

INCH-POUND

MIL-DTL-32477

22 October 2013

DETAIL SPECIFICATION

ROD AND BAR, COBALT-NICKEL-CHROMIUM-IRON-MOLYBDENUM ALLOY,
FOR USE IN CRITICAL SEAWATER APPLICATIONS

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers solution annealed and cold worked, and solution annealed, cold worked and age hardened cobalt-nickel-chromium-iron-molybdenum alloy rod (see 6.5.2) and bar (see 6.5.1) up to and including 3.50 inches in diameter or thickness for use in critical seawater applications.

1.2 Classification. Bar and rod are of the following form, grade, and finish, as specified (see 6.2).

1.2.1 Forms. Cobalt-nickel-chromium-iron-molybdenum alloy comes in the following forms:

- a. Rod
- b. Bar, round
- c. Bar, hexagonal
- d. Bar, octagonal
- e. Bar, square
- f. Bar, rectangular

1.2.2 Grades. Cobalt-nickel-chromium-iron-molybdenum alloy comes in the following grades:

- a. Grade 1 – Solution annealed and cold worked
- b. Grade 2 – Solution annealed, cold worked, and age hardened

1.2.3 Finishes. Cobalt-nickel-chromium-iron-molybdenum alloy comes in the following finishes:

- a. As cold worked
- b. Rough turned or rough ground (rounds)
- c. Semi-smoothed machined (rounds)
- d. Smooth finish machined (rounds)
- e. Bright finished
- f. Pickled

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

MIL-DTL-32477

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, or 5 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this specification, whether or not they are listed.

2.2 Government documents.

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

NAVAL SEA SYSTEMS COMMAND (NAVSEA) PUBLICATIONS

T9074-AS-GIB-010/271 - Requirements for Nondestructive Testing Methods

(Copies of this document are available online at <https://nll.ahf.nmci.navy.mil>. This publication can be located by searching the Navy Publications Index for the TMIN without the suffix.)

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

ASTM INTERNATIONAL

- ASTM E3 - Standard Guide for Preparation of Metallographic Specimens
- ASTM E8/E8M - Standard Test Methods for Tension Testing of Metallic Materials
- ASTM E18 - Standard Test Methods for Rockwell Hardness of Metallic Materials
- ASTM E23 - Standard Test Method for Notched Bar Impact Testing of Metallic Materials
- ASTM E29 - Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- ASTM E112 - Standard Test Methods for Determining Average Grain Size
- ASTM E354 - Standard Test Methods for Chemical Analysis of High Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys
- ASTM E399 - Standard Test Method for Linear-Elastic Plane-Strain Fracture Toughness K_{Ic} of Metallic Materials
- ASTM E407 - Standard Practice for Microetching Metals and Alloys
- ASTM E1019 - Standard Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Fusion Techniques
- ASTM E1473 - Standard Test Methods for Chemical Analysis of Nickel, Cobalt, and High Temperature Alloys
- ASTM E1820 - Standard Test Method for Measurement of Fracture Toughness

(Copies of these documents are available from ASTM International, 100 Barr Harbor Dr., PO Box C700, West Conshohocken, PA 19428-2959 or online at www.astm.org.)

MIL-DTL-32477

SAE INTERNATIONAL

- SAE-AMS2261 - Tolerances, Nickel, Nickel Alloy, and Cobalt Alloy Bars, Rods, and Wire
- SAE-AMS2750 - Pyrometry
- SAE-AMS2806 - Identification, Bars, Wire, Mechanical Tubing, Extrusions, Carbon and Alloy Steels and Corrosion and Heat-Resistant Steels and Alloys

(Copies of these documents are available from SAE World Headquarters, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or online at www.sae.org.)

