

INCH-POUND
MIL-T-24766
2 March 1992

MILITARY SPECIFICATION

TITANIUM FORGINGS AND FORGINGS STOCK, HIGH QUALITY FOR SHIPS SERVICE

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

1. SCOPE

1.1 Scope. This specification covers commercially pure titanium forgings and forging stock for use in potential mission or life threatening applications involving exposure to seawater.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

MILITARY

MIL-H-81200 - Heat Treatment of Titanium and Titanium Alloys.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 5523, Department of the Navy, Washington, DC 20362-5101 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A

AREA FORG

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited

STANDARDS

MILITARY

- MIL-STD-163 - Steel Mill Products Prepared for Shipment and Storage.
- MIL-STD-271 - Requirements for Nondestructive Testing Methods.
- MIL-STD-792 - Identification Marking Requirements for Special Purpose Components.
- MIL-STD-2154 - Inspection, Ultrasonic, Wrought Metals, Processing for.

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.2 Non-Government publications. The following document(s) form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

- E 8 - Standard Methods of Tension Testing of Metallic Materials.
(DoD adopted)
- E 29 - Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications.
(DoD adopted)
- E 120 - Standard Method for Chemical Analysis of Titanium and Titanium Alloys. (DoD adopted)
- E 340 - Standard Test Method for Macroetching Metals and Alloys.
(DoD adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein (except for related associated detail specifications, specifications, specification sheets or MS standards), 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. When specified (see 6.2), a sample shall be subjected to first article inspection (see 6.4) in accordance with 4.3.

3.1.1 No charge shall be made to the forging procedure used for first article sample (see 6.4).

3.2 Materials and manufacture. Forging stock used to make forgings that meet this specification shall be electron beam melted or shall be multiple melted with at least one of the melting cycles under vacuum. When multiple melted, the first melt shall be by consumable electrode, nonconsumable electrode, electron beam, or plasma melting practice. The subsequent melt or melts shall be made using consumable electrode practice.

3.2.1 atmosphere. The atmosphere for nonconsumable electrode melting shall be vacuum or inert gas at a pressure not higher than 250 millimeters (mm) of mercury.

3.2.2 Electrode tip. The electrode tip for nonconsumable electrode melting shall be water cooled copper.

3.3 Recovered materials. All material incorporated in the forgings covered by this specification shall be produced from recovered materials to the maximum extent practicable without jeopardizing the intended use. The term "recovered materials" means materials which have been collected or recovered from scrap, from manufacturing operations, or secondary metal sources and reprocessed to become a source of raw materials, as opposed to virgin raw materials.

3.4 Chemical composition. The chemical composition shall be in accordance with table I (see 6.3). Check analysis tolerances shall be as shown in table I.

TABLE I. Chemical composition requirements.

Element	Composition All values are maximums	Variation in product analysis
Nitrogen	0.05	0.02
Carbon	0.10	0.02
Hydrogen	0.0125	0.0020 (20 ppm) $\frac{1}{2}$
Iron	0.20	0.10
Oxygen	0.26	0.02
Residuals, each	0.1	--
Residuals, total	0.4	--
Titanium	remainder	--

$\frac{1}{2}$ Parts per million.

3.5 Mechanical properties.

3.5.1 Forgings. Mechanical properties shall be in accordance with table II (see 6.3).

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TABLE II Mechanical property requirements

Property	Requirement
Tensile strength, 1/ Ksi 2/ (MPa), min	65 (450)
Yield strength, Ksi (MPa), min (At 0.2 percent offset)	55 (380)
Elongation, percent, min	18
Red of area, percent, min	30

1/ Kilopounds per square inch.

2/ Megapascal.

3.5.2 Forging stock. When a sample of stock is forged to a test coupon and heat treated as specified in 3.7 or the stock is tested after heat treatment per 3.7 the mechanical properties shall meet those of table II.

3.6 Heat treatment. Forgings shall be furnished in the annealed condition. Annealing shall be by heating to an aim temperature of 1300 degrees Fahrenheit ($^{\circ}$ F) (705 degrees Celsius ($^{\circ}$ C)), holding at temperature for not less than 1 hour. Long term annealing shall not be performed to reduce mechanical properties. Only air cooling shall be permitted following annealing. Furnace surveys and calibration of temperature recorders and controllers shall be in accordance with MIL-H-81200.

3.7 Dimensions. The shape and dimensions, including tolerances, of the finished forging shall be as specified (see 6.2). Forging stock dimensions and tolerances shall be as specified (see 6.2). Sufficient intermediate shapes and dimensions shall be provided to identify test specimen location and inspection orientation (see 6.3).

