INCH-POUND

MIL-S-23284A(SH)
15 June 1990
SUPERSEDING
(See 6.4)

MILITARY SPECIFICATION

STEEL FORGINGS, CARBON AND ALLOY, FOR SHAFTS, SLEEVES, PROPELLER NUTS, COUPLINGS, AND STOCKS (RUDDERS AND DIVING PLANES)

This specification is approved for use within the Naval Sea Systems Command, Department of the Navy, and is available for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers carbon and alloy steel forgings for torsional shafts, including propulsion shafts for ships, sleeves, couplings, propeller nuts, rudder stocks, diving plane stocks, and related parts.

1.2 Classification. The forgings shall be made from the following classes of steel, as specified (see 3.4 and 6.2.1):

Class 1 - Nickel-molybdenum steel
Class 2 - Nickel-molybdenum steel
Class 3 - Carbon steel
Class 4 - Carbon steel
Class 5 - Nickel-chromium molybdenum steel
Class 6 - Nickel-chromium molybdenum steel

2. APPLICABLE DOCUMENTS

2.1 Government documents.

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 55Z3, 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

2.1.1 Specifications and standards. The following specifications and standards form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of these documents shall be those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation.

SPECIFICATIONS

FEDERAL

A-A-1894	- Paper, Kraft, Treated (Fire Resistant).

MILITARY

MIL-C-16173	- Corrosion Preventive Compound, Solvent Cutback, Cold-Application.
MIL-L-19140	- Lumber and Plywood, Fire-retardent Treated.

STANDARDS

MILITARY

MIL-STD-22	- Welded Joint Design.
MIL-STD-248	- Welding and Brazing Procedure and Performance Qualification.
MIL-STD-271	- Requirements for Nondestructive Testing Methods.
MIL-STD-278	- Welding and Casting Standard.
MIL-STD-731	- Quality of Wood Members for Containers and Pallets.
MIL-STD-792	- Identification Marking Requirements for Special Purpose Components.
MIL-STD-1684	- Control of Heat Treatment.
MIL-STD-2073-1	- DoD Materiel Procedures for Development and Application of Packaging Requirements.

(Copies of specifications and standards required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting activity.)

2.2 Other publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted shall be those listed in the issue of the DoDISS specified in the solicitation. Unless otherwise specified, the issues of documents not listed in the DoDISS shall be the issue of the nongovernment documents which is current on the date of the solicitation.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

B46.1 - Surface Texture (Surface Roughness, Waviness, and Lay). (DoD adopted)

(Application for copies should be addressed to the American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

A 370 - Standard Test Methods and Definitions for Mechanical Testing of Steel Products. (DoD adopted)

A 700 - Standard Practices for Packaging, Marking and Loading Methods for Steel Products for Domestic Shipment. (DoD adopted)

A 751 - Standard Methods, Practices, and Definitions for Chemical Analysis of Steel Products.

E 10 - Standard Test Method for Brinell Hardness of Metallic Materials. (DoD adopted)

E 45 - Standard Practice for Determining the Inclusion Content of Steel. (DoD adopted)

E 112 - Standard Methods for Determining Average Grain Size. (DoD adopted)

E 381 - Standard Method of Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings. (DoD adopted)

E 616 - Standard Terminology Relating to Fracture Testing.

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

(Nongovernment standards and other publications are normally available from the organizations which prepare or which 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 specification and the references cited herein (except for associated detail specifications, specification sheets or MS standards), the text of this specification shall take precedence. Nothing in this specification, however, shall supersede applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 First article. First article inspection is required for all classes of material listed herein (see 4.3 and 6.3) unless otherwise specified (see 6.2.1).

3.2 Melting. Unless otherwise specified (see 6.2.1), steel shall be cast in metal molds or continuous cast, and shall be electric furnace steel or vacuum induction melted (VIM) steel. Primary melting may incorporate separate degassing or refining and may be followed by secondary melting using electroslag remelting (ESR) or vacuum arc remelting (VAR).

3.2.1 Degassing. Unless otherwise specified (see 6.2.1), molten steel shall be vacuum degassed prior to or during pouring of the material to remove objectionable gasses, particularly hydrogen. When VAR is used, vacuum degassing of the primary melt is optional.

3.2.2 Recovered materials. Unless otherwise specified herein, all material covered by this specification shall be new and may be fabricated using 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 solid waste and reprocessed to become a source of raw materials, as opposed to virgin raw materials. When specified (see 6.2.1), virgin raw material may be required for critical applications.

3.3 Forging process. The original cross-sectional area of the ingot shall be at least three times the cross-sectional area of the main body of the forging. Flanges and other enlargements on forgings need not be reduced to the ratio of 3 to 1, but shall be reduced to a ratio of not less than 1.7 to 1. Total reduction of cross-sectional area shall also be sufficient so that the material conforms to the requirements of this specification. If bored ingots are used, the wall of the ingot shall be reduced to at least one-half its original thickness, or the reduction of cross-sectional area shall be at a ratio 3 to 1. When an upsetting operation is employed, or the forging is expanded on a mandrel, the metal shall be worked to an extent not less than specified above, but in no fixed ratio between the cross-sectional area of the ingot and that of the forging.

3.3.1 Centerline. When ingots or forgings are bored, the bored hole shall include the centerline of the ingots or forgings.

3.4 Chemical composition. The chemical composition of the forgings shall conform to table I (see 4.4.3.1.1) within the allowable check analysis limits of table II.

TABLE I. Chemical composition (weight percent). 2/ 4/

Element	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
	Percent, maximum unless a range is shown					
Carbon	0.28	0.26	0.35	0.30	0.27	0.30
Manganese	0.15 -- 0.45	0.15 -- 0.45	0.60 -- 0.90	0.60 -- 0.90	0.20 -- 0.45	0.20 -- 0.45
Phosphorus 1/	0.020	0.020	0.020	0.020	0.015	0.015
Sulphur 1/	0.015	0.015	0.015	0.015	0.015	0.015
Silicon 3/	0.35	0.35	0.35	0.35	0.35	0.35
Nickel	2.75 -- 3.50	2.75 -- 3.25	----	----	2.75 -- 3.90	2.75 -- 3.90
Chromium	0.50	0.50	----	----	1.50 -- 2.00	1.50 -- 2.00
Molybdenum	0.25 -- 0.60	0.25 -- 0.60	----	----	0.40 -- 0.60	0.40 -- 0.60
Vanadium	0.08	0.05	----	----	0.03	0.03
Copper	----	----	----	----	0.25	0.25
Tin	----	----	----	----	0.030	0.030
Arsenic	----	----	----	----	0.025	0.025
Titanium	----	----	----	----	0.02	0.02
Antimony	----	----	----	----	0.025	0.025
Boron	----	----	----	----	0.01	0.01
Bismuth 5/	----	----	----	----	0.003	0.003
Cadmium 5/	----	----	----	----	0.003	0.003
Lead 5/	----	----	----	----	0.003	0.003
Zinc 5/	----	----	----	----	0.003	0.003

1/ The percentage of phosphorus and sulphur together shall not exceed 0.03 percent.
2/ The chemical composition shall be adjusted for section size and heat treatment within the maximum limits in order to meet mechanical properties. The requirements for all classes are percent maximum unless a range is shown.
3/ When vacuum carbon deoxidation is used, the silicon maximum shall be 0.12 percent.
4/ Percentages of all elements in the table where limits are shown shall be recorded. In addition, any elements intentionally added by the manufacturer shall be reported.
5/ Not required for heat analysis (see 4.4.2.1).

3.4.1 Heat analysis. The heat analysis shall conform to the specified chemical analysis with the exception that analyses for bismuth, cadmium, lead and zinc are not required (see table I and 4.4.2.1).

3.4.2 Check analysis variation. Check analysis variations of the elements shall not be over the upper limits or under the lower limits by more than the percentages listed in table II. Check analysis variations are not allowed for heat analysis.

TABLE II. Allowable check analysis variations (weight percent).

Element	Cross-sectional area, square inches 1/				
	100 or less	Over 100 to 200, incl.	Over 200 to 400, incl.	Over 400 to 800, incl.	Over 800
Classes 1 and 2					
Carbon	0.01	0.01	0.02	0.02	0.02
Manganese	0.03	0.04	0.05	0.06	0.07
Phosphorous	None	None	None	None	None
Sulfur	None	None	None	None	None
Silicon	0.02	0.02	0.03	0.04	0.04
Nickel	0.07	0.07	0.07	0.07	0.07
Chromium	0.03	0.04	0.04	0.05	0.05
Molybdenum	0.03	0.04	0.05	0.06	0.07
Vanadium	None	None	None	None	None
Classes 3 and 4					
Carbon	None	None	None	None	None
Manganese	0.03	0.04	0.05	0.06	0.07
Phosphorous	0.008	0.010	0.010	0.010	0.015
Sulfur	0.008	0.010	0.010	0.010	0.015
Silicon	0.02	0.02	0.03	0.04	0.04
Classes 5 and 6					
Carbon	None	None	None	None	None
Manganese	0.04	0.04	0.05	0.06	0.07
Phosphorous	None	None	None	None	None
Sulfur	None	None	None	None	None
Silicon	0.02	0.02	0.03	0.04	0.04
Nickel	0.07	0.07	0.07	0.07	0.07
Chromium	0.06	0.06	0.06	0.07	0.07
Molybdenum	0.04	0.04	0.05	0.06	0.07
Vanadium	0.02	0.02	0.02	0.02	0.02
Copper	None	None	None	None	None

1/ Cross-sectional area is the maximum area intercepted by a plane normal to the principal forging axis in the final heat-treated configuration.