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

3. REQUIREMENTS

3.1 First article. Unless otherwise specified (see 6.2), a sample shall be subjected to first article inspection in accordance with 4.2 and test results shall be submitted as specified (see 6.2 and 6.3). The following information shall accompany the test results:

- a. Melt source.
- b. Melting, refining, and degassing procedures including furnace atmosphere, slag composition, pouring temperatures (when applicable), furnace controls, refining process parameters and controls, ingot size, and ingot handling procedures.
- c. Aim chemistries and an internal chemical composition range including aim and range percentages for major alloying elements and maximum percentages for the remaining elements.
- d. Cropping procedure to ensure that all finished material will meet specification requirements.
- e. Heat treatment procedures including the purpose of the heat treatment, heating rates, holding temperatures, time at temperature, cooling method, furnace atmosphere, accuracy and uniformity of the temperatures of the furnaces used, furnace survey method, and survey frequency.
- f. Forging, rolling, and hot working procedures, including the minimum and maximum processing temperatures and percent reduction for each step.
- g. Percent reduction obtained by cold working the solution annealed billet to the final product.
- h. Any lubricating, de-scaling, cleaning, and pickling procedures used during manufacture.

The above shall govern the manufacturer of all future materials unless otherwise approved by NAVSEA.

3.2 Material processing. The manufacturer shall document the material processing and heat treatment facilities and procedures used to produce the products for first article testing (see 6.3), and these same material processing and heat treatment facilities and procedures shall be used in the production of all product supplied to this specification. The manufacturing procedures used shall be controlled procedures and are subject to audit by NAVSEA or its authorized representative.

3.2.1 Recycled, recovered, environmentally preferable, or biobased materials. Recycled, recovered, environmentally preferable, or biobased materials should be used to the maximum extent possible, provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life cycle costs.

3.2.2 Processing. Material shall be produced by multiple melting using vacuum induction followed by vacuum consumable electrode melting. Cast ingots or billets shall be hot worked to a fine grain structure and solution annealed prior to cold working. Grade 2 rod and bar shall be cold worked prior to aging.

3.2.3 Chemical composition. The heat analysis shall conform to the requirements in [table I](#).

MIL-DTL-32477

TABLE I. Chemical composition requirements.

Elements ^{1/}	Requirements, % (maximum unless a range or a minimum is indicated)	Product (check) analysis variations, under minimum or over maximum, of the specified limit of the element, % ^{2/}
Nickel	Remainder	-
Cobalt	34.0 – 38.0	0.3
Chromium	18.0 – 20.0	0.25
Molybdenum	6.0 – 8.0	0.15
Iron	8.0 – 10.0	0.1
Titanium	2.5 – 3.25	0.07
Aluminum	0.1 – 0.3	0.05
Niobium	0.25 – 0.75	0.05
Boron	0.03	0.005
Carbon	0.04	-
Manganese	0.20	-
Silicon	0.20	-
Phosphorus	0.020	-
Sulfur	0.010	-
NOTES:		
^{1/} Elements listed must make up 99.5% of total composition.		
^{2/} Product check analysis variations are allowed only on a check analysis done upon receipt inspection of the product supplied to this specification.		

3.2.4 Heat treatment. Unless otherwise specified (see 6.2), heat treatment facilities and equipment utilized shall provide the system accuracy and temperature uniformity as specified in SAE-AMS2750.

3.2.4.1 Heat treatment information. Manufacturers supplying Grade 2 materials shall include heat treatment information as part of the certification report (see 4.8). For batch-type furnaces used for aging heat treatment, the heat treatment information shall include all the information presented in [figures 1](#) and [2](#) and a verification of inspection.

3.2.4.2 Working zone temperature uniformity. Working zone temperature uniformity shall be determined on batch type furnaces used for aging heat treatment of Grade 2 bar and rod in accordance with SAE-AMS2750, or as permitted in 3.2.4.

3.2.4.3 Contact thermocouples. Unless otherwise specified (see 6.2), for batch-type furnaces, a minimum of three thermocouples shall be attached to the furnace load. The hot junctions (or the caps of sheathed thermocouples) shall be in contact with the items.

