

**METRIC**

MIL-F-24669/8

2 May 1991

SUPERSEDING

MIL-S-860B(SHIPS)

21 November 1966

(See 6.7)

**MILITARY SPECIFICATION****FORGINGS AND FORGING STOCK, STEEL  
FOR INTEGRAL STEAM TURBINE ROTORS**

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

**1. SCOPE**

1.1 Scope. This specification covers integral turbine rotor forgings for use in steam atmospheres which do not exceed the rated operating temperatures as specified in 1.2.

1.2 Classification. Steel forgings are of the following grades, as specified (see 6.2):

	<u>Maximum operating temperatures</u>	
	340 degrees Celsius (°C)	(650 degrees Fahrenheit (°F))
Grade A - Carbon steel		
Grade B - Nickel-molybdenum-vanadium	400°C	(750°F)
Grade C - Nickel-chromium-molybdenum-vanadium	400°C	(750°F)
Grade D - Nickel-chromium-molybdenum-vanadium	400°C	(750°F)
Grade E - Nickel-chromium-molybdenum-vanadium	400°C	(750°F)
Grade F - Chromium-molybdenum-vanadium	565°C	(1050°F)
Grade G - 12 percent chromium	400°C	(750°F)

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.

MIL-F-24669/8

## 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).

## SPECIFICATION

## MILITARY

DOD-F-24669 - Forgings and Forging Stock, Steel Bars, Billets and Blooms, General Specification for. (Metric)

## STANDARD

## MILITARY

MIL-STD-271 - Requirements for Nondestructive Testing Methods.

(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)

- A 370 - Standard Test Methods and Definitions for Mechanical Testing of Steel Products. (DoD adopted)
- A 418 - Standard Method of Ultrasonic Examination of Turbine and Generator Steel Rotor Forgings.
- A 472 - Standard Test Method for Heat Stability of Steam Turbine Shafts and Rotor Forgings.
- A 751 - Standard Methods, Practices, and Definitions for Chemical Analysis of Steel Products.
- E 208 - Standard Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels.

(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.)

## MIL-F-24669/8

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

### 3. REQUIREMENTS

3.1 General. The material furnished under this specification shall be in accordance with the requirements of DOD-F-24669 and as specified herein (see 6.3 and appendix A).

3.2 Material. The steel shall be produced in accordance with DOD-F-24669 and shall be melted by the electric furnace and vacuum treated prior to or during pouring.

3.3 Welding. Welding of forgings, including weld repair, is prohibited.

3.4 Forging process. To insure proper working of the metal, the reduction in area of the ingot to the main body of the forging shall be at least 3 to 1; however, in the case of forgings over 7740 square centimeters (1200 square inches) in cross section, a reduction of 2-1/2 to 1 will be acceptable. When an upsetting operation is employed, the forging shall receive the same degree of longitudinal reduction except that no fixed ratio between original ingot cross section to final forged cross section shall be required.

3.4.1 Dimensions. Forgings shall conform to the dimensions as specified (see 6.2).

3.5 Heat treatment. Forgings shall be given such uniform heat treatment to produce material conforming to this specification (see 6.3). Heat treatment shall consist of quenching and tempering or normalizing and tempering. Multiple heat treatment operations are permitted and may be necessary to achieve the required mechanical properties in forgings with large cross sections. Straightening by any means is not permissible after heat treatment for mechanical properties. Minimum tempering temperatures shall be as follows:

<u>Grade</u>	<u>Temperature</u>
A	595°C (1100°F)
B	595°C (1100°F)
C	595°C (1100°F)
D	595°C (1100°F)
E	595°C (1100°F)
F	595°C (1100°F)
G	650°C (1200°F)

3.5.1 Stress relief. After heat treatment for mechanical properties and prior to heat stability testing, the forgings shall be rough machined completely and then stress relieved with the mechanical property test samples at a temperature of 27 to 55°C (50 to 100°F) below the final tempering temperature. For grade F, the stress relief temperature shall be not less than the maximum operating temperature of 565°C (1050°F). The forgings shall be held at the stress relief temperature for a period of 1 hour per inch of the forging's maximum radial thickness.

MIL-F-24669/8

3.5.2 Heat treating furnaces and controls. Heat treating furnaces and controls shall meet the requirements of DOD-F-24669.