3.5 Mechanical properties. After all heat treatments, including stress relief, the forgings shall meet the requirements for mechanical properties specified in table III (see 4.4.3.1.4). If it is not practical to test for mechanical properties after stress relief, a section of prolongation may be subjected to a simulated stress relief and tested (see 3.9) with the exception that all mechanical testing required for acceptance shall be performed. In the case where mechanical property data are required from each end of the forging and the manufacturer wishes to perform simulated stress relief, a section of prolongation from each end of the forging shall be subjected to simulated stress relief. It is not intended that mechanical properties be determined following stress relief of weld clad areas.

TABLE III. Mechanical properties.

	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
Yield strength at 0.01 percent offset, pounds per square inch (lb/in^2) minimum	75,000	55,000	45,000	35,000	75,000	90,000
Yield strength at 0.2 percent offset lb/in^2 minimum 5/						
Tensile strength, lb/in^2	95,000/ 115,000	80,000/ 100,000	75,000/ 95,000	60,000/ 80,000	105,000/ 130,000	110,000/ 140,000
Elongation in 2 inches, longitudinal, percent	20	22	22	25	20	18
Elongation in 2 inches, transverse, percent 1/	17	19	19	22	18	16
Reduction of area, longitudinal, percent	45	45	45	45	45	45
Reduction of area, transverse, percent 1/	30	30	30	40	40	40
Charpy V-notch impact (foot pounds) 2/ Test temperature, degrees Fahrenheit (°F)						
plus 10 ± 3	30	30	-	-	-	-
minus 30 ± 3	3/	3/	-	-	35	35
plus 28 ± 3	-	-	20	20	-	-
Brinell hardness 10-mm standard ball 3000-Kilogram load 4/	190-261	162-209	152-200	120-165	190-261	228-294

1/ When transverse properties are required (see 6.2.1), this applies to shaft couplings, sleeves, and as specified for similar parts.
2/ Average of three tests, minimum. No test shall be below the average required minimum by more than 5 foot-pounds.
3/ Impact values shall be recorded.
4/ See 3.7.3.
5/ To be reported for information only.

3.7 Dimensions. Finished dimensions of the forgings shall be as specified on the forging sketches or drawings. The rough forgings shall have sufficient stock to permit satisfactory finishing and provide for removal of test specimens (see 4.4.3.1.2 and 4.4.3.2.1).

3.7.1 Straightening of distorted forgings. If finished dimension cannot be met because of distortion, no corrective action shall be taken other than as specified. Straightening shall be performed at any stage of manufacture as required to meet the finished dimensions specified. When straightening is required after final temper for properties, a stress relief shall be performed at 50°F below the final tempering temperature.

3.7.2 Finished forgings. Each forging shall be forged as closely as possible to the finished (as supplied) shape and size.

3.7.2.1 Discard. Sufficient discard shall be taken from each ingot to insure freedom from piping and to meet the microstructural (see 3.8.4) and nonmetallic inclusion requirement (see 3.8.5).

3.7.3 Multiple unit forgings. If practicable, when multiple unit forgings are used, the forgings shall be machined apart to separate the individual units before heat treatment. For multiple unit forgings containing a variety of units with different section thicknesses, sample material representing each type of unit with a different section thickness shall be tested for mechanical properties. In this case, all units from one forging shall be heat treated in the same furnace charge and the sample material shall remain integrally attached to the part until after heat treatment is completed. For multiple unit forgings, each unit shall exhibit an average Brinell hardness, for three test determinations, that conforms to table III and that is within 20 points Brinell of the average hardness reported for the forgings which were tested for mechanical properties (see 4.4.3.1.5).

3.7.4 Hollow forgings from solid cylindrical forgings. Where hollow forgings are to be machined from solid cylindrical forgings, the forgings shall be bored before heat treatment. If it is not practical to bore prior to heat treatment, impact specimens shall be removed from the minimum distance possible below the final inside diameter of the component except that the test location is not required to be deeper than mid radius of the solid cross section.

3.7.5 Forgings weighing 1000 pounds or less. Unless otherwise specified (see 6.2.1), after heat treatment each forging weighing 1000 pounds or less shall be Brinell hardness tested as specified in 4.4.3.1.5 and shall conform to table III.

3.8 Heat treatment. The contractor shall determine the detailed heat treatment that shall produce forgings to meet the requirements of this specification. As appropriate for the required properties, the classes shall be either normalized and tempered, or quenched and tempered. For the quench and tempered condition, the forgings shall be normalized before heat treating (heating, quenching, and tempering) for properties and, when necessary, stress relief annealed after tempering.

3.8.1 Quenched and tempered forgings. Quenched and tempered forgings shall be rough machined and rough bored, as applicable, prior to heating, quenching, and tempering. If a spray quench is used, the number and location

of spray nozzles, and the flow rate of the quenchant shall be adequate to provide for proper quenching. Maintenance, number and location of spray nozzles, and flow rate of quenchant shall be specifically addressed in the quality control program (see 4.1.1).

3.8.1.1 Horizontal quenching. When horizontal quenching is employed for hollow forgings, a mechanism (e.g. water lance) shall be used to ensure that the inside diameter of the component receives adequate quenchant flow.

3.8.2 Heat treating equipment and controls. Continuous or automatic heat treating equipment may be employed, provided it produces heat treated material to meet the requirements of this specification. For the particular loading and size range of the pieces being heat treated, the temperature recording equipment shall be proven to correlate with actual temperature of the material and shall be maintained and calibrated on a regular basis. The temperature of the furnace charge shall be recorded during the heating, holding and cooling cycles of the heat treatment. After the charge reaches the selected temperature control setting, furnaces shall maintain the temperature of any point of the furnace charge within plus or minus 25°F.

3.8.2.1 Heat treatment equipment and procedures. Heat treating equipment and procedures shall be in accordance with MIL-STD-1684, when specified (see 6.2.1).

3.8.2.2 Heat treatment records. A record of the time and temperature of all heat treatments shall be available for inspection by the contracting activity.

3.8.3 Stress relief temperature. Unless otherwise specified (see 6.2.1), the stress relieving temperature shall be at least 50°F below the tempering temperature and shall be not less than 1050°F.

3.8.3.1 Cooling rate. For classes 1, 2, 3, and 4 stress relief shall be followed by furnace cooling to 600°F under uniform conditions at an average rate not to exceed 150°F per hour. The part may be cooled in still air when the temperature of the part is below 600°F. Report cooling rate for classes 5 and 6.

3.8.4 Microstructure. Specimens from all forgings, when examined at a magnification of 100 diameters, shall show a homogeneous structure; that is, one in which the normal constituents are evenly distributed, free from decided segregation of any constituents, or excessive inclusions (see 3.8.5). The material, when examined at a magnification of 100 diameters, shall have a grain size of 5 or finer (see 4.4.3.1.6). The area under examination shall show at least 95 percent of the structure with a grain size of number 5 or finer. Tests shall be in accordance with ASTM E 112.

3.8.5 Nonmetallic inclusion content Specimens from all final forgings shall be examined for inclusion content in accordance with ASTM E 45, method A. The inclusion content shall not exceed:

A	B	C	D
3.0t 1.5h	2.5t 1.0h*	3.0t 1.5h	2.0t 1.0h*

*Maximum allowable diameter of heavy oxide inclusion is 0.002 inch as determined by reference to ASTM E 45, method A.

3.9 Stress relief simulation. When specified (see 6.2.1), material to simulate stress relief treatments shall be heat treated in accordance with 4.4.3.1.8.

3.9.1 Weldment. When specified (see 6.2.1), a full section integral prolongation of material shall be welded, ground flush with the surface and subjected to simulated stress relief treatment in accordance with 4.4.3.1.8. After stress relief, testing shall be performed in accordance with weld procedure qualification requirements of MIL-STD-248.

3.10 Surface finish. The surface roughness of the forging shall not exceed 250 microinches roughness height rating in accordance with ANSI B46.1. The depth of scale, pits, or other defects shall not exceed 0.015 inch (0.381 millimeters (mm)) and shall not result in an undergauge condition. Isolated, individual pits not over 0.030 inch (0.762 mm) deep or within 6 inches (150 mm) of each other shall be acceptable provided the forging thickness shall not be reduced below the specified minimum (see 4.4.3.1.2, 4.4.3.1.3.1, and 4.4.3.1.3.2).

3.11 Soundness. Sufficient discard shall be taken from each ingot to ensure freedom from pipe and undue segregation. Unless otherwise specified herein, the forgings shall be uniform in quality and shall not contain bursts, pipe, flakes, cracks, undue segregation, hard spots, porosity, seams, laps, slivers, scabs, or forged in scale. Unless otherwise specified (see 6.2.1), the forgings shall not contain defects that exceed the acceptance criteria of appendix A.

3.12 Flame cutting. Flame cutting in the bore or metal removal from the bore by thermal means is not permitted. Flame cutting or metal removal from outer surfaces by any thermal means is not permitted after heat treatment.

3.13 Stability. Material shall be furnished in a stable condition to withstand, for an indefinite time, the development of external or internal cracks.

3.14 Macrostructure. The macrostructure shall be determined for first article (see 4.4.3.1.7). Deep acid etched forgings up to and including 36 square inches shall be equal to or better than S-3, R-2, and C-3 plates of ASTM E 381. Sizes over 36 and including 100 square inches shall be equal to or better than S-3, R-3 and C-3. For sizes in excess of 100 square inches, macrostructure requirements shall be as specified (see 6.2.1).