MIL-DTL-32477

3.2.4.4 Heat treatment procedures. Both Grade 1 and Grade 2 rod and bar shall be solution heat treated by heating to a temperature within the range of 1900 to 1925 °F, holding at the selected temperature within ± 25 °F for 4 to 8 hours, and quenching in water prior to cold working. After cold working, Grade 2 rod and bar less than or equal to 2.00 inches in diameter or thickness shall be aged by heating to a temperature within the range of 900 to 1100 °F, holding at the selected temperature within ± 25 °F for not less than 4 hours, and cooling at a rate equivalent to an air cool or faster. Grade 2 rod and bar greater than 2.00 inches up to 3.50 inches in diameter or thickness shall be aged by heating to a temperature in the range of 900 to 1225 °F, holding at the selected temperature ± 25 °F for not less than 4 hours, and cooling at a rate equivalent to an air cool or faster. When specified (see 6.2), manufacturers supplying Grade 1 rod and bar shall perform the latter aging heat treatment(s) on one sample selected at random from each lot prior to shipping and demonstrate the capability of conformance to the tensile property requirements in [table II](#), the hardness requirements for Grade 2 in [table III](#), and the impact and fracture toughness requirements in [table IV](#) and provide results with the certificate of conformance (see 4.8).

3.2.5 Detrimental material controls.

3.2.5.1 Low melting point materials. Contact with antimony, bismuth, cadmium, lead, tin, zinc, and consumable products, such as lubricants and marking materials, containing these low melting point materials in excess of 250 parts per million (ppm) each, shall be prohibited. This prohibition on low melting point materials applies during thermal treatments and to the finished or cleaned surfaces of the material offered for acceptance. Products do not need to be analyzed when product manufacturers certify that low melting point materials in excess of 250 ppm are not present in the products. A product containing low melting point materials, only in the form of stable chemical compounds which do not melt or decompose below 2200 °F, shall be exempt from this requirement.

3.2.5.2 Mercury. Contact with mercury and consumable products that contain more than 10 ppm mercury is prohibited. Products do not need to be analyzed when product manufacturers certify that mercury in excess of 10 ppm is not present in the product, or certify that mercury and mercury compounds have not been added to the product and have not come in contact with the product during processing.

3.2.5.3 Paint prohibition. Paint shall not be used for marking.

3.3 Dimensional tolerances. Dimensional tolerances of the rod and bar shall be in accordance with all applicable requirements of SAE-AMS2261.

3.4 Identification marking. Identification and marking of the rod and bar shall be in accordance with SAE-AMS2806.

3.5 Workmanship. Rod and bar surfaces shall be free from defects harmful to the intended use, such as laps, cracks, seams, scale, and fins.

3.6 Performance characteristics.

3.6.1 Soundness. Rod and bar shall be free from seams, pipe, cracks, and porosity.

3.6.2 Mechanical properties. Grade 1 rod and bar produced to this specification shall meet the hardness requirements specified on [table III](#). Unless otherwise specified (see 6.2), Grade 1 bar and rod is not required to meet the tensile, hardness and impact, and fracture toughness property requirements for Grade 2 specified in [tables II](#), [III](#) and [IV](#), respectively. Grade 2 rod and bar produced to this specification shall meet the mechanical property requirements on [tables II](#), [III](#), and [IV](#). Except for first article and conformance testing, where zero tolerance is required, the following tolerances may be applied upon receipt inspection of the product supplied to this specification to determine acceptability as part of the final acceptance or verification procedures.

- a. Minimum measured yield strength shall be not less than 98 percent of the minimum specified value.
- b. Maximum measured yield strength shall be not more than 102 percent of the maximum specified value.
- c. Minimum measured tensile elongation shall be not less than 98 percent of the minimum specified value.
- d. Minimum measured average CVN impact energy or fracture toughness shall be not less than 98 percent of minimum specified values.

MIL-DTL-32477

TABLE II. Tensile property requirements for grade 2. ^{1/}

Tensile strength, ksi (minimum)	Yield strength 0.2% offset, ksi	Elongation (% in 4D), (minimum)	Reduction of area, % (minimum)
170	150 to 180	15	50
NOTE: ^{1/} Average of two tests at room temperature from each sample required in 4.6.2.1.			

TABLE III. Hardness requirements.

Rockwell C ^{1/}	
Grade 1	Grade 2
30 HRC minimum	36 HRC to 45 HRC
NOTE: ^{1/} Average of 5 hardness readings (see 4.6.3.2).	

TABLE IV. Impact toughness requirements for grade 2 and fracture toughness requirements.