3.8 Soundness. Material shall be of uniform quality and condition and free of injurious defects harmful to its intended use, such as pipe, slivers, cracks, laps, laminations, seams, burrs, buckles, fins, porosity. Limits of acceptability shall be as specified (see 4.5.4.2 and 4.5.5).

3.9 Marking.

3.9.1 Individual forgings shall be marked with the following:

- (a) Producers name or trademark.
- (b) Specification number.
- (c) Part number or forging drawing number.
- (d) Lot number.

3.9.2 The method and location of marking shall be in accordance with MIL-STD-792 Forging stock may be marked with low stress die stamps or vibroetching.

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3.10 Cleanliness.

3.10.1 Contaminants. Forgings shall be free of foreign material and contaminants, such as sulfur, lead, marking paints or machining or forming lubricants. Forgings shall be cleaned prior to any heat treatment operations.

3.10.2 Mercury. During the manufacturing processes, examinations, and tests the material shall not come into direct contact with mercury or any of its compounds, nor with any mercury containing device employing a single boundary of containment.

3.10.3 Oxides. Forgings shall be free of any oxygen rich layer, such as alpha case.

3.11 Repair welds. No repair welding shall be permitted.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material.

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

- (a) First article inspection (see 4.3).
- (b) Quality conformance inspection (see 4.4).

4.3 First article inspection. First article inspection shall consist of the examinations and tests specified in 4.3.2 through 4.3.3.1 and the quality conformance tests and examinations of 4.4 (see 6.3 and 6.4).

4.3.1 Sampling for first article inspection. The first forging of a given design submitted for inspection shall be the first article sample.

4.3.2 Mechanical property tests. Mechanical properties for first article inspections shall be determined throughout the forging as specified (see 6.2) and shall meet the requirements as agreed upon between the Command or agency concerned and be compared to test values obtained from test bars of 4.4.2.2.3.

4.3.3 Macroscopic examination. A full cross-section shall be macroetched and examined for uniformity, soundness, grain size and grain flow.

4.3.3.1 Acceptance criteria. The macroetch cross-section shall evidence uniformity of quality, soundness and freedom from cracks and porosity. A fully wrought structure shall be evident. Variation in grain size shall be such that it will not interfere with ultrasonic examination. Flow lines shall not cross any pressure boundaries.

4.4 Quality conformance inspection.

4.4.1 Lot definition. Each forging over 125 pounds (57 kilogram (kg)) shall constitute a lot. For forgings up to and including 125 pounds (57 kg), a lot shall constitute all forgings from the same heat, of the same design and size and heat treated in the same heat treat furnace load.

4.4.2 Sampling.

4.4.2.1 Chemical analysis. One sample shall be taken from each heat except that for hydrogen determinations one sample shall be taken from each lot after thermal and chemical processing is completed.

4.4.2.2 Mechanical property.

4.4.2.2.1 Forgings up to 125 pounds (57 kg), as shipped. Two tensile specimens shall be taken from each lot.

4.4.2.2.2 Forgings over 125 pounds (57 kg), as shipped. Two tensile specimens shall be taken from each forging.

4.4.2.2.3 Source of specimens. The test specimens shall be taken from integral prolongations or extra forgings may be provided by the forger. Forgings under 3-1/2 inches (90 mm) in cross-section may use separately forged test bars, provided the wall thickness and amount of working are equivalent to the forgings being supplied. Extra forgings may be provided for samples when forgings are over 3-1/2 inches (90 mm) in cross-section, provided samples cannot be taken from prolongations or by trepanning. Samples shall be taken from the section of forging having the largest cross-section.

4.4.2.3 Nondestructive tests. Each forging shall be liquid penetrant inspected over 100 percent of its surface unless otherwise specified (see 6.2 and 6.3). Each forging shall be ultrasonically inspected over 100 percent of its volume unless otherwise specified (see 6.2 and 6.3).

4.4.2.4 Visual and dimensional examinations.

4.4.2.4.1 Forgings weighing 125 pounds and less. Samples shall be selected in accordance with table III.

TABLE III. Sampling plan for visual and dimensional inspections.

Lot size	Sample size
2 - 3	All
4 - 25	3
26 - 50	5
51 - 90	6
91 - 150	7
151 - 280	10
281 - 500	11
501 - 1200	15

4.4.2.4.2 Forgings weighing over 125 pounds. Each forging shall be visually and dimensionally examined.

4.5 Test methods.

4.5.1 Chemical analysis. The sample selected in 4.4.2.1 shall be analyzed by the wet chemical or spectrographic methods to determine conformance with table I. In the case of dispute, analysis shall be in accordance with ASTM E 120.

