INCH-POUND

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MILITARY SPECIFICATION

COUPLINGS FOR PROPULSION UNITS, AUXILIARY TURBINES AND LINE SHAFTS, NAVAL SHIPBOARD

This specification is approved for use by 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 flexible couplings for propulsion units, auxiliary equipment, and line shafts.

1.2 Classification. Couplings are of the following types and classes as specified (see 6.2):

Type I Dental coupling lubricated by oil circulation.
- Class 1 275 minimum Brinell tooth hardness.
- Class 2 350 minimum Brinell tooth hardness.
- Class 3 Nitrided, 49 minimum Rockwell C tooth hardness.
- Class 4 Carburized or induction hardened, 56 minimum Rockwell C tooth hardness.
- Class 5 Nitrided, 59 minimum Rockwell C tooth hardness.

Type II Dental coupling, self-contained (grease) lubricant.
- Class 1 Commercial, 160 minimum Brinell tooth hardness.
- Class 2 275 minimum Brinell tooth hardness.

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 05Q42, 2531 National Center, Bldg. 3, 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.

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Type III Laminated-disc coupling.
Type IV Nonmagnetic, noise-attenuation coupling.
Type V Line-shaft noise-attenuation coupling assembly.
Type VI Diaphragm coupling.
Type VII Elastomer flexible coupling.
Type VIII Connect or disconnect dental coupling.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

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

SPECIFICATIONS

FEDERAL

QQ-S-365 - Silver Plating, Electrodeposited: General Requirements for.
QQ-S-766 - Steel, Stainless and Heat Resisting, Alloys, Plate, Sheet and Strip.

MILITARY

MIL-S-901 - Shock Tests, H.I. (High-Impact) Shipboard Machinery, Equipment, and Systems, Requirements for.
MIL-A-907 - Antiseize Thread Compound, High Temperature.
MIL-S-1222 - Studs, Bolts, Hex Cap Screws, Socket Head Cap Screws and Nuts.
MIL-S-5000 - Steel, Chrome-Nickel-Molybdenum (E4340) Bars and Reforging Stock.
MIL-A-8625 - Anodic Coatings, for Aluminum and Aluminum Alloys.
MIL-I-8846 - Inserts, Screw-Thread, Helical Coil.
MIL-L-9000 - Lubricating Oil, Shipboard Internal Combustion Engine, High Output Diesel.
MIL-T-17286 - Turbines and Gears, Shipboard Propulsion and Auxiliary Steam; Packaging of.
MIL-L-17331 - Lubricating Oil, Steam Turbine and Gear, Moderate Service.
MIL-T-17523 - Turbine, Steam, Auxiliary (and Reduction Gear) Mechanical Drive.
MIL-G-17859 - Gear Assembly, Propulsion (Naval Shipboard Use).
MIL-F-18240 - Fastener Element, Self-Locking, Threaded Fastener, 250°F Maximum.
MIL-S-22698 - Steel Plate, Shapes and Bars, Weldable Ordinary Strength and Higher Strength: Structural.
MIL-S-24093 - Steel Forgings, Carbon and Alloy Heat Treated.
DOD-G-24508 - Grease, High Performance, Multi-Purpose. (Metric)
DOD-F-24669 - Forgings and Forging Stock, Steel Bars, Billets and Blooms, General Specification for. (Metric)

DOD-F-24669/1	- Forgings and Forging Stock, Steel (Carbon and Alloy) Blooms, Bars, Billets and Slabs. (Metric)
DOD-F-24669/3	- Forgings and Forging Stock, Steel Bars and Billets for Nitriding. (Metric)
MIL-N-25027	- Nut, Self-Locking, 250°F, 450°F, and 800°F.
MIL-C-26074	- Coatings, Electroless Nickel Requirements for.
MIL-C-83488	- Coating, Aluminum, High Purity.

STANDARDS

MILITARY

MIL-STD-129	- Marking for Shipment and Storage.
MIL-STD-130	- Identification Marking of U.S. Military Property.
MIL-STD-167-1	- Mechanical Vibrations of Shipboard Equipment (Type I - Environmental and Type II - Internally Excited).
MIL-STD-271	- Requirements for Nondestructive Testing Methods.
MIL-STD-278	- Welding and Casting Standard.

HANDBOOK

MILITARY

MIL-HDBK-149 - Rubber.

(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.)

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

PUBLICATION

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

0901-LP-420-0007 Chapter 241 - Propulsion Reduction Gears, Couplings, and Associated Components.

(Application for copies should be addressed to the Standardization Documents Order Desk, BLDG. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.2 Non-Government publications. The following documents form a part of this document 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 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 NATIONAL STANDARDS INSTITUTE (ANSI)
B46.1 - Surface Texture (Surface Roughness, Waviness, and Lay.

(Application for copies should be addressed to the American National Standards Institute, Inc., 11 West 42nd Street, 13th floor, New York, NY 10036.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)
A 516 - Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service.
A 537 - Standard Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel.
B 26 - Standard Specification for Aluminum-Alloy Sand Castings. (DoD adopted)
B 124 - Standard Specification for Copper and Copper-Alloy Forging Rod, Bar, and Shapes. (DoD adopted)
B 150 - Standard Specification for Aluminum Bronze Rod, Bar, and Shapes. (DoD adopted)
B 283 - Standard Specification for Copper and Copper-Alloy Die Forgings (Hot-Pressed). (DoD adopted)

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

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)
AMS 2680 - Electron-Beam Welding for Fatigue Critical Applications. (DoD adopted)
AMS 2681 - Electron-Beam Welding. (DoD adopted)

(Application for copies should be addressed to the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.)

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

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

3. REQUIREMENTS

3.1 First article. When specified (see 6.2), a sample shall be subjected to first article inspection (see 6.5) in accordance with 4.3.

3.2 Materials. Unless otherwise specified (see 6.2), materials shall be as listed in tables I and II.

TABLE I. Materials of principal parts.

Coupling type/ class	Applicable documents	Material	Hardness 1/	Case hardening method	Minimum case depth 3/,4/
I/1	Sleeves and hubs MIL-S-24093, class C, type I or II	Forged steel	275 Bhn 2/		
I/2	MIL-S-24093, class A, type I or II	Forged steel	350 Bhn		
I/3	DOD-F-24669/1, grade 4340	Forged steel	49 Rc 2/	Nitride induction harden	0.025 inch
I/4	DOD-F-24669 and DOD-F-24669/1, class 4615	Forged steel	56 Rc	Carburize	5/
I/5	DOD-F-24669/3, class C, condition 2, type III	Nitralloy N	59 Rc	Nitride	0.020 inch
II/1	Commercial	Forged steel	160 Bhn		
II/2	Same as type I, classes 1-5 6/				
III	Discs QQ-S-766	Corrosion resisting steel			
	Flanges and center member pieces MIL-S-24093, class C or grades 4140 or 4340	Forged steel			
	Spacing washers MIL-S-24093, class D, type I or II	Forged steel			

See footnotes at end of table.