Charpy V-Notch energy, ft-lbs (minimum) ^{1/}	Fracture toughness, ksi^{1/2}/in (minimum)
50	^{2/} , ^{3/}
NOTES: ^{1/} Average of three tests performed in air at room temperature. Not required where 10 mm by 10 mm size specimens in accordance with ASTM E23 cannot be removed. ^{2/} The ratio of average fracture toughness (three tests in air at room temperature) to average room temperature yield strength shall be equal to or greater than 1.15. ^{3/} Not required for round rod or bar less than 0.900 inches in diameter.	

3.6.3 Microstructure. The average grain size number shall be ASTM No. 4 or higher.

4 VERIFICATION

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

- a. First article inspection (see 4.2).
- b. Conformance inspection (see 4.3).

4.2 First article inspection. First article inspection shall include all the tests specified in 4.4 through 4.6 as summarized in [table V](#). First article testing shall include testing of bar and rod representing both the smallest and largest diameter and/or thickness of each grade expected to be produced by the mill. In addition to bracketing the sizes expected in future production, bar and rod subjected to first article inspection shall be from a production lot(s) and represent the same form for each grade to be supplied under this specification.

MIL-DTL-32477

4.3 Conformance inspection. Conformance inspection shall consist of the tests and inspections specified in 4.4 through 4.6, as summarized in [table V](#).

TABLE V. Summary of required tests.

Item	First article inspection	Conformance inspection	Requirement	Test method
Chemical composition	X	X	3.2.2	4.5
Dimensional tolerances	X	X	3.3	4.4.2
Identification marking	X	X	3.4	4.4.2
Workmanship	X	X	3.5	4.4.2
Soundness (NDT)	X	X	3.6.1	4.4.3
Tensile	^{1/}	^{1/}	3.6.2, table II	4.6.2
Impact toughness	^{1/}	^{1/}	3.6.2, table IV	4.6.4
Hardness	X	X	3.6.2, table III	4.6.3
Fracture toughness	^{1/}	^{2/} , ^{3/}	3.6.2, table IV	4.6.5
Microstructure	X	X	3.6.3	4.4.4.2
NOTES: ^{1/} Required for Grade 2 only. ^{2/} See 3.2.4.4 for Grade 1. ^{3/} When specified for Grade 2 (see 6.2).				

4.4 Examination.

4.4.1 Lot. A lot shall be all products from the same ingot, of the same grade, size (i.e., length and cross-section), form, shape (i.e., straight or coiled form), and heat treated in the same furnace charge (or, in the case of continuously processed lots, as part of the same continuous production run).

4.4.2 Dimensional, visual, and workmanship examinations.

4.4.2.1 Sampling. Sample size shall be in accordance with [table VI](#).

4.4.2.2 Inspection. Each sample representing the lot shall be visually examined for conformance to the requirements in 3.3 to 3.5.

4.4.2.3 Rejection criteria. Failure of a sample representing the lot to meet the requirements in 3.3 to 3.5 shall be cause for rejection.

MIL-DTL-32477

TABLE VI. Sample size for dimensional, visual, and workmanship examinations.

Lot size	Sample Size
1 to 8	All
9 to 90	8
91 to 150	12
151 to 280	19
281 to 500	21
501 to 1200	27
1201 to 3200	35
3201 or more	38

4.4.3 Nondestructive testing.

4.4.3.1 Liquid penetrant tests.

4.4.3.1.1 Sampling. Each piece of each lot shall be inspected by liquid penetrant.

4.4.3.1.2 Test procedure. Liquid penetrant inspection shall be performed in accordance with T9074-AS-GIB-010/271. Linear defects exceeding $\frac{1}{16}$ inch in length shall be removed by grinding or other suitable means.

4.4.3.1.3 Rejection criteria. Defect removal resulting in failure to meet the dimensional tolerances of 3.3 shall be cause for rejection of the rod or bar.

4.4.3.2 Ultrasonic tests.

4.4.3.2.1 Sampling. Each piece of each lot shall be inspected 100 percent by volume.

4.4.3.2.2 Test procedure. Ultrasonic testing shall be performed in accordance with T9074-AS-GIB-010/271, as modified by the requirements specified herein. Round rod and bar less than or equal to $1\frac{3}{16}$ inches in diameter shall be ordered with a ground or turned surface. Hot finished surfaces shall be 250 microinches arithmetic mean surface roughness (Ra) or smoother.