4.5.2 Mechanical properties. Mechanical property tests shall be performed in accordance with ASTM E 8. Unless otherwise specified (see 6.2), the longitudinal axis of tensile specimens shall be parallel to the major direction of metal flow in the forgings.

4.5.3 Macroscopic examination. Specimens selected in accordance with 4.3.3 shall be prepared for examination as stated in ASTM E 340 and examined at up to 10x magnification. Acceptance criteria shall be as specified in 4.3.3.1.

4.5.4 Ultrasonic inspection. Forgings shall be ultrasonically inspected in accordance with MIL-STD-2154 throughout 100 percent of their volume. Inspection shall be performed after heat treating when the forging is machined to the configuration for ultrasonic inspection as shown on the forging sketch. Inspection shall be performed prior to drilling holes, cutting keyways, tapers, grooves, or machining section to final contour.

4.5.4.1 Coverage. Forgings shall be scanned using a straight beam technique such that all major planes are covered.

4.5.4.1.1 Disc and disc-type forgings. Disc and disc-type forgings shall be scanned using a straight beam from at least one flat face and radially from the circumference when possible.

4.5.4.1.2 Cylindrical, ring and hollow forgings. Scan cylindrical sections, ring and hollow forgings from the entire external surface using the straight-beam technique, and scan the forging in the axial direction to the maximum extent possible. If axial penetration is not possible due to attenuation, angle-beam

examination directed axially may be substituted in place of axial straight beam. Examine ring and hollow forgings having an outside diameter to inside diameter ratio of less than 2 to 1 and a wall thickness less than 8 inches by angle-beam techniques from the outside or inside diameter or both.

4.5.4.2 Acceptance criteria. Unless otherwise specified (see 6.2), acceptance criteria shall be to class A of MIL-STD-2154.

4.5.5 Liquid penetrant inspection. Liquid penetrant inspection of 100 percent of the forging surface shall be performed in accordance with MIL-STD-271. Unless otherwise specified (see 6.2), the forging shall meet the following acceptance criteria:

- (a) Linear indications: None shall be allowed.
- (b) Rounded indications in excess of:
 - (1) Linear: Lines of four or more separated from each other by less than 1/16 inch shall be rejected.
 - (2) Nonlinear: Material exhibiting rounded indications in excess of those specified in table IV shall be rejected.

(Rounded indications are indications that are circular or elliptical with the long axis less than three times as long as the other axis and with no sharp corners.)

TABLE IV. Allowable nonlinear rounded indications.

Maximum size, inch (mm)	Cumulative number per square inch (25 mm square)
Up to 1/32 (0.8), inclusive	20
Over 1/32 (0.8) to 1/16 (1.9), inclusive	10
Over 1/16 (1.9)	0

4.5.5.1 Numerical limits. For purposes of determining compliance with the specified limits, an observed value or a calculated value shall be rounded off in accordance with the rounding off method of ASTM E 29.

4.6 Replacement, retest and resubmittal.

4.6.1 Mechanical property retests. If any test specimen shows defective machining or develops flaws, it may be discarded and a replacement test specimen substituted. If one of the specimens fail to meet the specified requirements two additional specimens shall be taken (one from the same piece as the failed specimen and one from a different sample piece) and tested. Failure to meet the specified requirements of either one of the retests shall cause the entire lot to be rejected.

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4.6.2 Rejected lots. A rejected lot may be resubmitted for acceptance testing only after rework as necessary is performed to correct the nonconforming condition without adversely affecting conforming properties. If the rejected lot is reheat treated to correct a nonconforming characteristic, all mechanical properties, including those which were initially conforming shall be determined.

4.6.3 Individual pieces. When a rejected lot consists of more than one piece, the contractor may resubmit each remaining piece in the lot for testing for the nonconforming characteristic and each piece that conforms to all specification requirements may be offered for acceptance.

4.7 Inspection of packaging. Sample packages and packs and the inspection of the packaging (preservation, packing and marking) for shipment and storage shall be in accordance with the requirements of section 5 and the documents specified therein.

5. PACKAGING

(The packaging requirements specified herein apply only for direct Government acquisition.)

5.1 Packaging. Material shall be preserved (level A, C or commercial) packed (level A, C or commercial) and marked including bar coding and other packaging (preparation for shipment and storage) acquisition options as specified (see 6.2) in accordance with MIL-STD-163.

6. NOTES

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

6.1 Intended use. Commercial pure titanium forgings are intended for use in mechanical and piping systems exposed to seawater and other corrosive environments where a lightweight, medium strength material is required.