TABLE I. Materials of principal parts - Continued.

Coupling type/ class	Applicable documents	Material	Hardness 1/	Case hardening method	Minimum case depth 3/,4/
IV	Tooth inserts DOD-F-24669/3, class C, condition 2, type III	Nitralloy N	59 Rc	Nitride	0.020 inch
	Hubs, sleeves, shafts ASTM B 124, B 150, or B 283 (UNS C63000)	Aluminum bronze or manganese bronze			
	Elastomer MIL-HDBK-149	7/			
V	Shaft MIL-S-24093, class C, type I	Forged steel			
	Flanges ASTM A 537, class II	Steel plate			
	Dental couplings				
	Sleeves and hubs DOD-F-24669/3, class C, condition 2, type III	Nitralloy N	59 Rc	Nitride	0.020 inch
	Retainer rings MIL-S-24093, class B, type I	Forged steel			
	Diaphragm couplings				
	Hubs, MIL-S-24093 type I, class B	Forged steel			
	Diaphragms	7/			
	Elastomer couplings				
	Plates ASTM A 516, grade 70	Steel plate			
	Elastomer MIL-HDBK-149	7/			
	Bushings and driver pins MIL-S-5000	Steel bar	7/	Carburize	7/
VI	Hubs MIL-S-24093 Diaphragms Type I, class B	Forged steel 7/			

See footnotes at end of table.

TABLE I. Materials of principal parts - Continued.

Coupling type/ class	Applicable documents	Material	Hardness 1/	Case hardening method	Minimum case depth 3/,4/
VII	Flanges, hubs, and sleeves MIL-S-24093	Forged steel			
	Pins and bushings DOD-F-24669/1	Steel bar	7/	Carburize	7/
	Cages MIL-S-22698, MIL-S-24093	Forged steel or steel plate			
	Elastomer for bushings or blocks MIL-HDBK-149	7/			
VIII	Same as type I				

1/ Hardness is minimum and for dental couplings hardness is applicable to tooth surface.
2/ Bhn is standard Brinell hardness number, Rc is hardness designated in Rockwell C scale.
3/ For carburized or induction hardened parts, case depth is defined as the depth below the surface at which the hardness has dropped to Rc 50 or to five points below the surface hardness, whichever is the lower hardness. For nitrided parts, case depth is defined as the depth below the surface at which the hardness has dropped to 110 percent of the core hardness. Depth of case specified is after finish machining.
4/ Case depth and case hardness shall be determined from lugs on forgings or from coupon samples (for case hardened coupling teeth, see 4.6.1.5).
5/ For carburized or induction hardened teeth, the minimum case depth shall be 10 percent of pitch line, chordal tooth thickness, or 0.025 inch, whichever is greater.
6/ See 3.6.1.2.
7/ See 6.9.

TABLE II. Materials other than principal parts.

Part	Applicable document	Material
Threaded fasteners 1/ Bolts, studs, and nuts Cap screws, socket head Cap screws	MIL-S-1222 2/	Carbon and alloy steel, corrosion resisting material
Locknut Self-locking element Threaded inserts	MIL-N-25027 2/ MIL-F-18240 2/ MIL-I-8846	
Gaskets 3/	MIL-T-17523 MIL-G-17859	
Housing or guard 4/	MIL-T-17523 MIL-G-17859 MIL-S-15083 class B or CW MIL-S-22698	 Cast steel Steel plate
Weight-critical housing or guard 5/	ASTM B 26 alloy 355.0 or 356.0	Aluminum alloy

1/ Except for type IV couplings. Fasteners for type IV couplings shall be nonmagnetic.
2/ See 3.4.6.7.
3/ In accordance with specification requirement of parent equipment.
4/ Except for type IV couplings. Material for type IV coupling housing or guard shall be nonmagnetic in accordance with requirements of specification for parent equipment.
5/ See 3.4.9 through 3.4.9.2.

3.2.1 Substitute materials. Materials other than those specified are substitute materials (see 6.8 and 6.8.1).

3.2.2 Use of cast iron. Unless otherwise specified (see 6.2), cast iron parts shall not be used.

3.2.3 Prohibited materials. Cadmium, asbestos, and any material containing asbestos which could become airborne shall not be used.

3.2.3.1 Mercury and mercury compounds. Couplings and parts shall not contain mercury or mercury compounds and shall be free of mercury contamination.

3.2.4 Surfaces. Metal surfaces shall be free of defects (see 4.6.1 through 4.6.1.2).

3.2.5 Surface hardened parts. Minimum case depth shall be in accordance with table I, where applicable. Paint, plastic, and zinc coatings shall not be applied to any surface exposed to oil.

3.2.6 Castings. Castings shall pass the inspection specified in 4.5.4.

3.2.7 Recovered materials. Unless otherwise specified herein, all equipment, material, and articles incorporated in the products covered by this specification shall be new and may be fabricated using materials produced from recovered materials to the maximum extent practicable without jeopardizing the intended use. The term "recovered materials" means materials which have been collected or recovered from solid waste and reprocessed to become a source of raw materials, as opposed to virgin raw materials. None of the above shall be interpreted to mean that the use of used or rebuilt products is allowed under this specification unless otherwise specifically specified.

3.3 Operating characteristics. Couplings shall be matched with driver and driven equipment to provide stable operation under steady state, maneuvering, reverse, windmilling, locked shaft, singling up, trail shaft, and disconnect operation (as applicable) conditions as well as load changes including overload for auxiliary couplings. Design shall also consider increased torque which occurs during maneuvering and crash astern from full operation ahead, and then crash ahead to full power for propulsion machinery. Time required for various operating conditions and increased torque shall be in accordance with parent equipment specifications when coupling requirements are contained therein or as required (see 6.2). When not otherwise provided, rated design torque of propulsion machinery couplings for continuous operation shall be 125 percent of full power torque.

3.3.1 Vibration calculations. Couplings shall be included in torsional and longitudinal vibration analyses of the system (propulsion or auxiliary, as applicable) (see 6.3 and appendix A).

3.3.2 Collaboration. The coupling contractor shall collaborate with the driven and driving machinery contractor as applicable, to ensure that design installation and operating requirement are identical and mutually acceptable (see 6.3 and appendix A).

3.3.3 Related parent equipment requirements and specifications. Numerous requirements for couplings under this specification (for example, space, horsepower, revolutions per minute (r/min), installation, misalignment requirements) when required (see 6.2), are related to requirements and specifications for propulsion or auxiliary prime mover (or propulsion electric motor) and reduction gear (or driven component).