3.15 Repair of defects.

3.15.1 Removal of defects by grinding or chipping. Defects may be removed by grinding or chipping provided the areas involved are well flared into the surrounding areas and sufficient stock is left to allow subsequent finishing. The areas involved shall be magnetic particle tested in accordance with MIL-STD-271 to ensure that the defects have been completely removed.

3.15.2 Repair welding. Unless otherwise specified (see 6.2.1), repair welding shall not be permitted.

3.15.3 Repair procedures. When permitted by the contracting activity (see 6.2.1), weld repair shall be performed in accordance with MIL-STD-278. Unless otherwise specified (see 6.2.1), welding procedure and performance qualification shall be in accordance with MIL-STD-248 prior to welding.

3.16 Cleaning and preservation of forging surface. Before the forgings are accepted by the contracting activity, the forging surfaces shall be descaled preserved for the specified environment and exposure duration (see 6.2.1). Markings and identification of forgings and test pieces shall be preserved with a protective coating, type P-19, in accordance with MIL-P-116 to prevent corrosion so that markings shall be discernible and legible without removing the protective coating.

3.17 Applicable fabrication document. If applicable, the fabrication document for the forging shall be specified (see 6.2.1).

3.18 Identification.

3.18.1 Marking. Individual forgings shall be marked with the following information order as follows:

(a) Military specification number, revision number, and alloy class, as in MIL-S-23284A-CLX.
(b) Heat or forging number (traceability code).
(c) Manufacturer's name, trademark or symbol.
(d) Final tempering temperature in °F as in TT XXXX F.
(e) Stress relief temperature in °F as in SR XXXX F.
(f) Drawing or die number.

3.18.2 Preparation for marking. Markings shall be in accordance with MIL-STD-792. Markings shall be clearly made following surface preparation by machining, grinding or polishing to assure readily discernible identification marking. Unless otherwise specified (see 6.2.1), the forgings shall be marked only in areas that will not be removed by final machining. Special markings shall be as specified (see 6.2.1).

3.18.3 Marking exceptions. If all the markings in 3.18.1 cannot be applied because of size or space limitations, then permanent marking shall be applied using the order specified in 3.18.1 (abbreviations shall be permitted). If there are size or space limitations, the forgings shall be packaged (bundled or boxed) and each package shall be identified with a metal or oil proof tag securely affixed to the package. The tags shall contain all the information specified in 3.18.1.

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 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 the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items must 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 assuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling in quality conformance does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to acceptance of 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 all examinations and tests as specified herein.

4.3.1 First article samples. The first article sample shall consist of sufficient material from one heat to obtain measurements of the notch toughness, mechanical properties of the materials, its weldability, response to stress relief, and the first article inspection.

4.3.2 First article inspection report. When specified in the contract or order, a first article inspection report shall be prepared (see 6.2.2 and appendix B).

4.4 Quality conformance inspection. Quality conformance inspection shall consist of the inspections specified in 4.4.3. When specified in the contract or order, a certificate of compliance shall be prepared (see 6.2.2 and appendix C).

4.4.1 Lot.

4.4.1.1 Lot for chemical composition. Each heat for ingot cast and each ladle for strand cast steel shall be a lot for chemical analysis. In the case of continuous casting, each bloom, billet or slab utilized for reforging shall be considered a lot. For remelted vacuum arc remelt or electroslag remelt products, a lot for analysis consists of the products of each remelted ingot of each melt. In the case of secondary melting or ladle refining, each charged vessel is considered a lot for heat analysis.

4.4.1.2 Lot for tensile and impact tests.

4.4.1.2.1 Forgings with an as heat treated weight of less than 1,000 pounds. Unless otherwise specified (see 6.2.1), all forgings of one design, produced from the same heat or melt, and heat treated in the same furnace charge, shall constitute a lot.

4.4.1.2.2 Forgings with an as heat treated weight of 1,000 pounds or more. Unless otherwise specified (see 6.2.1), each forging shall constitute a lot.

4.4.1.3 Lot for visual and dimensional test. Unless otherwise specified (see 6.2.1), each forging shall constitute a lot.

4.4.1.4 Lot for ultrasonic, magnetic particle and dye penetrant tests. Unless otherwise specified (see 6.2.1), each forging shall constitute a lot.

4.4.1.5 Lot for microstructure. The lot for microstructure tests shall be as specified (see 6.2.1).

4.4.2 Sampling.

4.4.2.1 Sample for chemical analysis. One sample from a forging in each lot shall be taken for chemical analysis or in the case of propulsion shafting, one sample shall be taken from each end of the forging. If more than one heat is used for a forging, a sample shall be taken from each end of the forging and analyzed separately. In addition, when three or more heats are used for a single forging, heat analyses from each heat shall be required and shall conform to 3.4.1. Samples shall be taken at the mid-radius of solid forgings and at the mid-wall thickness of hollow forgings, near the end of the forging, usually in a prolongation. Each sample for chemical analysis shall consist of at least 2 ounces of chips and shall be free of oil, grit or other foreign matter. Solid samples shall be taken in lieu of chips when the analysis is made by the spectrographic method.

4.4.2.2 Sampling for mechanical tests. One sample from a forging in each lot shall be taken for mechanical tests. Forgings for shafts, sleeves, rudder stocks and diving plane stocks shall have one sample removed from each end of a forging in each lot. For forgings with large flanges or other enlargements, the cross-sectional area of each prolongation shall be approximately the same as the average cross-sectional area of the rough forging, exclusive of flanges or enlargements.

4.4.3 Inspection.

4.4.3.1 Tests and examinations.

4.4.3.1.1 Chemical analysis. The samples selected in accordance with 4.4.2.1 shall be analyzed in accordance with ASTM A 751 and shall conform to 3.4.

4.4.3.1.2 Dimensional inspection. Each forging shall be dimensionally inspected and shall conform to 3.7 and 3.10.

4.4.3.1.3 Soundness inspection.

4.4.3.1.3.1 Visual inspection. Each forging shall be visually examined after final heat treatment, stress relief, and machining. The entire forging surface (including bores) shall be visually examined in accordance with MIL-STD-271 and shall conform to 3.10 and 3.11.

4.4.3.1.3.2 Magnetic particle inspection. Unless otherwise specified (see 6.2.1), all exterior surfaces of each forging from each lot shall be inspected in accordance with the appendix and shall conform to the acceptance criteria or shall be rejected. Forgings shall be in the finish machined condition and shall have a suitable finish (see 3.10). When allowed, defects

shall be repaired (see 3.15). When geometric configuration prevents meaningful magnetic particle inspection, liquid penetrant inspection shall be performed in accordance with MIL-STD-271.

4.4.3.1.3.3 Ultrasonic inspection. Forgings 3/4 inch (19 mm) or greater in section thickness shall be ultrasonically inspected in accordance with appendix A. When specified (see 6.2.1), each forging of less than 3/4-inch (19-mm) thickness shall be ultrasonically inspected in accordance with the appendix A. Sections of forgings which exceed limits of ultrasonic examination requirements shall be repaired in accordance with 3.15.

4.4.3.1.4 Mechanical property. Unless otherwise specified (see 6.2.1), each lot shall be inspected in accordance with ASTM A 370 and shall conform to 3.5. Mechanical property tests shall be performed after the final heat treating operation, including the stress relieving treatment.

4.4.3.1.5 Brinell hardness tests. Brinell hardness tests shall be conducted in accordance with ASTM E 10. The test shall be conducted subsequent to heat treatment and at least three determinations shall be conducted on each unit.

4.4.3.1.6 Grain size determinations. The actual grain size of the material offered for acceptance shall be determined in accordance with ASTM E 112 and shall meet the requirements of 3.8.4.

4.4.3.1.7 Inspection for macrostructure. The macrostructure on the final forging product prolongation shall be determined and shall conform to 3.14.

4.4.3.1.8 Stress relief simulation. Material to simulate stress relief treatments shall be heat treated in accordance with the following:

(a) Sample material shall remain attached to the forging during heat treatment and shall be taken from an integral prolongation. After heat treatment, and prior to stress relief, the sample material shall be removed from the forging. Sufficient sample material shall be obtained for impact testing in the non-stress relieved condition. Impact testing in the non-stress relieved condition shall duplicate Charpy V-notch tests required for acceptance with respect to quantity, location, depth and orientation. Remaining material shall be subjected to the simulated stress relief.

(b) Simulated stress relief heat treatment of sample material shall be identical to that of production forgings in every respect. This shall include, but shall not be limited to, stress relief temperature, time at stress relief temperature, number of stress relief heating cycles, and maximum cooling rate for each cycle from the stress relief temperature.

(c) Total time at temperature for stress relief of sample material shall be equal to the total time anticipated for stress relief of the production forging.

(d) The average cooling rate for the stress relieving temperature to 600°F shall be determined and recorded. Sample material may be air cooled after the material temperature is reduced to 600°F.

4.4.3.1.8.1 Weld procedures. Welding shall be in accordance with MIL-STD-278. Weld procedure and performance qualification shall be in accordance with MIL-STD-248.

4.4.3.1.8.1.1 Electrodes. Low hydrogen electrodes compatible with S-1 materials for class 3 and 4 base materials and with S-11A materials for class 1, 2, 5, and 6 base materials shall be used.