6.2 Acquisition requirements. Acquisition documents should specify the following:

- (a) Title, number and date of this specification.
- (b) Issue of DODISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2.1.1 and 2.2).
- (c) If first article inspection is required (see 3.1).
- (d) Shape, dimensions and tolerances of forgings (see 3.7).
- (e) Forging stock dimensions and tolerances (see 3.7).
- (f) Whether a forging sketch is required (see 3.7).
- (g) Location of first article mechanical tests and acceptance criteria (see 4.3.2).
- (h) Whether ultrasonic and liquid penetrant inspection are not required (see 4.4.2.3).
- (i) Whether mechanical property shall be taken across the direction of metal flow (see 4.5.2).

- (j) Whether ultrasonic inspection criteria are other than specified (see 4.5.4.2).
- (k) Whether liquid penetrant acceptance criteria are other than specified (see 4.5.5).
- (l) Level of preservation, level of packing and other packaging acquisition options required (see 5.1).

6.3 Consideration of data requirements. The following data requirements should be considered when this specification is applied on a contract. The applicable Data Item Descriptions (DID's) should be reviewed in conjunction with the specific acquisition to ensure that only essential data are requested/provided and that the DID's are tailored to reflect the requirements of the specific acquisition. To ensure correct contractual application of the data requirements, a Contract Data Requirements List (DD Form 1423) must be prepared to obtain the data, except where DoD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1423.

<u>Reference Paragraph</u>	<u>DID Number</u>	<u>DID Title</u>	<u>Suggested Tailoring</u>
3.4, 3.5.1	DI-MISC-81020	Certification/data for nonnuclear level I material	----
4.4.2.3, 4.3.3	DI-MISC-80678	Certification data/report	10.3.1 does not apply
3.7, 4.4.2.2.3	DI-FORG-80412	Manufacturers forging sketch	----
4.3	DI-FORG-80962	First article forging report	----

The above DID's were those cleared as of the date of this specification. The current issue of DoD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL), must be researched to ensure that only current, cleared DID's are cited on the DD Form 1423.

6.3.1 Data requirements waiver instructions. The data requirements of 6.3 and any task in sections 3, 4 or 5 of this specification required to be performed to meet a data requirement may be waived by the contracting/acquisition activity upon certification by the offeror that identical data were submitted by the offeror and accepted by the Government under a previous contract for identical item acquired to this specification. This does not apply to specific data which may be required for each contract regardless of whether an identical item has been supplied previously (for example, test reports).

6.4 First article. When first article inspection is required, the contracting officer should provide specific guidance to offerors whether the item(s) should be a preproduction sample, a first article sample, a first production sample, or a standard production item from the contractor's current inventory, and the number of items to be tested as specified in 4.3.1. The contracting officer should also include specific instructions in acquisition

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documents regarding arrangements for examinations, approval of first article test results, and disposition of first articles. Invitations for bids should provide that the Government reserves the right to waive the requirement for samples for first article inspection to those bidders offering a product which has been previously acquired or tested by the Government, and that bidders offering such products, who may wish to rely on such production or test, must furnish evidence with the bid that prior Government approval is presently appropriate for the pending contract. Bidders should not submit alternate bids unless specifically requested to do so in the solicitation.

6.5 Subject term (key word) listing.

Consumable electrode melt
Electron beam melt
Macroscopic exam
Ultrasonic inspection
Liquid penetrant inspection

Custodians:

Army - MR
Navy - SH
Air Force - 99

Preparing activity

Navy - SH
(Project FORG-0216)

Review activities:

Army - ME
Navy - YD
Air Force - 20

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of the form.

NOTE: This form may not be used to request copies of documents, nor to request waivers, or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements.

I RECOMMEND A CHANGE:		1. DOCUMENT NUMBER MIL-T-24766	2. DOCUMENT DATE (YYMMDD) 920302
3. DOCUMENT TITLE TITANIUM FORGINGS AND FORGINGS STOCK, HIGH QUALITY FOR SHIPS SERVICE			
4. NATURE OF CHANGE (Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)			
5. REASON FOR RECOMMENDATION			
6. SUBMITTER			
a. NAME (Last, First, Middle Initial)		b. ORGANIZATION	
c. ADDRESS (Include Zip Code)		d. TELEPHONE (Include Area Code) (1) Commercial (2) AUTOVON (If applicable)	e. DATE SUBMITTED (YYMMDD)
8. PREPARING ACTIVITY			
a. NAME Technical point of contact: Mr. John Forney SEA 5142		b. TELEPHONE (Include Area Code) (1) Commercial 703-602-0143	(2) AUTOVON 332-0143
c. ADDRESS (Include Zip Code) Commander, Naval Sea Systems Command SEA 5523 Washington, DC 20362-5101		IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403, Falls Church, VA 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340	