3.3.4 Service life. Insofar as practicable, couplings shall be designed for 30-year life. When life required for the parent equipment (see 6.2) is other than 30 years, couplings shall be designed for the same life. Where different life is indicated for each parent equipment, couplings shall be designed for the greater life requirement. Required operating hours for couplings shall be equal to the greater value required for driver or driven equipment. When not otherwise provided, coupling life in hours shall be in accordance with 3.3.4.1 and 3.3.4.2.

3.3.4.1 Operating hours, propulsion couplings, steam turbine powered units and all propeller shaft speed applications. Coupling life in operating hours shall be as follows:

(a) Total hours - 150,000.
(b) Full power hours - 15,000.
(c) Between 50 and 100 percent full power hours - 60,000.
(d) Less than 50 percent full power hours - 75,000.

3.3.4.2 Operating hours, propulsion couplings, gas turbine and diesel powered units, intermediate and high speed applications. Coupling life in operating hours shall be as follows:

(a) Total hours - 150,000.
(b) Full power hours - 75,000.
(c) Between 50 and 100 percent full power hours - 37,500.
(d) Less than 50 percent full power hours - 37,500.

3.3.4.3 Operating hours, auxiliary couplings. Auxiliary coupling life shall be 100,000 hours at design rated conditions.

3.4 General.

3.4.1 Maintenance.

3.4.1.1 Accessibility. Construction shall be within space limitations and provide the maximum accessibility to parts which require routine inspection, maintenance, and repairs (see 6.3). Design shall provide for minimum effort required to accomplish planned maintenance actions and to effect repairs.

3.4.1.2 Interchangeability. Couplings shall be furnished as a complete assembly. The following individual coupling parts shall be replaceable: tab or lock washers, snap rings, seals, hub and sleeve inserts, and noise attenuating elastomer elements. With the exception of flange fitted bolting holes, coupling assemblies produced in accordance with given drawings (see 6.3 and appendix B), shall be functionally and physically interchangeable without the necessity for further machining, selective assembly, or hand fitting. In no case shall parts be physically interchangeable or reversible unless such parts are also interchangeable or reversible with regard to function, performance, and strength.

3.4.2 Safety.

3.4.2.1 Safety objectives. Couplings shall be designed and constructed to minimize or preclude hazard to equipment or personnel during tests and when installed and operational on board ship (see 6.3). Couplings shall always be contained in guards, casings, or shields. Guards, casings, and shields shall be furnished by parent equipment contractor or by the shipbuilder as is required by parent equipment specification (see 6.2). When not specified, shields which are secured to ship's structure are shipbuilder furnished, and casings and guards secured to engine or reduction gear are furnished by the parent equipment contractor.

3.4.2.2 Safety hazard. Where coupling operating requirements (for example, connect or disconnect) may be hazardous to equipment or personnel, the hazard shall be identified and alleviated via design, special instructions and safety requirements, warning plates, and training requirements.

3.4.3 Calculations and stress diagrams. For each application, the following calculations shall be made (see 6.3 and appendix A):

(a) Shear stress in torque-transmitting bolts neglecting friction.
(b) Stress in distance piece that connects flexible members of double-engagement coupling.
(c) All items listed in 3.4.3.1 through 3.4.3.3 for the coupling types specified therein.
(d) Stresses in elements used to limit fore-and-aft travel of floating member of double-engagement dental-tooth coupling in type V assembly (see 3.9.3.1).

Unless otherwise specified (see 6.2), the calculations shall be made at 125 percent of full-power torque for propulsion couplings and 110 percent of full-power torque for auxiliary couplings. Calculations shall be made using contractor's procedure except where otherwise specified herein or in the contract or order. When calculations are for stress or percent deformation, (the calculated values shall be compared to allowable limits).

3.4.3.1 Dental tooth couplings. The following calculations for dental tooth elements of type I, type II class 2, type IV, type V, and type VIII couplings and coupling assemblies shall be made:

(a) Hertzian contact stress in dental teeth for coupling in aligned condition with 100 percent of the teeth in contact, calculated in accordance with the following formula:

$$Sc = 2290 \sqrt{T/(rRhN)}$$

Where:

Sc - contact stress, pounds per square inch (psi).
T - torque, inch-pounds.
r - radius of pitch circle, inches.
R - radius of tooth face crown, inches.
h - active tooth height, inches.
N - number of teeth in hub or sleeve.

The calculated value of Sc shall not exceed the following allowable values unless approved by the contracting activity :

Minimum tooth surface hardness	Maximum allowable contact stress in psi
275 Bhn	8,000
350 Bhn	12,000
49 Rc	15,000
56 Rc	18,000
59 Rc	19,500

(b) Pitch line shear stress in dental teeth for coupling in aligned condition with 100 percent of the teeth in contact.

3.4.3.2 Diaphragm couplings. The following calculations for type V and type VI couplings and coupling assemblies that incorporate flexible diaphragm elements shall be made:

(a) Total mean and total alternating stresses in diaphragm elements. The individual stress components that are combined to establish the total mean and total alternating stresses, as well as the procedures used to combine these component stresses shall be defined. Mean stress components shall include those due to:

(1) Drive torque.
(2) Axial deflection.
(3) Temperature gradients.
(4) Centrifugal force.

Alternating stress components shall include those due to:

(1) Parallel and angular misalignments.
(2) Torque fluctuations (for propulsion couplings).
(3) Thrust load fluctuations (for propulsion couplings).
(4) Rotating weight of coupling assembly supported by diaphragm elements.
(5) Vibratory stresses (see 3.10.7).

Stress concentration factors shall be determined and used where applicable.

(b) Factor of safety calculated in accordance with the following formula:

$$FS = [(SM/SY) + (SA/SFL)]^{-1}$$

Where:

FS = factor of safety.
SM = calculated total mean stress, psi.
SY = yield strength of diaphragm material, psi.
SA = calculated total alternating stress, psi.
SFL = fatigue limit of diaphragm material, psi.

The factor of safety calculated in accordance with the above formula shall be not less than 2.0. Calculated total mean and total alternating stresses shall be at inside diameter if diaphragm thickness is constant, or maximum values if diaphragm thickness is tapered or contoured. When the diaphragm is welded, the values of yield strength and fatigue limit in the weld region shall be used where applicable.

(c) For multiple diaphragm pack couplings where there is a potential for fretting of the diaphragms and adjoining filler pieces due to interference under high misalignment, a fretting factor of safety shall be defined as follows:

$$FS = MA/DA$$

where:

FS = Factor of Safety

MA = Maximum angular misalignment that can be applied to a diaphragm pack, concurrent with the maximum design point axial misalignment, before fretting becomes imminent.

DA = Design point (maximum continuous) for angular misalignment.

The fretting factor of safety, calculated in accordance with the above formula, shall not be less than 1.2. The fretting factor of safety shall be verified either by test or detailed calculations.

