its origin to its terminus regardless of the design temperature or pressure. Specifically excluded are pipe joints meeting the classification criteria of class P-DED-LT.

(3) Class P-DED-LT. Class P-DED-LT includes fabrication welds for all piping of design pressures greater than 50 lb/in^2 and service temperatures of -20 °F or below.

c. Pressure vessels and tanks, class A-DED. Class A-DED pressure vessels and tanks include production builds for parts of drums, tanks, or closed receptacles (including nozzles) and valves that are designed to contain gases or liquids. This includes all feed tanks, lubricating oil storage tanks, and similar vessels that contain only the static head of the obtained liquid. It does not include tubing or piping that joins to the pressure vessel, which are subject to the requirements of class P-DED piping. Valves to be installed in class P-DED-1 piping systems shall be fabricated and inspected in accordance with class A-DED-2 pressure vessel requirements. Valves to be installed in other classes of piping systems shall be fabricated and inspected in accordance with the appropriate pressure vessel category as determined by design temperatures and pressures. S9074-AR-GIB-010/278 shall be the governing document for any requirements for this class outside of those listed in this document. Tanks governed by T9074-AD-GIB-010/1688 and MIL-STD-1689 shall not be classified as class A-DED.

(1) Class A-DED-F. Class A-DED-F includes production builds for fired and unfired pressure vessels for all pressures and temperatures that are specifically designed for a finite fatigue life and are consequently required to undergo low-cycle fatigue evaluations. Also included are any structural builds made for the internal or external surfaces of a fluid boundary that are subject to the system pressure of the adjacent A-DED-F pressure vessel, but that do not form a part of the fluid boundary. Examples of pressure vessels in this class are all submergence pressure seawater cooled submarine heat exchangers and catapult steam receivers.

(2) Class A-DED-1. Class A-DED-1 includes production builds for fired pressure vessels, drums, and headers in which steam is generated by the application of heat resulting from the combustion of fuel. It includes economizer and superheater headers. Specifically excluded are builds for pressure vessels meeting the classification criteria of classes A-DED-2, A-DED-3, A-DED-4, or A-DED-LT.

(3) Class A-DED-2. Class A-DED-2 consists of production builds of unfired pressure vessels with design pressures or design temperatures exceeding 400 lb/in^2 or 600 °F, respectively, for liquids at 300 °F or higher, and for lethal gases and liquids at any temperature or pressure. Class A-2 also includes valves to be installed in class P-1 piping systems. Specifically excluded are builds for pressure vessels meeting the classification criteria of classes A-DED-3, A-DED-4, or A-DED-LT.

(4) Class A-DED-3. Class A-DED-3 consists of production builds of unfired pressure vessels with design pressures and design temperatures less than 400 lb/in^2 and 600 °F. Specifically excluded are builds for pressure vessels meeting the classification criteria of classes A-DED-4 or A-DED-LT.

(5) Class A-DED-4. Class A-DED-4 consists of production builds of unfired pressure vessels with design pressures or design temperatures less than 150 lb/in^2 and 450 °F, including tanks subject only to the static head of the liquid contained. Specifically excluded are builds for pressure vessels meeting the classification criteria of class A-DED-LT.

(6) Class A-DED-LT. Class A-DED-LT consists of production builds of pressure vessels with design pressures greater than 50 lb/in^2 and service temperatures of -20 °F and below.

1-6.2 OTHER CLASSIFICATIONS. Any part covered by any NAVSEA fabrication or other governing document that is not included in this section, including but not limited to, class T turbines in S9074-AR-GIB-010/278, or any components governed by T9074-AD-GIB-010/1688 or MIL-STD-1689, shall be considered a special DED part. The document in which these classes are described shall be the governing document for any requirements for this class outside of those listed in this document.

CHAPTER 2
QUALIFICATION REQUIREMENTS AND TEST REPORTS

2-1 SCOPE.

This section provides general requirements for the qualification of a DED Procedure, qualification of a part-specific Part Verification Procedure, and use of these procedures during production. Part review in accordance with NAVSEA's requirements on the use of AM may require changes to the requirements of this manual, which may include testing and acceptance criteria.

2-2 GENERAL REQUIREMENTS AND TEST REPORTS.

2-2.1 RESPONSIBILITY. Each activity shall prepare written DED Procedures and perform the required tests to qualify these procedures and parts prior to production DED builds.

2-2.1.1 Qualification Builds. Personnel performing procedure qualification builds and part verification builds shall be regular employees of the activity (i.e., not subcontractors or temporary specialists) and under the full supervision and control of the activity. Execution of procedure qualification builds and part verification builds should be accomplished at one of the activity's sites with the activity's DED equipment or equipment similar to that being acquired by the activity; if builds are performed at a site other than the activity's site, the activity's employee(s) responsible for developing the procedure being qualified and ensuring that it is correctly implemented shall also be present and directing the activity's operator during all builds.

2-2.2 CERTIFICATION OF QUALIFICATION TESTING. After testing, the responsible official of the activity shall certify that the tests, test results, and DED Procedure meet all requirements of this document. Qualification tests and data containing deviations from requirements may be submitted for approval if such deviations are specifically identified as deviations and the technical justification for each deviation is provided. Deviations shall not be used for production pieces until written approval is received from NAVSEA.

2-2.2.1 Approval of Other Procedure Qualifications. Procedure qualifications previously prepared for other Government agencies or other established regulatory codes may be submitted for approval to the AM Authorized Representative if the qualification testing and approval (to the other Government agencies or regulatory bodies requirements) occurred prior to an activity's invitation for bid or request for proposal. NDT requirements as specified in this document but not required by other agencies shall be accomplished on additional test samples or, if approved by an AM Authorized Representative, on a production application. Such data shall be submitted for approval as required in 2-2.3.

2-2.3 SUBMITTAL OF PROCEDURES, TEST PLANS, AND TEST REPORTS. Procedures are the activity's responsibility. Prior to the production application of the DED Procedure, the activity shall obtain approval of all documents required by 2-2.3.2, and shall submit for review for adequacy all documents required by 2-2.3.1. The activity shall submit all documents to the TP 248 Authorized Representative and the AM Authorized Representative for concurrent review. When required, or otherwise at their discretion, the AM Authorized Representative shall submit documents to NAVSEA for approval or review for adequacy. Once all requirements are met, the AM Authorized Representative shall be given notice of a minimum of 15 business days prior to the start of production to provide the opportunity to conduct an initial production audit. During production, the activity shall submit all documents required by 2-2.3.3 for part acceptance.

2-2.3.1 Review for Adequacy. The review for adequacy does not eliminate the need for waivers from the requirements herein. The activity shall submit the following documents for review for adequacy:

a. The DED Procedure in accordance with 3-2.
b. The Part Manufacturing Plan in accordance with 4-2.
c. Quality Assurance Plan in accordance with 7-2.
d. Process Control Plan in accordance with 7-3.
e. The activity may submit the draft DED Test Plan in accordance with 3-3 for review for adequacy.

If any submitted documents are found to not be adequate during the review for adequacy, appropriate controls shall be implemented and revised documentation shall be submitted prior to fabrication of any additional builds.

2-2.3.2 Procedure Approval. The activity shall provide the following for approval:

a. Procedure Qualification Test Report in accordance with 3-4.
b. Part Verification Test Plan in accordance with 4-3.
c. Part Verification Test Report in accordance with 4-4.
d. Production Conformance Evaluation Plan in accordance with chapter 5, unless already approved per 5-2.1.
e. New DED Procedure and Procedure Qualification Test Report when level 1 changes are made to the DED Procedure in accordance with 3-4, or when level 2 changes are made to the DED Procedure in accordance with 3-5
f. New Part Verification Test Plan and Part Verification Test Report when part level changes are made to the DED Procedure in accordance with 4-5.

2-2.3.3 Part Acceptance. During production, the activity shall provide the following for part acceptance:

a. Production Conformance Test Report in accordance with 5-6.
b. Certificate of Conformance in accordance with 5-6.1.

2-2.3.4 Approval by Audit. The activity shall identify the cases for which on-site audits shall be used to meet requirements for approval, review for adequacy, and part acceptance. Procedure Qualification Test Reports, Part Verification Test Reports, and all NDT and destructive testing data and procedures shall not be eligible for approval by audit. The activity shall submit a list of the proposed items to be approved by audit to NAVSEA for approval prior to submission of any other documents.

2-2.3.5 AM Authorized Representative Advanced Notification. The activity shall notify the AM Authorized Representative and TP 248 Authorized Representative no fewer than 5 business days prior to the production of any DED qualification builds. The applicable authorized representatives shall be afforded the opportunity to observe the building of the procedure qualification blocks, part verification build, and the performance of the required nondestructive and destructive testing. Notifications shall be in writing. Observations shall be at the discretion of the AM Authorized Representative.

2-2.4 VENDOR PROCEDURE QUALIFICATION. It shall be the responsibility of each activity to ensure that its subcontractors have qualified procedures based on approved qualification data.

2-2.5 WAIVER OF QUALIFICATION. Procedure qualification testing may be waived if deemed appropriate in accordance with NAVSEA's guidance on the use of AM or if otherwise approved by NAVSEA. A DED Procedure, including all required essential elements and acceptance criteria, shall be required even when procedure qualification testing is waived.

2-2.6 APPROVAL OF CRITICAL APPLICATIONS. NAVSEA approval of qualification and part verification data shall be obtained for parts with service condition level severities of level 1 through 5 in accordance with NAVSEA's requirements on the use of additive manufacturing. AM Authorized Representative approval shall be obtained for parts with service condition level severity of level 6 in accordance with NAVSEA's requirements on the use of additive manufacturing.

2-2.7 APPROVAL OF PROCEDURE QUALIFICATION FOR SPECIAL DED PARTS AND APPLICATIONS. NAVSEA approval of the procedure qualification and part verification data shall be obtained for special parts and applications (e.g., SUBSAFE, Critical Ship Systems, Pressure Hull Boundaries, and Material Identification and Control level I). The submittal shall include evaluation methods, the proposed qualification tests, and proposed operator qualification in accordance with 6-2.5.

2-2.7.1 DED Repair. DED for repair of components previously used in service shall be considered a special DED application.

2-2.7.2 Alternative Heat Sources. DED processes other than arc-wire, laser-wire, and electron beam-wire DED shall be considered a special DED application.

2-2.8 QUALIFICATION LEVEL. When this document is specified in the contracting documents, procedure qualification is required. The essential elements for DED process shall be incorporated into the DED Procedure and be in accordance with the requirements of this document.

2-2.8.1 Level 1. This qualification level covers the initial qualification of DED processing procedures for the fabrication of material by any activity, or requalification of DED Procedures due to variations specified in 3-5. These are changes that are expected to have a significant impact on material properties.

2-2.8.2 Level 2. This qualification level is intended to permit qualification for a variation in a procedure or expansion of a procedure that has already been qualified by qualification level 1 due to variations specified in 3-6. These are changes where material properties can be expected not to change significantly. Level 2 requalification requires qualification of one procedure build for any or all level 2 variations made to the procedure at one time. Unless otherwise stated herein, the procedure qualification build shall use the nominal values of all other essential variables.

2-2.8.3 Part Level. This qualification level is intended to qualify the specific procedures and files used to produce a specific build. Changes that require part requalification invalidate the specific Part Verification Test Report. Previous part verification test reports are not invalidated when new reports are generated to support new or modified parts. Changes that require part requalification shall be specified in 4-5.

2-2.9 REPAIR OF PROCEDURE QUALIFICATION BUILDS AND PART VERIFICATION BUILDS. Repair of procedure qualification builds shall not be permitted. Unless otherwise approved by NAVSEA, repair of part verification builds shall not be permitted. Repair of production parts shall be in accordance with S9074-AR-GIB-010/278 and the special welds paragraph in S9074-AQ-GIB-010/248, with approval from NAVSEA prior to repair.

2-2.9.1 Insufficient Procedure Qualification and Part Verification. If a procedure qualification or part verification fails to meet the destructive or nondestructive requirements, the procedure qualification builds or part verification shall be rejected by the performing activity, and the AM Authorized Representative shall be notified of all rejections in writing.

2-2.10 TRANSFER OF PROCEDURE QUALIFICATION FOR DED MATERIAL. Transfer of qualified DED Procedures from one activity to another shall not be permitted unless requalification testing is performed and approved.

2-2.10.1 Transfer of Qualified Procedures Between Sites of an Activity. Transfer of qualified procedures between sites of an activity shall be governed by requirements stated in the activity's quality assurance plan (see 7-2) and shall require approval by the AM Authorized Representative.

2-2.11 TRANSFER OF OPERATOR QUALIFICATION. Transfer of performance qualification from one activity to another shall not be permitted without specific approval by the AM Authorized Representative.

CHAPTER 3
DED PROCEDURE QUALIFICATION

3-1 SCOPE.

This chapter provides general requirements for the qualification of DED Procedures for general applications. The purpose of the qualification of the DED Procedure is to verify the process and material performance.

3-2 DED PROCEDURE.

A DED Procedure shall be developed. The DED Procedure shall be used in conjunction with the Process Control Plan and Quality Assurance Plan to control all DED operations.

3-2.1 ESSENTIAL ELEMENTS OF THE DED PROCEDURE. Unless otherwise specified in the fabrication document, if applicable, the DED Procedure shall include the essential elements listed in table 3-1 at a minimum.

Table 3-1. Essential Elements of DED [1/, 2/]

Element	Arc Wire DED	Laser Wire DED	Electron Beam Wire DED
	Essential	Essential	Essential
Machine Manufacturer, model number, and machine software version of all major subsystems [3/], processing software, and processing software version	X	X	X
Digital files CAD files, slice files, and build files	X	X	X
Deposition Strategy Type (e.g., weave, stringer), perimeter strategy, path planning strategy, maximum bead width [7/]	X	X	X
Bead overlap [7/]	X	X	X
Build platform material Specification, chemistry, temper, and thickness	X	X	X
Build platform cleaning [4/]	X	X	X
Feedstock material Specification, designation and diameter	X	X	X

Table 3-1. Essential Elements of DED - Continued

Element	Arc Wire DED [2/]	Laser Wire DED	Electron Beam Wire DED
	Essential	Essential	Essential
Process	X	X	X
Arc-metal transfer mode [5/]	X	---	---
Arc electrical characteristics [6/, 7/] Arc voltage range, current, and polarity	X	---	---
Laser characteristics [7/] Programmed power, focus position, pulse characteristics, beam offset, spot shape, spot size	---	X	---
Electron beam characteristics [7/] Accelerating voltage, beam current, deflection profile, amplitude, frequency, focus position, gun filament material	---	---	X
Heat input [7/]	X	X	X
Wire feed rate [7/]	X	X	X
Work, travel, and wire feed angles	X	X	X
Position Relative offset from vertical centerline in flat position	X	X	X
Contact tip to work distance	X	---	---
Heat source to work distance	---	X	X
Oscillation [7/] Amplitude, frequency, and dwell	X	X	X
Travel speeds [7/]	X	X	X
Position (including progression vertical-up or vertical-down)	X	X	X

Table 3-1. Essential Elements of DED - Continued

Element	Arc Wire DED [2/]	Laser Wire DED	Electron Beam Wire DED
	Essential	Essential	Essential
In-process shielding, trailing, backing, and purge gases Grade, mixture, oxygen content, dew point, chamber, flow rates	X	X	---
Vacuum pressure	---	---	X
Gas cup size	X	---	---
Preheat and interpass Temperature limits, measurement method, inter-bead or inter-layer, active cooling [8/]	X	X	X
In-process grinding, machining, and cleaning	X	X	X
Post-build processing	X	X	X

Table 3-1. Essential Elements of DED - Continued

NOTES:

1/ Any essential element that changes on a per-layer or per-bead basis shall be individually specified per layer or per bead.

2/ The following shall also be specified as essential elements:

a. Details of current slope, if used

b. For the gas tungsten arc process: (1) a detailed description of pulsed current, if used, including all pulsed current and voltage parameters that can be varied by adjustment of pulsed power supply controls, and manufacturer and model number of pulsed power supply and (2) tungsten electrode diameter and type

c. For the gas metal arc process, a description of pulsed welding, if used, including current and average voltage, and, if welding equipment permits monitoring and independent control, peak pulse voltage and pulse frequency

d. For hot wire feed, the hot wire amperage and voltage

e. For pulsed or modulated laser powers, a detailed description of the pulse shape and duration

f. Type of arc length or voltage control

3/ Subsystems shall include the following, if applicable, at a minimum:

a. Welding, laser, or electron power supply

b. Wire feeder

c. Torch type and neck angles

d. Motion controller

e. Welding leads and cable bundles

f. Positioners

g. Vision systems

h. Chamber

i. Laser fiber

4/ Shall only apply for integrated build platforms.

5/ It is the activity's responsibility to ensure the extent of the operating ranges does not alter the transfer mode that is qualified.

6/ For deposition via waveform-controlled welding, the program ID.

7/ Where a range is used, the range shall be specified and maximum and minimum heat input shall be specified per 3-3.2.3.

8/ For active cooling, the following shall be specified as essential elements:

a. Details of cooling element design, including control system, nozzle or attachment design, and piping configuration

b. Cooling medium

c. Cooling medium flow rate

d. Cooling element placement

e. Cooling schedule

3-2.2 BUILD PLATFORM AND FEEDSTOCK MATERIAL. Unless otherwise approved, the build platform and feedstock materials used for the DED Procedure shall be as specified in table 3-2 and table 3-3.

3-2.3 MATERIAL ACCEPTANCE CRITERIA. The DED Procedure shall specify the acceptance criteria for destructive testing. Destructive testing acceptance criteria shall include, at a minimum, the mechanical properties of the part to be manufactured, including yield and ultimate strength, elongation to failure, hardness, bend radius, impact toughness, and metallographic features listed in 8-4.4.3, and any additional testing identified via the review conducted in accordance with NAVSEA's requirements on the use of AM.

3-2.3.1 Established DED Acceptance Criteria. Where applicable, the use of material acceptance criteria established for wire DED of a specific material by NAVSEA shall be required. The use of material acceptance criteria established by other government agencies or commercial standard organizations for wire DED shall be permitted with approval from the AM authorized representative.

3-2.3.2 Input Material Derived Acceptance Criteria. Where build platform and feedstock materials listed in table 3-2 and table 3-3 are used, acceptance criteria shall be as required in the applicable document specified in that table for those materials. The feedstock material acceptance criteria in table 3-3 shall take precedence.