4.4.3.1.8.1.2 Weld joint. The weld shall be circumferential for cyulindrical pieces. The weld shall conform to plate requirements for other shapes. The depth of the weld joint shall be 1 inch, or 1/2 the wall thickness of hollow forgings, or 1/2 the thickness of solid forgings, whichever is less. A weld joint design in agreement with B2J.1 of MIL-STD-22 shall be used except a maximum incline of 7 degrees shall be allowed on the non-beveled edge. Impact specimens shall be removed from the non-beveled edge.

4.4.3.1.8.1.3 Impact specimens. Impact specimens shall be removed as near as practical to mid-depth of the weld joint. The longitudinal axis of heat affected zone specimens shall be perpendicular to the "non-beveled" (maximum bevel of 7 degrees) face of the weld joint. The notch opening shall face the free surface of the piece. They shall be polished and etched to define the heat affected zone prior to machining the notch. Coupons shall be cut in such a manner as to include as much as possible of the heat affected zone in the resulting fracture.

4.4.3.2 Test specimens.

4.4.3.2.1 Types of specimens. The test specimens shall conform to the largest test specimens which can be produced from the test prolongation in accordance with ASTM A 370.

4.4.3.2.2 Location of test specimens. For solid shafts, rudder stocks, diving plane stocks and propeller nuts, the specimens shall be taken at a distance from the end of the forging equal to at least the radius. For hollow forgings, the specimens shall be taken at a distance from the end of the forging equal to at least the wall thickness.

4.4.3.2.3 Longitudinal test specimens. Longitudinal test specimens shall be taken from a full-size prolongation of the forging in the direction in which the material is most drawn.

4.4.3.2.4 Transverse test specimens. Transverse test specimens shall be taken from a full-size prolongation of the forging in the direction perpendicular to which the metal is most drawn. When it is impractical to obtain transverse test specimens, longitudinal test specimens shall be taken from the appropriate locations.

4.4.3.2.5 Tensile specimens. In the case of shafts, stocks, sleeves, and couplings, tensile specimens shall be taken from each end of each forging. For solid shafts or stocks, the specimens shall be taken as shown on figure 1. For hollow shafts or stocks, the specimens shall be taken as shown on figure 2. For couplings and sleeves, the specimens shall be taken as shown on figure 3. For propeller nuts, the specimens shall be taken as shown on figure 4.

4.4.3.2.6 Macrostructure specimens. The macrostructure test specimens shall be in accordance with ASTM E 381.

4.4.3.2.7 Charpy V-notch specimens. For shafts, stocks and sleeves, a group of three Charpy V-notch specimens shall be taken from each end of each forging for each test temperature. Other forgings shall have a group of three charpy V-notch specimens removed from one end of the forging. Specimens shall be taken at mid-radius for solid forgings and at mid-wall thickness for hollow forgings (see figures 1, 2, 3, and 4). Specimen and notch position shall be in accordance with the C-L orientation of ASTM E 616 for the crack plane orientation code for bars and hollow cylinders.

4.4.3.2.8 Brinell hardness determination. At least three hardness test determinations on the outside diameter spaced 120 degrees apart shall be made on each forging in an area representing the heaviest section of each forging which is to subsequently be machined.

4.4.3.2.9 Grain size determination. Two cross-sectional grain size specimens shall be obtained from undeformed ends of two broken mechanical property acceptance test specimens from each lot and tested. When a lot consists of more than one forging the two specimens (mid-wall or mid-radius specimens) shall be obtained from different forgings. For those forgings with test areas provided on each end of the forging, one specimen shall be obtained from each test area of two forgings in the lot or from one forging if the lot consists of one forging. At the option of the contractor, samples may be taken from material adjacent to the acceptance mechanical property specimens in lieu of samples taken from broken mechanical property acceptance test specimens.

4.4.3.2.10 Macroscopic etch specimens. Cross-sectional specimens for the macroscopic etch test shall consist of material approximately 1/2-inch thick cut from each end of the forging and subject to a hot acid etch.

4.4.3.2.11 Microscopic specimens. One or more cross-sectional specimens shall be taken from each location where a tensile specimen is taken. When a broken tensile or Charpy impact specimen is used for this test, the microscopic specimen shall be taken from the unbroken end of the specimen.

4.4.3.2.12 Nonmetallic inclusion content specimens. One longitudinal specimen shall be taken from each end of each hollow forging as shown in figure 5. The specimen shall be removed a minimum of 1-inch below the outside surface. In the case of propeller nuts and couplings, only one specimen shall be taken.

4.4.3.2.13 Specimens required when multiple parts are forged from one piece. When multiple parts are made and heat treated as one forging, both ends of the forging shall be sampled. Location and number of specimens for the sampling required shall be governed by the largest or principal forgings of the combined forging. Tests will not be required for the individual pieces when tests are made on the forging as a whole.

4.5 Resubmittal of rejected forgings or lots.

4.5.1 Rejection. Individual forgings not meeting requirements of this specification shall be subject to rejection. If a forging representing a lot

fails to meet chemical composition requirements, the lot shall be rejected. Retests shall be allowed and shall be in accordance with this section.

4.5.2 Identification and separation of rejected lots. The contractor shall keep rejected lots identified and separate from acceptable lots until the rejected lots are withdrawn by the contractor or demonstrated as meeting specification requirements.

4.5.3 Rejected forgings or lots. A rejected forging or lot shall be resubbmitted for acceptance testing at the contractor's option provided the forging or forging lot is reworked, reheat treated, or retempered to correct the nonconforming condition and reinspected to all applicable requirements of this specification at the contractor's expense.

4.5.4 Rejection if more than one piece. When a rejected lot consists of more than one piece, each remaining piece in the lot other than the nonconforming piece may be tested for the nonconforming characteristic and each piece that conforms to specification requirements shall be offered for acceptance.

4.5.5 Retests (tensile test). One retest shall be permitted if any test characteristic fails to meet specification requirements.

4.5.6 Retests (Charpy impact). One retest of three new specimens shall be permitted if the average value of the three initial specimens equals or exceeds 25 foot-pounds at 10°F for class 1 or class 2, or equals or exceeds 15 foot-pounds at 28°F for classes 3 and 4, or equals or exceeds 30 foot-pounds at minus 35°F for classes 5 and 6. The values of each of the retest specimens shall equal or exceed the required average values.

4.5.7 Retests (defective materials). If results of mechanical tests do not conform to the specified requirements because a flaw is found in the specimen during testing, a retest may be allowed if the defect is not caused by ruptures, cracks, or flakes in the steel.

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

5. PACKAGING

5.1 General.

5.1.1 Navy fire-retardant requirements.

a. Treated lumber and plywood. When specified (see 6.2.1), all lumber and plywood including laminated veneer material used in shipping container and pallet construction, members, blocking, bracing, and reinforcing shall be fire-retardant treated material conforming to MIL-L-19140 as follows:

Levels A and B - Type II - weather resistant.
Category 1 - general use.

Level C - Type I - non-weather resistant.
Category 1 - general use.

5.2 Preservation. Preservation shall be level A or commercial as specified (see 6.2.1).

5.2.1 Level A.

5.2.1.1 Preservation application. Machined or finished surfaces of forgings shall be protected with an application of preservative conforming to grade 1 or grade 4 of MIL-C-16173.

5.2.1.2 Wrapping. Forgings without preservation application, shall be individually wrapped with a minimum of two thicknesses of 40-pound basic weight kraft paper. Forgings with preservative application, two thicknesses of equal weight greaseproof paper shall be used for wrapping. When complete wraping is not pratical because of configuration, size or weight, the finished or polished surface(s) shall be provided protection from damage with suitable covers. When specified (see 6.2.1), the kraft paper shall be fire resistant meeting the requirements of A-A-1894.

5.2.2 Commercial. Unless otherwise specified (see 6.2.1), commercial preservation (packaging) shall be in accordance with the requirements for "castings" of ASTM A 700, section 14.

5.3 Packing. Packing shall be level A, B, C, or commercial as specified (see 6.2.1).

5.3.1 General requirements for levels A, B, and C. Shipping containers selected (see 5.3.2) shall be of minimum weight and cube of uniform size and construction, and contain identical quantities of identical forgings of one size, melt or lot number. Forgings that are packed into containers shall be blocked, braced or otherwise secured to prevent their movement and damage. Forging having projections that may be damaged during handling, shipment and storage shall have the projections protected with batten strips.

5.3.2 Levels A, B, and C containers. Forgings shall be packed in nailed wood, wood cleated plywood or wirebound boxes, or in open or covered wood or wirebound crates as specified in MIL-STD-2073-1A, Appendix C for the level of packing specified (see 5.3) and herein. Unless otherwise specified (see 6.2.1), containers selection shall be at the option of the supplier.

5.3.2.1 Packing quantity and weight.

5.3.2.1.1 Small forgings (finished or polished and other). Forgings weighing less than 200 pounds shall be packed individually, or in multiple units in boxes (see 5.3.2). Unless otherwise specified (see 6.2.1), the gross weight of boxes shall not exceed 500 pounds. Boxes exceeding 100 pounds shall be modified with skids in accordance with the applicable box specification.

5.3.2.1.1.1 Small forgings (other). Forgings, in lieu of boxing, may be bundled for shipment, unless by so doing the forgings may be subject to damage. Bundles shall be secured or reinforced with tensioned steel strapping

as required for wood boxes. For level A packing the gross weight shall not exceed 250 pounds and for levels B and C packing the gross weight shall not exceed 500 pounds.