(d) Axial, flexural (bending), and torsional stiffnesses of each diaphragm assembly or diaphragm pack. When the axial deflection of the diaphragm assembly or diaphragm pack does not increase linearly with axial load, a plot or tabulation of the axial load versus axial displacement shall be furnished in lieu of the axial stiffness.

(e) Axial, flexural (bending), and torsignal natural frequencies of double-engagement couplings.

3.4.3.3 Elastomer, noise-attenuation elements. The following calculations for type IV and type V coupling assemblies that incorporate elastomer, noise-attenuation elements shall be made:

(a) Total compressive and shear stresses in elastomer elements, as well as corresponding percent deformations of the elements. Both the mean and alternating components of the stresses and percent deformations shall be calculated. Mean stress and percent deformation components are those due to:

(1) Pre-compression (where applicable).
(2) Drive torque.
(3) Axial deflection.
(4) Radial and axial temperature gradients.
(5) Centrifugal force.

Alternating stress and percent deformation components are those due to:

(1) Parallel and angular misalignments.
(2) Torque fluctuations (for propulsion couplings).
(3) Thrust load fluctuations (for propulsion couplings).
(4) Rotating weight of coupling assembly supported by elastomer elements.

Contouring of corners and edges to eliminate or reduce stress concentrations shall be defined. Calculated total stresses and percent deformations shall not exceed the limits for continuous or frequent loading designated in MIL-HDBK-149, both in shear and in compression. Tensile loading of the elastomer shall be avoided. Stress reversals in shear shall also be avoided except during torque reversals.

(b) Axial, flexural (bending), and torsional stiffnesses of coupling members (at each end of double-engagement coupling).
(c) Axial, flexural (bending), and torsional natural frequencies of coupling assembly (for double-engagement couplings only).

3.4.4 Distance piece. Distance pieces in double-engagement couplings shall be readily removable to facilitate handling of large couplings, or where such a feature is not required, the complete coupling may be furnished as a permanent assembly. Unless otherwise approved, distance-piece material shall be high-strength, low-alloy steel, coated to afford corrosion protection in a marine environment.

3.4.5 Securing to shaft. Sleeves, hubs, plates, and flanges shall be secured to shafts or distance pieces by fitted bolts or shall be splined, shrunk, or keyed, as applicable. Unless otherwise approved by the contracting activity, retaining nuts shall be employed where such parts are splined or shrunk. Retaining nuts shall be locked against turning. Nuts used on through bolts shall be of the self-locking type.

3.4.5.1 Coupling hubs. Wall thickness of coupling hubs shall be sufficient to prevent cracking or fracture under shrink fit, torque, bending moment, and centrifugal and other loading imposed during normal operation of the coupling, and allowing for the effects of keyways, splines, holes, or other features that introduce stress concentrations.

3.4.6 Fasteners.

3.4.6.1 External bolting for casings. Fasteners for casings shall be in accordance with table II.

3.4.6.2 Bolting for rotating parts and internal fasterners. Fasteners, for all rotating parts and internal fasterners shall be in accordance with table II and shall conform to grade 5 or better of MIL-S-1222 (see 3.2). All fasteners shall be locked in accordance with MIL-N-25027 and MIL-F-18240.

3.4.6.3 Bolt holes. When couplings are nitrided or carburized, bolt hole and adjacent areas shall not be case hardened to permit reaming at assembly.

3.4.6.4 Fasteners, weight balance. Coupling bolts, nuts, and cap screws shall be weight balanced to values given below for main reduction gear intermediate couplings, couplings operating above 2200 revolutions per minute (r/min), and type V couplings.

Speed, r/min	Balance, grams
0 to 1000	± 1.0
1000 to 2000	± 0.5
2000 to 3600	± 0.2
over 3600	± 0.1

3.4.6.5 Fastener sets. Bolts shall be furnished as sets, or for line shaft couplings, and they may be sized for their respective holes and marked.

3.4.6.6 Fastener torque. Installation torque limits and thread lubricant requirements shall be established by the coupling contractor and specified in the component drawings for all threaded fasteners. The lower limit of installation torque shall be sufficient to prevent joint separation under the normal operating loads and, when required (see 3.4.10), under shock. Where not otherwise specified:

(a) Combined stress in the fastener threads under the upper limit of installation torque shall not exceed 75 percent of yield strength of the bolt material.
(b) Compressive stress of load-bearing surfaces including washers at the upper limit of installation torque shall not exceed 100 percent of ultimate compressive strength of the material.

3.4.6.7 Corrosion protection. Cadmium and zinc plating are prohibited. Substitute with QQ-S-365, MIL-C-26074, or MIL-C-83488.

3.4.7 Flanges.

3.4.7.1 Centering. Flange connections shall be provided with a rabbet for centering, except for line-shaft couplings, which may use fitted bolts or dowels in place of the rabbet fit. Rabbets shall be machined to achieve a loose diametral fit not greater than 0.001 inch total or 0.001 inch per foot of diameter, whichever is larger. Fitted bolts or dowels used in place of the rabbet fit shall maintain equal or better concentricity at the locating diameter.

3.4.7.2 Counterboring. Flanges for main gear intermediate couplings and couplings operating above 2200 r/min shall be counterbored to shroud bolt heads and nuts.

3.4.8 Disassembly. For all coupling types, when feasible, the construction shall permit coupling removal or installation without removal of connected shafts. Furthermore, removal of connected shaft for coupling removal or installation for the following is prohibited: double reduction gear, main reduction gear, high-speed pinions, main steam turbine rotors, gas turbine rotors, diesel engine crank shafts, and electric motor armatures.

3.4.9 Use of aluminum alloys. Housing parts or guards may be made of aluminum alloy in weight critical applications (see table II), if approved by the contracting activity.

3.4.9.1 Corrosion protection. In order to prevent deterioration due to corrosion, bolts, nuts, studs, pins, springs, screws, cap screws, and other fastenings or fittings used with aluminum alloy parts shall be of a corrosion resistant material, or of a material treated in a manner to render it resistant to corrosion. Aluminum alloy parts shall be anodized in accordance with MIL-A-8625 or otherwise treated by a process that provides at least equal protection against corrosion. Contact between dissimilar aluminum alloys or dissimilar metals shall be avoided as much as possible. Where assembly of dissimilar metals with aluminum alloys is unavoidable, the alloys shall have their faying surfaces anodized. Where threaded surfaces or faying surfaces may require disassembly in service, an antiseize compound in accordance with MIL-A-907 shall be used.

3.4.9.2 Fastener installation. Though bolting is preferred for the assembly of aluminum alloy parts and is mandatory when the assemblies are highly stressed or subject to vibrating loads (see 3.4.6.7). Where the use of cap screws, stud bolts, or machine screws is necessary, parts shall be threaded into steel inserts cast or screwed into the aluminum alloy. The steel inserts shall be pinned or prick punched in such a manner to prevent their backing out. Cap screws, stud bolts, and machine screws shall be steel with zinc plating. Copper alloys, such as brass or bronze, shall not be used in threaded contact with aluminum alloys.