Table 3-2. Build Platform Materials [1/]

Letter No.	Applicable Document	Class or Type
S-1	**Carbon Steel**	
	ABS 2 P2	Grade A (plate, wide flats, sections, and bars) Grade B (plate, wide flats, sections, and bars) Grade D (plate, wide flats, sections, and bars) Grade AH-36 (plate, wide flats, sections, and bars) Grade DH-36 (plate, wide flats, sections, and bars)
	ASTM A27/A27M	Grade 60-30 (castings) Grade 65-35 (castings) Grade 70-36 (castings)
	ASTM A36/A36M	A36 (shapes, plates, and bars)
	ASTM A53/A53M	Grade A, type E (resistance welded pipe) Grade A, type F (furnace welded pipe) Grade A, type S (seamless pipe) Grade B, type E (resistance welded pipe) Grade B, type S (seamless pipe)
	ASTM A105/A105M	A105 (flanges, fittings, and valves)
	ASTM A106/A106M	Grade A (seamless pipe) Grade B (seamless pipe)
	ASTM A131/A131M	Grade A (plates, shapes, and bars) Grade B (plates, shapes, and bars) Grade D (plates, shapes, and bars) Grade AH-36 (plates, shapes, and bars) Grade DH-36 (plates, shapes, and bars)
	ASTM A134/A134M	A283 (pipe) A285 (pipe)
	ASTM A178/A178M	Grade A2 (tube) Grade B2 (tube)
	ASTM A178/A178M	Grade A (tube) Grade C (tube) Grade D (tube)
	ASTM A179/A179M	A179 (tube)
	ASTM A192/A192M	A192 (seamless tube)
	ASTM A210/A210M	Grade A-1 (seamless tube)
	ASTM A214/A214M	A214 (tube)
	ASTM A216/A216M	Grade WCA (castings) Grade WCB (castings)

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-1 (Cont.)	ASTM A234/A234M	WPB (fittings) WPC (fittings)
	ASTM A283/A283M	Grade B (plate) Grade C (plate)
	ASTM A285/A285M	Grade A (plate) Grade B (plate) Grade C (plate)
	ASTM A333/A333M	Grade 1 (seamless and welded pipe) Grade 6 (seamless and welded pipe)
	ASTM A334/A334M	Grade 1 (welded tube) Grade 6 (welded tube)
	ASTM A350/A350M	Grade LF1 (forging)
	ASTM A352/A352M	LCA (castings) LCB (castings)
	ASTM A369/A369M	FPA (forged pipe) FPB (forged pipe)
	ASTM A372/A372M	Type I/grade A (forging)
	ASTM A414/A414M	Grade A (sheet) Grade B (sheet) Grade C (sheet) Grade D (sheet) Grade E (sheet) Grade F (sheet) Grade G (sheet)
	ASTM A420/A420M	Grade WPL6 (fittings)
	ASTM A441	A441 (plates, shapes, and bars)
	ASTM A500/A500M	Grade A (tube) Grade B (tube) Grade C (tube) Grade D (tube)
	ASTM A501/A501M	Grade A (tube) Grade B (tube)
	ASTM A512	1008 (mechanical tubing) 1010 (mechanical tubing) 1012 (mechanical tubing) 1015 (mechanical tubing) 1016 (mechanical tubing) 1018 (mechanical tubing) 1019 (mechanical tubing) 1020 (mechanical tubing)

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-1 (Cont.)	ASTM A512	1021 (mechanical tubing) 1025 (mechanical tubing)
	ASTM A513/A513M	1008 (mechanical tubing) 1010 (mechanical tubing) 1012 (mechanical tubing) 1015 (mechanical tubing) 1016 (mechanical tubing) 1018 (mechanical tubing) 1019 (mechanical tubing) 1020 (mechanical tubing) 1021 (mechanical tubing) 1025 (mechanical tubing)
	ASTM A515/A515M	Grade 55 (plate) Grade 60 (plate) Grade 65 (plate) Grade 70 (plate)
	ASTM A516/A516M	Grade 55 (plate) Grade 60 (plate) Grade 65 (plate) Grade 70 (plate)
	ASTM A519/A519M	1008 (mechanical tubing) 1010 (mechanical tubing) 1012 (mechanical tubing) 1015 (mechanical tubing) 1016 (mechanical tubing) 1018 (mechanical tubing) 1019 (mechanical tubing) 1020 (mechanical tubing) 1021 (mechanical tubing) 1025 (mechanical tubing)
	ASTM A524/A524M	Grade I (pipe) Grade II (pipe)
	ASTM A537/A537M	Class 1 (plate)
	ASTM A556/A556M	Grade A2 (tube) Grade B2 (tube)
	ASTM A562/A562M	A562 (plate)
	ASTM A572/A572M	Grade 42 (plate, bar, and shapes) Grade 50 (plate, bar, and shapes)
	ASTM A575	M 1008 (bar) M 1010 (bar) M 1012 (bar) M 1015 (bar) M 1017 (bar)

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-1 (Cont.)	ASTM A575	M 1020 (bar) M 1023 (bar) M 1025 (bar)
	ASTM A576	1008 (bar) 1010 (bar) 1012 (bar) 1015 (bar) 1016 (bar) 1017 (bar) 1018 (bar) 1019 (bar) 1020 (bar) 1021 (bar) 1022 (bar) 1023 (bar) 1025 (bar)
	ASTM A587	A587 (pipe)
	ASTM A606/A606M	Type 2 (sheet and strip) Type 4 (sheet and strip)
	ASTM A659/A659M	1015 (sheet) 1016 (sheet) 1017 (sheet) 1018 (sheet) 1020 (sheet) 1021 (sheet) 1023 (sheet)
	ASTM A660/A660M	WCA (pipe)
	ASTM A662/A662M	Grade A (plate) Grade B (plate)
	ASTM A671/A671M	Grade CA55 (pipe) Grade CB60 (pipe) Grade CB65 (pipe) Grade CC60 (pipe) Grade CC65 (pipe) Grade CE55 (pipe) Grade CE60 (pipe)

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-1 (Cont.)	ASTM A672/A672M	Grade A45 (pipe) Grade A50 (pipe) Grade A55 (pipe) Grade B55 (pipe) Grade B60 (pipe) Grade B65 (pipe) Grade C55 (pipe) Grade C60 (pipe) Grade C65 (pipe) Grade E55 (pipe) Grade E60 (pipe)
	ASTM A709/A709M	Grade 50W (plate, bar, and shapes)
	ASTM A727/A727M	A727 (forging)
	ASTM A765/A765M	Grade I (forging)
	ASTM A794/A794M	1015 (sheet) 1016 (sheet) 1017 (sheet) 1018 (sheet) 1020 (sheet) 1021 (sheet) 1023 (sheet)
	ASTM A830/A830M	1006 (plate) 1008 (plate) 1009 (plate) 1010 (plate) 1012 (plate) 1015 (plate) 1016 (plate) 1017 (plate) 1018 (plate) 1019 (plate) 1020 (plate) 1021 (plate) 1022 (plate) 1023 (plate) 1025 (plate)

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-1 (Cont.)	ASTM A945/A945M [2/]	Grade 65 (also referred to as HSLA-65) (plate)
	ASTM A1008/A1008M	Grade CS, type A (sheet) Grade CS, type B (sheet)
	ASTM A1011/A1011M	Grade 36, type 1 (sheet and strip) Grade 36, type 2 (sheet and strip) Grade CS, type B (sheet and strip) Type A (sheet and strip) Type B (sheet and strip) Type C (sheet and strip)
	WW-P-404	Grade A (seamless and welded pipe) Grade B (seamless and welded pipe) Type F (furnace welded pipe)
	MIL-S-15083	Grade 70-36 (cast) Grade 65-35 (cast) Grade CW (cast) Grade B (cast)
	MIL-T-16286	Class A (seamless tube) Class G (seamless tube)
	MIL-T-20157	Type E (tube and pipe)
	MIL-F-20236	Flanges, pipe
	MIL-F-20670	Flanges, pipe
	MIL-S-22698	Plate, bar, and shapes
	MIL-DTL-23194	Composition C (forgings)
	MIL-S-23284	Class 3 Class 4
	MIL-S-24093	Type V (forgings)
	MIL-S-24238	Composition C (plate)
	MIL-P-24338	Pipe
	MIL-DTL-24339	Fittings and flanges
	MIL-S-24412	Grade HT (shape)
	MIL-P-24691/1	Grade B (tube and pipe)
	MIL-C-24707/1	ASTM A757, grade A1Q (castings), grade A2Q ASTM A216/A216M, grade WCA (castings) Grade WCB Grade WCC

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-2	**Quenched and tempered carbon steel**	
	ASTM A537/A537M	Class 2
S-3	**Carbon molybdenum steel**	
	MIL-S-870	CMo (cast)
	MIL-T-16286	CMo, class D (tube)
	MIL-T-20155	CMo (tube and pipe)
	DOD-F-24669/1	CrNi, type 8620 (bar and forgings)
	DOD-F-24669/2	CMo, class A (forgings) CMo, class B (forgings)
	MIL-C-24707/2	ASTM A217/A217M, grade WC1 (castings)
S-3A	**Alloy steels** **(Cr content not to exceed ¾ percent; total alloy not to exceed 2 percent)**	
	ASTM A302/A302M	MnMo, grade B (plate)
	MIL-DTL-23194	NiCrMo, composition A (forgings)
	MIL-S-24238	NiMnMo, composition A (plate)
S-4	**Alloy steels** **(Cr content ¾ to 2 percent; total alloy not to exceed 2¾ percent)**	
	ASTM A182/A182M	Grade F11
	ASTM A213/A213M	Grade T11 (tube)
	SAE AMS6530	CrNiMo, type 8630 (tube)
	MIL-T-6736	CrMo, type 4130 (tube)
	MIL-S-8699	CrMoV, type 4330 (bar, forging)
	MIL-S-15464	CrMo, class 1 (casting)
	MIL-S-18728, SAE AMS6345, SAE AMS6350, SAE AMS6351	CrNiMo, type 8630 (plate)
	MIL-S-18729, SAE AMS6345, SAE AMS6350, SAE AMS6351	CrMo, type 4130 (plate)
	DOD-F-24669/1	CrMo, type 4130 (bar)
	DOD-F-24669/2	CrMo, class A (forgings)
	MIL-P-24691/2	CrMo, grade P11 (tube and pipe)
	MIL-C-24707/2	ASTM A217/A217M, grade WC6 (casting)

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-5	**Alloy steels (total alloy content 10 percent max)**	
	ASTM A182/A182M	Grade F22
	ASTM A213/A213M	T22
	MIL-S-860	CrMoV, grade F (forgings)
	MIL-S-15464	CrMo, class 2 (casting)
	MIL-T-16286	CrMo, class E (tube)
	DOD-F-24669	CrMo (bar and forgings)
	DOD-F-24669/2	CrMo, class B (forging)
	MIL-F-24669/8	CrMoV, grade F (forgings)
	MIL-P-24691/2	CrMo, grade P22 (tube and pipe)
	MIL-C-24707/2	ASTM A217/A217M grade WC9 (casting)
S-6	**High alloy steels (martensitic)**	
	QQ-S-763, SAE AMS-QQ-S-763	403 (bars, rods, and forgings) 410 414 420
	QQ-S-766	410 (plate, sheet, and strip) 420
	MIL-S-16993	12 percent Cr, class 1 (casting) 12 percent Cr, class 2 (casting)
	MIL-DTL-24128	403 (bars, rods, and forgings)
	DOD-F-24669/7	403 (bars) 410
	DOD-F-24669/6	403 (bars) 410 414 420
	MIL-C-24707/6	ASTM A217/A217M, grade CA-15 (casting) ASTM A487/A487M, grade CA-15M, class A
S-6A	**High alloy steels (martensitic)**	
	ASTM A176	410S (plate, sheet, and strip)
	ASTM A182/A182M	F6NM (forgings)
	ASTM A240/A240M	410S (plate, sheet, and strip)
	ASTM A473	410S (forgings)
	ASTM A487/A487M	CA-6NM (castings)

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-7	**High alloy steels (ferritic)**	
	QQ-S-763, SAE AMS-QQ-S-763	405 (bar, shapes, and forgings) 430
	QQ-S-766	430 (plate, sheet, and strip)
S-8	**High alloy steels (austenitic)**	
	ASTM A182/A182M	F304 (flanges, fittings, and valves) F304L (flanges, fittings, and valves) F316 (flanges, fittings, and valves) F316L (flanges, fittings, and valves)
	ASTM A213/A213M	TP 304 (seamless tube) TP 304L (seamless tube)
	ASTM A240/A240M	304 (plate, sheet, and strip) 304L (plate, sheet, and strip) 309S 310S 316 (plate, sheet, and strip) 316L (plate, sheet, and strip) 321 (plate, sheet, and strip) 347 (plate, sheet, and strip) 348 (plate, sheet, and strip)
	ASTM A269/A269M	TP 304 (seamless welded pipe) TP 304L (seamless welded pipe) TP 316 (seamless welded pipe) TP 316L (seamless welded pipe)
	ASTM A276/A276M	304 (bar) 304L (bar) 316 (bar) 316L (bar)
	ASTM A312/A312M	TP 304 (seamless and welded pipe) TP 304L (seamless and welded pipe) TP 316 (seamless and welded pipe) TP 316L (seamless and welded pipe) TP 321 (seamless and welded pipe) TP 347 (seamless and welded pipe) TP 348 (seamless and welded pipe)
	ASTM A351/A351M	CF3 (castings) CF3M (castings) CF8 (castings) CF8M (castings)

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-8 (Cont.)	ASTM A403/A403M	304 (fittings) 304L (fittings) 316 (fittings) 316L (fittings)
	ASTM A473	316 (forging)
	ASTM A479/A479M	304 (bar and shapes) 304L (bar and shapes) 316 (bar and shapes) 316L (bar and shapes) 321 (bar and shapes) 347 (bar and shapes) 348 (bar and shapes)
	ASTM A511/A511M	304 (seamless tube) 304L (seamless tube) 316 (seamless tube) 316L (seamless tube)
	ASTM A554	MT-304 (mechanical tubing) MT-304L (mechanical tubing) MT-316 (mechanical tubing) MT-316L (mechanical tubing) MT-321 (mechanical tubing) MT-347 (mechanical tubing)
	ASTM A666	304 (sheet, strip, plate, and flat bar) 304L (sheet, strip, plate, and flat bar) 316 (sheet, strip, plate, and flat bar) 316L (sheet, strip, plate, and flat bar)
	ASTM A743/A743M	CF3 (casting) CF8 (casting) CF8M (casting) CN-7M (castings) CN-7MS
	ASTM A744/A744M	CN-7M (castings) CN-7MS
	ASTM A793	304 (floor plate) 304L (floor plate) 316 (floor plate) 316L (floor plate)

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-8 (Cont.)	ASTM A813/A813M	TP 304 (pipe)
	QQ-S-763, SAE AMS-QQ-S-763	304 (bar, shapes, and forgings) 304L 309 310 316 316L 321 347
	QQ-S-766	304 304L 309S 310S 316 316L 321 347 348
	MIL-S-867	Class I (castings) Class II Class III
	MIL-T-8504	304 (tubing)
	MIL-T-16286	Class C (seamless tube)
	MIL-S-17509	Class I, II, III
	MIL-DTL-23193	Composition A (304) Composition B (348) Composition C (316)
	MIL-DTL-23195	304 (bar and forgings) 304L 347 348
	MIL-DTL-23196	304 (plate, sheet, and strip) 304L 347 348
	MIL-DTL-23226	304 (tube and pipe) 304L 347 348

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-8 (Cont.)	MIL-DTL-23467	304 (fittings and flanges) 304L 347 348
	MIL-P-24691/3	304 (pipe and tube) 304L (pipe and tube) 316 (pipe and tube) 316L (pipe and tube) 321 (pipe and tube) 347 (pipe and tube)
	MIL-C-24707/3	ASTM A744/A744M, grade CF-8 (castings) ASTM A744/A744M, grade CF-8C (castings) ASTM A744/A744M, grade CF-8M (castings)
S-10H [2/]	**High alloy steel (duplex stainless)**	
	ASTM A240/A240M	UNS 31803 (plate) [3/] Type 2205, UNS S32205 (plate) [3/]
	ASTM A276/A276M	UNS 31803 (plate) [3/] Type 2205, UNS S32205 (bar) [3/]
S-11A	**Quenched and tempered alloy steels**	
	MIL-S-16216, T9074-BD-GIB-010/0300	HY-80 (plate) HY-100
	MIL-S-21952, T9074-BD-GIB-010/0300	HY-80 (bars) HY-100
	MIL-S-23008, T9074-BD-GIB-010/0300	HY-80 (castings) HY-100
	MIL-S-23009, T9074-BD-GIB-010/0300	HY-80 (forgings) HY-100
	MIL-S-24451, T9074-BD-GIB-010/0300	HY-80 (heads) HY-100
	T9074-BD-GIB-010/0300	HY-80 (shapes) HY-100

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-11B	**Quenched and tempered alloy steels**	
	MIL-S-24371, T9074-BD-GIB-010/0300	HY-130 (plate, castings, bars, forgings, extrusions, and shapes)
S-11C	**Age hardening alloy steel**	
	MIL-DTL-24652, T9074-BD-GIB-010/0300	HSLA-80 (plate, sheet, or coil)
S-11D	**Age hardening alloy steel**	
	MIL-S-24645, T9074-BD-GIB-010/0300	HSLA-100 (plate, sheet, or coil)
S-11E [2/]	**Age hardening alloy steel**	
	Specification as approved by NAVSEA.	HSLA-115 (plate)
S-11F [2/]	**Low alloy steels**	
	MIL-S-23284	Class 1 Class 2
S-21	**Aluminum and aluminum base alloys**	
	ASTM B241/B241M	3003 (pipe and tube)
	QQ-A-200/1, ASTM B221	3003 (extruded bars and rods)
	QQ-A-225/1, ASTM B211/B211M	1100 (bars and rods)
	QQ-A-225/2, SAE AMS-QQ-A-225/2, ASTM B211/B211M	3003 (bars and rods)
	QQ-A-250/1, ASTM B209/B209M	1100 (plate)
	QQ-A-250/2, ASTM B209/B209M	3003 (plate and sheet)
	WW-T-700/1, ASTM B210/B210M	1100
	WW-T-700/2, ASTM B210/B210M	3003

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-22	ASTM B241/B241M	5454 (pipe and tube)
	QQ-A-200/6, SAE AMS-QQ-A-200/6, ASTM B221	5454 (extruded bars and rods)
	QQ-A-225/7, ASTM B211/B211M,	5052 (bar and rod)
	QQ-A-250/8, SAE AMS-QQ-A-250/8, ASTM B209/B209M	5052 (plate)
	QQ-A-250/10, SAE AMS-QQ-A-250/10, ASTM B209/B209M	5454
S-23 [7/]	**Aluminum and aluminum base alloys**	
	ASTM B209/B209M ASTM B210/B210M ASTM B211/B211M ASTM B308/B308M ASTM B483/B483M ASTM B547/B547M	6061
	ASTM B221 ASTM B241/B241M ASTM B361 ASTM B429/B429M	6061, 6082
S-25	**Aluminum and aluminum base alloys**	
	ASTM B241/B241M	5086 (pipe and tube)
	QQ-A-200/4 SAE AMS-QQ-A-200/4 ASTM B221 ASTM B241/B241M	5083
	QQ-A-200/5 SAE AMS-QQ-A-200/5 ASTM B221	5086 (extruded bar and rod)

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-25 (Cont.)	ASTM B209/B209M	5086 5456
	ASTM B928/B928M	5083 (plate, sheet, and extrusions) 5086 5456
	SAE AMS-QQ-A-200/7 ASTM B221 ASTM B241/B241M	5456
	QQ-A-250/6 SAE AMS4056 ASTM B209/B209M	5083
	WW-T-700/5, SAE AMS-WW-T-700/5	5086 (seamless tube)
S-26	**Aluminum and aluminum base alloys**	
	ASTM B26/B26M	Alloy A03550 (castings) Alloy A03560 Alloy A05140 Alloy A24430
	QQ-A-601	B443 (castings) 514 355 356
	MIL-A-21180 SAE AMS-A-21180	A356 (castings)
S-31	**Copper and copper base alloys**	
	ASTM B152/B152M	Alloy C10200 (plate and bar) Alloy C10400 Alloy C10500 Alloy C11000 Alloy C11300 Alloy C11400 Alloy C12200 Alloy C12300
	QQ-C-576	99.9 Cu (plate and bar)