4.4.3.2.3 Rejection criteria. The following criteria shall be used to determine whether a rod or bar in the lot is rejected. Any rod or bar which produces indications equal to or larger than the response from the reference reflector, or contains areas which result in a 90 percent or greater loss of back reflection (except when the transducer is within one transducer diameter of the side of the bar) shall be rejected. Material shall be tested using a square, rectangular, or circular transducer having an effective area of 1 square inch or less, but no dimensions shall be smaller than the diameter of the reference hole. In the event of disagreement on the degree of back reflection loss, it shall be determined by the contact method using a 1- to $1\frac{1}{8}$ -inch diameter transducer or one whose area falls within this range.

4.4.4 Microstructure tests.

4.4.4.1 Sampling. Two rods or bars shall be selected at random from each lot. Where there is only one piece in the lot only, one rod or bar is required.

4.4.4.2 Test procedure. Grain size determination shall be performed on a transverse cross-section taken within 12 inches of each end of each sample selected to represent the lot (i.e., two specimens per sample). Each microstructure specimen shall be prepared in accordance with ASTM E3 and etched in accordance with ASTM E407 to reveal the grain structure. The grain size of each specimen shall be determined at $100 \times$ magnification in accordance with ASTM E112.

MIL-DTL-32477

4.4.4.3 Rejection criteria. Failure of a sample representing the lot to meet the requirements in 3.6.3 shall be cause for rejection.

4.5 Chemical composition.

4.5.1 Lot. A lot for establishing chemical composition shall consist of all products from the same ingot.

4.5.2 Sampling. Two representative samples shall be obtained from each lot. One sample shall be taken from the head of the ingot, and the other sample shall be taken from the toe of the ingot. Samples shall be taken after any discarded material is cropped off.

4.5.3 Test procedure. Samples selected in accordance with 4.5.2 shall be analyzed by wet chemical or spectrographic-chemical methods in accordance with ASTM E354 to determine conformance with [table I](#). In case of disagreement, the composition of carbon and sulfur shall be determined in accordance ASTM E1019, and the composition of all other elements listed in [table I](#) shall be determined in accordance with ASTM E1473.

4.5.4 Rejection criteria. Results of chemical analyses that fail to meet the requirements in [table I](#) shall be cause for rejection.

4.6 Mechanical property tests.

4.6.1 Lot. A lot shall consist of all rod and bar from the same ingot, of the same size (i.e., cross-section and nominal length equal to or shorter than the length tested), form, shape (i.e., straight or coiled), and heat treated in the same furnace charge (or, in the case of continuously processed lots, as part of the same continuous production run).

4.6.2 Tensile test.

4.6.2.1 Sampling. Two sample rods or bars shall be selected at random from each lot. Where there is only one bar or rod in the lot, only one sample is required.

4.6.2.2 Test procedure. One tensile specimen shall be taken from each end of each sample representing the lot. Tensile testing shall be performed on each specimen in accordance with ASTM E8/E8M. Unless otherwise specified (see 6.2), specimens shall be 0.252 inch diameter standard round specimens in accordance with ASTM E8/E8M. The long axis of the tensile test specimen shall coincide with the central axis of the bar or rod for samples less than or equal to 0.800 inch in diameter or thickness. For samples having a diameter or thickness greater than 0.800 inch, the long axis of the specimen shall coincide with the mid-radius or quarter-thickness of each sample.

4.6.2.3 Rejection criteria. Failure of the results from any sample representing the lot to meet the requirements in [table II](#) shall be cause for rejection. Failure to meet the tolerances specified in 3.6.2 when properties are measured upon receipt of inspection of the product delivered to this specification shall also be cause for rejection.

4.6.3 Hardness test.

4.6.3.1 Sampling. Two sample rods or bars shall be selected at random from each lot. Where there is only one bar or rod in the lot, only one sample is required.

4.6.3.2 Test procedure. Rockwell hardness shall be determined on each sample representing the lot in accordance with ASTM E18. For samples less than or equal to 0.5 inch in diameter or thickness, five hardness readings shall be taken on the surface of each sample representing the lot. For samples greater than 0.5 inch in diameter or thickness, the five hardness readings shall be taken at mid-radius or quarter-thickness on a flat cross-section of each sample representing the lot.