3.6 Rough machining. The forging shall be rough machined to within 13 millimeters (mm) (1/2 inch) per surface of the finished forging dimensions prior to heat treatment for mechanical properties. Machining of the material between the discs (gashes) is not required. When boring is specified prior to heat treatment (see 6.2), the forging shall be bored and the minimum diameter of the bored hole shall be not less than the finish machined internal diameter of the rotor minus 25 mm (1 inch).

3.7 Chemical composition. The chemical composition of the heat shall conform to table I.

TABLE I. Chemical composition (ladle analysis). 1/

Element	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F	Grade G
Carbon	0.45	0.25	0.28	0.28	0.28	0.25/0.35	0.15
Manganese	0.90	0.20/0.60	0.20/0.60	0.20/0.60	0.20/0.60	1.00	1.00
Phosphorus	0.025	0.012	0.012	0.012	0.012	0.012	0.012
Sulphur	0.025	0.015	0.015	0.015	0.015	0.015	0.015
Silicon 2/	0.15/0.35	0.15/0.30	0.15/0.30	0.15/0.30	0.15/0.30	0.15/0.35	0.50
Nickel	----	2.50 min	2.50 min	3.25/4.00	3.25/4.00	0.75	0.50
Chromium	----	0.75	0.75	1.25/2.00	1.25/2.00	0.90/1.50	11.5/13.0
Molybdenum	----	0.25 min	0.25 min	0.30/0.60	0.30/0.60	1.00/1.50	0.50
Vanadium 3/	0.03/0.12	0.03 min	0.03 min	0.05/0.15	0.05/0.15	0.20/0.30	----
Antimony	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Arsenic	0.020	0.020	0.020	0.020	0.020	0.020	0.020
Tin	0.020	0.020	0.020	0.020	0.020	0.020	0.020

1/ Weight percent are maximum unless a range is shown or otherwise noted.

2/ Silicon shall be 0.10 weight percent maximum for grades B, C, D, E, and F when vacuum-carbon deoxidized.

3/ Vanadium is not mandatory. When vanadium is used it shall conform to the specified range.

MIL-F-24669/8

3.7.1 Check analysis tolerances. A check analysis shall be conducted in accordance with 4.2.1.2. Check analysis tolerances of the elements shall be not over the upper nor under the lower limits by more than the percentages specified in table II.

TABLE II. Permissible check analysis tolerances in weight percent.

Elements	Cross-sectional area, sq cm (sq in)			
	1290 or less (200 or less)	1290-2581 (200-400)	2581-5161 (400-800)	Over 5161 (Over 800)
Carbon	0.03	0.04	0.05	0.06
Manganese	0.04	0.05	0.06	0.07
Phosphorus	0.003	0.003	0.003	0.003
Sulfur	None	None	None	None
Silicon	0.02	0.03	0.04	0.04
Nickel	0.07	0.07	0.07	0.07
Molybdenum	0.04	0.04	0.05	0.06
Chromium	0.04	0.04	0.05	0.05
Vanadium	0.01	0.01	0.01	0.02
Antimony				
Arsenic	None	None	None	None
Tin				

3.8 Mechanical properties. The forgings shall meet the mechanical property requirements specified in table III following all heat treatments including stress relief. If the material to be used for mechanical test specimens is removed prior to stress relief, the material shall be stress relieved with the forging.

TABLE III. Mechanical property requirements.

	Grade A	Grade B	Grade C	Grade D	Grade E	Grade F	Grade G
Tensile strength, MPa (ksi), min (except where range is indicated)	517 (75)	551 (80)	620 (90)	723-861 (105-125)	792-896 (120-135)	723-861 (105-125)	620-758 (90-110)
Yield strength, MPa (ksi), min (0.02 percent offset)	276 (40)	379 (55)	482 (70)	586 (85)	655 (95)	586 (85)	482 (70)
Percent elongation, in (50 mm) (2 in)							
Longitudinal, min	22	22	20	18	18	17	18
Radial, min	20	20	17	17	17	14	16
Percent reduction of area							
Longitudinal, min	40	50	48	52	52	43	50
Radial, min	30	50	45	50	50	38	45
Impact, Charpy V-notch, min Joules (ft-lb) at 21°C (70°F) 1/	14 (10)	38 (28)	34 (25)	61 (45)	54 (40)	8 (6)	20 (15)
Fracture appearance transition temperature (FATT) °C (°F), max 2/	79 (175)	38 (100)	43 (110)	4 (40)	10 (50)	121 (250)	60 (140)

1/ Average of the tests required.