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-32	**Brass**	
	ASTM B21/B21M	Alloy C46400 (rod, bar, and shapes)
	ASTM B124/B124M	Alloy C46400 (forging rod, bar, and shapes)
	ASTM B283/B283M	Alloy C46400 (die forgings)
	QQ-C-390	Alloy C85700 (castings)
	QQ-B-637	Naval brass (alloy 464) (rod, bar, and forgings)
	QQ-B-639	Naval brass alloy (rod, bar, and forgings) Alloy 462 Alloy 464
S-33	**Silicon bronze**	
	ASTM B98/B98M	Alloy C65500 (rod, bar, and shapes)
	ASTM B124/B124M	Alloy C65500 (forging rod, bar, and shapes)
	QQ-C-390	Alloy C87200 (castings)
	QQ-C-591	Alloy 655 (rod, shapes, and flats)
S-34	**Copper nickel**	
	ASTM B369/B369M	Alloy C96200 (castings) Alloy C96400
	MIL-T-15005	70/30 (tube) 90/10
	MIL-C-15726	70/30 (plate, bar, and rod) 90/10
	MIL-T-16420	70/30 (tube) 90/10
	MIL-C-20159	UNS No. C96200 (castings) C96400
	MIL-DTL-24342	70/30 (fittings and flanges)
S-35	**Aluminum bronze**	
	ASTM B124/B124M	Alloy C64200 (forging rod, bar, and shapes)
	ASTM B150/B150M	Alloy C60600 (rod, bar, and shapes) Alloy C61400 Alloy C64200
	ASTM B169/B169M	Alloy C61400 (plate, sheet, strip, and rolled bar)
	ASTM B283/B283M	Alloy C64200 (die forgings)
	QQ-C-390	Alloy C95200 (castings) Alloy C95400 (castings)

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-35 (Cont.)	QQ-C-450	Alloy 606 (plate and bar) Alloy 613 Alloy 614
	QQ-C-465	(rod, bar, plate, strip, flats, and forgings) Alloy 606 Alloy 614 Alloy 642
	MIL-C-15345	Alloy 13 (castings) Alloy 15
S-36A	**Nickel-aluminum bronze**	
	ASTM B124/B124M	Alloy C63000 (forging rod, bar, and shapes) Alloy C63200
	ASTM B150/B150M	Alloy C63000 (rod, bar, and shapes) Alloy C63200
	ASTM B283/B283M	Alloy C63000 (die forgings) Alloy C63200
	QQ-C-390	Alloy C95500 (castings)
	QQ-C-465	Alloy 630 (bar, rod, plate, strip, and forging) Alloy 632M
	MIL-C-15345	Alloy 14 (castings) Alloy 15
	MIL-B-21230	Alloy 1 (castings)
	MIL-B-24059	Flat products, shapes, and forgings
	MIL-B-24480	Castings
S-36B	**Manganese-nickel-aluminum bronze**	
	MIL-B-21230	Alloy 2 (castings)
S-37A	**Manganese bronze**	
	ASTM B138/B138M	Alloy C67000 (rod, bar, and shapes) Alloy C67500
	QQ-C-390	Alloy C86100 Alloy C86200 Alloy C86300 Alloy C86400 Alloy C86500
	QQ-B-728	Class A Class B

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-37B	**Nickel-manganese bronze**	
	QQ-C-390	Alloy C86800
S-38	**Tin bronze**	
	QQ-C-390	Alloy C94700
	MIL-B-16541	Castings
S-39	**Phosphor bronze**	
	ASTM B139/B139M	Alloy C51000 (rod, bar, and shapes) Alloy C52400
	QQ-B-750	Composition A Composition D
	MIL-T-3595	Composition D (tubing)
S-42	**Nickel and nickel base alloys**	
	ASTM A494/A494M	Composition M-30C (casting)
	QQ-N-281	NiCu, class A (bar, plate, rod, and forgings) Class B
	QQ-N-288	NiCuSiCb, composition E (casting)
	MIL-T-1368	NiCu (tubing)
	MIL-C-15345	NiCuSiCb, Alloy 19 (casting)
	MIL-N-17163	NiCu (bar, rod, plate, and forgings)
	MIL-DTL-23509	Fittings and flanges
	MIL-DTL-23520	NiCu (tube and pipe)
	MIL-DTL-24106	NiCu, class A (bar, rods, and forgings)
	MIL-C-24723	Composition M-30C (casting)
S-43	**Nickel-chromium iron**	
	ASTM B166	Bar, rod, and forgings
	ASTM B564	Forgings
	MIL-DTL-15382	Bar and rod
	MIL-DTL-23227	Tube and pipe
	MIL-DTL-23228	Condition A (plate)
	MIL-DTL-23229	Condition A (bar, rod, and forgings)
	MIL-DTL-23508	Fittings and flanges
	MIL-N-24271	Castings

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-43 (Cont.)	ASTM A494/A494M	GR CW-6MC [5/] GR CW-6MC MOD [6/, 5/]
	ASTM B443	UNS N06625 (plate) [5/]
	ASTM B444	UNS N06625 (pipe and tube) [5/]
	ASTM B446	UNS N06625 (bar and rod) [5/]
S-44 [4/]	**Nickel-molybdenum-chromium alloy**	
	ASTM B574	UNS N10276 (rod)
	ASTM B575	UNS N10276 (plate, sheet, and strip)
	ASTM B622	UNS N10276 (pipe and tube)
S-51	**Titanium and titanium base alloys**	
	ASTM B265	Grade 7 (sheet, strip, and plate)
	ASTM B338	Grade 1 (tubing) Grade 2 (tubing) Grade 7 (tubing)
	ASTM B348/B348M	Grade 1 (bars and billets) Grade 2 (bars and billets) Grade 7 (bars and billets)
	ASTM B363	WPT 1 (fittings) WPT 2 (fittings) WPT 7 (fittings)
	ASTM B381	Grade F-1 (forgings) Grade F-2 (forgings)
	ASTM B861 ASTM B862	Grade 1 (pipe) Grade 2 (pipe) Grade 7 (pipe)
	MIL-T-9046	CP-3 (sheet, strip, and plate) CP-4 (sheet, strip, and plate)
S-52	**Titanium and titanium base alloys**	
	ASTM B338	Grade 3 (tubing)
	ASTM B861 ASTM B862	Grade 3 (pipe)
	MIL-T-9046	CP-1 (sheet, strip, and plate) CP-2 (sheet, strip, and plate)
	MIL-T-9047	CP-70 (bars and reforging stock)

Table 3-2. Build Platform Materials - Continued

Letter No.	Applicable Document	Class or Type
S-52 (Cont.)	ASTM B363	WPT 3 (fittings)
	ASTM B367	Grade C-2 (castings) Grade C-3 (castings)
S-53 [8/]	**Titanium and titanium base alloys**	
	ASTM B265	Grade 5 (sheet, strip, and plate)
	ASTM B367	Grade C-5 (castings)
	ASTM B381	Grade F-5 (forgings)
	MIL-T-9046	AB-1 (sheet, strip, and plate) AB-2 (sheet, strip, and plate)
	MIL-T-9047	6A1-4V (bars and forgings) 6A1-4V (ELI) (bars and forgings)
S-53A [8/]	**Titanium and titanium alloy, high toughness, and high seawater stress corrosion cracking resistance**	
	ASTM B348/B348M	Grade F-32 (bars and billets)
	ASTM B381	Grade F-32 (forgings)
	MIL-DTL-32528	Ti-5111 (UNS R5111)

NOTES:

[1/] If material of similar chemistry and mechanical properties is not listed under an S-group, it may be considered as part of a group upon approval. S-23 materials are as stated; other alloys shall be approved as special DED builds by NAVSEA.

[2/] Qualification requirements shall be as approved by NAVSEA.

[3/] With additional requirements for toughness, composition, heat treatment, and testing for absence of intermetallic phases (e.g., ASTM A923, test method B) imposed by the component specification.

[4/] Procedure qualifications for these materials shall be submitted to NAVSEA for approval.

[5/] See 3-6.1.

[6/] Si = 0.40 maximum, Al = 0.15 maximum, and Nb + Ta = 3.15 - 4.50.

[7/] DED Procedures for S-23 shall identify each specific application for which the procedure will be used. Applications shall be limited to those specifically approved by NAVSEA.

[8/] With additional toughness, composition, melting, processing, and other controls as approved by NAVSEA. Toughness testing for DED Procedure qualification is required as approved by NAVSEA.

Table 3-3. Feedstock Materials [1/]

Group	Applicable Document	Feedstock Material Type
A-2B	**Carbon and low alloy steel (bare electrode)**	
	MIL-E-23765/1	MIL-70S-1 MIL-70S-2 MIL-70S-3 MIL-70S-4 MIL-70S-5 MIL-70S-6
A-3B	**Carbon and low alloy steel (bare electrode)**	
	MIL-E-23765/2	MIL-80S-3
A-5B	**Low alloy, high yield steel (bare electrode)**	
	T9074-BC-GIB-010/0200	MIL-100S-1 [2/] MIL-100S-2 [2/] MIL-120S-1 [2/] MIL-120S-2 [2/]
	MIL-E-24355 (see T9074-AD-GIB-010/1688 for direction)	MIL-140S-1 [2/]
A-6B	**CrMo steel (1.0 to 3.0 percent Cr, 0.4 to 1.2 percent Mo) (bare electrode)**	
	AWS A5.23/A5.23M	EB2 EB3
	AWS A5.28/A5.28M	ER70S-B2L (1.25Cr to 0.5Mo) ER80S-B2 (1.25Cr to 0.5Mo) ER80S-B3L (2.25Cr to 1Mo) ER90S-B3 (2.25Cr to 1Mo)
A-7B-2	**Cr and CrNiMo (martensitic) (11 to 13.5 percent Cr), (4-5 percent Ni, 0.75 percent max Mo) (bare electrode)**	
	MIL-E-19933	MIL-410
	AWS A5.9/A5.9M	ER410NiMo

Table 3-3. Feedstock Materials - Continued

Group	Applicable Document	Feedstock Material Type
A-8B	**High alloy steel (austenitic) (bare electrode)**	
	MIL-E-19933	MIL-308 MIL-308L MIL-308HC MIL-309 MIL-310 MIL-312 MIL-316 MIL-316L MIL-317 MIL-318 MIL-321 MIL-347
	AWS A5.9/A5.9M	ER309L ER316LSi ER320
A-9B	**High alloy steel (duplex stainless) (bare electrode)**	
	AWS A5.9/A5.9M	ER 2209 [2/]
A-21B	**Aluminum alloy (bare electrode)**	
	AWS A5.10/A5.10M	ER-1100, R1100
A-22B	**Aluminum alloy (bare electrode)**	
	AWS A5.10/A5.10M	ER5183, R5183 ER5356, R5356 ER5554, R5554 ER5556, R5556 ER5654, R5654
A-23B	**Aluminum alloy (bare electrode)**	
	ANSI A5.10/A5.10M AWS A5.10/A5.10M	4043 ER4043, R4043
A-24B	**Aluminum alloy (bare electrode)**	
	AWS A5.10/A5.10M	ER2319, R2319
A-31B	**Copper alloy (bare electrode)**	
	AWS A5.7/A5.7M	ER Cu
A-32B	**Copper alloy (silicon bronze bare electrode)**	
	MIL-E-23765/3	MIL-CuSi

Table 3-3. Feedstock Materials - Continued

Group	Applicable Document	Feedstock Material Type
A-33B	**Copper-tin alloy (phosphor bronze) (bare electrode)**	
	MIL-E-23765/3	MIL-CuSn-C
	AWS A5.7/A5.7M	ERCuSn-A
A-34B	**Copper nickel (bare electrode)**	
	MIL-E-21562	MIL-EN67 MIL-RN67
A-35B	**Copper-zinc alloy (bare rod)**	
	AWS A5.7/A5.7M	RB CuZn-A RB CuZn-B RB CuZn-C RB CuZn-D
A-36B	**Copper-aluminum alloy (aluminum bronze) (bare electrode)**	
	MIL-E-23765/3	Type CuAl-A2
A-37B	**Copper-aluminum-nickel alloys (NiAl and MnNiAl bronze) (bare electrode)**	
	MIL-E-23765/3	MIL-CuNiAl MIL-CuMnNiAl
A-42B	**Nickel-base alloys (bare electrode)**	
	MIL-E-21562	MIL-EN60
A-43B	**Nickel-base alloys (bare electrode)**	
	MIL-E-21562	MIL-EN62 MIL-RN62 MIL-EN82 MIL-EN82HEN6A EN625
A-45B	**Nickel-molybdenum-chromium alloy (bare electrode)**	
	AWS A5.14/A5.14M (UNS-N10276)	ER-NiCrMo-4 [2/, 3/, 4/]
A-51B	**Titanium-base alloys (bare electrode)**	
	AWS A5.16/A5.16M	ER Ti-1 ER Ti-2 ER Ti-3 ER Ti-7
A-53B [5/]	**Titanium-base alloys (bare electrode)**	
	AWS A5.16/A5.16M	ER Ti-5 ER Ti-23
A-53B-1 [5/]	**Titanium-base alloys (bare electrode)**	
	AWS A5.16/A5.16M	ER Ti-32

Table 3-3. Feedstock Materials - Continued

NOTES:

Where feedstock specifications are not covered by table 3-3, the Process Control Plan shall include a feedstock material testing plan and identify the tolerances in accordance with 7-3.5. At a minimum, Schedule J testing in accordance with AWS A5.01M/A5.01 shall be employed, and feedstock lot classification shall be in accordance with AWS A5.01M/A5.01, class S3.

1/ If material of similar chemistry and mechanical properties is not listed under an A-group, it may be considered as part of a group upon approval.

2/ NAVSEA approval is required.

3/ The feedstock metal shall conform to all the conformance requirements for EN/RN625 specified in MIL-E-21562 but shall have a minimum tensile strength of 100 kilopounds per square inch (ksi), an elongation of 25 percent, and a chemical composition of ERNiCrMo-4, as specified in AWS A5.14/A5.14M.

4/ These materials shall be used with the gas tungsten arc, gas metal arc, and plasma arc processes only.

5/ Melt control and composition, toughness, and other testing as approved by NAVSEA. Feedstock material specification requirements require NAVSEA approval prior to production builds.

3-2.3.3 Other Existing Acceptance Criteria. Where acceptance criteria from 3-2.3.2 and 3-2.3.3 are not applicable, the rationale for using the material acceptance criteria established for processes and product forms other than DED (e.g., casting or forging) from other NAVSEA technical publications, federal or military specifications and standards, or reputable standard development organization documents shall be provided, if applicable.

3-2.3.4 New Acceptance Criteria. Where acceptance criteria from 3-2.3.1, 3-2.3.2, and 3-2.3.3 are not applicable, alternative acceptance criteria for DED shall be generated.

a. Where tensile strength is specified in the filler metal specification instead of yield strength, minimum yield strength acceptance criteria shall be identified based on industry (e.g., filler metal manufacturer) or other appropriate data, and the criteria shall include consideration of yield strength variation both within a build as well as build-to-build variability. Where tensile strength is not specified, this guidance and that of S9074-A1-GIB-010/1628 shall apply. These values shall require NAVSEA approval

b. Where filler metal specifications do not specify toughness criteria, individual and average toughness results shall be reported to NAVSEA for approval; in the absence of other requirements, testing shall be performed at the minimum design temperature or as approved by NAVSEA.

c. Where tensile properties are not specified in the filler metal specification, minimum property requirements shall be proposed for NAVSEA approval. Guidance may be sought by considering industry data, S9074-A1-GIB-010/1628 for tensile strength, and properties for corresponding appropriate base materials (e.g., O temper base material properties for aluminum alloys, equivalent alloys grades for titanium, or CP2 base metal for CP2 filler metal).

d. For any other acceptance criteria, the test plan and test report approved by NAVSEA shall detail the method used for determining the alternative acceptance criteria and tolerances.

3-2.4 PREHEAT AND INTERPASS TEMPERATURES. Preheat and interpass temperatures shall be as specified in, or derived from, the limits listed in table 3-4. If any preheat and interpass temperatures outside these ranges are used, submittal of the DED Procedure shall include written justification to include, at a minimum, metallographic images of test samples fabricated with both the temperature limits prescribed in table 3-4 and those proposed for qualification. Where preheat and interpass temperatures are not provided in table 3-4, the temperatures used and documented for the qualification build shall be considered the minimum and maximum. Preheat and interpass temperatures and control measures shall be provided in the Process Control Plan in accordance with 7-3. If the procedure does not include controlling preheat and interpass temperatures or if the procedure uses interlayer temperature control, it shall be considered a Special DED Procedure per 2-2.7.

3-2.4.1 Methods of Preheating and Interpass Temperature Control. Preheat may be applied by any method that ensures uniform temperature of the build platform or build in progress. Interpass temperature shall be controlled by the following factors:

a. Proper placement of preheat elements and control of heat input

b. Proper build sequence

Rationale for other methods for preheat and interpass control shall be provided. Non-contact methods for measuring preheat and interpass temperature (e.g., thermal cameras) shall be per 3-2.7.

Table 3-4. Preheat and Interpass Temperature Limits

Material Group Number	Material Identification	Minimum Preheat Temperature (°F)	Maximum Interpass Temperature (°F)	Supplementary Provisions for Preheat and Interpass Temperatures
S-1	Carbon steel	200	---	N/A
S-2	Quenched and tempered carbon steel	200	300	N/A
S-3	Carbon molybdenum steel	175	---	Where either the specified minimum tensile strength is greater than 70 ksi or thickness is greater than ⅝ inch.
		60	---	All other S-3 materials.
S-3A	Carbon molybdenum steel	300	500	N/A

Table 3-4. Preheat and Interpass Temperature Limits - Continued

Material Group Number	Material Identification	Minimum Preheat Temperature (°F)	Maximum Interpass Temperature (°F)	Supplementary Provisions for Preheat and Interpass Temperatures
S-4	Alloy steels (Cr content ¾ to 2%; total alloy not to exceed 2¾%)	250	---	Where either the specified minimum tensile strength is greater than 60 ksi or thickness is greater than ½ inch.
		60	---	All other S-4 materials.
S-5	Alloy steels (total alloy content 10% max)	400	---	Where either the specified minimum tensile strength is greater than 60 ksi or chromium content is greater than 6.0% and thickness is greater than ½ inch.
		300	---	All other S-5 materials.
S-6	High alloy steels (martensitic)	400	---	For all S-6 materials except as permitted below.
		300	500	For 410 baseplate and 410NiMo feedstock.
		60	500	For 410S baseplate and 410NiMo feedstock.
S-6A	High alloy steels (martensitic)	200	500	For all S-6A materials except as permitted below.
		60	500	For thicknesses less than 1.5 inches and 410NiMo feedstock.
S-7	High alloy steels (ferritic)	---	---	Preheat is not mandatory. Preheat and interpass temperatures shall be as recorded in the Process Control Plan.

Table 3-4. Preheat and Interpass Temperature Limits - Continued

Material Group Number	Material Identification	Minimum Preheat Temperature (°F)	Maximum Interpass Temperature (°F)	Supplementary Provisions for Preheat and Interpass Temperatures
S-8	High alloy steels (austenitic)	---	350	Preheat and interpass temperature shall not exceed 350 °F.
S-10H	High alloy steels (duplex stainless)	60	350	N/A
S-11	---	---	---	Preheat and interpass temperatures shall require NAVSEA approval.
S-21 **S-22** **S-23** **S-25** **S-26**	Aluminum and aluminum-base alloys	60	---	Preheat may be used to control distortion and prevent cracking provided the preheat and interpass temperatures are supported by qualification tests. To mitigate a reduction in resistance to stress corrosion cracking, the maximum preheat and interpass temperature for S-25 materials should ideally be no more than 110 °F but shall not exceed 150 °F in any case.
S-33	Silicon bronze	60	---	Preheat may be used to control distortion and prevent cracking provided the preheat and interpass temperatures are supported by qualification tests.