5.3.2.1.2 Large forgings. Forgings weighing more than 500 pounds shall be packed individually, or in multiple units in crates (see 5.3.2). Unless otherwise specified (see 6.2.1), the gross weight of crates shall not exceed 1000 pounds. Open type crates shall be provided with flexible, reinforced, waterproof, barrier material shrouds. Plastic shrouds shall be of minimum 0.006 inch thickness. Shrouds shall be secured to prevent damage and loss during handling, shipment and storage.

5.3.3 Commercial. Unless otherwise specified (see 6.2.1), commercial packing (packaging) shall be in accordance with the requirements for "castings" in ASTM A 700, section 14 and herein.

5.3.3.1 Container modification. Shipping containers exceeding 100 pounds gross weight shall be provided with a minimum of two, 3- by 4-inch nominal wood skids laid flat, or a skid- or still-type base which will support the material and facilitate handling by mechanical handling equipment during shipment, stowage and storage

5.4 Marking.

5.4.1 Levels A, B, and C. In addition to any special marking required (see 6.2.1), 3.18 and herein, interior (unit) packs, shipping containers and bundles shall be marked including bar coding in accordance wtih MIL-STD-2073-1A.

5.4.2 Commercial. In addition to any special marking required (see 6.2.1), 3.18 and herein and unless otherwise specified (see 6.2.1), marking shall be in accordance with the requirements for "castings" in ASTM A 700, section 14. Bar coding in accordance with MIL-STD-2073-1A shall apply."

6. NOTES

6.1 Intended use. The six classes of steel are used to make torsional shafts, shafts for ships, sleeves, couplings, propeller nuts, rudder stocks, diving plane stocks, and related parts.

6.2 Ordering data.

6.2.1 Acquisition requirements. Acquisition documents should specify the following:

(a) Title, number, and date of this specification.
(b) The class of steel required (see 1.2).
(c) When first article inspection is required (see 3.1).
(d) Melting practices, if other than specified (see 3.2).
(e) When vacuum degassing is not required (see 3.2.1).
(f) Macrostructure requirements for sizes in excess of 100 square inches (see 3.14).
(g) When virgin raw material is required for critical applications (see 3.2.2)

(h) Weather transverse mechanical and impact properties are required (see table III).
(i) When each forging under 1000 pounds is not to be Brinell hardness tested (see 3.7.5).
(j) When heat treatment equipment and procedures shall be in accordance with MIL-STD-1684 (see 3.8.2.1).
(k) Stress relief temperature if other than specified (see 3.8.3).
(l) When the contractor is to provide a stress relief simulation (see 3.9).
(m) When sample material weldment is to be subjected to stress relief heat treatment (see 3.9.1).
(n) If forgings may contain defects exceeding the specified criteria (see 3.11).
(o) If repair welding is permitted (see 3.15.2 and 3.15.3).
(p) If repair welding is to be performed other than specified (see 3.15.3).
(q) The environment and exposure duration for preservation (see 3.16).
(r) Fabrication document to be used (see 3.17).
(s) If forgings are to be marked in areas to be removed by final machining (see 3.18.2).
(t) Special markings required for forgings (see 3.18.2 and 5.4.1).
(u) When the lots for the quality conformance inspections are other than specified (see 4.4.1.2 through 4.4.1.4).
(v) Lot for macrostructure test (see 4.4.1.5).
(w) If nondestructive inspection is to be other than specified (see 4.4.3.1.3.2).
(x) Whether forgings of less than 3/4 inch (19 mm) are to be ultrasonically inspected (see 4.4.3.1.3.3).
(y) Whether mechanical property tests are to be other than specified (see 4.4.3.1.4).
(z) When packaging shall conform to MIL-L-19140 (see 5.1.1).
(aa) Type of preservation (see 5.2).
(bb) When kraft paper shall conform to A-A-1894 (see 5.2.1.2).
(cc) When commercial preservation is not to the requirements for "castings" of ASTM A 700, section 14 (see 5.2.2).
(dd) Level of packing (see 5.3).
(ee) Type of container when container is not at option of supplier (see 5.3.2).
(ff) When gross weight of boxes containing small forgings shall exceed 500 pounds (see 5.3.2.1.1).
(gg) When gross weight of crates containing large forgings shall exceed 1000 pounds (see 5.3.2.1.2).

(hh) When commercial packing is not to the requirements for "castings" of ASTM A 700, section 14 (see 5.3.3).
(ii) When commercial marking is not to the requirements for "castings" of ASTM A 700, section 14 (see 5.4.2).
(jj) Whether test methods are to other than as specified (see appendix A. 30.1 and 50.1).

6.2.2 Data requirements. When this specification is used in an acquisition and data are required to be delivered, the data requirements identified below shall be developed as specified by an approved Data Item Description (DD Form 1664) and delivered in accordance with the approved Contract Data Requirements List (CDRL), incorporated into the contract. When the provisions of DoD FAR Supplement, Part 27, Sub-Part 27.475-1 (DD Form 1423) are invoked and the DD Form 1423 is not used, the data specified below shall be delivered by the contractor in accordance with the contract or purchase order requirements. Deliverable data required by this specification are cited in the following paragraphs.

Paragraph no.	Data requirement title	Applicable DID no.	Option
4.3.2 and Appendix B	Test Reports	DI-MISC-80653	-----
4.4 and Appendix C	Certification/data report	DI-MISC-80678	-----

(Data item descriptions related to this specification, and identified in section 6 will be approved and listed as such in DoD 5010.12-L., AMSDL. Copies of data item descriptions required by the contractors in connection with specific acquisition functions should be obtained from the Naval Publications and Forms Center or as directed by the contracting officer).

6.2.2.1 The data requirements of 6.2.2 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).

6.3 First article. When a first article inspection is required, the item should be a first article sample. The first article should consist of units as specified. The contracting officer should include specific instructions in acquisition 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 of the same class material which has been previously acquired or tested by the Government, and that bidders offering such products, who 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.

6.4 Supersession data. This revision supersedes MIL-S-20137A, MIL-S-23284, MIL-S-24093 (in part) and MIL-S-23009 (in part). It indirectly supersedes MIL-S-890 (in part).

TABLE IV. Supersession.

MIL-S-23284A	MIL-S-23284	MIL-S-24093	MIL-S-890	MIL-S-23009	MIL-S-20137A
(see note)	-------	Class A	Alloy No. 1	-------	-------
(see note)	-------	Class B	Alloy No. 2	-------	-------
-------	-------	Class D	Alloy No. 3	Grade HY80	-------
-------	-------	Class C	Alloy No. 4	Grade HY100	-------
Class 1	Class 1	Class D	Class HG	-------	-------
Class 2	Class 2	Class F	Class An	-------	-------
Class 2	Class 2	Class F	Class Ac	-------	-------
Class 3	Class 3	Class G	Class B-S	-------	Class B-S
Class 4	Class 4	Class H	Class B	-------	-------
Class 4	Class 4	Class H	Class C	-------	-------
Class 5	-------	-------	-------	Grade HY80	-------
Class 6	-------	-------	-------	Grade HY100	-------

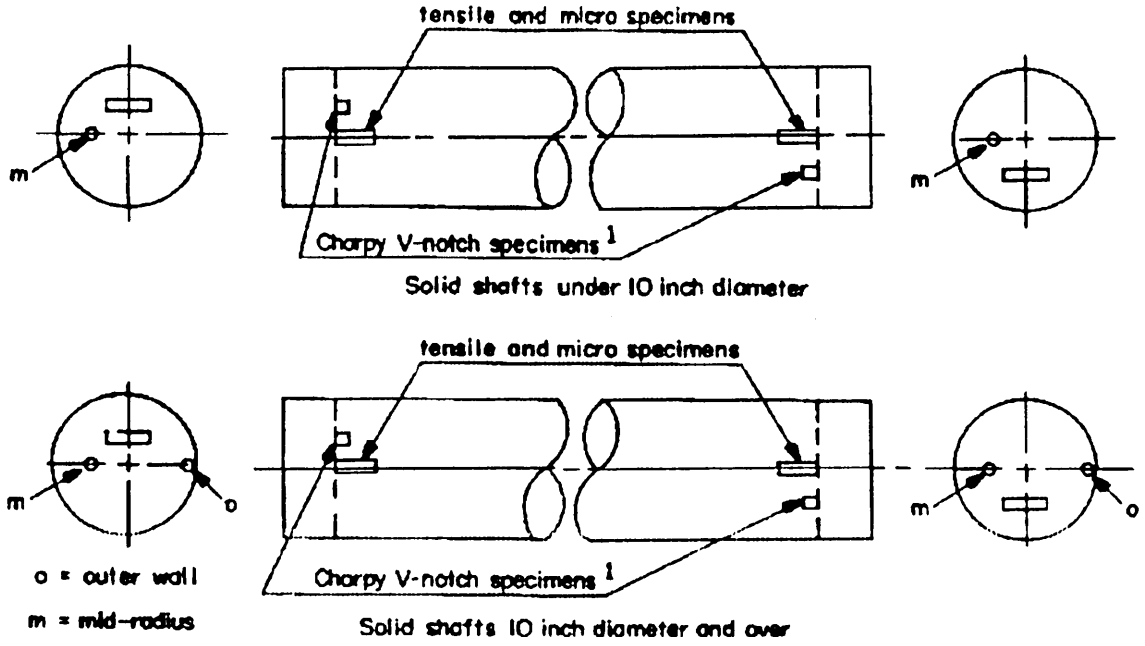
NOTE: These high strength grades should be handled on an individual basis since the section size would be critical in determining ability to meet the specified properties