3.4.10 Shock. When high-impact shock design is required for parent equipment (see 6.2), the same requirements shall apply for couplings. When high-impact shock design is required, couplings shall meet the grade A, hull-mounted equipment requirements as specified in MIL-S-901. Couplings shall be tested with parent equipment.

3.4.11 Balance. Balancing shall be in accordance with MIL-STD-167-1. Coupling parts rotating at more than 150 r/min shall be balanced dynamically. Balance shall be accomplished by removal of metal. The addition of weights to correct for unbalance after finish machining is not permitted. The permissible amount of unbalance shall be subject to approval by the contracting activity if specified (see 6.2). Also, see 3.4.6.4 for fastener weight balance and 3.4.6.5 for bolt sets.

3.4.11.1 Assembly dynamic balance. Distance-pieces with all integral parts shall be dynamically balanced as a unit. Coupling elements which are mounted on connected machinery (for example, sleeve and oil dam) shall be given a final dynamic balance with the attached machinery assembly where possible.

3.4.11.2 Low noise or vibration. When low noise or vibration requirements are imposed for parent equipment or when in situ balancing is required for parent equipment (see 6.2), the parent equipment requirements shall also apply for internal or connecting couplings (see 6.3 and appendix B).

3.4.12 Welding, brazing, and allied processes. Welding, brazing, and allied processes shall conform to MIL-STD-278. Electron-beam welding procedures shall be in accordance with SAE AMS 2680 for fatigue critical applications and SAE AMS 2681 for applications not covered by AMS 2680.

3.4.13 Housing (guards). Housing (guards) shall be split to permit removal. Flange jack bolts shall be provided for parts heavier than 35 pounds.

3.4.14 Lifting. Provision or arrangement shall be made for lifting coupling parts which weigh more than 35 pounds.

3.4.15 Weight. Weight of couplings shall be plus or minus 5 percent of the weight specified on the drawings.

3.4.16 Marking.

3.4.16.1 Match marking. For dental coupling elements, meshing position of internal and external teeth shall be clearly and permanently marked for the engagement made at the 80 percent tooth contact check (see 3.5.2.5). Parts that may affect balance if not reinstalled to the original position or are individually fitted, shall be marked so that they may be reinstalled in their original position.

3.4.16.2 Part identification. Major coupling parts and subassemblies shall be marked to indicate contract number, manufacturer, date manufactured, and manufacturer's assembly or detail drawing number. Proprietary marking may be added at the discretion of the contractor. Other markings required by MIL-STD-130 shall also be applied to coupling parts and assembly.

3.4.16.3 Mark application. Markings shall be in accordance with MIL-STD-130 and shall be applied in an area of low stress. Depth of marking shall be not greater than 0.020 inch.

3.5 Type I dental couplings lubricated by oil circulation.

3.5.1 Construction (type I). Unless otherwise specified (see 6.2), type I couplings shall be of the double-engagement type and shall consist of sleeves with internal gear teeth which mesh with external gear teeth on the distance piece. Materials for principal parts, tooth hardness, case hardening method, and minimum case depth shall be as specified in table I.

3.5.2 Dental coupling teeth.

3.5.2.1 Tooth form. Teeth used for couplings shall be of the involute or modified involute form.

3.5.2.2 Tooth crown. Unless otherwise specified (see 6.2), dental couplings shall be constructed with crowned faces on external teeth (face barrelled). Tooth crown profile shall be a full radius with maximum crown height at midpoint of tooth length. Crown radius shall be chosen to provide crown height necessary for misalignment specified, but resulting Hertzian contact stress shall not exceed limits specified in 3.4.3.1. Outer (tip) diameter of external teeth shall also be crowned with a rocker projection to accommodate misalignment specified. Internal teeth shall have straight faces and shall be longer than the external teeth.

3.5.2.3 Tooth finish. Dental tooth contacting surfaces shall have a maximum surface finish of 32 roughness height rating (RHR).

3.5.2.4 Tooth corners. Corners at ends of dental coupling teeth, which might dig in when they slide, shall be chamfered or rounded off.

3.5.2.5 Tooth contact. Dental couplings shall be checked in an aligned position to assure that at least 80 percent of the total number of teeth are in contact or as specified in the contract or order (see 6.2).

3.5.2.6 Sleeve root diameter concentricity. For dental couplings used with main reduction gear intermediate assemblies and for dental couplings operating above 2200 r/min, the root diameter of coupling sleeve teeth shall be concentric with the locating rabbet diameter to within 0.001 inch total or 0.001 inch per foot of diameter, whichever is larger.

3.5.2.7 Hub tooth concentricity. For dental couplings where hubs are secured to connected shaft and are used with main reduction gear intermediate assemblies and for dental couplings operating above 2200 r/min, the outside diameter of the hub teeth shall be concentric with the locating diameter in the bore of the hub to within 0.001 inch total or 0.001 inch per foot of diameter, whichever is larger.

3.5.2.8 Fore and aft movement. Provision shall be made to restrict the fore and aft movement of the floating members of dental tooth couplings to that required for necessary working clearance. Lubricant dams or seals shall not be utilized for this purpose.

3.5.2.9 Mechanical constraints. Mechanical constraints which would cause cocking of the face-barrelled element tending to displace the contact from the center of the barrel face shall be avoided.

3.5.2.10 Wear margin. Toothed couplings shall be constructed so that replacement due to wear is not required until backlash is at least equal to design backlash plus 20 percent of the male tooth design chordal tooth thickness for through-hardened teeth, and design backlash plus 50 percent of case thickness for surface-hardened teeth.

3.5.2.11 Sliding velocity. Sliding velocity of coupling teeth under maximum continuous misalignment shall not exceed 2.5 inches per second.

3.5.3 Lubrication.

3.5.3.1 Lubrication method. Type I dental coupling teeth shall be continuously lubricated by means of sprays or jets. If oil sprays or jets are removable, the design shall provide for one-way installation to ensure proper alignment.

3.5.3.2 Lubricating oil. Unless otherwise specified (see 6.2), lubricating oil for the coupling shall be supplied from the lubricating oil system of the propulsion gear or the driver element and shall conform to the following:

(a) Symbol 2190 TEP, MIL-L-17331, when driver element is a gas turbine, a steam turbine, or an electric motor.
(b) NATO code 0-278, MIL-L-9000, when driver element is a diesel engine.

3.5.3.3 Oil dams. Oil dams shall be incorporated to keep the coupling teeth totally submerged in oil during operation. Dams attached by fasteners shall be centered on the coupling by a rabbet. Cap screws used to secure the dam to the sleeve shall be of the self-locking type. Tab-type lock washers or staking of fasteners shall not be used. Oil dams shall not serve as bumpers or to limit axial float (see 3.5.2.8).