Table 3-4. Preheat and Interpass Temperature Limits - Continued

Material Group Number	Material Identification	Minimum Preheat Temperature (°F)	Maximum Interpass Temperature (°F)	Supplementary Provisions for Preheat and Interpass Temperatures
S-34	Copper nickel	---	350	Preheating is not required.
S-35	Aluminum bronze	300	---	N/A
S-36A	Nickel aluminum bronze	---	---	Preheat is not mandatory. Preheat and interpass temperatures shall be as recorded in the Process Control Plan.
S-36B	Manganese nickel aluminum bronze	---	---	Preheat is not mandatory. Preheat and interpass temperatures shall be as recorded in the Process Control Plan.
S-37A	Manganese bronze	300	---	Depending on process used, preheat and interpass temperatures from 500 to 800 °F may be necessary to eliminate residual stress cracking.
S-37B	Nickel manganese bronze	---	---	Preheat is not mandatory. Preheat and interpass temperatures shall be as recorded in the Process Control Plan.
S-38	Tin nickel bronze	---	---	Preheat is not mandatory. Preheat and interpass temperatures shall be as recorded in the Process Control Plan.
S-39	Phosphor bronze	---	---	Preheat is not mandatory. Preheat and interpass temperatures shall be as recorded in the Process Control Plan.

Table 3-4. Preheat and Interpass Temperature Limits - Continued

Material Group Number	Material Identification	Minimum Preheat Temperature (°F)	Maximum Interpass Temperature (°F)	Supplementary Provisions for Preheat and Interpass Temperatures
S-42	Nickel copper	---	350	Preheating is not required.
S-43	Nickel chromium iron and nickel chromium molybdenum columbium	---	350	Preheating is not required.
S-44	Nickel molybdenum chromium alloy	---	200	Preheating is not required.
S-51 **S-52** **S-53** **S-53A**	Titanium and titanium alloys	60	250	When deposition is performed in an environmental chamber, interpass temperatures shall be as recorded in the Process Control Plan.

3-2.5 HEAT TREATMENT. Heat treatment furnaces, temperature recording and other equipment, and working zone temperature surveys shall be in accordance with SAE AMS-H-6875, SAE AMS2772, SAE AMS-H-81200, or similar, as approved. The heat treatment schedule shall be provided and approved. The activity shall maintain a complete record of all heat treatments, including stress relief, to be included in the Procedure Qualification Test Report.

3-2.5.1 Minimum Requirement. If no other heat treatment is included in the DED Procedure, a stress relief heat treatment shall be required unless otherwise approved by NAVSEA.

3-2.6 TITANIUM BUILD CONTROL PLAN. Activities, including all involved subcontractors, seeking to fabricate DED titanium (S-51, S-52, S-53, and S-53A) metal parts shall prepare a written plan for DED fabrication that describes in detail all the titanium-specific controls for ensuring the quality and integrity of DED parts. The plan shall describe and assign duties and responsibilities for each aspect of fabrication and quality assurance. The plan shall include detailed workmanship, inspection, post-processing (e.g., heat treatment), safety, and all necessary quality controls for DED fabrication to preclude contamination. The requirements of S9074-AR-GIB-010/278 for fabrication, facilities, equipment, materials, gas shielding systems, personnel training, cleaning, tooling, build platform and wire handling, and storage and receipt inspection (as they relate to DED) shall be addressed in the activity's plan. The activity shall submit the plan to NAVSEA for approval prior to the start of production. Requirements of this paragraph that are addressed in the plan of 7-3.2 shall be referred to in this titanium-specific plan.

3-2.7 THERMAL MONITORING EQUIPMENT. Where active thermal monitoring is used to measure or control any part of the build process, the thermal monitoring equipment shall be considered a subsystem of the machine per table 3-1, note 3. Placement and usage of the thermal monitoring equipment shall be detailed in the Process Control Plan per 7-3 and shall be correlated with test and inspection data.

3-2.7.1 Thermal Monitoring Equipment Calibration. Thermal monitoring equipment shall be calibrated prior to the deposition of any material submitted for approval. Details and results of the calibration process shall be included in the DED Procedure.

3-2.8 ACTIVE COOLING. Where active cooling is used for interpass temperature control, the active cooling equipment shall be considered a subsystem of the machine per table 3-1, note 3. Placement and usage of the active cooling equipment shall be detailed in the Process Control Plan per 7-3. Any DED Procedure that uses active cooling shall be considered a Special DED Procedure per 2-2.7.

3-2.9 OSCILLATION. Where oscillation is used, deposition material shall remain molten across the entire amplitude for the duration of a single oscillation cycle. Where deposition material solidifies prior to the completion of the oscillation cycle, the solidified material shall be subject to interpass temperature requirements.

3-2.10 PROCEDURES WITH AS-BUILT SURFACES. Any DED Procedure for applications with as-built surfaces shall be considered a Special DED Procedure per 2-2.7.

3-2.11 REVIEW FOR ADEQUACY. The DED Procedure shall be submitted concurrently with the DED Test Report for review for adequacy.

3-3 DED PROCEDURE QUALIFICATION TEST PLAN.

3-3.1 SCOPE. The activity shall develop a test plan for qualifying the DED Procedure.

3-3.2 PROCEDURE QUALIFICATION BUILDS. Unless otherwise specified, the DED Procedure shall be used to make procedure qualification builds that meet the requirements specified in table 3-5 and table 3-6. The qualification build shall meet the acceptance requirements established in 3-2.3. Specimens extracted from procedure qualification builds shall be evaluated in accordance with 8-4.

3-3.2.1 Procedure Qualification Build Design. Procedure qualification builds shall be rectangular blocks with thicknesses as specified in table 3-5 and table 3-6, and length and height shall be sufficient to extract all required destructive test specimens.

3-3.2.1.1 Procedure Qualification Build Quantity. As many procedure qualification builds as needed shall be produced to meet the specimen quantity requirements in table 3-5 and table 3-6 for each thickness condition and end of the essential element parameter range established per 3-3.2.3. A full procedure qualification shall be no less than four builds.

3-3.2.1.2 Procedure Qualification Thickness Limits. Where procedure qualification builds are performed for only one thickness specified in table 3-5 or table 3-6, production builds shall be limited to the thickness described therein. Where qualification builds are performed for both thicknesses, the minimum thickness allowed for production shall be the limit from the thinner qualification builds and the maximum thickness allowed shall be unlimited.

3-3.2.2 Procedure Qualification Build Platform and Feedstock Material. Procedure qualification builds shall be made using build platform and feedstock material as specified in 3-2.3.

3-3.2.2.1 Build Platforms for Integrated Build Procedure Qualification Builds. For procedure qualification builds, build platforms shall be thick enough that specimens required for testing of the HAZ as specified in in table 3-5 and table 3-6 can be extracted. Where build platform material is not sufficiently thick, the DED Procedure shall be used to deposit additional material on the other side of the build platform as needed. Build platform thickness shall not be less than 1 inch, unless otherwise approved by NAVSEA prior to deposition of the procedure qualification builds.

3-3.2.3 Essential Element Parameter Ranges. Procedure qualification builds shall be made using the full range of heat input and preheat and interpass temperatures to be qualified. At a minimum, one build shall be made using the maximum heat input and maximum interpass temperature, and one build shall be made using the minimum heat input and minimum interpass temperature per thickness qualified. The minimum interpass temperature tested shall be equivalent to the preheat temperature qualified.

3-3.2.3.1 Interpass Temperature for Procedure Qualification Builds. Unless otherwise approved, prior to deposition, the interpass temperature shall be within 10 percent or 25 °F, whichever is less, of the maximum or minimum interpass temperature being qualified.

3-3.2.3.2 Fixed Heat Input Procedures. Where the DED Procedure will have a nominally static heat input, the interpass temperature shall be the only essential element that is changed between procedure qualification builds.

3-3.2.3.3 Requirements for Maximum and Minimum Heat Input. The activity shall be responsible for determining the combinations of essential elements that result in the maximum and minimum heat inputs for qualification. For procedure qualification builds performed at the maximum heat input, at least 80 percent of deposited beads shall be at least 90 percent of the heat input qualified or greater. For procedure qualification builds performed at the minimum heat input, at least 80 percent of deposited beads shall be no more than 20 percent above the heat input qualified or greater, and the average heat input shall not exceed the minimum heat input qualified.

3-3.3 BUILD LAYOUT. The Procedure Qualification Test Plan shall contain figures in the form of computer-aided design (CAD) drawings that show the build layouts in three dimensions. At a minimum, the figures shall provide the following:

a. Build platform layout
b. Orientation and scaling information
c. Extraction locations for destructive tests
d. If applicable, markings on the part(s) to include identification scheme

3-3.3.1 Post Processing.

3-3.3.1.1 Surface Finish. All testing shall be performed in the as-machined condition. Where testing of as-built surfaces is required, testing shall require a test plan to be developed and approved by NAVSEA.

3-3.3.1.2 Heat Treatment. The activity shall maintain a complete record of all heat treatments, including stress relief, to be included in the Procedure Qualification Test Report.

3-3.3.1.3 Other Post-Processing Procedures. Any other post-processing procedure that will be performed on production builds that impacts material performance (e.g., nitriding, shot peening) shall be performed on procedure qualification builds. These shall be performed according to Government or commercial specifications or standards or as approved by the AM Authorized Representative.

Table 3-5. Destructive Testing Requirements for Maximum Thickness Blocks

2+ Inch-Thick Blocks						
Specimen Type	**Build Materials, Bulk** [1/]	**Build Materials, Edge** [1/]	**HAZ, Bulk** [1/, 2/]	**HAZ, Edge** [1/, 2/]	**Total, Per Block** [1/, 3/]	**Notes**
Tensile	4	0	4	0	8	Specimens do not need to be extracted exactly on centerline (i.e., may be in a 2x2 grid).
Bend	2	0	2	0	4	Bend tests outside the HAZ shall be oriented to capture the maximum number of bead overlaps possible. Bend tests in the HAZ shall be in the same orientation as those outside the HAZ.
Charpy V-Notch	4	4	4	4	16	Per temperature required.
Metallographic, transverse orientation	1	1	1	1	2 [4/]	---
Metallographic, into thickness	1	0	1	0	2	Microstructure only.
Hardness	---	---	---	---	---	Hardness testing shall be done on all microstructural specimens, with a minimum of 10 indents per specimen.
Chemistry	2	0	0	0	2	---

NOTES:

[1/] Bulk shall refer to material greater than 0.5 inch from any surface. Edge shall refer to material where the nearest edge of the test coupon was within 2 mm of the surface of the build remaining after removing the as printed surface.

[2/] Non-integrated build platform procedures shall not be required to test specimens in the HAZ.

[3/] Total specimen count is for summary purposes per cooling rate condition. Total count may be split across multiple blocks.

[4/] A single metallographic specimen may capture the centerline and edge for macroetch. Specimens may then be cut for microstructural analysis.

Table 3-6. Destructive Testing Requirements for Minimum Thickness Blocks

Specimen Type	Build Materials, Bulk [1/]	Build Materials, Edge [1/]	HAZ, Bulk [1/] [2/]	HAZ, Edge [1/], [2/]	Total, per Block [3/]	Notes
Tensile	4	0	4	0	8	---
Bend	2	0	2	0	4	Bend tests outside the HAZ shall be oriented to capture the maximum number of bead overlaps possible. Bend tests in the HAZ shall be in the same orientation as those outside the HAZ.
Charpy V-Notch	4	0	4	0	8	Per temperature required.
Metallographic, transverse orientation	1	0	1	0	2	Shall capture full thickness.
Metallographic, into thickness	1	0	1	0	2	Microstructure only.
Hardness	---	---	---	---	---	Hardness testing shall be done on all microstructural specimens, with a minimum of 10 indents per specimen.
Chemistry	2	0	0	0	2	---

NOTES:

[1/] Bulk shall refer to material greater than 0.5 inch from any surface. Edge shall refer to material where the nearest edge of the test coupon was within 2 mm of the surface of the build remaining after removing the as printed surface.

[2/] Non-integrated build platform procedures shall not be required to test specimens in the HAZ.

[3/] Total specimen count is for summary purposes per cooling rate condition. Total count may be split across multiple blocks.

3-3.4 START AND STOP POSITIONS. Where bead start and stop locations will be integrated into production builds as opposed to removed via mechanical or other means, the procedure qualification builds shall be evaluated such that these areas are captured in NDT.

3-3.5 NDT. Prior to performing any destructive tests, all DED Procedure qualification builds shall be nondestructively tested as specified herein. Unless otherwise specified, NDT shall be evaluated in accordance with 8-3 and shall meet the requirements of MIL-STD-2035, class 1, for welds. Unless the activity's level III examiner is performing the inspection, the activity's level III examiner shall be on site with the level II examiner performing inspection of procedure qualification builds. NDT procedures shall be submitted with the DED Procedure.

3-3.6 VISUAL TESTING. Visual testing (VT) shall not be required except that for titanium and titanium alloys, VT shall be performed in the as deposited condition to inspect for color per 8-3.1.1.

3-3.7 SURFACE INSPECTION. Magnetic-particle testing (MT) or liquid-penetrant testing (PT) shall be performed on all accessible surfaces. As-built surfaces shall be removed via appropriate mechanical methods prior to surface inspection. Indications due to surface finishing shall not be repaired and shall be submitted for dispensation.

3-3.8 VOLUMETRIC INSPECTION. Volumetric inspection by ultrasonic testing (UT) shall be performed through the thickness of the Procedure Qualification Build. Volumetric inspection shall be performed by UT, radiographic testing (RT), or both if the activity plans to use both inspection methods for production applications. As-built surfaces shall be removed via appropriate mechanical methods prior to inspection. Design material thickness shall be the intended thickness of the specific build. Substitution of RT in lieu of UT shall require NAVSEA approval prior to testing.

3-3.8.1 UT Calibration. UT procedures shall be calibrated per 8-3.5.2 prior to use. Unless otherwise approved, this calibration shall be done using printed material. Where UT calibration has not been performed, Procedure Qualification Blocks may be used for calibration. UT calibration details and results shall be submitted with the Procedure Qualification Test Report per 3-4.

3-3.9 NDT FOR INTEGRATED BUILD PLATFORMS. For integrated build platforms, at least ½ inch of the build platform material shall be machined away to expose the interface of the build platform and the deposited material to allow for NDT along the interface.

3-3.10 DESTRUCTIVE TESTING. Destructive testing shall be evaluated in accordance with 8-4. The number and type of specimens tested shall be in accordance with table 3-5 and table 3-6. All testing shall be performed in the Z orientation, with notches for all Charpy specimens oriented along the longitudinal direction. For acceptance, destructive testing shall meet the requirements established per 3-2.3.

3-4 PROCEDURE QUALIFICATION TEST REPORT.

The Procedure Qualification Test Report shall include the required and measured values for each of the essential elements of the procedure as specified in table 3-1 (an example is shown in table 3-8) and the nondestructive and destructive test results in sufficient detail to ensure compliance with the requirements. This shall include metallographic photos and any work instructions referenced in the procedure or test report that contain the required essential element information. The report shall contain a certification statement in accordance with 2-2.2. The report shall include the build layout figures in accordance with 3-3.2.1.

3-5 CHANGES REQUIRING LEVEL 1 REQUALIFICATION OF PROCEDURE.

Changes other than those listed in this section and those listed in 3-6 for level 2 qualification may be made in a DED Procedure without the necessity for requalification; however, the revised procedure with all changes identified shall be submitted to the AM Authorized Representative. If the AM Authorized Representative or NAVSEA has a concern with the revised procedure, requalification using the revised procedure may be required. The changes specified in 3-5.1 through 3-5.11 require requalification of the DED Procedure for level 1 qualification.

3-5.1 MACHINE.

a. A change in manufacturer or manufacturer model number of any subsystem of the machine from that recorded on the qualification test report where the previous procedure can no longer be performed as qualified (see table 3-1, note 3).

b. A change in machine software version from that recorded on the qualification test report, unless otherwise allowed in the Process Control Plan.

3-5.2 BUILD PLATFORM.

a. For integrated build platforms and when using material acceptance criteria in accordance with 3-2.3.2 or 3-2.3.3, any change in base platform material from one S-group to another S-group or to any material not covered in table 3-2.

b. For alloys not part of an S-group listed in table 3-2, the change from one build platform alloy to another build platform alloy.

c. A change from a non-integrated build platform to an integrated build platform.

d. For integrated build platforms, a change in build platform thickness to less than 1 inch or to less than what was used for procedure qualification if build platform thickness less than 1 inch was approved per 3-3.2.2.1.

3-5.3 FEEDSTOCK MATERIAL.

a. When using material acceptance criteria in accordance with 3-2.3, any change in feedstock material from one A-group to another A-group or to any material not covered in table 3-3.

b. For alloys not part of an A-group listed in table 3-3, the change from one feedstock alloy to another feedstock alloy.

c. Any change in specified wire diameter.

d. The addition or removal of any supplemental feedstock material or a change in the number of supplemental feedstock wires. Also, any supplemental feedstock material shall be subject to a, b, and c above.

3-5.4 DEPOSITION PROCEDURE.

a. A change in the path planning strategy outside what is allowed in the Process Control Plan.

b. The addition or removal of perimeter passes, or change in the number of perimeter passes, where the total width of the perimeter passes is greater than 10 percent of the layer width.

3-5.5 PROCESS.

a. A change from one arc process to another process (gas metal-arc, gas tungsten-arc, etc.).

b. For gas tungsten-arc processes and plasma-arc processes, a change from electrically hot to cold wire or vice versa.

c. A change within a process of arc-metal transfer characteristics. For instance, in gas metal-arc welding, a change from one mode to any other mode (e.g., spray transfer to globular transfer or vice versa or globular transfer to short-circuiting arc transfer or vice versa). A change to or from the pulsed arc mode in gas metal-arc welding.

d. In the plasma-arc process, a change in the arc from transferred to non-transferred or vice versa.

e. The addition or elimination of an oscillating motion of the heat source or feedstock material, or the addition of a dwell in the oscillating motion.

f. Any change in oscillation that results in deposition material solidifying prior to completion of a single oscillation cycle.

g. For gas-tungsten arc DED, a change in the electrode material.

h. A change to a position not already qualified.

3-5.6 POWER SOURCE PARAMETERS.

a. For arc power sources:

(1) Any change in polarity.

(2) The omission of self-regulating arc length or voltage control if the procedure was qualified with such control. In this regard, a constant potential power supply is a self-regulating voltage control.

(3) For waveform-controlled welding, a change in the program ID, or any change in the waveform.

b. For laser power sources:

(1) A change in focus position or spot size on the build surface by more than 5 percent.

(2) The addition or removal of pulsing control or another control method.

(3) A change from pulsing control to another control method, or vice versa.

c. For electron beam power sources:

(1) A change in focus position by more than 5 percent.

(2) Any change in electron gun filament material that is not a direct replacement.

(3) A change in source region vacuum by more than one order of magnitude.

3-5.7 SHIELDING GAS (TORCH, PURGE GAS).

a. A change from a mixture of gases to another mixture of gases or to a single gas.

b. A change from a single gas to another gas or mixture of gases.

c. For the plasma arc process, a change in the orifice gas composition.

d. A change in the nominal percentage of any non-inert gas in a gas mixture.

e. When using mixed inert gas, a change of ±25 percent or 5 cubic feet per hour (whichever is larger) in the flow rate of the minor constituents of the gas mixture.

f. The addition or deletion of a shielding gas.

g. Elimination of purge gas.

h. For plasma arc keyhole processes, a change in the nominal composition of the backing (i.e., purge) gas or gas mixture.

i. For titanium materials, a change from building in a chamber to outside a chamber.

j. For titanium materials built outside a chamber, the omission of a trailing shield or backing (i.e., purge) gas.

k. For titanium materials, the requirements of 3-5.7 a, b, d, e, and f also apply to trailing shield gas. Also, addition of a trailing shield gas other than a gas of the same composition as the torch shielding gas.

l. An increase in nominal dew point of the shielding gas above that reported in the test report.

m. For electron beam power sources, a change in vacuum pressure by more than an order of magnitude (torr) of a vacuum.