2/ Based on 50 percent fibrous fracture appearance of Charpy V-notch tests.

## MIL-F-24669/8

3.9 Nil ductility temperature. When specified (see 6.2), the drop weight shall be conducted to determine the nil ductility temperature. The nil ductility temperature for each forging shall be determined.

3.10 Nondestructive requirements.

3.10.1 Ultrasonic. Ultrasonic inspection acceptance criteria shall be as follows:

- (a) Any indication whose response exceeds the response equivalent to a 3 mm (1/8 inch) diameter flat bottom hole shall be cause for rejection.
- (b) A reduction in normal back reflection amplitude of 50 percent or more, not attributed to configuration, shall be cause for rejection.

3.10.2 Magnetic particle. Magnetic particle inspection acceptance criteria shall be as follows:

- (a) Linear indication longer than 3 mm (1/8 inch) shall be cause for rejection.
- (b) Twenty or more indications in 9290 square centimeters (10 square feet) of forging surface shall be cause for rejection.
- (c) No cracks of any size shall be permitted.
- (d) For grade G forgings, presence of indications due to delta ferrite stringers on the external surfaces or on the bore shall be confirmed by micro-inspection or replication techniques. Discrete, isolated, non-massive, and/or discontinuous ferrite stringers shall not be cause for rejection.

3.10.3 Stability. Unless otherwise specified (see 6.2), each forging shall be subjected to a heat indication test to determine its stability or freedom from tendency to distort during high temperature operating conditions. Maximum excursion from the final hot reading to the final cold reading shall be not greater than 0.025 mm (0.001 inch) at any point.

3.11 Marking. Each forging shall be legibly marked with the forging and heat number, specification number, grade, contract or order numbers, and with such other information as may be required (see DOD-F-24669).

3.12 Workmanship. The forging shall be free from defects such as seams, pipe, scale, fins, porosity, hard spots, excessive nonmetallic inclusions, cracks and flakes.

#### 4. QUALITY ASSURANCE PROVISIONS

4.1 The quality assurance provisions shall be in accordance with DOD-F-24669 and as specified herein.



MIL-F-24669/8

## 4.2 Sampling.

### 4.2.1 Chemical analysis.

4.2.1.1 Ladle analysis. An analysis of each heat shall be made by the manufacturer. The test specimen shall be taken during the pouring of the heat. An ingot analysis may be made when a heat analysis is not available or declared inadequate for chemical analysis. The ingot analysis shall be taken from a sample taken from the top and a sample taken from the bottom of the ingot body. The average chemical composition thus determined shall conform to the heat analysis requirements of table I.

4.2.1.2 Check analysis. One check analysis shall be made on one forging from each heat. The sample may be taken from a broken tensile specimen.

### 4.2.2 Sampling for mechanical property testing.

4.2.2.1 Heat treatment. Test samples shall be heat treated with the forgings.

4.2.2.2 Location of specimens. Location of the test specimens shall be as shown on the forging drawing (see 3.1).

4.2.2.2.1 Radial and longitudinal tension tests. Radial and longitudinal tensile specimens shall be removed from material between the integral discs or from prolongation outboard of the last integral disc. The prolongations shall be the same diameter as the main body of the forging. In either case, the specimen shall be removed such that the mid point of the specimen is the mid radius of the forging (mid wall thickness for bored rotors) and a minimum of one fourth of the main body radius (wall thickness) from any heat treated surface. If the part configuration does not permit locating the specimen at mid radius (mid wall if bored) when testing between integral discs, the specimen shall be located as deep as is permitted by the configuration.

4.2.2.2.2 Impact and drop weight tests. Charpy V-notch specimens shall be removed from material between the integral discs or from prolongation outboard of the last integral disc. The prolongations shall be the same diameter as the main body of the forging. In either case, the specimen shall be removed such that the mid point of the specimen is the mid radius of the forging (mid wall thickness for bored rotors) and a minimum of one fourth of the main body radius (or wall thickness) from any heat treated surface. If the part configuration does not permit locating the specimen at mid radius (wall thickness if bored) when testing between integral discs, the specimen shall be located as deep as is permitted by the configuration. The length of the specimen shall be oriented radially and the notch axis shall be perpendicular to the axis of the forging. When the drop weight test is required (see 6.2), the specimen location and orientation shall be as specified in ASTM E 208 (see 6.2).