3.5.3.4 Oil flow and sludge. Provisions shall be made for flow of oil across full length of teeth to flush out contaminants and prevent sludge buildup from centrifugal action at the outside diameter of the teeth.

3.5.3.5 Blockage of oil. Provision shall be made to prevent blockage of inlet oil and covering of sludge-removal holes, over the full range of fore and aft movement of the floating member (see 3.5.2.8).

3.5.3.6 Lubrication drain holes. Tapered pipe threads are not permitted for use in lubrication drain holes. Lubrication drain hole plugs shall be provided with a positive locking feature.

3.5.4 Housing (guards). Couplings lubricated by oil sprays or jets shall be enclosed in oiltight guards, with provisions made for oil drainage. Housing or guard materials shall be in accordance with 3.2, table II. For couplings used to connect engine or turbine shafts to pinion shafts, the guards shall terminate in flanged connections for bolting to the engine or turbine and gear housings. Such guards shall also be split horizontally and provided with a circumferential packed slip-joint to permit axial displacement.

3.6 Type II dental coupling, self-contained (grease) lubricant.

3.6.1 Construction (type II). Unless otherwise specified (see 6.2), type II couplings shall be of the double-engagement type and shall consist of sleeves with internal gears which mesh with external gear teeth on the hub.

3.6.1.1 Class 1. The type II, class 1 coupling may be a commercial (off-shelf) design or a special design for the application. Coupling teeth shall be of the involute or modified involute form and coupling design shall include provision to restrict fore and aft movement of floating member to that required for working clearance. Unless otherwise specified (see 6.2), tooth hardness shall be not less than 160 Bhn (see table I) and tooth surface finish shall be not greater than 64 RHR.

3.6.1.2 Class 2. The type-II, class 2 coupling shall meet all the requirements specified in 3.5.2 through 3.5.2.11, and tooth hardness shall be not less than 275 Bhn . Unless otherwise specified (see 6.2), coupling teeth may be either through-hardened surface-hardened and the material and case thickness requirements specified in table I for type I couplings shall apply.

3.6.2 Lubricant. Lubricant shall be a grease in accordance with DOD-G-24508. Use of proprietary greases is prohibited.

3.6.3 Seals. Grease retention seals shall be of the split type if disassembly or removal of connected machinery would be required for replacement of one-piece seals. Seals shall not serve as bumpers or to limit axial float.

3.7 Type III laminated disc coupling.

3.7.1 Construction (type III). Type III couplings shall be arranged for single- or double-engagement as specified (see 6.2). For double-engagement couplings, the forward and after disc stacks shall be connected by a forged center member or distance piece. Materials of principal parts shall be as specified in table I.

3.7.1.1 Discs. Each laminated disc assembly shall consist of one or more stacks of corrosion-resistant steel discs mounted between flanges.

3.7.1.2 Securing of discs. Disc stacks consisting of loose discs shall be secured to flanges by fitted bolts. Disc stacks using a pilot ring shall be secured to flanges by through bolts and nuts. Nuts used on coupling bolts shall be a self-locking type.

3.8 Type IV nonmagnetic, noise-attenuation coupling.

3.8.1 Arrangement. Type IV coupling assemblies shall consist of either, or a combination of, high-misalignment dental coupling elements and elastomer torque transmitting elements, whichever is specified (see 6.2). Type IV coupling assemblies are intended for use in noise-attenuated propulsion and auxiliary systems where low magnetic permeability is required.

3.8.2 Materials. The magnetic permeability (relative to air) of the coupling assembly shall not exceed 2.0. Each portion of the coupling shall be of nonmagnetic material, except for steel inserts that may be required to improve wear resistance in dental tooth, or other critical regions. The projected outline of such magnetic material shall be made as small as possible consistent with life and reliability. Materials shall be as specified in tables I and II.

3.8.3 Over-torque capability. Couplings shall transmit 200 percent of rated torque at the maximum misalignment condition for a period of 1 minute for each such application (see 4.6.4), without adverse effect on coupling operation or life.

3.8.4 Dental coupling elements. Unless otherwise specified (see 6.2), dental couplings shall be of the double-engagement type. Tooth construction shall meet all requirements for type I couplings specified in 3.5.2 through 3.5.2.11.

3.8.4.1 Lubrication. Dental tooth inserts shall be designed for either circulating oil lubrication or for self-contained grease lubrication, whichever is specified (see 6.2). Where lubrication by oil circulation is specified, the lubrication requirements of type I couplings (see 3.5.3 through 3.5.3.6) shall apply. Where self-contained grease lubrication is specified, lubricant and seal requirements of type II couplings (see 3.6.2 and 3.6.3) shall apply.

3.8.4.2 Connections. Flanged connections or straight or tapered bored hubs shall be provided for connections to driving and driven machinery.

3.8.5 Noise-attenuation elastomer elements.

3.8.5.1 Noise path. Elastomer elements shall be arranged to prevent any direct metal-to-metal noise path between input and output ends. The elastomer shall be located so as to allow removal of generated heat by normal air circulation inside coupling housing.

3.8.5.2 Inert to lubricant. Elastomer elements shall not be affected by direct and prolonged contact with mineral oil and grease.

3.8.5.3 Elastomer element arrangement. Elastomer elements may be arranged for normal loading in either compression or shear, or combination thereof. The elements shall not allow appreciable sag of the supported coupling portions which would cause dynamic unbalance. Provision shall be made for positive mechanical drive in the event of failure of the elastomer elements or excessive torque overload.

3.9 Type V line-shaft noise-attenuation coupling assembly.

3.9.1 Arrangement. The type V coupling assembly shall consist of one of the following as specified (see 6.2):

(a) A double-engagement dental tooth coupling in series with an elastomer, noise-attenuation coupling .
(b) A single- or double-engagement diaphragm coupling in series with an elastomer, noise-attenuation coupling .
(c) A double-engagement elastomer, noise-attenuation coupling.

3.9.2 General.

3.9.2.1 Design torque. The coupling shall have the same overload and speed requirements as the propulsion system gearing. Unless otherwise specified (see 6.2), the rated design torque shall be 125 percent of full power torque.

3.9.2.2 Misalignments. The values of normal, maximum continuous, and maximum transient misalignments that the coupling assembly must accommodate in service shall be specified (see 6.2) based on consideration of the additive effects of the following factors where applicable:

(a) Installation tolerances of the resiliently mounted propulsion machinery sub-base.
(b) Static shaft deflections at the connections to the driver and driven equipment.
(c) Long-term drift (sag) of the resilient mounts.
(d) Long-term bearing wear down.
(e) Translatory and angular displacements of resiliently mounted equipment relative to solidly chocked equipment due to:

(1) Hull deflections caused by variations in seawater temperature and pressure.
(2) Thermal expansions of connected equipment.
(3) Torque loading.
(4) Propulsion turbine vacuum conditions.
(5) Trim, list, roll, and pitch motions of ship (see 3.13.1).