3-5.8 PREHEAT AND INTERPASS TEMPERATURES.

a. The removal of preheat or interpass temperature limits.

b. A change from interpass temperature control to interlayer temperature control, or vice versa.

3-5.9 IN-PROCESS MACHINING AND GRINDING.

a. The addition or omission of in-process grinding or machining used for control of layer height.

b. The removal of in-process grinding used for surface cleaning.

3-5.10 POST-BUILD PROCESSING.

a. The addition or omission of any post-build heat treatment or any steps thereof.

b. The change in temperature or time range in any post-build heat treatment or steps thereof outside what is allowed in the Process Control Plan.

c. For materials having impact requirements, a change in the heat treatment temperature and time range from that recorded in the test report. If applicable, a change in temperature that is within the range specified by the fabrication document does not require requalification.

3-5.11 ACTIVE COOLING.

a. The addition or removal of any active cooling equipment.

b. Any change in active cooling medium.

c. A change in active cooling flow rate greater than ±5 percent.

d. Any change in the design of the active cooling system.

3-6 CHANGES REQUIRING LEVEL 2 REQUALIFICATION OF PROCEDURE.

One additional procedure qualification block per thickness as specified in 3-2 shall be fabricated for changes to an essential element specified in 3-6.1 through 3-6.9 from that recorded in the procedure previously qualified under level 1. These builds shall undergo nondestructive and destructive testing. Where these changes result in a new upper or lower cooling rate, the qualification block(s) shall be fabricated at these conditions. Where these changes do not result in changes to the upper or lower cooling rates, these blocks shall be fabricated using typical values. Unless otherwise specified by NAVSEA, changes to an essential element specified in 3-6.10 shall require fabrication of one procedure qualification block per thickness, as specified in 3-3.2; these builds shall undergo NDT, but shall not be required to undergo destructive testing.

3-6.1 MACHINE. A change in manufacturer or manufacturer model number of any subsystem of the machine from that recorded on the qualification test report where the previous procedure can be executed (see table 3-1, note 3), except for the laser fiber, and welding leads and cable bundles.

3-6.2 DEPOSITION PROCEDURE.

a. A change in the maximum or minimum programmed travel speed from that recorded on the test report.

b. A change in the bead overlap outside what was qualified.

c. An increase in maximum bead width to greater than what was qualified.

3-6.3 BUILD PLATFORM.

a. For non-integrated build platforms, any change in base platform material from one S-group to another S-group or to any material not covered in table 3-2.

b. For integrated build platforms, a change in product form or temper.

3-6.4 PROCESS.

a. A change by more than 5 degrees of the lead or trail angle or a change by more than 5 degrees of the angle perpendicular to the travel direction.

b. A change of the angle of the arc weld torch by more than 15 degrees from the vertical centerline for the horizontal position.

c. A change in oscillation amplitude beyond what was qualified.

d. A change in the frequency of oscillation beyond what was qualified.

3-6.5 POWER SOURCE PARAMETERS.

a. Any change in programmed voltage, current, or power resulting in a heat input outside of what is qualified.

b. Any change in programmed power source start or stop dwell time.

c. For arc power sources, a change to pulse rate beyond what was qualified.

3-6.6 WIRE FEED. A change in nominal wire feed speed beyond what was qualified .

3-6.7 SHIELDING GAS (TORCH, PURGE GAS).

a. For the plasma arc process, a change greater than 5 percent in the flow rate of orifice gas.

b. A decrease greater than 10 percent or 5 cubic feet per hour (whichever is larger) in the rate of gas flow below that used during qualification for torch shielding gases only.

c. A change of gas cup size for arc processes that use a gas cup.

3-6.8 PREHEAT AND INTERPASS TEMPERATURE.

a. An increase or decrease of either preheat or interpass temperature limits beyond what was qualified.

b. A change in the method of establishing and measuring preheat and interpass temperatures.

3-6.9 IN-PROCESS MACHINING AND GRINDING.

a. Decrease in the frequency of in-process machining or grinding used for any purpose.

b. The addition of in-process grinding used for cleaning.

3-6.10 POST-BUILD PROCESSING.

a. The addition or removal of, or change in the number of perimeter passes, where the total bead width of perimeter passes is less than 10 percent of the layer width.

b. Post processing: for parts that are chemically processed, a change in the chemical process conditions from those in the test report.

Table 3-7. Sample Procedure Qualification Report for Directed Energy Deposition

General

Company: _____ Approved by: _____

_____ (Signature Required) _____

Machine Operator(s):

_____

Part: _____ Date: _____

Process: _____ Transfer Mode: _____

Build File Name:

_____

Date of Last Maintenance: Date of Last Calibration:

_____ _____

Materials

Build Platform Material S-Group, Spec, Type, and Grade: Build Platform Thickness:

_____ _____

Build Platform Preparation:

_____

Feedstock Material A-Group, Spec, Type, and Grade: Feedstock Diameter:

_____ _____

Machine

Manufacturer and Model: Serial Number:

_____ _____

Power Source Manufacturer and Model: Power Source Serial Number:

_____ _____

Shielding Gas Type and Grade: Shielding Gas Flow Rate:

_____ _____

Supplemental Gas Type and Grade: Supplemental Gas Flow Rate:

_____ _____

Table 3-7. Sample Procedure Qualification Report for Directed Energy Deposition – Continued

Build Parameters

Build parameters in this record must document each set of parameters used in a build (e.g., parameter sets for interior, surface, overhangs, interfaces, etc. within the same build). Parameter descriptions may be replaced with machine-specific parameter names where applicable. Machine-specific parameters, process monitoring feedback parameters, and any other parameters not listed in this table required to replicate the build must also be specified and documented within this record.

Parameter Set Name:	Parameter Set Description:
Part Identification:	Layer Height:
Power Source:	Deposition Travel Pattern:
Bead Spacing Offset:	Travel Speed:
In-Process Machining and Grinding:	
Preheat Temperature:	Interpass Temperature:

Post Processing

Method of Part Removal from Build Platform:

HIP Atmospheric Conditions:

HIP Procedure:

Heat Treatment Method:

Heat Treatment Procedure:

Surface Finish Method:

Table 3-8. Sample Form: Tensile Test Results

Test Date:											
Testing Standard:											
Specimen ID	Specimen Orientation	Specimen Location	Width	Thickness	Area	Yield Strength	Ultimate Strength	Strain at Failure	Failure Type	Failure Location	% Elongation

Table 3-9. Sample Form: Charpy V-Notch Test Results

Test Date:					
Testing Standard:					
Specimen ID	Specimen Orientation	Specimen Location	Test Temperature	Absorbed Energy	Notes

Table 3-10. Sample Hardness Test Results Form

Test Date:				
Specimen ID	Specimen Orientation	Specimen Location	Hardness	Notes

CHAPTER 4
PART VERIFICATION PROCEDURE

4-1 SCOPE.

This chapter provides general requirements for the qualification of the Part Verification Procedure for general applications. The purpose of the Part Verification Procedure is to verify that geometry- and orientation-dependent preproduction parts meet material and nondestructive testing and evaluation performance requirements.

4-2 PART MANUFACTURING PLAN.

This section provides the requirements for the Part Manufacturing Plan. The Part Manufacturing Plan shall be used to manufacture a specific component for Part Verification Testing and production.

4-2.1 ESSENTIAL ELEMENTS. All components shall be made using the same essential elements qualified in the DED Procedure in accordance with 3-2. Essential elements for Part Verification and Production Builds shall be controlled using the same Quality Assurance and Process Control Plans as in the DED Procedure.

4-2.2 MATERIAL ACCEPTANCE CRITERIA. Part verification builds and production builds shall meet application-specific requirements and meet the acceptance criteria in the qualified DED Procedure.

4-2.2.1 NDT Acceptance Criteria. NDT acceptance criteria shall be defined based on the part classification per 5-4 or as approved by NAVSEA.

4-2.3 BUILD LAYOUTS. The Part Manufacturing Plan shall contain figures that show the build in three dimensions. At a minimum, the figures shall provide the following:

a. Build platform layout including part(s), specimens, and witness coupons
b. Orientation and scaling information
c. Extraction locations for destructive tests
d. If applicable, markings on the part(s) to include identification scheme
e. Locations for NDT

4-2.4 PART MANUFACTURING BUILD SEQUENCE. The Part Manufacturing Plan shall contain details of all sequences of the build, including, if applicable:

a. Details of when and how the part will be reoriented to deposit features on previously deposited material in a different orientation.
b. Details of when and how the part will receive in-process machining, grinding, or cleaning beyond the DED Procedure. This shall include when the build is removed from the DED system to receive machining.
c. Details of when and how NDT will be performed after partial completion of the build to inspect areas prior to these areas becoming uninspectable.

4-2.4.1 Family of Part Changes Not Requiring Part Requalification. For a family of part applications (where applicable), the Part Manufacturing Plan shall identify features (i.e., geometric, dimensional) where changes do not require part requalification per 4-5 when the digital files (i.e., CAD) are changed. Supporting evidence for allowing the feature changes shall be provided to NAVSEA.

4-2.4.2 Witness Coupons. The Part Manufacturing Plan shall contain details of witness coupons that will be used for conformance testing of Production Builds. Witness coupons shall be designed such that they can be deposited during production builds and can be removed from different locations of the build or are deposited next to the part(s). Unless otherwise approved by NAVSEA, for parts that are subjected to heat treatment during post processing, the geometry of the witness coupon shall accurately simulate the thickest portion of the part, which shall be the diameter of the greatest inscribed sphere at any location in the part. If witness coupons remain attached to the part during heat treatment, they shall be of a design that does not increase the thickest portion of the part. Witness coupons shall be placed such that they can be removed from excess material throughout the height of the part and removed without otherwise damaging the part. Witness coupons shall be evaluated in accordance with 8-3 and 8-4 to the criteria specified in 3-2.3. Witness coupons shall undergo post-processing procedures concurrently with the build.

4-3 PART VERIFICATION TEST PLAN.

This section provides the requirements for testing part verification builds.

4-3.1 PART VERIFICATION BUILDS. The part verification builds shall be the same as the builds made in production DED including the digital files and quantities of witness coupons. As in production DED, part verification builds shall be made using the same method including control methods, thermal management controls, and build files. The part verification build shall go through all post-processing that was qualified in the DED Procedure per 3-3.2.3. Deviations in build files for sub-scale or representative part verification builds shall be as approved by NAVSEA.

4-3.1.1 Start and Stop Positions. Where applicable, the integrated start and stop positions in the part verification build shall be the same as the production part.

4-3.2 NONDESTRUCTIVE TESTING.Unless otherwise approved by NAVSEA, all part verification builds shall be evaluated as required for production components in accordance with 5-4. Where a component has multiple uses that have different NDT requirements, NDT of part verification builds shall satisfy the requirements for the highest classification of the component. Unless the activity's level III examiner is performing the inspection, the activity's level III examiner shall be on site with the level II examiner performing inspection of part verification builds.

4-3.2.1 Use of Sensors. If applicable, NDT requirements shall be met using validated and verified sensing and monitoring systems for identifying and classifying indications in-situ. Supporting evidence demonstrating that in-situ sensing meets inspection requirements shall be approved by NAVSEA.

4-3.3 DESTRUCTIVE TESTING.Destructive testing shall be evaluated in accordance with 8-4 to the acceptance criteria approved as specified in 3-2.3. Destructive testing types, numbers, locations, and orientations shall be determined in accordance with NAVSEA's guidance on the use of AM. At a minimum, witness coupons shall be tested in accordance with table 5-1.

4-3.3.1 Metallographic Specimens. Specimens shall be evaluated in accordance with 8-4.4. Sectioning plans for the part verification builds and witness coupons shall be included in the Part Verification Test Plan.

4-3.3.2 Application-Specific Requirements. In addition to parts and witness coupons, part verification builds shall contain specimens of the types and quantities that reflect application-specific requirements. When witness coupon material is not sufficient to meet the required application-specific testing, additional coupons for testing shall be produced as part of the part verification. If applicable, additional builds shall be produced and evaluated to meet application-specific requirements. All additional testing shall occur prior to production.

4-4 PART VERIFICATION TEST REPORT.

The Part Verification Test Report shall include the values employed for each of the essential elements of the procedure in accordance with 4-2.1 and all the results of the nondestructive and destructive testing. Metallographic photos and any work instructions referenced in the procedure or test report that contain the required essential element information shall be submitted with the test report. If applicable, the report shall contain supporting evidence for allowing a family of part feature changes in accordance with 4-2.4.1. The report shall contain a certification statement in accordance with 2-2.2. The build layout figures in accordance with 4-2.3 shall be included in the Part Verification Test Report.

4-4.1 WORK INSTRUCTIONS. All work instructions or other documents referenced in the submitted test reports, plan, or procedures that contain essential element information shall be made available upon request.

4-5 PART REQUALIFICATION.

Changes other than those listed in this section may be made to a qualified build without the necessity for requalification; however, the revised procedure with all changes identified shall be submitted to the AM Authorized Representative. If the AM Authorized Representative or NAVSEA has a concern with the revised procedure, requalification using the revised procedure may be required. The changes specified in 4-5.1 through 4-5.6 require re-execution of the Part Verification Procedure for Part qualification. Any changes to the previously approved Part Verification Procedure, including the omission of any application specific testing, shall require NAVSEA approval. A change specified in 4-5.2.b shall only require re-execution of nondestructive testing specified in the Part Verification Procedure.

4-5.1 QUALIFICATION LEVEL 1 CHANGES.

a. A change to a different level 1-qualified DED Procedure than listed on the Part Verification Test Report.
b. A change from one level 1-qualified DED Procedure to a level 1-qualified DED Procedure not listed on the Part Verification Test Report.

4-5.2 DIGITAL FILES.

a. Any change to the CAD files used to make the part verification build, except where a representative part verification build was used or as approved by NAVSEA.
b. A change in the slice file used for the part verification build.

4-5.3 BUILD PLATFORM.

a. A change from one alloy in an S-group to another alloy in the same S-group.
b. For a specific alloy, a change in temper from that reported in the test report.
c. A change from one build platform cleaning method to another method.
d. A change from one build platform product form to another build platform product form.

4-5.4 FEEDSTOCK MATERIAL. A change from one alloy in an A-group to another alloy in the same A-group.

4-5.5 IN-PROCESS MACHINING. Any change of in-process machining order.

4-5.6 ACTIVE COOLING. A change in the placement and movement of cooling elements.

CHAPTER 5
PRODUCTION CONFORMANCE EVALUATION PLAN

5-1 SCOPE.

This chapter provides general requirements for the Production Conformance Evaluation Plan for general applications. The purpose of the Production Conformance Evaluation Plan is to identify conformance testing and NDT requirements for production builds.

5-2 GENERAL REQUIREMENTS.

5-2.1 PRODUCTION CONFORMANCE TESTING. A Production Conformance Evaluation Plan shall include destructive and NDT requirements. The Production Conformance Evaluation Plan shall include application-specific production testing requirements. At a minimum, composition and destructive testing shall be performed in accordance with table 5-1. Specimens shall be oriented in the build direction or in the weakest known orientation if not the build direction. NDT shall be performed as required in 5-4. The frequency, type, orientation, and quantity of specimens to be tested shall be identified.

Table 5-1. Conformance Testing

Specimen Type	Quantity	Frequency
Tensile	2	Every production build
Charpy V-Notch	3	Every production build
Bend	1	Every production build
Metallographic	1	Every production build
Chemistry	1	Every production build

5-2.2 BUILD LAYOUT FIGURES. The Production Conformance Evaluation Plan shall contain figures that show the build in three dimensions. At a minimum, the figures shall provide the following:

a. Build platform layout including part(s), specimens, and witness coupons
b. Orientation and scaling information
c. Extraction locations for destructive tests
d. If applicable, markings on the part(s) to include identification scheme
e. Locations for NDT

5-2.3 USE OF PART VERIFICATION TEST PLAN AS PRODUCTION CONFORMANCE EVALUATION PLAN. Where a previously approved Part Verification Test Plan meets all requirements of the Production Conformance Evaluation Plan, the activity may use the previously approved Part Verification Test Plan for production conformance evaluation without additional approval required by 2-2.3.2 d. When this section is invoked, it shall be referenced in the Part Verification Test Plan.

5-3 WITNESS COUPONS.

Witness coupons shall be stored as a record of each build. Specimens used for conformance testing shall be extracted from witness coupons. The witness coupons shall be the same as those in the part verification build and shall follow all requirements per 4-2.4.2. Storage duration shall be agreed upon by the activity and NAVSEA.

5-4 NDT AND REPAIRS.

Production builds shall undergo NDT based on the relevant classification in accordance with 1-6. NDT shall be performed in accordance with 8-3. NDT shall be described in the Production Conformance Evaluation Plan. Extent of NDT coverage for each build and part on a build requiring the listed NDT shall be as follows:

a. VT, and MT or PT, as appropriate, shall be conducted on all accessible surfaces that comprise the part in final condition.

b. Pressure tests shall be applied to all areas containing pressure.

c. Volumetric inspection coverage shall be 100 percent except when build configurations and thickness variations prevent 100 percent inspectability in some locations and for the purpose of defining coverage required, a build is considered to contain the following areas:

   (1) 75 percent minimum coverage areas. Areas include areas containing pressure, areas designed for dynamic loads, and areas stressed to ⅔ or more of the yield strength under high-impact shock.

   (2) 50 percent minimum coverage areas and any remaining areas in the build.

The 75 or 50 percent minimum coverage is defined as build areas in the film that are within the specified density limits and are interpretable. It is not the intent that only 75 or 50 percent of build surfaces be radiographed and that any specific area be excluded. Areas that will not be interpretable shall be identified in the Production Conformance Evaluation Plan and subject to approval. In submitting for approval, the criticality of the areas not to be covered by RT or UT, and whether the area can be inspected by alternative NDT methods, shall be described.

5-4.1 NON-PRESSURIZED MACHINERY. Non-pressurized machinery builds shall be inspected in accordance with table 5-2.

5-4.2 PRESSURIZED MACHINERY AND PRESSURE VESSELS. Pressurized machinery and pressure vessel builds shall be inspected in accordance with table 5-3.

5-4.3 PIPING. Piping builds shall be inspected in accordance with table 5-4.

5-4.4 OTHER BUILDS. Parts that do not fall under one of these classifications shall be as approved by NAVSEA.

5-4.5 ACCEPTANCE CRITERIA. Minimum acceptance criteria shall be in accordance with NAVSEA Letter 9074 Ser 05Z/223 dated 8 May 2024 or as superseded.

5-4.6 USE OF SENSORS. If approved by NAVSEA, in-situ sensing in accordance with 4-3.2.1 shall be used for inspection.

Table 5-2. Non-Pressure Containing Builds in Machinery [1/]

Category	Application Rules	Stress Due to	Stress Level, Percent of Yield	NDT Requirements			Sub-Category
				Volumetric	MT/PT	VT	
A [1/]	Builds that, by failure of any one build, would prevent steering, diving, or propulsion with no standby capability.	Dynamic loads [2/]	All	X [1/]	X [1/]	X	A1
		High-impact shock grade A	>⅔	X	X	X	A2
			⅔ and <	---	X	X	A3
B	Builds that, by failure of any one build, would reduce the capability of the ship to launch, land, or transfer aircraft between flight and hangar decks.	Dynamic loads [2/]	All	X	X	X	B1
		High-impact shock grade A	>⅔	X	X	X	B2
			⅔ and <	---	X	X	B3
C	Builds for weapons handling systems that, by failure of any build, would result in dropping or damaging a weapon or result in reduction of weapons service to any space, launcher, or aircraft by 50 percent or more.	Dynamic loads [2/]	All	X	X	X	C1
		High-impact shock grade A	>⅔	X	X	X	C2
			⅔ and <	---	X	X	C3

The following requirements apply to all builds not covered in categories A, B, or C above:

Machinery Classification	Category	Stress Due To	Stress Level, Percent of Yield	NDT Requirements			Sub-Category
				Volumetric	MT/PT	VT	
M-1	A	All	All	Each build, 100 percent	X	X	E1
	B	All	All	Each build, 100 percent	X	X	E2
	C	All	All	---	---	X	E3
M-2	A	All	All	Each build, 100 percent	X	X	F1
	B	All	All	---	X	X	F2
	C	All	All	---	---	X	F3

Table 5-2. Non-Pressure Containing Builds in Machinery - Continued

NOTES:

In the event of a conflict in NDT requirements between this table, the ship specifications, the component specification, or other document, the more stringent NDT requirements shall be invoked.