6.5 Subject term (key word) listing.

Charpy V-notch transition curves
Nickel-chromium-molybdenum steel
Nickel-molybdenum steel
Stress relief annealed
Torsional shafts
Rudder stocks
Diving plane stocks

6.6 Changes from previous issue. Asterisks are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Preparing activity:
Navy - SH
(Project FORG-N153)

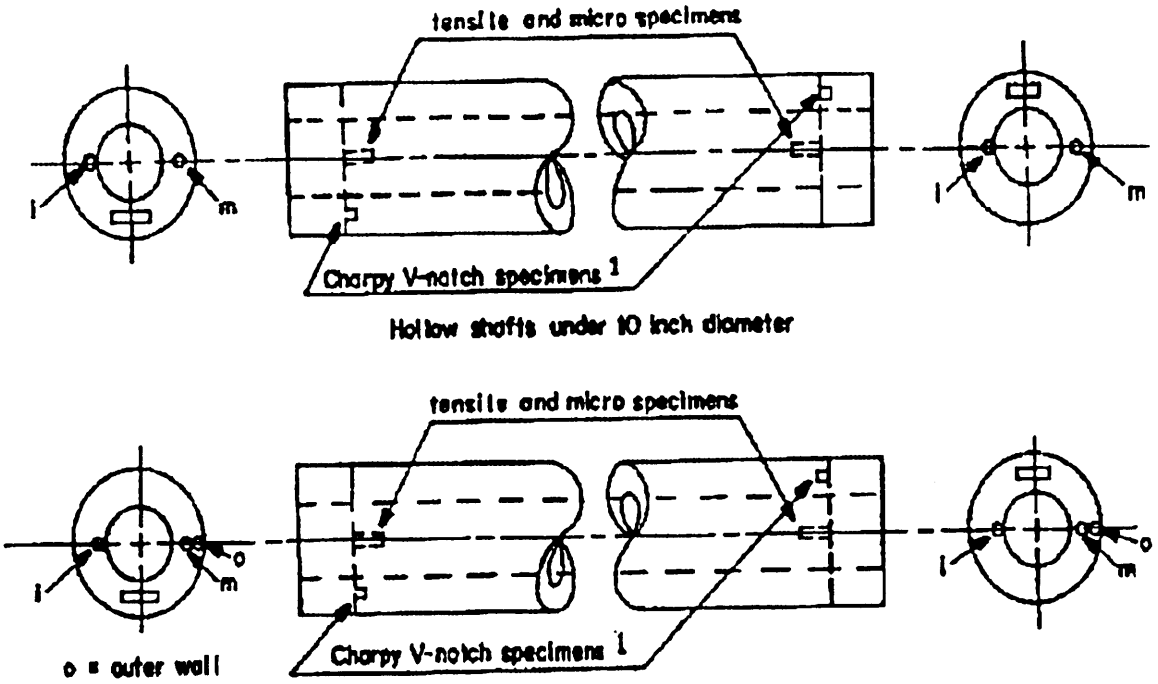


1. See 4.4.3.2.1 for specific location of Charpy V-notch specimens.

NOTE: The symbols used indicate the location of specimens on this diagram and are not required marking for the specimens (see 3.18.1).

SH 7119

FIGURE 1. Solid shafts.



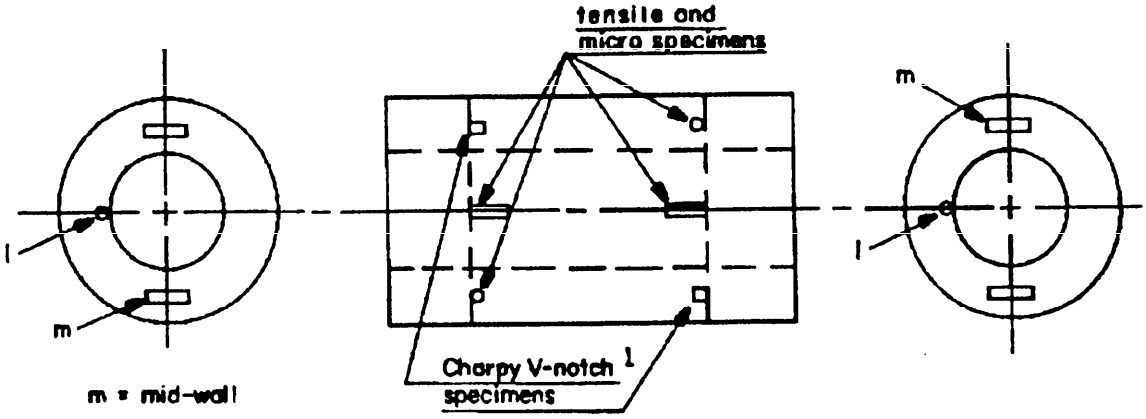
1. See 4.4.3.2.7 for specific location of Charpy V-notch specimens.

NOTE: The symbols used indicate the location of specimens on this diagram and are not required marking for the specimens (see 3.18.1).

The test location is not required to be deeper than mid radius of the solid cross section (see 3.7.4.1).

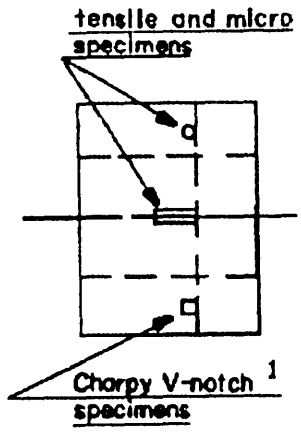
SH 7120

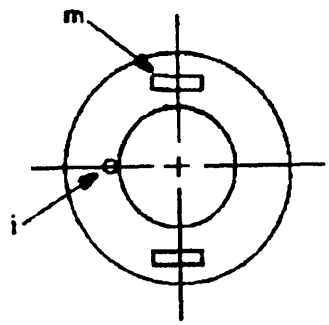
FIGURE 2. Hollow shafts.



SH 7121

FIGURE 3. Sleeves and couplings.





m = mid-wall

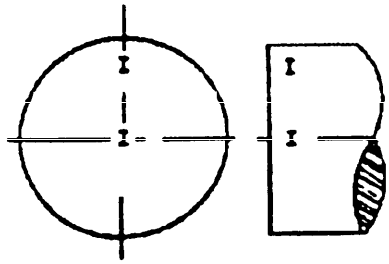
i = inside wall

1. See 4.4.3.2.7 for specific location of Charpy V-notch specimens.

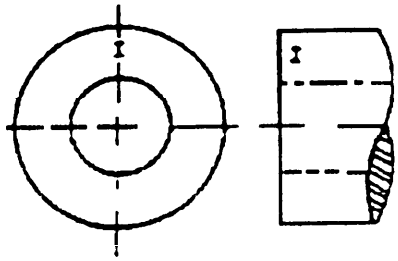
NOTE: The symbols used indicate the location of specimens on this diagram and are not required marking for the specimens (see 3.18.1).

SH 7122

FIGURE 4. Propeller nuts.



SOLID FORGINGS



HOLLOW FORGINGS

I - Nonmetallic inclusion content specimen (see 4.4.3.2.12)

SH 132317674

FIGURE 5. Location of nonmetallic inclusion content test specimens.

APPENDIX A

NONDESTRUCTIVE TESTING REQUIREMENTS

10. SCOPE

10.1 Scope. This appendix outlines the nondestructive inspection of forgings used on naval ships. These test methods are intended for application in low speed shafting, such as propulsion shafting, rudder stocks, diving plane stocks, and general operational shafting. This appendix forms a mandatory part of this specification. The information contained herein is intended for compliance.

20. APPLICABLE DOCUMENTS

Not applicable to this appendix.

30. APPLICATION

30.1 Application. Unless otherwise specified (see 6.2.1), the following methods shall be used for acceptance of shafting.

40. QUALIFICATION OF EQUIPMENT AND PERSONNEL

40.1 Qualification of equipment and personnel. The qualification of nondestructive testing equipment and personnel shall be in accordance with MIL-STD-271.

50. TEST PROCEDURES

50.1 Magnetic particle. Magnetic particle inspection shall be performed in accordance with MIL-STD-271. Unless otherwise specified (see 6.2.1), the entire exterior surface of the forging shall be inspected to include flanges, keyways, grooves, and other parts. Inspection shall be performed after final heat treatment and machining. The forging shall be inspected before installing any sleeves. The forging shall be demagnetized at the completion of the inspection.

50.1.1 Acceptance criteria. Magnetic particle indications over 1/16 inch in length shall be rejected unless they can be verified to be resulting from nonmetallic inclusion. Indications from nonmetallic inclusions shall be rejected if their length exceeds 1/2 inch or if six or more indications are located in any two by two square inch area.

50.2 Ultrasonic inspection. The ultrasonic inspection shall be performed in accordance wih MIL-STD-271 with the exception that the test method shall be as specified herein. The entire volume of the forging shall be subjected to ultrasonic inspection to the maximum extent possible. Inspection shall be performed after machining, but before drilling flanges, cutting keyways, tapers, or grooves. Ultrasonic inspection shall be performed after complete heat treatment including stress relief heat treatment. For hollow shafts, the inspection shall be performed after boring. When slots or similar features are machined into the forging before heat treatment, the entire forging shall be ultrasonically inspected before such machining and as completely as possible after the final heat treatment.

APPENDIX A

50.2.1 Radial inspection. The forging shall be machined to provide cylindrical surfaces for testing where possible. Stocks with oblong areas shall have these areas machined and tested by hand held scanning of two surfaces.