4.6.3.3 Rejection criteria. Failure of the results from any sample representing the lot to meet the requirements in [table III](#) shall be cause for rejection.

MIL-DTL-32477

4.6.4 Impact toughness test.

4.6.4.1 Sampling. Two sample rods or bars shall be selected at random from each lot. Where there is only one bar or rod in the lot, only one sample is required.

4.6.4.2 Test procedure. Three 10 millimeter by 10 millimeter Charpy V-Notch (CVN) specimens in accordance with ASTM E23 shall be prepared and tested from each sample representing the lot. Specimens shall be in the L-T or L-R (rounds only) orientation in accordance with ASTM E399 and all specimens shall be removed from the same end of each sample representing the lot. Specimens shall be prepared and tested in accordance with ASTM E23. For samples less than or equal to 1.5 inches in diameter or thickness, the long axis of test specimens shall coincide with the central axis of the sample. For product greater than 1.5 inches in diameter or thickness, the long axis of test specimens shall coincide with the mid-radius or quarter-thickness of each sample.

4.6.4.3 Rejection criteria. Failure of the results from each sample representing the lot to meet the requirements in [table IV](#) shall be cause for rejection. Failure to meet the tolerances specified in 3.6.2 when properties are measured upon receipt inspection of the product delivered to this specification shall also be cause for rejection.

4.6.5 Fracture toughness test.

4.6.5.1 Sampling. When specified for Grade 2 (see 6.2), two sample rods or bars shall be selected at random from each lot. This does not apply to first article inspection for Grade 2 where fracture toughness testing is required. Where there is only one bar or rod in the lot, only one sample is required.

4.6.5.2 Test procedure. One specimen shall be removed from each end of each sample representing the lot. Specimens shall be in the L-T or L-R (rounds only) orientation in accordance with ASTM E399. The long axis of the specimen shall coincide with the long axis of the sample. Fracture toughness specimens shall be as thick as possible, except when thickness exceeds 1.5 inches, in which case 1.5 inches shall be the minimum thickness. Fracture toughness shall be determined in accordance with ASTM E1820.

4.6.5.3 Rejection criteria. Failure of the results from each sample representing the lot to meet the requirements in [table IV](#) shall be cause for rejection. Failure to meet the tolerances specified in 3.6.2 when properties are measured upon receipt inspection of the product delivered to this specification shall also be cause for rejection.

4.7 Replacement and retest.

4.7.1 Replacement of a test specimen. If any test specimen shows defective machining or develops flaws which cause inaccurate test results, it may be discarded and a replacement test specimen substituted. If the percentage of elongation of any tension test specimen is less than that specified and any part of the fracture is outside of the middle two-thirds of the gage length or in a punched or scribed mark within the reduced section, a retest shall be allowed.

4.7.2 Retests. If the mechanical property test results from one of the samples representing a lot fail to meet the acceptance criteria, the manufacturer may (a) reprocess and conduct verification according to section 4; or (b) conduct two additional sets of tests on the same sample that failed to meet specified requirements. The results for both retest sets shall meet the specified requirements for acceptance of the lot. For results of mechanical property tests on specimens from coiled rod or bar that fail to meet specified requirements (see 6.2).

4.8 Certification of conformance. Unless otherwise specified (see 6.2), a certificate of conformance shall be prepared for each lot of material offered for acceptance. A certification for conformance for each lot shall provide requirements and test results, including results that required retesting, for all specified chemical and mechanical tests. Results of nondestructive tests and other inspections or tests shall be recorded on the certificate. In addition, the manufacturer shall report the melt processes used and the melting source of the material if the manufacturer is not the melter. The certificate shall state that each lot has been produced using manufacturing facilities and processes demonstrated in first article testing and sampled, tested, and inspected in accordance with the specification requirements herein, and shall be signed and dated by a responsible representative of the manufacturer.

4.9 Rounding of test results. For purposes of determining conformance with the limits in this specification, an observed value or a calculated value shall be rounded in accordance with the rounding method of ASTM E29.