1/ Ship propellers shall be subjected to VT with PT used only as an aid in locating discontinuities as specified in MIL-STD-2035. RT shall be performed on practicably inspectable areas in accordance with a plan approved by NAVSEA. Critical areas not inspectable by RT shall be subject to UT in accordance with 8-3.5 with coverage to be approved by NAVSEA.

2/ For purposes of clarification, builds stressed by dynamic loads are builds with areas that are designed for normal-service dynamic loads of a degree and frequency. Such loads are used in the strength equations that determine dimensions of the area (Note: high-impact shock is not a dynamic load for purposes of this rule).

Table 5-3. Inspection for Pressurized Machinery and Pressure Vessels

Application	Pressure [1] (lb/in^2)	Size [2] (inches)	NDT Requirements					Sub-Category
			Volumetric	Extent	MT/PT	Pressure [3]	VT	
Lethal or gasoline service	All	All	X	Each build, 100 percent	X	X	X	A
Oxygen or hydrogen service	All	All	X	Each build, 100 percent	X	X	X	B
Steam service	≥300	≥½	X	Each build, 100 percent	X	X	X	C1
	<300	≥2½	X	---	X	X	X	C2
		½ to 2½	X	---	X	X	X	C3
		<½	X	---	X	X	X	C4
Gas (other than lethal, oxygen, or hydrogen) [5] Water or hydraulic service [5]	≥1,000	≥2½ [4]	X	Each build, 100 percent	X	X	X	D
	300 to 1,000	≥2½ [4]	X	Each build, 100 percent	X	X	X	E
Special shipboard systems: Weapon service – all ships: Builds for weapons handling systems	All	All	X	Each build, 100 percent	X	X	X	F
Submarine service: a. Builds associated with hull boundary and subject to submergence pressure	All	All	X	Each build, 100 percent	X	X	X	G1
b. Builds in sea-connected systems from the inboard flange of the backup valve outboard to the hull	All	All	X	Each build, 100 percent	X	X	X	G2

Table 5-3. Inspection for Pressurized Machinery and Pressure Vessels – Continued

Application	Pressure [1/] (lb/in^2)	Size [2/] (inches)	NDT Requirements					Sub-Category
			Volumetric	Extent	MT/PT	Pressure [3/]	VT	
c. Builds in sea-connected systems inboard of the backup valve that are open to the sea below 200 ft submergence depth during any mode of operation	All	For sizes ≥4, see [6/]. For sizes <4 not RT'd per [6/], see [7/].	X	Each build, 100 percent	X	X	X	G3
Aircraft carrier service: Builds, the failure of which would reduce the capability to launch, land, or transfer aircraft between the flight and hangar decks	All	≥2½	X	Each build, 100 percent	X	X	X	H
Builds for normal steering systems	All	≥2½	X	Each build, 100 percent	X	X	X	I
Class A-F, A-1, A-2, A-LT, and A-3 builds, excluding builds in categories A-I	Temperature and pressure per class definitions	≥2½	X	Each build, 100 percent	X	X	X	J1
		½ to <2½	---	---	X	X	X	J2
		<½	---	---	---	X	X	J3

Table 5-3. Inspection for Pressurized Machinery and Pressure Vessels – Continued

Application	Pressure [1/] (lb/in^2)	Size [2/] (inches)	NDT Requirements					Sub-Category
			Volumetric	Extent	MT/PT	Pressure [3/]	VT	
For builds not covered by Categories A-J, including builds in surface ship sea-connected systems below the V lines not isolatable from the sea and all refrigerant systems of 50 psi design pressure and greater	All	≥2 ½	---	---	---	X	X	K
Builds not covered above (e.g., generic class A-4 <2.5)	All	All	---	---	---	X	X	L

NOTES:

In the event of a conflict in NDT requirements within this table or between this table, the ship specifications, the component specification, or other document, the more stringent NDT requirements shall be invoked.

1/ "Pressure" is the design pressure of the system in which the build is used.

2/ For machinery and pressure vessel builds, the size shown is the inside diameter (or an equivalent cross-sectional area).

3/ Refer to the applicable system or component specifications for pressure test requirements. Pressure tests shall be conducted on uncoated builds.

4/ For hydraulic components with cylindrical datum features, this size is the largest diameter subject to normal operating pressure. For components with non-cylindrical datum features, the size shall be the largest dimension of the largest cross-sectional area subject to normal operation pressure.

5/ Also excluding special shipboard system categories.

6/ Builds of sizes less than 4 inches shall be RT inspected where their failure would result in the loss of propulsion power due to lack of cooling water necessitated by the closing of the hull and back-up valves in the main seawater system for the purpose of isolating defective builds.

7/ Builds of sizes less than 4 inches that are not RT inspected per note 6 shall be inspected in accordance with category J1, J2, J3, K, or L, as applicable.

Table 5-4. Class P Piping Component Inspection Requirements

Piping Class	Design Pressure [1]	Pipe Size, (inches nps) [2]	Required Examinations and Tests [3]					Category
			VT	MT/PT	Volumetric		Pressure [5]	
			Final Build	Final Build [4]	Final Build	Extent		
Lethal or gasoline	All	All	X	X	X	Every build, 100 percent	X	A
Oxygen or hydrogen service [6]	≥100 [7]	≥½ [8]	X	X	X	Every build, 100 percent	X	B
Steam service	≥300	≥½ [8]	X	X	X	Every build, 100 percent	X	C
Submarine Service: [9] a. Builds associated with pressure hull boundary and subject to submergence pressure	All	All	X	X	X	Every build, 100 percent	X	D1
b. Builds in sea-connected systems from the inboard flange of the backup valve outboard to the hull	All	All	X	X	X	Every build, 100 percent	X	D2
c. Builds in sea-connected systems inboard of the backup valve that are open to the sea below 200 ft submergence depth during any mode of operation	All	For sizes ≥4, see [10]. For sizes not RT'd per [10], see [11]	X	X	X	Every build, 100 percent	X	D3

Table 5-4. Class P Piping Component Inspection Requirements - Continued

Piping Class	Design Pressure [1/]	Pipe Size, (inches nps) [2/]	Required Examinations and Tests [3/]					Category
			VT	MT/PT	Volumetric		Pressure [5/]	
			Final Build	Final Build [4/]	Final Build	Extent		
P-1 other than categories A thru D-3	>3,400	1 and > [12/]	X	X	X	Every build, 100 percent	X	E1
	300 thru 3,400, and all if T >650 °F	≥2½	X	X	X	Every build, 100 percent	X	E2
	300 thru 3,400, and all if T >650 °F	½ to <2½	X	X	X	[13/]	X	E3
	300 thru 3,400, and all if T >650 °F	<½	X	X	---	---	X	E4
Class P-2: a. Steam service	All, excluding drains	≥2½	X	---	---	---	X	F1
		½ to 2½	X	---	---	---	X	F2
		<½	X	---	---	---	X	F3
b. Surface ship sea-connected piping components below the V lines not isolatable from the sea	All	≥2½	X	---	---	---	X	F4
c. Refrigerant	50 and above	≥2½	X	---	---	---	X	F5
d. P-2 other than listed above	All	All	X	---	---	---	X	F6
P-LT	All	[14/]	[14/]	[14/]	[14/]	[14/]	[14/]	G

Table 5-4. Class P Piping Component Inspection Requirements – Continued

NOTES:

In the event of a conflict in NDT requirements between this table, the ship specifications, the component specification, or other document, the more stringent NDT requirements shall be invoked.

1/ "Pressure" is the design pressure of the system in which the build is used.

2/ The size shown is nominal pipe size (nps).

3/ In the event of a conflict in NDT requirements within this table or between this table, the ship specifications, the component specification, or other document, the more stringent NDT requirements shall be invoked.

4/ The outer surface and, when accessible, the inner surface shall be MT/PT inspected, and the inspection shall be performed after machining operations. When post-weld heat treatment or stress relief is performed, this inspection shall be accomplished after heat treatment or stress relief.

5/ Refer to the applicable system or component specifications for pressure test requirements. Pressure tests shall be conducted on uncoated builds.

6/ RT and MT/PT requirements do not apply to builds in open-ended oxygen or hydrogen vents or drains that are located between the last isolation valve and the open end.

7/ For lower maximum design pressures, inspect in accordance with category E3 for all sizes ½ inch and greater.

8/ For smaller sizes, inspect in accordance with category E4.

9/ RT of DED valve discs and balls that form a part of the hull boundary where failure could permit direct flooding inside the ship shall be the same as for other components of the category involved; for discs and balls not meeting this criteria, RT shall be in accordance with note 4, and when specifically approved by NAVSEA, note 4 RT may be omitted for identified sizes and applications.

10/ Builds of sizes less than 4 inches shall be RT inspected where their failure would result in the loss of propulsion power due to lack of cooling water necessitated by the closing of the hull and backup valves in the main seawater system for the purpose of isolating defective builds.

11/ For sizes less than 4, excluding those covered by note 5 of this table, inspect in accordance with category E1, E2, E3, or E4 as applicable, except for pressures and temperatures less than 300 PSI and less than 650 °F (that are not P-LT) where inspection shall be the same as F1, F2, or F3 for equivalent sizes.

12/ For smaller sizes, inspect in accordance with category E3 or E4 as applicable.

Table 5-4. Class P Piping Component Inspection Requirements – Continued

[13/] (a) Refer to the applicable system or component specifications for testing requirements. Testing shall be conducted on uncoated components after final machining and thermomechanical processing. Where the component specification does not explicitly address component produced by AM and where each component is planned to not receive the pressure test for time and pressure generally specified, prior NAVSEA approval of full pressure testing details shall be obtained.

(b) For repairs to builds that have passed a hydrostatic test, hydrostatic re-testing is not required where repairs do not exceed 3⁄16 inch or 20 percent of the thickness at the repair location, whichever is less. This exception does not apply if the repair weld is subjected to post weld heat treatment.

[14/] Inspection for class P-LT shall be the same as categories E2, E3, or E4 based on equivalent sizes.

5-4.7 REPAIR OF PRODUCTION BUILDS. In-process and post-build repair methods, including NDT requirements for excavations prior to repair and completed repairs, shall be described in a written procedure in accordance with 7-3.6.

5-4.7.1 Post-Build Repair. Post-build rejectable defects shall be removed and repaired; completed repairs shall be inspected the same as required for the build. Where MT/PT is required for the build, completed excavation surfaces shall be subject to MT/PT or VT at 5X magnification prior to deposition of repair metal to ensure absence of linear indications greater than 1/16 inch. Where repair depth does not exceed 3/16 inch or 20 percent of the build or part thickness in an area previously subject to satisfactory RT/UT, MT/PT may be used in lieu of RT/UT.

5-4.7.1.1 Post-Build Repair NDT Records. NDT results, including NDT of excavations prior to further repair, shall be recorded and included along with other build NDT records.

5-5 DESTRUCTIVE TESTING.

Destructive testing shall be evaluated in accordance with 8-4 to the acceptance criteria approved as specified in 3-2.3. Destructive testing shall be specified in the Production Conformance Evaluation Plan.

5-6 PRODUCTION CONFORMANCE TEST REPORT.

The Production Conformance Test Report shall include the results from the evaluation performed in accordance with the Production Conformance Evaluation Plan. Metallographic photos and any work instructions referenced in the test report that contain the required essential element information shall be included with the test report. Conformance testing results shall be maintained in accordance with 7-2.2.2 and available for audit in accordance with 2-2.3.4.

5-6.1 CERTIFICATE OF PRODUCTION CONFORMANCE. A certificate of production conformance shall be prepared for each part offered for acceptance in accordance with 2-2.2. The certificate shall state that the part has been made in accordance with the Production Conformance Evaluation Plan and that quality assurance practices ensure the part meets requirements. The certificate shall include the revisions of the Production Conformance Evaluation Plan, Quality Assurance Plan, and Process Control Plan used and the date of the most recent approval.

5-7 RESPONSIBILITY FOR PRODUCTION CONFORMANCE.

All production parts shall meet the requirements in this document. The absence of any requirements in this document shall not relieve the activity of the responsibility of ensuring that all parts submitted for acceptance comply with all the requirements of the contract or purchase order. Sampling for conformance neither authorizes submission of known defective parts (either indicated or actual), nor requires acceptance of defective parts.

CHAPTER 6
DED OPERATOR QUALIFICATION

6-1 SCOPE.

This chapter provides the requirements for qualification testing of DED operators. Also included are the requirements for operator qualification records with a suggested record format and forms for data accumulation and reporting.

6-2 GENERAL REQUIREMENTS.

6-2.1 RESPONSIBILITY. Prior to fabrication of production DED builds, each activity shall establish that each DED operator employed for DED has been trained as described in the Process Control Plan in accordance with 7-3.2.

6-2.2 PREREQUISITE. As a prerequisite to operator qualification, each activity shall have qualified the applicable DED Procedure in accordance with chapter 3 and at least one part verification build in accordance with chapter 4.

6-2.3 METHODS OF ESTABLISHING QUALIFICATION. Qualification of DED operators requires satisfaction of all the following conditions:

a. Each DED operator shall be trained and tested in accordance with the activity's DED operator training program.

b. Each DED operator shall satisfactorily fabricate an operator qualification test build.

6-2.3.1 DED Operator Training in Workmanship. Training shall be administered in accordance with a program approved by one of the activity's level III NDT examiners certified in accordance with T9074-AS-GIB-010/271 or another NAVSEA-approved individual. This program shall include the following:

a. A written procedure covering all aspects of this training program and associated responsibilities. This procedure shall be included in the Process Control Plan in accordance with 7-3.

b. Workmanship requirements and visual inspection requirements detailed in the activity's Process Control Plan in accordance with 7-3 and, if applicable, the fabrication documents to which the DED operator will be working.

c. Examinations covering detail workmanship requirements to be passed by each person with a grade of no less than 75 percent.

d. Examination records for each DED operator, which shall include name, fabrication/acceptance standards covered, date of test, results of test (in percent), and certifying signature of test administrator.

e. Re-testing of each DED operator every 3 years, at a minimum.

f. Auditing of the entire program by the level III examiner or another NAVSEA-approved individual to ensure adequacy. Audits shall be conducted at least once every 2 years and, where applicable, the audit shall be extended to specifically address DED of titanium.

6-2.3.2 System Training and Testing Requirements. DED operators shall be trained and tested in accordance with the training program established in accordance with 7-3.2 to meet the following requirements, as applicable, for each procedure:

a. Identification and use of DED system equipment.

b. Routine operator maintenance of the DED system equipment.

c. Operation of the teach pendant, control station, or both to execute, modify, or stop a DED program cycle.

d. Creation or modification of DED programs and routines.

e. Use of adaptive DED technologies.

f. Use of audio and vision aids (e.g., weld puddle cameras).

6-2.4 ALTERNATIVE QUALIFICATION METHODS. Upon approval from the AM Authorized Representative, as an alternative to 6-2.3.1c., operator qualification requirements for DED operators shall be satisfied as follows:

a. Fabrication of a DED production build that is RT- or UT-inspected and found satisfactory. This method is not applicable to titanium materials.

b. Fabrication of a satisfactory DED Procedure qualification build or part verification build.

6-2.5 REQUIREMENTS FOR SPECIAL DED BUILDS. For special DED builds, a DED operator qualification program specific to these builds shall be developed.

6-2.5.1 Separation of Operator Roles. The activity may establish separate roles for operators that may be qualified independently or together. When different roles are established, operators shall be qualified for all roles they will perform during production DED. Where multiple operators perform different roles during a single operator qualification build or using an alternative qualification method as described in 6-2.4, all operators shall be considered qualified for the role(s) they performed only if they performed the role without assistance. A single build shall qualify no more than one operator for a given role unless otherwise approved.

6-2.5.2 Operator Roles Not Requiring Operator Qualification Testing. Establishment of roles not requiring operating qualification testing shall require NAVSEA approval. The activity shall submit a description of and all training plans for the role(s) not requiring operator qualification testing to NAVSEA for review and approval prior to any production builds. Operator roles involving the manipulation of the DED system or of partially completed builds during the build, and operator roles involving resumption of a build after any pause, shall not be exempted from operator qualification testing.

6-2.6 REPAIR TO OPERATOR QUALIFICATION TEST BUILDS. Test builds shall not be repaired.

6-2.7 RETESTS. If a performance qualification test build fails to meet the applicable requirements, retests may be allowed under the following conditions:

a. One retest may be made without further training for each performance qualification test build that failed.

b. Subsequent retests may be made for each performance qualification test build that failed to meet the requirements and the DED operator has had at least 4 hours of training or practice designed to correct the reasons for the previous failures.

6-2.8 MAINTENANCE OF OPERATOR QUALIFICATION. Each activity shall establish that an active qualification status is maintained for each DED operator. For each qualified power source and process, evidence of maintenance of qualification consisting of at least one verification of power source and process used (i.e., activity certification of the use of gas metal arc or gas tungsten arc) within 6 months after the month the person last used the process shall be maintained. Power source and process use shall be production DED builds, completion of a procedure qualification or part verification build, or completion of an additional performance qualification test build.

6-2.8.1 Renewal of Qualification. Renewal of qualification shall occur by making one test build with all the essential elements used on any one of the DED operator's previous test builds. The build shall be inspected in accordance with table 6-1. These renewal requirements will reestablish the DED operator's qualification for all conditions for which he or she had previously qualified with the DED process employed. Renewal of qualifications due to a lapse of process greater than 1 year and under all other conditions shall be in accordance with initial qualifications required by this document.

Table 6-1. Sample DED Operator Qualification Record

Operator Qualification Record for Directed Energy Deposition	
General	
Company:	Machine Operator and ID No.:
Date Machine Operated:	
Process:	Transfer Mode:
Build File Name:	
Materials	
Build Platform Material Spec, Type and Grade:	Build Platform Thickness:
Feedstock Material Spec, Type and Grade:	Feedstock Material Size:
Machine	
Manufacturer and Model:	Serial Number:
Power Source Manufacturer and Model:	Power Source Serial Number:
Shielding Gas, Type and Grade:	Supplemental Gas, Type and Grade:
Build Parameters	
Build parameters in this record must document each set of parameters used in a build (e.g., parameter sets for interior, surface, overhangs, interfaces, etc., within the same build). Parameter descriptions may be replaced with machine-specific parameter names where applicable. Machine-specific parameters, process monitoring feedback parameters, and any other parameters not listed in this table required to replicate the build must also be specified and documented within this record.	
Parameter Set Name:	Parameter Set Description:
Part Identification:	Layer Height:
Power Source Power:	Deposition Travel Pattern:

Table 6-1. Sample DED Operator Qualification Record – Continued

Bead Spacing Offset:	Travel Speed:
In Process Machining and Grinding:	
Preheat Temperature:	Interpass Temperature:
Nondestructive Test Acceptance Criteria & Results	
RT:	UT:
MT:	PT:
VT:	
NDT Acceptance Criteria & Standard:	
Other:	
Destructive Test Results	
Bends:	Bend Radius:
Macros:	
Other:	
VT Criteria Exam (Attach original exam certificate copy)	
Other:	
	Activity Name:
Activity Certification Statement & Signature:	
The statements in this record are correct and the test builds were prepared, built, and tested in accordance with S9074-A4-GIB-010/AM-WIRE DED _____ and _____.	
Name (Print):	Signature: Date:

6-2.8.1.1 Renewal of Qualification for Titanium. For renewal of qualification for titanium, the DED operator shall make the operator qualification test build on titanium base metal and shall conform to the color criteria as defined in 6-2.9.