### 4.2.2.3 Number of specimens.

4.2.2.3.1 Forgings weighing less than 2270 kilograms (5000 pounds). For forgings weighing less than 2270 kilograms (5000 pounds), two longitudinal, two radial tension specimens, and at least twelve Charpy V-notch impact specimens

## MIL-F-24669/8

shall be taken as specified in 4.2.2.2. When specified (see 6.2), at least four ASTM E 208 drop weight test specimens shall be taken as specified in 4.2.2.2.2.

4.2.2.3.2 Forgings weighing more than 2270 kilograms (5000 pounds). For forgings weighing more than 2270 kilograms (5000 pounds), in addition to those tests required by 4.2.2.3, two radial tension and at least twelve Charpy V-notch specimens shall be taken from the opposite end of the forging.

4.2.2.4 Types of specimens. The longitudinal and radial tension test specimens shall be the standard round 12.5-mm diameter (0.500-inch), 50-mm gauge (2-inch) length test specimen in accordance with ASTM A 370. The drop weight specimen shall conform to type P-2 of ASTM E 208.

#### 4.3 Examination.

4.3.1 Dimensional examination. Each forging shall be subjected to dimensional examination.

4.3.2 Magnetic particle inspection. Each forging shall be magnetic particle inspected in accordance with MIL-STD-271 (see 6.3). This inspection shall be performed after all machining is accomplished. The entire exterior of the forging shall be inspected. For bored forgings, the bore shall be inspected in one direction with the indirect circular magnetization method (central conductor). Inspection shall be performed after final heat treatment and machining. The forging shall be demagnetized at the completion of the inspection.

4.3.3 Ultrasonic inspection. The forgings shall be examined as specified in MIL-STD-271 with the exception that the test method shall be as specified in ASTM A 418 (see 6.3 and appendix B). The entire volume of the forging shall be inspected. For bored rotors, inspection shall be performed after boring.

4.3.4 Visual examination. Each forging shall be visually examined after final heat treatment, stress relief and machining. The entire forging surface shall be visually examined in accordance with MIL-STD-271 (including bores using a borescope) to verify requirements of 3.12.

4.4 Tests. Tests shall be as specified in 4.4.1 through 4.4.4 (see 6.3 and appendix C).

4.4.1 Chemical analysis. The samples as specified in 4.2.1.1 and 4.2.1.2 shall be analyzed in accordance with ASTM A 751 to determine whether the steel composition is in accordance with 3.7 and 3.7.1.

4.4.2 Tension and impact tests. Tension and impact testing shall be conducted in accordance with ASTM A 370 to determine compliance with 3.8.

4.4.2.1 Transition temperature impact tests. The average percent shear of impact specimen fracture surfaces for three Charpy impact tests at each of at least four temperatures shall be used in the determination of the transition temperature. The compliance of the transition temperature (FATT) with 3.8 shall be determined in accordance with ASTM A 370.

## MIL-F-24669/8

4.4.3 Nil ductility temperature determination. Nil ductility transition temperature shall be determined by the drop weight test method in accordance with ASTM E 208.

4.4.4 Stability or heat indication test. Unless otherwise specified (see 6.2), each forging shall be subjected to the heat indication test in accordance with ASTM A 472 and meet the requirements of 3.10.3. The testing shall be conducted after heat treatment, machining, and stress relieving.

4.5 Rejection. Forgings failing to conform to the requirements of this specification shall be rejected (see 6.5).

## 5. PACKAGING

5.1 Packaging requirements. Preservation, packing, and marking shall be in accordance with DOD-F-24669.

## 6. NOTES

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

6.1 Intended use. Forgings acquired under this specification are intended for use as turbine rotors at temperatures not exceeding those specified in 1.2.

6.2 Acquisition requirements. In addition to the acquisition requirements specified in DOD-F-24669, acquisition documents must specify the following:

- (a) Grade of forging and rated operating temperature (see 1.2).
- (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) Forging dimensions required (see 3.4.1).
- (d) If forgings are to be bored prior to heat treatment (see 3.6).
- (e) When the drop weight test is required (see 3.9, 4.2.2.2.2, and 4.2.2.3.1).
- (f) When the determination of stability is not required (see 3.10.3).
- (g) The location and orientation of drop weight test specimens (see 4.2.2.2.2).
- (h) When heat indication test is not applicable (see 4.4.4).

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.