MIL-DTL-32477

5. PACKAGING

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

6. NOTES

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

6.1 Intended use. This specification covers requirements for MP98T rod and bar intended for use in critical wetted seawater applications, including those affecting safety of nuclear submarine systems (SUBSAFE), where high strength, fracture toughness, and seawater corrosion resistance is required at low to moderate temperatures. This alloy can display hydrogen assisted cracking under cathodic polarization of -800 and -1000 millivolts versus Ag/AgCl in seawater. However, for fastener applications this sensitivity is mitigated by requiring that threads be rolled and the fillet under the head of bolts or screws be rolled after final aging heat treatment.

6.2 Acquisition requirements. Acquisition documents should specify the following:

- a. Title, number, and date of this specification.
- b. Form, grade, and finish required (see 1.2).
- c. When first article testing is not required (see 3.1 and 6.3).
- d. How test results should be submitted (see 3.1 and 4.7.2).
- e. When heat treatment facilities, equipment, and procedures may provide system accuracy and temperature uniformity other than SAE-AMS2750 (see 3.2.4).
- f. When less than three thermocouples may be attached to the furnace load in batch-type furnaces (see 3.2.4.3).
- g. When a lot of Grade 1 bar and rod requires Grade 2 mechanical property capability to be demonstrated (see 3.2.4.4 and 3.6.2).
- h. When tensile test specimens other than the 0.252 inch diameter standard round specimen in ASTM E8/E8M may be used (see 4.6.2.2).
- i. When fracture toughness testing is required for Grade 2 conformance inspection (see 4.6.5.1).
- j. When certification of conformance is not required with each lot of material offered for acceptance (see 4.8).
- k. Packaging requirements (see 5.1).
- l. The applicable command or agency to review alternate ultrasonic inspection procedures (see 6.4).

6.3 First article inspection. When first article inspection is required, the contracting officer of the Command or Agency should provide specific guidance to offerors whether the item should be a first article sample or a sample selected from first production items (see 3.1), and the number of items to be tested as specified in the individual test procedures listed in section 4. The contracting officer should also include specific instructions on acquisition documents regarding arrangements for examinations, approval of first article inspection test results, other requirements in 3.1, and disposition of first articles. The contracting officer should advise the offerors that NAVSEA approval is required on first article inspection test results. Invitations for bids should stipulate that the Government reserves the right to waive the requirement for first article inspection testing to those bidders offering a product that has previous first article inspection tests results approved by NAVSEA to this specification, and that for such bidders offering such products, who wish to, Government approval is presently appropriate for the pending contract. Bidders should not submit alternate bids unless specifically requested to do so in the solicitation.

MIL-DTL-32477

6.3.1 Exemption from first article inspection. Manufacturers that supply evidence of having met the requirements of 4.2 may obtain a letter of confirmation from NAVSEA excusing them from future first article inspections. This does not exempt suppliers from the requirements in 4.8.

6.3.2 New manufacturers. Prior to delivery, manufacturers that have not previously produced products of the strength level specified under this specification should demonstrate to the Commander, Naval Sea Systems Command, Ship Integrity and Performance Engineering Group (NAVSEA 05P), that their facilities produce products conforming to the requirements of this specification.

6.3.3 Forwarding test results. When a contract does not exist, first article test results may be submitted directly to NAVSEA. The first article inspection test results should be verified by the Defense Contract Administration Services Management Area (DCASMA) or by the American Bureau of Shipping (ABS) representative. The report should be forwarded to the Commander, Naval Sea Systems Command, Ship Integrity and Performance Engineering Group (NAVSEA 05P) via DCASMA.

6.3.4 Manufacturing and testing. The manufacture of the first article, the laying out of test specimens, and the testing should be witnessed by an ABS or DCASMA representative.

6.4 Alternate ultrasonic inspection procedure. Consideration may be given to alternate ultrasonic inspection procedures. These procedures will be reviewed by the Command or Agency concerned (see 6.2).

6.5 Definitions.

6.5.1 Bar. Round, hexagonal, octagonal, square, or rectangular product with a cross sectional area less than 16 square inches.