6-2.9 VISION TEST REQUIREMENTS. Each DED operator shall be required to pass an annual vision test. Vision tests shall be conducted using standard test methods for determining visual acuity. The standard of acceptance for vision acuity testing shall be natural or corrected near-distance acuity such that the individual can read J1 letters on the standard Jaeger-type chart for near vision. Other equivalent visual tests, such as the Snellen chart, may be substituted for the Jaeger chart. When corrective aids are used for the vision test, equivalent aids shall be employed in production work.

6-2.9.1 Titanium. Vision tests for DED operators for titanium materials shall include a color perception test on workmanship samples displaying the colors and shades expected in titanium welds, which shall be passed with no errors. As a minimum, these colors and shades shall include silver, straw, light blue, dark blue, purple, and gray; the silver loss of luster condition should also be included in this test unless it cannot be replicated. DED operators who do not pass the color perception part of the vision test shall not be permitted to produce builds using titanium materials.

6-2.10 LOSS OF OPERATOR QUALIFICATION. Requalification is required when the AM Authorized Representative or TP 248 Authorized Representative has specific reason to question the ability of the DED operator to make builds that meet the requirements of this document.

6-3 OPERATOR QUALIFICATION TEST REQUIREMENTS.

DED operators shall qualify using equipment possessing control features similar to those of the equipment that will be used to make production DED builds. DED operators shall be required to set the equipment with regard to adjustments and settings that will affect the build characteristics and bead placement.

6-3.1 OPERATOR QUALIFICATION TEST BUILDS. Operator qualification test builds shall be fabricated. Test build dimensions shall be no less than 6 inches long by 2.5 inches wide by 3 inches or 20 layers in height (whichever is greater).

6-3.2 REQUIREMENTS FOR TITANIUM. For qualification for titanium, the DED operator shall make the operator qualification test build on titanium base metal and shall conform to the color criteria as defined in 6-2.9.1.

6-4 TEST AND EVALUATION OF QUALIFICATION TEST BUILDS.

The tests required for each operator qualification test build are as specified in table 6-2.

Table 6-2. Test Requirements for DED Operator Qualification

Type of Test	Quantity
Bend test	1
Metallographic	1

6-4.1 NDT. NDT shall be performed in accordance with 8-3. Qualification test builds shall be 100 percent inspected using PT/MT and VT. All acceptance criteria shall be in accordance with the acceptance criteria used in 3-3.5.

6-4.2 DESTRUCTIVE TESTS. Destructive testing shall be performed in accordance with 8-4.

6-5 DATA ACCUMULATION AND RECORDS.

6-5.1 OPERATOR QUALIFICATION TEST RECORDS. Qualification records for a DED operator shall be kept by the activity. The qualification test record shall include, at a minimum, the following information:

a. DED operator identification (name and clock number or badge number)
b. Date of qualification test
c. Qualification build design, power source, process, position, base material form/type and thickness, filler metal type and size, shielding gas, and other attributes of table 3-1
d. Results of each qualification test. For NDT and titanium appearance, list the NDT standard and acceptance criteria. For bend tests, bend radius and thickness shall be listed.
e. Certifying signature by activity
f. The current examination specified in 6-2.3.a

An example is given in table 6-1.

6-5.2 DISPOSABLE DATA. Radiographs, test assemblies, and metallographic sections required for DED personnel qualifications are not required to be retained.

6-5.3 QUALIFICATION CURRENCY RECORD. The qualification test record shall be retained while the person is employed to perform DED builds. Records shall be maintained for the length of time specified in 7-2.2. Detailed records of maintenance of personnel qualification shall be retained for the current and preceding 6-month period.

6-5.4 VISION TEST RECORDS. Current vision test records shall be maintained for the length of time specified in 7-2.2.

6-6 CHANGES REQUIRING REQUALIFICATION OF DED OPERATOR.

Requalification of the DED operator is required for the changes specified in 6-6.1 through 6-6.3.

6-6.1 FILLER MATERIAL. A change from a filler material under one other A-number in table 3-3 to A-51, A-52, A-53, or A-53a filler material.

6-6.2 PROCESS. A change in any of the following process parameters:

a. A change in the manufacturer of the DED system
b. A change from one welding process to any other welding process (as defined in the master chart of welding and allied processes of AWS A3.0M/A3.0) or from one power source to any other model power source that is not a direct replacement
c. For plasma arc, a change from transferred arc mode to non-transferred arc mode and vice versa
d. The deletion of automatic arc voltage control for arc welding processes
e. The deletion of automatic joint tracking
f. The addition, deletion, or change in the method of seam tracking (e.g., arc, laser)
g. A change in method of adaptive bead placement
h. A change from direct visual control to remote visual control and vice versa

6-6.3 SHIELDING GAS. A change in any of the following shielding gas parameters:

a. For gas-shielded arc welding, a change from argon, helium, or mixtures thereof to mixtures containing more than 5 percent oxygen, more than 25 percent carbon dioxide, or to 100 percent carbon dioxide (CO_2) and vice versa

b. For plasma arc welding, when using the keyhole technique, a change in orifice gas from argon to mixtures of argon and helium or the addition of hydrogen to the orifice gas or gas mixture and vice versa

c. For torch shielding gas for S-51, S-52, S-53, and S-53A materials, a change from a single gas to any other gas or a change from a single gas to a gas mixture and vice versa

d. For S-51, S-52, S-53, and S-53A materials, a change from welding in a chamber to welding outside of a chamber

e. For trailing or backing shielding gas used for S-51, S-52, S-53, and S-53A materials when welding outside of a chamber, a change from a single gas to any other gas, a change from a single gas to a gas mixture and vice versa, or the omission of the shielding gas

6-6.4 FABRICATION DOCUMENT REQUIREMENTS. DED builds subject to the requirements of a fabrication document shall require training and testing on the requirements of that document in accordance with 6-2.3.a.

CHAPTER 7
QUALITY ASSURANCE, PROCESS CONTROL, AND TRAINING PLANS

7-1 SCOPE.

This chapter provides general requirements for the Quality Assurance Plan and Process Control Plan for general applications. The purpose of the Quality Assurance Plan is to maintain the quality of the qualified procedures and production parts. The purpose of the Process Control Plan is to ensure quality processes throughout manufacturing and evaluation.

7-2 QUALITY ASSURANCE SYSTEM.

The activity shall maintain an adequate quality assurance system to ensure that all the requirements of this document have been met and are continuously being met. The Quality Assurance Plan shall detail the elements of the quality assurance system. Written procedures shall be prepared to assign responsibility and provide accountability for performing work and inspections.

7-2.1 MATERIAL CONTROL. The activity shall inspect and evaluate feedstock, build platforms, and other materials upon receipt to ensure that material and chemical requirements are met. Receipt inspection shall consist of, but not be restricted to, comparing the manufacturer's data with the specified requirements and sampling of the activity's material and data.

7-2.1.1 Identification System. An identification system shall be established and maintained that enables feedstock, build platforms, completed builds, and witness coupons to be tracked. The feedstock lot number and material type shall be maintained in the identification system. Specimens shall be labeled to be traceable to the build and their location within the build. At a minimum of twice per year, periodic internal audits of the inventories, stocking facilities, and shops shall be performed to ensure that materials are correctly identified.

7-2.1.2 Visual Verification of Materials Prior to Use. A system shall be established that requires visual verification of materials to make any procedure qualification build, part verification, or production run to ensure that the identification of the material corresponds to that specified by the applicable document.

7-2.2 RECORDS. The quality control system shall include preparation and maintenance of physical, written, or digital records of all the following:

a. DED system operation to include maintenance and usage
b. Destructive testing and NDT, including reports and specimens
c. Feedstock and build platform material
d. Post-processing operations

7-2.2.1 Record Form. A record form shall be prepared prior to the commencement of the operation that it covers. Operations shall be recorded prior to the commencement of the next operation. The records shall be signed and dated by the applicable personnel performing the operation.

7-2.2.2 Maintenance of Records. Unless otherwise specified, all required records shall be maintained by the activity and be available to the AM Authorized Representative throughout the life of the contract and for 3 years after delivery. The AM Authorized Representative shall be given a written notification at the expiration of the record retention period. Disposition of records shall be as agreed upon by NAVSEA and the contractor.

7-2.3 NONCONFORMANCE. If the AM Authorized Representative has evidence that the requirements of this document are not being met, they can suspend, upon written notification, the use of any questionable materials, equipment, procedures, personnel, and so forth, on work covered by this document until conformance with the requirements of this document is judged satisfactory by NAVSEA.

7-3 PROCESS CONTROL PLAN.

The activity shall demonstrate an adequate Process Control Plan that outlines process control for all aspects of the manufacturing and evaluation process. The activity shall ensure the employees responsible for manufacturing and testing the approved product(s) understand the appropriate procedures in the plan. The activity shall ensure that an up-to-date copy of the Process Control Plan, including any amendments, is readily available at the facility for use by auditors when evaluating compliance with procedures approved by part verification testing. The plan must indicate problems with their product that have been identified by the activity, customers, or the AM Authorized Representative, including during receipt inspection, fabrication, or in service; how these problems were resolved; and whether the necessary changes were made in the manufacturing procedures to ensure that these problems will not occur in the future. The Process Control Plan shall include the following:

a. Change Control Plan (see 7-3.1)
b. Personnel Training Plan (see 7-3.2)
c. Maintenance Control Plan (see 7-3.3)
d. Digital File Handling Procedure (see 7-3.4)
e. Feedstock Material Plan (if applicable, see 7-3.5)
f. Build Procedure (see 7-3.6)
g. Post-Processing Procedure (see 7-3.7)
h In-Process Monitoring Plan (if applicable, see 7-3.8)

7-3.1 CHANGE CONTROL PLAN. The Process Control Plan shall contain a Change Control Plan. The Change Control Plan shall specify the criteria and plan to verify the acceptability of any change in the Process Control Plan. The Change Control Plan shall specify how a change is determined and whether it requires approval.

7-3.2 PERSONNEL TRAINING PLAN. The activity shall maintain a Personnel Training Plan that covers training and qualification of personnel involved in the DED and testing operations. The plan shall detail training required, initial qualification requirements, and requalification timeframes. Personnel shall include, but not be limited to, DED operators, personnel preparing build files, NDT personnel, the various inspectors responsible for work performance, and materials and other engineers in production or support positions. The plan shall include personnel responsible for work performance of the procedure qualification build, part verification builds, and production builds. Written procedures shall be prepared to assign responsibility and provide accountability for performing work and inspections. NDT personnel shall meet the requirements of T9074-AS-GIB-010/271 and shall have additional training specific to NDT of DED parts.

7-3.3 MAINTENANCE CONTROL PLAN. The Process Control Plan shall contain a Maintenance Control Plan for the DED system and critical associated equipment. At a minimum, the plan shall include maintenance and calibration plans and schedules for all components that control essential machine elements provided in table 3-1. At a minimum, the plan shall include the calibration metrics identified by the DED machine manufacturer to declare the equipment fit for service. The plan shall also include the tests or machine checks that will be performed following maintenance, component replacement, or repair to verify the procedures for when the tests or machine checks are failed, and that the equipment is functioning properly. The Maintenance Control Plan shall include the method and schedule for maintenance and calibration of the following:

a. Power source controls
b. Power source start and stop time
c. Position controls
d. Build platform motion, alignment, and levelness
e. Atmospheric sensors (e.g., oxygen, pressure [if applicable])
f. Positioning equipment and subcomponents

7-3.4 DIGITAL FILE HANDLING PLAN. The Process Control Plan shall contain a Digital File Handling Plan. The Digital File Handling Plan shall provide the sequence and tracking method of the digital files necessary to make the procedure qualification builds and part verification builds, beginning with the creation of the build files through installation of the build files onto the DED system. The Digital Handling Plan shall detail control measures as necessary to ensure the build files and any dependent files called by the build files (e.g., program files, subroutines, and procedural files) are not compromised. The Digital Handling Plan shall contain a verification plan to demonstrate the build files have not changed during digital transfer. The Digital File Handling Plan shall detail continuous active computer security on all computer systems and associated devices, including storage devices used to transfer files that are associated with any aspect of the build file design and build process. At a minimum, the Digital File Handling Plan shall include the following:

a. Names of individual part surface mesh files (e.g., STL, additive manufacturing file format [AMF]) used in creation of the procedure qualification builds and part verification
b. Names of build files used to produce the procedure qualification builds and part verification
c. Build file processing software and version
d. DED machine software and version
e. Build file transfer verification method
f. Relevant Government or commercial digital specifications used

7-3.4.1 Software Configuration Management Plan. If applicable, the Digital File Handling Plan shall include a Software Configuration Management Plan. This plan shall contain methods of evaluating potential software updates applied to the DED system or any major subsystems for if and when requalification is required in accordance with 3-5, 3-6, 4-5, or 6-6. Evaluations of any software updates shall be maintained as records and made available to the AM Authorized Representative upon request. Where software updates are made without evaluation, or where evaluation cannot be performed, Level 1 Requalification in accordance with 3-5 shall be performed.

7-3.5 FEEDSTOCK MATERIAL PLAN. If applicable, the Process Control Plan shall contain a Feedstock Material Plan. The plan shall contain methods and tolerances for chemical and non-chemical material testing requirements. The method used and supporting testing data, including the impact of feedstock tolerances on the DED Procedure, shall be provided.

7-3.6 BUILD PROCEDURE. The Process Control Plan shall contain details of build procedures that ensure a consistent, repeatable process. At a minimum, the procedure shall provide the following:

a. System cleaning method when changing materials (e.g., swapping from steel to aluminum)
b. Feedstock handling and storage
c. In-process grinding, machining, and cleaning
d. Preheat and interpass temperature control methods
e. Build platform dimensions
f. Build platform storage and handling methods
g. Build platform preparation methods
h. Repair procedures, including but not limited to, in-process repairs, post-build repairs, NDT requirements for defect excavations and completed repairs, and repair criteria

7-3.7 POST-PROCESSING PROCEDURE. The Process Control Plan shall contain post-processing procedures (e.g., heat treatment, surface finishing, chemical processing) and relevant controls in accordance with 3-3.3.1 and relevant material specification.

7-3.8 IN-PROCESS MONITORING PLAN. If applicable, the Process Control Plan shall contain an In-Process Monitoring Plan. For essential elements, the In-Process Monitoring Plan shall include the step-by-step procedure for conducting continuous in-process monitoring, electronic data collection, recording, and storage to demonstrate adequate process controls and compliance to the qualification limits. The In-Process Monitoring Plan shall include the monitoring method (such as human monitoring, data acquisition, infrared cameras, sensors, etc.), frequency, sampling rate, and step-by-step procedures used for monitoring. If applicable, the data shall be traceable to locations on the build platform.

7-3.9 DATA COLLECTION SYSTEM. Where the DED system is equipped with a data collection system, the following shall be identified:

a. The data available to be recorded
b. The procedure for collecting the data
c. The method of how the data will be used
d. The method for verifying the collected data

Monitored data shall be logged and retained as supporting data until all destructive testing and NDT for the parts made corresponding to the data have been completed and validated against the monitored data. Data shall be retained in accordance with 7-2.2.2.

CHAPTER 8
EVALUATION

8-1 SCOPE.

This chapter provides evaluation requirements. The purpose of evaluation is to ensure appropriate methods for required testing. The requirements are classified as follows:

a. General Evaluation Requirements (see 8-2)

b. NDT (see 8-3)

c. Destructive testing (see 8-4)

8-2 GENERAL EVALUATION REQUIREMENTS.

8-2.1 REJECTION AND RETESTS. When a test specimen fails to meet the requirements, the build shall be rejected. The activity may rework or retest the material as provided herein. The activity shall identify and separate rejected material from acceptable material until the rejected lots are withdrawn by the activity or are demonstrated as meeting the requirements. Only one retest of a nonconforming original test is permitted, and the retest specimen shall be taken in the vicinity of the initial location of the failed specimen(s), except for PT and MT failures that are caused by operator error or can be fixed by hand work. If any retest specimen fails, the material shall be rejected with no further testing permitted. Unless otherwise approved by the AM Authorized Representative, all test results, including failures, shall be reported, with the exception of DED operator qualification failures. In all cases, all test results, including failures, shall be available for review upon request.

8-2.2 REHEAT TREATMENT. The activity shall be permitted to reheat-treat material that fails to meet the requirements. Required tests originally performed on the failed material shall be repeated. Witness coupon material used for testing of reheat-treated material shall be from the same build and have undergone all heat treatments performed at the same time as the material it represents. Where sufficient witness coupon material is not available, reheat treatment shall be as approved by NAVSEA.

8-2.3 DEFECTIVE SPECIMEN/REPLACEMENT OF TEST SPECIMENS. The test specimen shall be discarded and a replacement specimen extracted from the same build under the following conditions:

a. When the specimen is incorrectly machined

b. When the test procedure is incorrect

c. When there is a malfunction of the testing equipment

d. When a flaw that is not indicative of an inferior or defective lot of material develops during the test; however, internal flaws such as cracks, ruptures, and porosity are not reasons for the selection of a replacement test specimen

In the event that there is insufficient material to extract a specimen from the same build, additional builds using the same process parameters may be used to produce additional test specimens.

8-3 NDT.

Prior to performing any destructive tests, all DED Procedure specimens shall undergo NDT in accordance with the Procedure Qualification Test Plan. Part verification builds and witness coupons shall undergo NDT as required in the Part Verification Plan. Conformance parts shall undergo NDT as required in the Production Conformance Evaluation Plan.

8-3.1 VISUAL INSPECTION. Visual inspection shall be performed in the final surface condition in accordance with T9074-AS-GIB-010/271.

8-3.1.1 Titanium and Titanium Alloys. Titanium and titanium alloy specimens shall also meet the following criteria.

a. All as-deposited surfaces shall exhibit a bright, shiny, and silvery luster. Other conditions are unacceptable and shall be removed unless otherwise approved by NAVSEA. In all cases, the shielding deficiencies shall be corrected prior to fabrication of further builds, and for interpass inspection per item b below, prior to the deposition of the next bead.

b. All beads shall be inspected for color prior to the deposition of the next bead. This may be performed by the DED operator, provided they have been trained in titanium color inspection, tested to confirm 100 percent discrimination on expected acceptable and rejectable colors, and periodically audited to ensure proficiency in accordance with a program approved by the activity's T9074-AS-GIB-010/271 test examiner or other NAVSEA-approved individual. If production occurs in a vacuum or inert chamber, this requirement shall not apply where the dew point and oxygen content are monitored and have been recorded to maintain atmospheric protection.

c. Inspections shall be performed in the as-deposited condition before any brushing, cleaning, grinding, machining, etc.

d. After completion of deposition, all accessible surfaces shall be inspected for color prior to any heat treatment. Builds with surfaces exhibiting conditions other than a bright, shiny, and silvery luster per item a above shall be rejected, unless a test plan showing that contamination is limited to the surface intended to be removed has been executed and approved by NAVSEA.

8-3.2 DIMENSIONAL EXAMINATION. Dimensional examination shall be performed in accordance with a standardized method approved by the AM Authorized Representative. Prior to performing dimensional examination, build surfaces shall be machined to final surface condition.