(f) Shock (for maximum transient misalignment only).

3.9.2.3 Axial displacement. The range of relative axial displacement between the resiliently mounted and solidly chocked equipment that the coupling assembly must accommodate in service shall be specified (see 6.2). Coupling assembly shall be designed for continuous operation anywhere within this range of axial displacement over its operating life.

3.9.2.3.1 Mechanical stops. Mechanical stops or other such provisions may be used to protect the flexible elements of the coupling in the event that axial displacements in service exceed the design range of the coupling (see 3.9.2.3). Such provisions shall be designed to meet the high-impact shock requirements specified for the parent equipment and to withstand all other loading that they may experience in service.

3.9.2.4 Operating life. Unless otherwise specified (see 6.2), coupling assembly shall have the operating life in hours stipulated for propulsion couplings in 3.3.4.1 and shall operate at rated design torque during full-power hours under:

(a) Maximum transient misalignment for number of occurrences and duration of each occurrence specified (see 6.2).
(b) Maximum continuous misalignment for number of hours specified (see 6.2).
(c) Normal misalignment for balance of full-power hours.

3.9.2.5 Static stiffness. The torsional and axial static stiffnesses of complete coupling assembly (comprising diaphragms, quill shaft, and elastomer elements), as well as the bending (or flexural) static stiffnesses of the individual diaphragm and elastomer coupling elements, shall not exceed the values specified in the ordering document (see 6.2).

3.9.2.5.1 Vibratory response. The design of the coupling assembly shall be integrated closely with that of the propulsion machinery system and the coupling shall serve to block or attenuate the transmission or vibratory forces at turbine frequencies, gear mesh frequencies, and harmonics thereof. In addition, the design of the coupling shall strive for low axial (fore and aft) and torsional elastic spring constants, consistent with coupling life and reliability, in order to minimize system vibration response at propeller blade passing frequencies.

3.9.2.6 Flange connections. Flange connections shall be provided with a rabbet or fitted bolts for centering. Shrouding is not required for bolt heads and nuts.

3.9.2.7 Balancing. Balancing shall be the best obtainable using manufacturer's facilities. Unbalance shall be not greater than specified on approved drawings.

3.9.2.8 Coupling distance-piece design. Coupling distance-piece (quill shaft) design shall be as specified in appendix E.

3.9.2.9 Housing. Housing shall connect between mounted equipment and nearest after solidly chocked member. Connection of housing to solidly chocked member shall be designed to avoid a sound short. Housing design shall have provision to permit relative motions between mounted equipment and solidly chocked member.

3.9.2.9.1 Oil drainage. When coupling assembly includes members lubricated by oil sprays or jets, the housing shall be oiltight and shall include provisions for oil drainage.

3.9.2.9.2 Port covers. When required (see 6.2), covers or guards shall be constructed so that elastomer elements and lubrication sprays (or jets) can be sighted to determine condition. Port covers (removed for sighting) which are secured to cover (or guard) by cap screw or bolts, shall be oiltight. Cover bolts shall be secured to prevent unauthorized removal in accordance with MIL-G-17859.

3.9.2.9.3 Accessibility. When specified (see 6.2), sprays (or jets) which supply oil to couplings shall be cleaned without lifting guards or covers. If oil sprays (or jets) are removable, the design shall provide for one-way installation to ensure proper alignment of nozzle or jets.

3.9.2.10 Dimension and arrangement. Dimension and arrangement requirements shall be not greater than those specified (see 6.2).

3.9.2.11 Disassembly. Where possible, the coupling shall be constructed to permit removal without disturbing connecting shafting.

3.9.3 Dental tooth coupling. Dental tooth couplings used in type V coupling assemblies shall meet all materials, dental tooth design, and lubrication requirements of type I, class 5 couplings (see table I, and 3.5.2 through 3.5.3.6).

3.9.3.1 Retaining rings and bolts. Bolted-on retainer rings or other elements used to limit fore and aft travel of floating member shall meet the high-impact shock requirement specified for the parent equipment (see 6.2). In addition, such motion-limiting elements shall withstand the following loads without fatigue failure:

(a) Unlimited impacts by the floating member under continuous misalignment. Unless otherwise specified (see 6.2), a relative velocity at impact of 1 inch per second shall be assumed.
(b) Other cyclic loading imposed by the floating member when it is forced against the stop as a result of hull compression, ship angle, thrust forces transmitted from the main propulsion shafting, and other such conditions of operation. Calculations shall be made for operation at up to maximum design torque (see 3.9.2.1)

and maximum continuous misalignment. Information required by contractor for this analysis, including the range of values of friction coefficient in the dental-tooth coupling meshes that must be allowed for in the calculations and the sequence of application of the factors that contribute to the loading, shall be as specified (see 6.2).

3.9.4 Diaphragm coupling. Diaphragm couplings used in type V coupling assemblies shall meet all requirements of type VI couplings (see 3.10.2 through 3.10.7).

3.9.4.1 Backup drive provision. Positive mechanical drive in event of any failure of a diaphragm element (see 3.10.4) shall be by means of dental teeth with sufficient backlash to prevent tooth engagement during normal operation of the diaphragm coupling.

3.9.4.1.1 Capability. The dental teeth of the backup drive shall transmit rated design torque under maximum transient misalignment following any failure of a diaphragm element. The subsequent operational capability of the dental teeth, including operating hours and allowable torque under maximum continuous misalignment shall be specified (see 6.2). The tooth design requirements in 3.5.2 through 3.5.2.11 shall apply. Elements used to limit fore-and-aft motions between the mating members of backup dental couplings shall meet the requirements of 3.9.3.1.

3.9.4.1.2 Lubrication. Unless otherwise specified (see 6.2), lubrication of dental teeth shall be by oil spray or jet and the lubrication requirements specified in 3.5.3 through 3.5.3.6 shall apply.

3.9.4.1.3 Indication of engagement. Provision shall be made to indicate when the load shifts from the diaphragm to the backup dental coupling.

3.9.4.2 Diaphragm and backup drive analysis. Contractor shall make, in addition to the other items required in 3.4.3.1 and 3.4.3.2, computations of torque, bending moment, reaction forces, tensile stresses, diaphragm shear stresses, thermal gradient stresses, tooth compressive stresses, relative sliding velocities between mating teeth, frictional heat input to the coupling teeth, and oil cooling flow requirements if applicable (see 6.3 and appendix A). Stresses in the distance-piece shall be computed for both the dental backup coupling teeth engaged and non-engaged conditions. Unless otherwise specified (see 6.2), the coefficient of friction shall be assumed to average 0.38 for lockup condition and 0.25 for sliding condition. Lockup assumes no relative sliding motion to occur between mating teeth of hub and sleeve. Distribution of load between coupling teeth assumed in the calculations shall be defined.