## MIL-F-24669/8

<u>Reference Paragraph</u>	<u>DID Number</u>	<u>DID Title</u>	<u>Suggested Tailoring</u>
3.1 and appendix A	DI-DRPR-80651	Engineering drawings	---
3.5, 4.3.2, 4.3.3, and appendix B	DI-MISC-80678	Certification/data report	10.3.2 does not apply
4.4 and appendix C	DI-MISC-80653	Test reports	---

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.

6.4 Waiver requirement for heat stability test. When the Command or agency approves that an alloy and geometry is insensitive to dimensional change at operating temperatures, the heat stability test may be waived.

6.5 Reheat treatment. When any forging fails to conform to requirements as specified in 3.8 or 3.9, it may be reheat treated and subsequently retested as applicable.

6.6 Subject term (key word) listing.

Ultrasonic inspection  
Charpy V-notch  
Magnetic particle inspection

6.7 Supersession data. This associated detail specification supersedes MIL-S-860B(SHIPS) dated 21 November 1966. The applicable grades of MIL-S-860, together with the superseding grades of this specification are as follows:

MIL-S-860B(SHIPS)

Grade A  
Grade B  
Grade C  
Grade D  
Grade E  
Grade F  
Grade G

MIL-F-24669/8 (see 1.2)

Grade A  
Grade B  
Grade C  
Grade D  
Grade E  
Grade F  
Grade G

Custodians:

Army - MR  
Navy - SH  
Air Force - 99

Preparing activity:

Navy - SH  
(Project FORG-0195)

Review activities:

Army - AR, MI, GL  
Navy - AS, OS  
Air Force - 84  
DISC - ESA

User activity:

Navy - MC

MIL-F-24669/8

## APPENDIX A

### ENGINEERING DRAWINGS TECHNICAL CONTENT REQUIREMENTS

#### 10. SCOPE

10.1 Scope. This appendix covers information that shall be included on the drawing unless otherwise specified in the contract or order. Data item description DI-DRPR-80651 shall be cited on the DD Form 1423 to obtain the information.

#### 20. APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

#### 30. DRAWING CONTENTS

30.1 Drawings. Forging drawings shall be prepared in accordance with DOD-F-24669 and shall show the following information:

- (a) The shape of the as forged forging and the principle steps in the forging process in sufficient detail to determine the direction of metal flow.
- (b) The locations from which the test specimens are to be taken.
- (c) The locations of any marking specified.
- (d) The dimension of the forging at the time of ultrasonic inspection.
- (e) A superimposed outline of the finished part.

MIL-F-24669/8

## APPENDIX B

## CERTIFICATION/DATA REPORT TECHNICAL CONTENT REQUIREMENTS

## 10. SCOPE

10.1 Scope. This appendix covers information that shall be included in certification data/reports when specified in the contract or order. This appendix is mandatory only when data item description DI-MISC-80678 is cited on the DD Form 1423.

## 20. APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

## 30. DATA REPORTS

30.1 Data reports content. Data reports shall contain the following information:

- (a) Magnetic particle inspection reports shall contain a description of the forging, drawing number, order number, a description of each discontinuity requiring repair as a result of magnetic particle inspection, inspection data including the inspection procedure identification number, description of equipment used, date, inspector's name, inspector's level of certification, and inspector's signature.
- (b) Ultrasonic inspection reports shall classify indications as either stationary or travelling. Stationary indications are those that appear at a fixed position on the sweep as the transducer is moved along the surface and traveling indications are those that move along the sweep trace as the transducer is moved along the surface. Reduction in back surface reflection below 20 percent of the normal back surface reflection shall also be reported. In addition to the reporting requirements in ASTM A 418, the inspection report shall include a description of the forging, drawing number, order number, inspection procedure identification number, date, inspector's name, inspector's level of certification, and inspector's signature.
- (c) A complete record of heat treatment (time and temperatures for austenitizing, tempering, and stress relieving) including reheat treatments.

MIL-F-24669/8

## APPENDIX C

### TEST REPORTS TECHNICAL CONTENT REQUIREMENTS

#### 10. SCOPE

10.1 Scope. This appendix covers information that shall be included in test reports when specified in 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. TEST REPORTS

30.1 Test reports. Test reports shall contain the following information:

- (a) Chemical analysis.
- (b) Tension test report.
- (c) Impact tests reports.
- (d) Transition temperature impact test reports.
- (e) Nil ductility transition temperature.
- (f) Stability test.