8-3.3 MT AND PT. MT and PT inspection shall be performed in accordance with T9074-AS-GIB-010/271 for weld inspection with any modifications as approved by the AM Authorized Representative. Prior to performing MT or PT, build surfaces shall be machined to final surface condition. Where the final surface condition is as-built, testing methods shall be as approved by NAVSEA.

8-3.3.1 MT and PT Suitability. In general, MT shall be used on ferrous materials and PT on nonferrous materials and austenitic corrosion-resisting steels. Where applicable, PT may be substituted for MT on ferrous materials where both procedures have been qualified on an approved DED Procedure. Production builds shall use the same testing method as the relevant part verification build.

8-3.4 RT INSPECTION. RT inspection shall be performed in accordance with T9074-AS-GIB-010/271 for castings and forgings with any modifications as approved by the AM Authorized Representative. Where the final surface condition is as-built, testing methods shall be as approved by NAVSEA.

8-3.4.1 Radiographic Shooting Sketch. In accordance with AWS A2.4, the activity shall select and identify areas requiring radiography on the engineering drawing. The activity performing the inspection shall prepare the radiographic shooting sketch that shows film placements and radiation directions to ensure adequate radiographic coverage as specified by the engineering drawing. The radiographic shooting sketch shall be validated by a signature of a certified radiographic inspector. The requirements of T9074-AS-GIB-010/271 provide specific detailed requirements that shall be contained on the radiographic shooting sketch.

8-3.5 UT INSPECTION. UT inspection shall be performed prior to the machining of features (such as corners and other details) which render areas un-inspectable to the degree practical. A combination of shear wave and longitudinal wave scanning (as applicable) shall be employed to scan the entire build or component volume for defects oriented parallel and perpendicular to the direction of weld travel and in the plane between weld layers. Inspection shall be in accordance with T9074-AS-GIB-010/271 for weld inspection with any modifications necessary as approved by the AM Authorized Representative. Where the final surface condition is as-built, testing methods shall be as approved by NAVSEA.

8-3.5.1 UT Scan Plan. In accordance with AWS A2.4, the activity shall select and identify areas requiring UT on the engineering drawing. The activity performing the inspection shall prepare the UT scan plan that shows ensure adequate UT coverage as specified by the engineering drawing. The UT scan plan shall be validated by a signature of a certified UT inspector. The Interpretation of Radiographs requirements specified in T9074-AS-GIB-010/271 provide specific detailed requirements that shall be contained on the radiographic shooting sketch.

8-3.5.2 Calibration Block Weld Process Equivalency. A calibration block shall be prepared with each DED process to be used, except where feedstock material deposited with one DED process is shown to be acoustically similar to feedstock material of the same alloy deposited with another DED process or is shown to be acoustically similar to a similar alloy within the same A-group deposited with the same or a different DED process. A single calibration block may be prepared with any DED process shown to be acoustically similar in this manner in accordance with T9074-AS-GIB-010/271. In establishing acoustic similarity, in addition to requirements of T9074-AS-GIB-010/271, the DED deposits evaluated for each process shall be at least ½ inch in thickness. For carbon and low alloy steels deposited on carbon and low alloy build platforms, feedstock materials of differing alloys, A-groups, and corresponding base metals may be evaluated for acoustic similarity and, where validated, one calibration block may be used for all.

8-3.6 INTEGRATED BUILD PLATFORM. Where the build platform is integrated to the final part and RT is a required inspection, RT shall include a shot parallel to and approximately in the plane of the interface of the fusion zone of the first layer deposited on the build platform. The entire fusion zone shall be radiographed. Where component geometry does not allow for this shot, then in addition to RT, UT of the entire fusion zone area of each component requiring RT shall be accomplished in accordance with 8-3.6.1. Inspection shall be completed with at least ¼ inch of buildup present unless thinner deposits are approved by NAVSEA.

8-3.6.1 UT of Integrated Build Platform. Where RT of the initial fusion zone of integrated build platform cannot be performed in accordance with 8-3.6, longitudinal wave UT inspection of this zone shall be performed in accordance with the following requirements. UT shall be completed with at least ¼ inch of buildup present unless thinner deposits are approved by NAVSEA. UT shall conform to T9074-AS-GIB-010/271 and the requirements of this paragraph.

8-3.6.1.1 UT Calibration for Integrated Build Platform. Prior to UT inspection for defects and lack of bond, the test equipment shall be calibrated by using a calibration block that has been fabricated using the same process, filler metal, and base metal as the production part. Equivalent S-number base metal may be used. For this purpose, S-1, S-2, S-3, S-4, S-5, and S-11 material shall be considered equivalent. To establish equivalent weld processes for the same filler metal, see 8-3.5.2. The calibration block shall have equivalent weld thickness and surface finish as the production part at the point in the build at which this UT is performed, and it shall be sufficiently thick to accommodate the required calibration holes needed to establish the distance amplitude correction (DAC) curve. The calibration block shall be as follows:

a. Holes shall be drilled into the block as follows: either ⅛-inch diameter flat-bottomed holes shall be drilled from the base metal side with their axes perpendicular to the sound beam entry surface or 1/16-inch diameter holes at least 1½ inches long shall be drilled parallel to the sound beam entry surface. The holes shall be positioned so that the following test metal distances (TMD) from the sound beam entry surface to the nearest surface of a hole are obtained:

   (1) For deposited thickness (T) up to and including ½ inch:

   1/16-inch TMD

   (T/2) TMD ±1/32 inch

   (T)TMD ±1/16 inch

   (2) For deposited thickness (T) over ½ inch:

   ½-inch TMD

   (T/2 + ¼ inch) TMD ±1/32 inch

   (T)TMD ±1/16 inch

   For deposits greater than ½ inch and less than 1 inch, the (T/2 + ¼ inch) TMD hole may be omitted.

   All holes in the test block shall be sufficiently separated to preclude acoustic or mechanical interference with calibration.

b. In the case of deposited metal ½ inch or less in thickness, the test equipment shall be adjusted to provide an indication 85 to 90 percent of full screen height from the hole at T/2 TMD. At this equipment setting, the signal amplitudes received from the other two holes shall be marked on the screen, and all three signals shall be connected by means of straight lines to provide a DAC curve. If the T/2 TMD hole is omitted, the test equipment shall be adjusted to provide an indication 85 to 90 percent of full screen height from the hole that reflects the greatest signal amplitude. The peaks of the signals received from the two holes shall be connected by a straight line to form the DAC. In the case of deposited metal thicker than ½ inch, the test equipment shall be adjusted to provide an indication 85 to 90 percent full screen height from the hole that reflects the greatest signal amplitude. At this equipment setting, the indications from the remaining holes (or hole) shall be marked on the screen and a DAC curve made. When inspecting production hardware, the first ½ inch of weld deposited metal shall be evaluated using the DAC curve specified in 8-3.6.1.1 a(1) and the remaining thickness shall be evaluated using the DAC curve specified in 8-3.6.1.1 a(2). The horizontal sweep shall be adjusted so that the position of the indication from the calibration hole at TMD + 1/16 inch is at least 25 percent of full screen width.

8-3.6.1.2 UT Acceptance Criteria for Integrated Build Platform. The acceptance criteria for integrated build platform shall be as follows:

a. Indications greater than the DAC curve specified are unacceptable.

b. Indications greater than 50 percent of the DAC curve and longer than that permitted by figure 8-1 are unacceptable.

c. Separate indications greater than 50 percent of the DAC curve shall be separated by a minimum of 2 inches in any direction.

d. Indications greater than 50 percent of the DAC curve shall be recorded on the UT report as to amplitude, extent, and location.

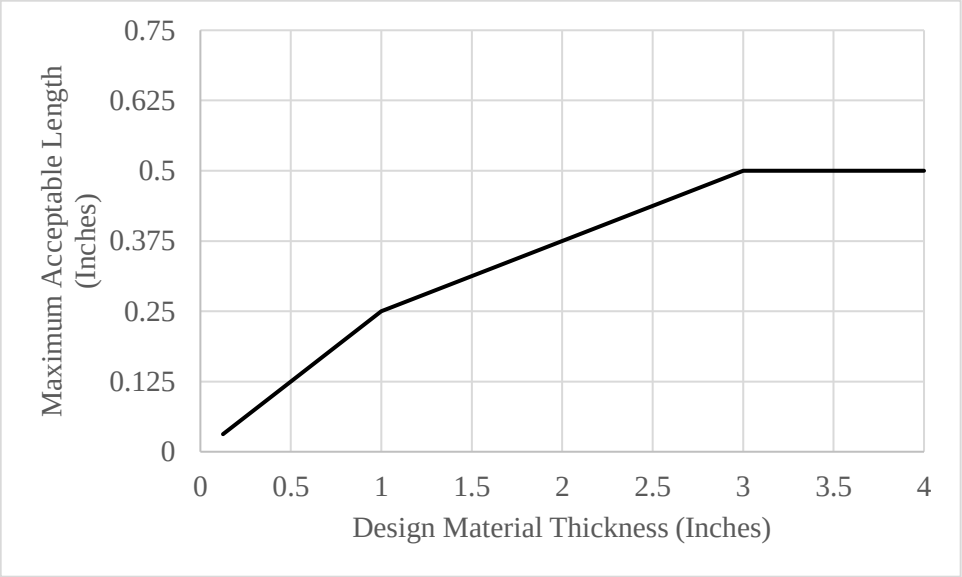

Figure 8-1. Maximum Acceptable Ultrasonic Indication Length for Deposition-to-Build Platform Fusion Zone

8-3.7 ALTERNATE NDT METHODS. Alternate NDT methods (such as x-ray computed tomography, phased array UT, full matrix capture) shall be as approved by NAVSEA. Calibrations and procedures shall follow a commercial standard, such as ASME BPVC Section V, with additional requirements from NAVSEA. This shall include where alternate NDT methods are used to replace or supplement traditional NDT methods.

8-3.8 WELD ACCEPTANCE CRITERIA AREAS VERSUS DED BUILD AREAS FOR RT, MT, AND PT. In adapting the acceptance criteria of MIL-STD-2035 for welds to DED builds, the following shall apply unless otherwise approved by NAVSEA:

a. For RT, criteria for accumulated lack of fusion, accumulated slag, and random porosity indications shall be evaluated for worst-case concentration within a rectangular area that is 6 inches long by the maximum width specified by MIL-STD-2035 for random porosity for the thickness involved. The orientation of the rectangular area shall be the worst-case orientation.

b. For MT/PT, criteria for nonlinear indications, including maximum size indications, shall be evaluated for worst-case concentrations within a rectangular area that is 6 inches long by the following maximum width:

(1) For T ≤ ¾ inch: Width = 2T plus ¼ inch

(2) For T ≥ ¾ inch: Width = 2 inches

The orientation of the rectangle shall be the worst-case orientation.

8-3.9 START AND STOP LOCATION. Where the start and stop locations are required to be machined off by the procedure, a maximum of ½ inch of the start, stop, and edge bead regions (as applicable) on procedure and part qualification test builds and production builds shall be exempt from inspection, except for titanium weld appearance in accordance with 8-3.1.1.

8-4 DESTRUCTIVE TESTING.

8-4.1 TENSION TESTS. Where tensile specimen testing is required, the specimen shall be prepared and evaluated according to ASTM E8/E8M. Tension test specimens shall have ultimate tensile strength, yield strength, and percent elongation that are not less than the minimum requirements established in 3-2.3.

8-4.2 GUIDED BEND TEST. Where bend testing is required, specimens shall be prepared and evaluated according to AWS B4.0. The bend radius shall be chosen by using the standard correlation between exterior strain and on the specimen and percent elongation based on the minimum requirement in accordance with 3-2.3. For materials with 20 percent or less minimum elongation requirements, elongation for determining bend radius shall be selected based on the base metal or feedstock specification minimum elongation requirement, whichever is lower, for integrated build platform builds, and shall be based on the acceptance criteria established in 3-2.3 for non-integrated build platform builds. For welds and materials with elongation requirements exceeding 20 percent elongation, bend testing at 20 percent elongation is required.

8-4.2.1 Criteria for Acceptance. For acceptance, the guided bend specimen after bending shall have no cracks or other open defects greater than ⅛ inch or as determined and approved in 3-2.2, whichever is less. Cracks occurring on the corners of the specimen during testing shall not be considered unless there is definitive evidence that they result from slag inclusions or other internal defects. Openings in the base plate outside of the deposited material and heat-affected zone shall not be cause for rejection.

8-4.3 CHARPY V-NOTCH (CVN). Where CVN testing is required, specimens shall be prepared and evaluated according to ASTM E23. The testing temperature shall be in accordance with 3-2.3. For acceptance, CVN testing shall meet the minimum requirements established in 3-2.2. Build material tests shall be evaluated to the requirements in the feedstock material specification, while heat-affected zone (HAZ) specimens shall be evaluated to the base material specification. Specimen thickness shall be the full size (0.394 inch [10 millimeters]) unless sufficient material is not available. In the case where sufficient material is not available, reduced thickness specimens shall be used of as large a size as possible with proportionally small energy requirements. Impact testing using reduced specimen sizes shall require NAVSEA approval. Submissions shall include data and technical justification supporting an appropriated reduction in the minimum energy requirements.

8-4.3.1 HAZ Photomacrographs. Before testing, color photomacrographs of at least one side view of all HAZ CVN specimens clearly showing the root of the notch and its location relative to the fusion line and the entire etched HAZ/fusion line shall be taken. The distance of the root of the notch from the fusion line shall be measured and recorded, along with the energy required to break the specimen. These shall be submitted along with other qualification test data for approval.

8-4.4 METALLOGRAPHIC SPECIMENS. For transverse specimens, cross-sections shall have a minimum width of 3 inches or the width of the area, whichever is smaller; have a minimum height of 3 inches or the height of the part, whichever is smaller; and require macroetch and microstructural analysis. Macroetched samples shall be examined prior to sectioning for microstructural analysis. Longitudinal specimens shall require microstructural analysis. In the case of an integrated build platform, transverse specimens shall encompass the build platform fusion line region, including the entirety of the HAZ.

8-4.4.1 Macroetch Specimens. Macroetch metallographic specimens shall be sectioned, ground, and etched in the transverse and longitudinal directions relative to the direction of deposition, with 90 degrees between them in accordance with ASTM E340. Each metallographic specimen shall be identified. The specimen face shall be examined at a length scale between 5× and 10× magnification. For acceptance, macroetch specimens as a minimum shall be free of discontinuities in the deposition greater than 1/32 inch or 10 percent of the thickness of the deposition (thickness is to be measured transverse to weld travel direction), whichever is less, and free of any cracks or lack of fusion indications.

8-4.4.2 Microstructural Analysis Specimens. Microstructural analysis specimens shall be sectioned, polished, and etched in the transverse and longitudinal directions relative to the build layers in accordance with ASTM E3 and ASTM E407. Microstructural analysis specimens may be sectioned from macroetch specimens and shall consist of representative sections from each macroetch specimen. Each metallographic specimen shall be identified. The specimen face shall be examined and an image be recorded at a length scale (at least 50× minimum magnification) capable of identifying microstructural attributes. Image size shall be the appropriate field of view for the magnification in use. For acceptance, metallographic specimens shall meet the minimum requirements established in 3-2.3 and shall be free of any cracks or lack of fusion indications.

8-4.4.3 Metallographic Features. Metallographic specimens shall be evaluated for the following features:

a. For porosity: maximum size, average size, size distribution, quantity, locational distribution, shape(s), and type(s) (e.g., lack of fusion, keyhole porosity, gas porosity)
b. Cracking
c. Microstructural phases
d. Grain structure and grain size, where applicable (see ASTM E112)
e. Any other discontinuities present

8-4.5 HARDNESS TEST. Hardness specimens shall be prepared and evaluated in accordance with ASTM E92. Hardness testing shall be performed in longitudinal and transverse orientations relative to the build layers. A minimum of 10 indents shall be made per specimen, with 5 indents being from a single layer and 5 indents being perpendicular to that layer. After hardness testing, specimens shall be prepared for metallographic examination in accordance with 8-4.4. For acceptance, hardness testing shall meet the minimum requirements established in 3-2.3. If the material requirements are not established in accordance with 3-2.3, they shall be determined by ASTM hardness correlation between ultimate strength established in 3-2.3 and hardness.

8-4.6 CHEMISTRY. For acceptance, the chemical composition of an as-built specimen shall be tested and meet the requirements established in 3-2.3. Specimens shall be analyzed in accordance with a standard ASTM method, or a method shall be provided that will ensure equally accurate results for conformance to the chemistry requirements of the range over which the chemical analysis test methods can be shown to be accurate for the particular element reported. Specimens shall be extracted from a location sufficiently removed from the build platform to ensure lack of dilution. The accuracy and precision of the chemical analysis method(s) used for each element being analyzed shall be provided.

8-4.7 SPECIAL TESTS. When tests, such as explosion-bulge, dynamic tear, and other tests not detailed in this document, are required in part verification testing, these tests will be specified by NAVSEA and information as to methods and guidance for performance of the required test and acceptance criteria will be provided at that time.

CHAPTER 9
ACQUISITION

9-1 SCOPE.

This section is intended to provide the general requirements for acquisition of DED parts.

9-2 ACQUISITION REQUIREMENTS.

Acquisition documents shall specify the following in addition to any additional requirements:

a. Title, number, and date of this document
b. When part verification testing is not required per approval received by NAVSEA
c. Dimensions of non-standard tensile test specimens
d. Any special packaging requirements

9.3 PART VERIFICATION BUILD.

The contracting officer shall include specific instructions in acquisition documents regarding arrangements for examinations and disposition of part verification builds. Invitations for bids should provide that the Government reserves the right to waive the requirement for samples for first inspection to those bidders offering a product that has been previously acquired or tested by the Government, and that bidders offering such products who wish to rely on production or test must furnish evidence with the bid that prior Government approval is presently appropriate for the pending contract.

9-3.1 NEW VENDORS. Prior to delivery, the contracting officer shall ensure that activities that have not previously supplied products as described in this document demonstrate to NAVSEA that their facilities produce products conforming to the requirements of this document.

9-4 PREPARATION FOR PACKAGING AND PACKING.

Preparation for packaging and packing shall be as follows:

a. Part(s) shall be clean and free of foreign matter
b. Part(s) shall be segregated as to composition

9-4.1 PACKAGING, PACKING, AND MARKING FOR SHIPMENT. Unless additional requirements are specified by the purchaser, the part(s) shall be prepared for shipment in accordance with commercial practices to ensure delivery of the component(s) in full compliance with this document. The level of packaging and marking for shipment shall meet the requirements of carrier rules and regulations applicable to the mode of transportation.

9-4.2 PACKAGING BY DEPARTMENT OF DEFENSE (DOD) PERSONNEL. When actual packaging of parts is to be performed by DoD personnel, these personnel need to contact the responsible packaging activity to ascertain requisite packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activity within the Military DoD Agency or within the Military Department's System Command. 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.

APPENDIX A
ABBREVIATIONS AND ACRONYMS

A-1 ABBREVIATIONS AND ACRONYMS.

ACRONYM	TITLE
AM	Additive manufacturing
AMF	Additive manufacturing file format
CAD	Computer-aided design
CVN	Charpy V-notch
DAC	Distance amplitude correction
DED	Directed Energy Deposition
DoD	Department of Defense
HAZ	Heat-affected zone
HIP	Hot isostatic pressing
MT	Magnetic-particle testing
NAVSEA	Naval Sea Systems Command
NDT	Nondestructive testing
PT	Liquid-penetrant testing
RT	Radiographic testing
STL	Stereolithography
SUBSAFE	Submarine Safety Program
TMD	Test metal distances
UT	Ultrasonic testing
VT	Visual testing

Ref: NAVSEAINST 4160.3 NAVSEA S0005-AA-PRO-010/TMMP

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