50.2.1.1 Preparation of forging. The surface of the forging shall be free of loose scale, machining or grinding particles, paint, or other material that may interfere with the ultrasonic test. Scanning surfaces shall have a finish of 250 micro-inch roughness height rating or better. If forging geometry allows, the forging shall be mounted in a machine lathe or other mechanism that shall rotate the forging and traverse the transducer along the surface.

50.2.1.2 Equipment. Ultrasonic inspection equipment shall be as follows:

(a) Ultrasonic instrument - The ultrasonic instrument shall meet the requirements of MIL-STD-271 and be equipped with a fast-acting alarm that shall trigger on a 20 millisecond signal.
(b) Straight beam transducer - 1-5 megahertz (MHz), 3/4, 1, or 1-1/8 inch diameter contact transducer.
(c) Tool post mount - A lathe tool post mount shall be required to automatically traverse the transducer along the shaft.

50.2.1.3 Calibration. The reject control shall be in the off position. The amplitude of the first back reflection shall be set to full screen height. The front surface signal shall be set to the left edge of the screen and the first back reflection to at least 50 percent of full screen width.

50.2.1.4 Scanning. Scanning shall be performed in accordance with the following:

(a) Shaft forgings shall be inspected with the shaft rotating for applicable areas. The transducer shall be held in a tool post mount and mechanically advanced along the shaft.
(b) The overlap established by the lathe or by the inspector shall be at least 25 percent of the transducer element width.
(c) The maximum transducer surface speed shall be 6 inches per second.
(d) The ultrasonic instrument shall be equipped with a fast acting gate that shall trigger on a 20 millisecond signal. The alarm gate shall be set to monitor the entire volume of the shaft excluding the back surface reflection and any dead zone resulting from front surface noise. The alarm shall be used in the manual reset mode. The alarm level shall be set at 10 percent of full screen height. If necessary, circuitry may be added to simultaneously shut off power to the lathe and provide braking.
(e) During scanning, an adequate supply of clean oil shall be supplied ahead of the transducer scan path. The same grade and weight oil used to calibrate the search unit shall be used. Oil emulsion or other coupling fluids may be used provided they have been approved by the ultrasonic examiner.

(f) Immediately after the fast acting gate triggers or a reduction in back surface reflection is noted, the lathe shall be stopped and the area shall be searched manually to maximize the signal or reduction of back reflection. Alternatively, the area may be marked for further evaluation after the automated scan is complete.

(g) Indications above 10 percent of full screen height and each reduction in back surface reflection below 80 percent of full screen height that cannot be attributed to geometry or shaft surface conditions shall be recorded. Indications shall be classified as a stationary or traveling indication. Stationary indications are those that appear at a fixed position on the sweep as the transducer is moved along the shaft surface. Traveling indications are those that move along the sweep trace as the transducer is moved along the surface a distance equal to 10 percent of the material thickness being examined or 1 inch, whichever is less.

50.2.1.5 Acceptance criteria. A forging shaft shall be rejected if it contains the following:

(a) Indications classified as traveling.

(b) Any reportable indication or reportable loss of back reflection shall be mapped out. If the area of the indication or loss of back reflection is over 2 square inches, it shall be rejected.

(c) Twenty or more reportable conditions within 10 square feet of forging.

50.2.2 Axial inspection. The following axial ultrasonic inspection shall be required for hollow shafting to detect circumferential gouges, machine grooves, cracks, and internal discontinuities in the shaft.

50.2.2.1 Preparation of shaft. The surface of the shaft shall be free of loose scale, machining or grinding particles, paint, or other material that may interfere with the ultrasonic test. Scanning surfaces shall have a finish of 250 microinch roughness height rating or better. The shaft shall be mounted in a machine lathe or other mechanism that shall rotate the shaft and transverse the transducer along the surface.

50.2.2.2 Equipment. Ultrasonic inspection equipment shall be as follows:

(a) Ultrasonic instrument - The ultrasonic instrument shall meet the requirements of MIL-STD-271 and be equipped with a fast acting alarm that shall trigger on a 20 millisecond signal.

(b) Straight beam transducer - 1-5 MHz, 3/4, 1, or 1-1/8 inch diameter contact transducer.

(c) Angle beam transducer - 2-5 MHz round or rectangular transducers having a minimum dimension of 1/2, maximum width of 3/4, and maximum length of 1 inches.

(d) Wedges - Wedges shall be required to produce the following refracted angles in steel. The wedges shall be constructed to minimize the effects of sound reflecting within the wedge. The wedge shall be countoured to fit the radius of the shaft.

(1) 38 ± 3 degrees in steel (31.6 degrees incident angle)
(2) 45 ± 3 degrees in steel (37.0 degrees incident angle)
(3) 59 ± 3 degrees in steel (47.0 degrees incident angle)

(e) Tool post mount - A lathe tool post mount shall be required to automatically traverse the 45 degree wedge along the shaft.
(f) Reference standard - See figure 6.

50.2.2.3 Calibration. The reject control shall be in the off position.

50.2.2.3.1 Straight beam transducer. The straight beam transducer shall be placed on the reference standard for the thinner section of the shaft. The amplitude of the first back reflection shall be set to full screen. The horizontal position of the back reflection signal shall be set to 50 percent of full sweep length and the initial pulse at the left edge of the screen.

50.2.2.3.2 Angle beam transducer. Each search unit combination (transducer and appropriate wedge) shall require calibration. Using an IIW weld inspection block or equivalent, the refracted sound angle shall be measured to ensure that the plus or minus 3 degree tolerance shall be maintained. Using the 0.100-inch notches in the two reference standards (if two thicknesses are involved), the screen shall be calibrated for depth by setting the signal from the thicker standard to at least 50 percent of full screen width. The left edge of the screen shall represent the surface of the shaft. The signal shall be peaked from the 0.100-inch notch in the reference standard for the thinner section of shaft. This signal shall be set to 80 percent of full screen height. The peak of the signal shall be be marked on the screen. The 0.100-inch notch shall be peaked in the thicker standard and its position shall be marked on the the screen. A line on the screen shall be marked from the left edge of the screen horizontally to the first mark and then the first mark shall be connected to the second mark. Six decibels (dB) of gain shall be added to the instrument to establish reference sensitivity. The line on the screen shall represent the reference sensitivity.

50.2.2.4 Scanning. Scanning shall be performed as follows:

(a) Except for the initial exploratory straight beam scan to locate the transition zone, scanning shall be performed with the lathe rotating. The 45 degree scans of the shaft shall be performed with the wedge in a tool post mount to automatically advance the transducer along the shaft.
(b) The overlap established by the lathe or by the inspector shall be at least 25 percent of the transducer element width.
(c) The lathe revolutions per minute shall be set to provide a surface speed not greater than 6 inches per second.
(d) The ultrasonic instrument shall be equipped with a fast-acting gate that shall trigger on a 20 millisecond signal. The alarm gate shall be set to monitor the entire volume of the shaft excluding any dead zone resulting from wedge noise. The alarm shall be used in the manual reset mode. The alarm level shall be set so that a reportable discontinuity will trigger the alarm. If necessary, circuitry may be added to simultaneously shut off power to the lathe and provide braking.

(e) During scanning, an adequate supply of clean oil shall be supplied ahead of the transducer scan path. The same grade and weight oil shall be used to calibrate the search unit. Oil emulsion or other coupling fluids may be used provided they are approved by the ultrasonic examiner.

(f) Immediately after the fast-acting gate triggers, the lathe shall be stopped and the area shall be searched manually to maximize the discontinuity signal. Alternatively, the area may be marked for further evaluation after the automated scan is complete.

50.2.2.4.1 Straight beam. Straight beam scan shall be performed as follows:

(a) The straight beam scan shall be used for locating both ends of the transition zone in the bore of the shaft.

(b) Scanning shall be done by hand along a convenient axial strip of the shaft, beginning at a point approximately 12 inches forward of the transition zone. Scanning shall continue toward the aft end until one end of the wall thickness transition is found.

(c) When the transducer is over the transition zone, the back surface signal shall drop markedly or shall completely disappear. If a small signal remains, it shall move along the sweep line denoting a changing wall thickness. The signal shall increase in amplitude as the other end of the transition zone is passed.

(d) Both ends of the transition zone shall be marked on the shaft surface.

50.2.2.4.2 Angle beam - 38 and 59 degree axial shear. Thirty-eight and 59-degree axial shear angle beam scan shall be performed as follows:

(a) The 38 and 59 degree axial shear wave scans shall be used for the inspection of the transition zone. Both angles shall be used in both directions for a total of four scans.

(b) After calibration in accordance with 50.2.2.3.2, 12 dB gain shall be added for scanning purposes.

(c) With the lathe rotating, the transition zone area shall be scanned to ensure that there is complete coverage of the bore transition plus 6 inches on both ends of the transition.

(d) Indications greater than 20 percent of the reference sensitivity line established in 50.2.2.3.2 (as measured at reference sensitivity, not scanning sensitivity) shall be marked for further evaluation in accordance with 50.2.2.5. A separate line shall be marked on the screen indicating the recording level. Indications shall be recorded.

50.2.2.4.3 Angle beam - 45-degree axial shear. Forty-five degree axial shear angle beam scan shall be performed as follows:

(a) The 45 degree axial shear wave shall be used for the inspection of the entire shaft. The scanning shall be performed with the wedge mounted in a tool post to automatically advance the transducer along the shaft. Tapered areas and keyed areas shall be scanned manually to obtain as much coverage as possible. Flanges shall not require this inspection.