6.5.2 Rod. A round bar with a diameter greater than or equal to 0.312 inch.

6.6 Subject term (key word) listing.

Corrosion-resistant

High strength

High toughness

MIL-DTL-32477

A. Procedure: _____		Revision: _____	Date: _____	
B. Heat Treater: _____				
C. Item Material Specification: _____		Revision: _____	Amend.: _____	
Interim Change: _____				
D. Material Composition: _____		Type: _____	Condition: _____ Grade: _____	
Class: _____				
E. Pre-Heat Treatment Burn Out:				
Time: _____		Temperature: _____		
F. Time and temperature:				
Heat Treatment	Aim Temperature	Tolerance*	Holding Time	Cooling Method and Rate**
Anneal				
Age hardening				
Stress relieving				
Other (specify)				
* Include temperature tolerance if the tolerance is other than ± 25 °F.				
**If items are cooled by quenching, include quenching method (immersion, spray, etc.) and quenching medium (include additives, if any). If not quenched, specify how items are cooled and include cooling rate.				
G. Working Zone Atmosphere:				
1. Type of Atmosphere: _____				
2. Dew Point (maximum): _____ °F or °C				
3. Temperature above which the dew point must be controlled if other than 600 °F: _____				
4. Flow Rate: _____ cubic feet per hour				
5. Vacuum – maximum pressure: _____ torr (mm Hg) or _____ microns Hg				
6. Type of inert gas backfill (if used): _____ Backfill dew point (maximum) _____ °F or °C				
NOTES:				
1. Enter “NA” when an item does not apply.				
2. A single heat treatment procedure may cover more than one heat treatment process, provided that the required information for each process is clearly distinguished.				

FIGURE 1. Heat treatment procedure information for grade 2 rod and bar.

MIL-DTL-32477

A. Heat Treater:	_____
B. Items Heat Treated:	_____
C. Lot Numbers or Serial Numbers:	_____
D. Heat Treatment Procedure Used (including revision and date of revision):	_____
E. Date of Heat Treatment:	_____
F. Time/Temperature Data (the original temperature chart or the original manually recorded data). Include a standard time interval, such as one hour, or the starting time and chart speed marked on the chart.	
G. Specific Furnace(s) Used:	_____
H. Method of Thermocouple Attachment (batch furnace only):	_____
I. Furnace Information:	
1. Furnace Type(s):	
Batch Furnace:	_____
Vacuum Furnace – Integral Quench:	_____ Yes _____ No _____
2. Method of Preventing Flame Impingement:	_____
J. Temperature Measurement and Control Information:	
1. Thermocouple Information:	
a. How many thermocouples were used? Contact: _____ Non-contact: _____	
b. Describe the location of each thermocouple (may provide a sketch):	_____

2. How was working zone temperature recorded? Automatically: _____ Manually: _____ (Monitoring interval) _____	
3. How was working zone temperature controlled? Automatically: _____ Manually: _____ (Monitoring interval) _____	
4. If manual temperature control was used, how was the temperature adjusted (may reference a written standard practice):	_____

5. If thermocouples were not used, briefly describe the type, number, and location of the temperature measuring devices used to indicate, record, and control temperature:	_____

6. Distance between the thermocouples and the load in an oscillating furnace:	_____ inches

FIGURE 2. Information to be documented on the grade 2 rod and bar heat treatment record.

MIL-DTL-32477

K. Furnace Loading Information:

1. General description of item distribution in the load (not required when a thermocouple is attached to each item in the load).
NOTE: A sketch or reference to a written standard practice is acceptable.

- a. Approximate weight or size of batch furnace load: Pounds: _____ or no. of pieces: _____ and size: _____
- b. Approximate continuous furnace production rate: _____ lbs/hr

2. General description of the supporting method used. NOTE: A sketch or reference to a written standard practice is acceptable.

L. Location of test coupons (when used) in relation to items and attached thermocouples (when used). NOTE: A sketch or reference to a written standard practice is acceptable.

FIGURE 2. Information to be documented on the grade 2 rod and bar heat treatment record – Continued.

MIL-DTL-32477

Custodians:

Army – MI
Navy – SH
Air Force – 99

Preparing Activity:

Navy – SH
(Project 9530-2009-009)

Review Activities:

Army – MR
Navy – AS
Air Force – 16, 84
DLA – IS
GSA – FAS

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