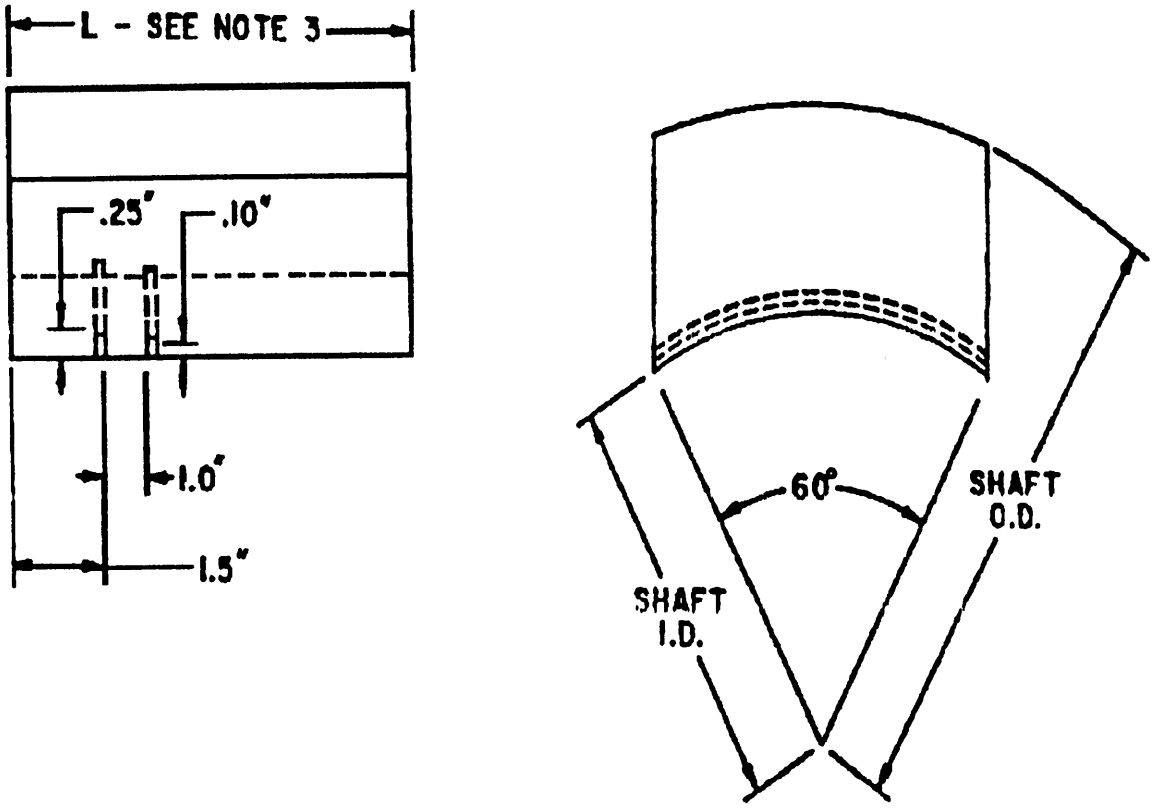
APPENDIX A

(b) The shaft shall be inspected in both the forward and aft directions.
(c) After calibration in accordance with 50.2.2.3.2, 12 dB gain shall be added for scanning.
(d) Indications greater than 20 percent of the reference sensitivity line established in 50.2.2.3.2 (as measured at reference sensitivity, not scanning sensitivity) shall be marked for further evaluation in accordance with 50.2.2.5. A separate line shall be marked on the screen indicating the recording level. Indications shall be recorded.

50.2.2.5 Acceptance criteria. A shaft shall be rejected if it contains either of the following:

(a) A recordable discontinuity on the shaft bore surface.
(b) A discontinuity whose signal amplitude exceeds the reference sensitivity line (DAC).

APPENDIX A



SH 13231741

NOTES:
1. Material shall be acoustically similar to shaft as defined in reference 1-4 (c).
2. Maximum notch widths shall be 0.06 inch.
3. Minimum block length, L, shall be 2 times the shaft thickness plus 2.5 inch.
4. A block is required for each separate shaft thickness.
5. The 0.25" notch is optional (used for shaft refurbishment inspections).

FIGURE 6. Reference standard.

APPENDIX B

TESTS REPORTS, TECHNICAL CONTENT REQUIREMENTS

10. SCOPE

10.1 Scope. This appendix covers the technical content requirements that should be included in tests reports when required by the contract or order. This appendix is mandatory only when data item description DI-MISC-80653 is cited on the DD Form 1423.

20. APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

30. REPORTS

30.1 First article inspection report. When required by the contract or order, the first article inspection report should contain the following information:

(a) Standard specification data (chemistry, mechanical properties, visual, dimensional and nondestructive inspection results) from typical production stock.
(b) Charpy V-notch curves (transverse to direction of grain flow) with data points for five different temperatures from the nondestructive test temperature.
(c) Report of production line operations (such as melt practice, processing history and heat treatement details).
(d) Weld procedure qualification test data.
(e) Dynamic tear test transition curves (transverse to direction of grain flow) with data points at each of the following temperatures: minus 40°F (minus 40°C), 0°F (minus 17.7°C), 40°F (4.4°C) and room temperature.
(f) Average ferrite grain size.
(g) Percent fibrous fracture for all Charpy V-notch and dynamic tear test specimens.
(h) Direction of grain flow as verified by macro-etching the cross section of the forging.
(i) Information shown on figure 7, when required for first article heat treating information

APPENDIX C

CERTIFICATION/DATA REPORT

10. SCOPE

10.1 Scope. This appendix covers the technical content requirements that should be included in the certification data report. This appendix is mandatory only when data item description DI-MISC-80678 is cited on the DD Form 1423.

20. APPLICABLE DOCUMENTS

20.1 Government documents.

This section is not applicable to this appendix.

30. Certification/data report.

30.1 Certification/data report. When required by the contract or order, the certificate of compliance should state that each lot has been manufactured, stamped, tested and inspected in accordance with this specification and meets all specification requirements. The certificate should contain the following information:

(a) Chemical analysis.
(b) Mechanical test results.
(c) Grain size.
(d) Macroscopic etch.
(e) Microscopic test results.
(f) Nonmetallic inclusion test results.
(g) Dimensional test results.
(h) Visual test results, including component's serial number; purchase order number; drawing number; inspection procedure number; inspection date; inspector's name, level of certification, and signature.
(i) Ultrasonic test results, including:

(1) Sketch showing the physical outline of the forging that notes each discontinuity detected; any areas not inspected, drawing number; contracting activity's order number; contractor's serial number.
(2) Description of each discontinuity, its location, orientation, depth, amplitude, and repair if accomplished or reason for not being repaired.
(3) Inspection data, including inspection procedure identification; date; inspector's name, level of certification, and signature; ultrasonic instrument manufacturer, model, and serial number; transducer sizes, frequencies, and angles used.

APPENDIX C

(j) Magnetic particle results, including:

(1) Sketch showing the physical outline of the forging, noting any areas not inspected (for example, bores), drawing number, contracting activity's order number, contractor's serial number.
(2) Description of each discontinuity requiring repair as a result of magnetic particle inspection.
(3) The location, length, and method of verification for indications from nonmetallic inclusions over 1/16 inch in length.
(4) Inspection data, including the inspection procedure identification; procedure used; date; inspector's name, level of certification, and signature

APPENDIX C

Purchaser _____ Order No. _____ Date _____
Contract No. _____ Date _____

1. Company performing heat treatment _____
2. Name of part _____ Purchaser Dwg. No. _____ Rev. __
3. Specification _____ Material Comp., Grade and Type _____
4. Part quenched individually _____ Multiple length quenched; inches ___
   _____ No. of multiples quenched _____
5. Normalizing temp., °F: _____ max. ____ min. ___ Time at temp. _____hrs.
6. Austenitizing temp. for quenching, °F ____ max. ____ min. ____
   Time at temp. _____ hrs.
7. Tempering temp., °F: ___ max. ___ min. ___ Time at temp _____ hrs.
8. Quenching medium: water _____ oil _____ brine _____(%) other (specify)
9. Approximate quench tank liquid volume _____ Cu. ft. or _____ gallons
10. No. and sizes of flow pipes to quench tank _____
11. Rate of liquid flow exchange to quench tank _____ Gal/min.
12. No., location, and type of agitation devices _____
13. Approximate total flow rate if spray is used _____ Gal/min.
14. Time interval from opening of furnace door to start of quench __ Min/sec.
15. Forgings over 1000 lbs: fixtured during quenching _____ Orientation in quenching medium 1/
16. Quenching medium temp., °F: _____ at start; _____ highest
17. Total time in quenching medium _____ hr. _____ min.
18. Temperature of thickest section surface immediately after removal from quenching medium _____ °F.
19. Method of cooing from tempering temp. _____ Furnace _____ Air; _____ Other.
20. Description of method for supporting forging(s) in furnace during heat treatments in order to prevent or minimize distortion. Include also the method for transferring the hot forging from the furnace to other operations such as quenching, and in particular, how the forging is supported during lifting.
21. Sample material stress relief: Temperature _____ °F; Time ___ hrs; Cooling rate to 600°F _____ °F/hour.
22. Other pertinent information _____
    _____
    _____

Authorized signature _____
Title _____

1/ Orientation in the quenching medium can be indicated by referencing approved forging drawings for forgings weighing over 1000 lb.

FIGURE 7. Detailed heat treating information.