3.9.5 Elastomer noise-attenuation coupling. The elastomer coupling shall prevent any direct metal-to-metal noise path between input and output ends. The coupling shall be constructed to transmit not less than 150 percent of the rated design torque without shorting out any of the elastomer elements or causing torque to be transmitted by metal-to-metal contact.

3.9.5.1 Elastomer elements. The elastomer elements shall be arranged for normal loading in either compression or shear or a combination thereof. The elements shall not allow appreciable sag of the supported coupling portions which would cause dynamic unbalance. "As-cured" properties of the elastomer used shall be determined by test (see 4.6.9).

3.9.5.1.1 Inert to lubricant. Elastomer element shall not be affected by direct and prolonged contact with mineral oil or grease. Elastomers that are inherently oil resistant are preferred. Natural rubber may be proposed for use in installations where rubber elements are remote and separated by oiltight seals from oil sprays or jets, and all exposed rubber surfaces protected by an oil-resistant coating (see table I for approval requirements).

3.9.5.1.2 Heat dissipation. Elastomer elements shall provide for removal of heat generated in the coupling by normal ventilation inside the coupling housing.

3.9.5.2 Backup drive. Provision shall be made for positive mechanical drive in the event of any failure or excessive deflection of an elastomer element. The drive shall engage automatically in the event of any elastomer element failure and shall transmit the rated design torque under maximum transient misalignment. The subsequent capability of the backup drive shall be as specified (see 6.2).

3.9.5.2.1 Indication of engagement. Provision shall be made to indicate when the backup drive has been engaged.

3.9.5.3 Solidification. Provision shall be made to permit operation with a solid connection between driver and driven elements (solidification) in lieu of connection through the noise attenuating elastomer elements. Unless otherwise specified (see 6.2), the design of the coupling shall permit on-site installation of the solidification hardware. Instructions for on-site installation of this hardware shall be prepared by the coupling contractor.

3.9.5.3.1 Solidification requirements. Solidification of the elastomer elements of a type V coupling assembly shall not reduce operating life (see 3.3.4 and 3.3.4.1) and design torque capability (see 3.9.2.1). Solidification shall not reduce misalignment capability (see 3.9.2.2) when elastomer elements are used in series with double-engagement dental coupling (arrangement (a) of 3.9.1). When elastomer elements are in series with a single- or double-engagement diaphragm coupling (arrangement (b) of 3.9.1) or when assembly consists of a double-engagement elastomer coupling (arrangement (c) of 3.9.1), the allowable reduction in misalignment capability shall be as specified (see 6.2).

3.9.5.3.2 Solidification hardware. Acquisition of solidification hardware is a special requirement. Coupling contractor shall furnish such hardware with the coupling only if specified (see 6.2), and in the quantities required therein. The activity responsible for review and approval of the procedure for on-site solidification shall be as specified (see 6.2).

3.10 Type VI diaphragm coupling.

3.10.1 Arrangement. Unless otherwise specified (see 6.2), type VI couplings shall be of double-engagement type and shall consist of hubs mounted on a distance piece and attached through flexible diaphragms to flanged connections in the parent equipment shafts.

3.10.2 Diaphragms. Each flexible diaphragm assembly shall comprise either a single diaphragm, or diaphragms in series, or multiple diaphragms in parallel (diaphragm pack). The profile of the individual diaphragms may be straight or convoluted and the thickness of each diaphragm may be constant, or contoured to equalize stress. Diaphragms shall be made of corrosion-resistant material or protected by means of a corrosion-resistant coating. Diaphragm material and hardness, as well as composition and application procedure for any coating used, must be approved by the contracting activity (see table I).

3.10.3 Securing of component parts. Misalignment and relative motions between the flanged connections to the parent equipment shall be accommodated by deflections of the diaphragms. All joints between distance piece, hubs, diaphragms, and parent equipment or adaptor flanges shall be configured so as to prevent relative motions at the joints. The hubs and distance piece shall be integral (single forging or by welding), or connected by means of a fixed spline or fitted bolts. Connection between series-mounted diaphragms shall be by welding between end rings, or by fitted bolts. Attachment of the diaphragm end ring or of the diaphragm pack to the adaptor piece or to the parent equipment flange shall be by means of fitted bolts. All fitted bolts and self-locking nuts shall be in accordance with table II. Fastener heads and nuts shall be in countersunk holes or channels. Nuts, cap screws and studs shall have self-locking provisions. Corrosion-resistant shims may be used to adjust axial location of the coupling.

3.10.3.1 Retention of self-locking nuts. When coupling connection is to turbine, engine, generator, or reduction gear, fastening shall be accomplished so that if self-locking nuts fail, the nuts and bolts are captured by means of shields, snap rings, or similar devices to prevent falling off.

3.10.4 Backup drive. A positive, mechanical drive which shall be normally non-engaged, shall engage automatically to continue to transmit the drive torque in the event of a diaphragm failure. This backup drive shall be provided for diaphragm couplings used in type V coupling assemblies (see 3.9.4). For other diaphragm coupling assemblies, the backup drive is required only when specified (see 6.2), which shall set forth also the life, torque, speed, and misalignment capabilities of the backup drive.

3.10.5 Diaphragm guards. The inboard face of each diaphragm assembly shall be protected by a piloted, radial diaphragm guard which shall also serve as a catcher in event of a diaphragm failure.

3.10.6 Drainage. Drainage holes shall be provided at the periphery of the coupling assembly (at each end for a double-engagement coupling) to remove trapped fluids.

3.10.7 Natural frequencies. Where practical, the axial natural frequencies of the coupling shall not fall between 80 percent and 120 percent of any of the following:

(a) Any speed and two times any speed within the range from minimum to full power r/min.
(b) Any other speed or exciting frequency specified in the contract or order (see 6.2).

When this criterion is not met, coupling contractor shall incorporate damping provisions to minimize vibratory motions of the diaphragms, and shall calculate the diaphragm vibratory stresses.

3.11 Type VII elastomer flexible coupling.

3.11.1 Construction (type VII). Type VII couplings shall be arranged for single- or double-engagement as specified (see 6.2). For double-engagement coupling, the forward and after flexible elements shall be connected by a forged center ring or distance piece.

3.11.1.1 Elastomer flexible members. Coupling shall utilize elastomer members in compression to effect a flexible connection for torque transmission between driver and driven shafts. Two types of elastomer flexible members are specified in 3.11.1.2 and 3.11.1.3. Others may be proposed by coupling contractor for approval by contracting activity .

3.11.1.2 Elastomer block-type. The elastomer block-type coupling shall transmit torque between driver and driven members through elastomer blocks inserted with precompression in individual cavities formed by external steel blades of the hub of one member, internal steel blades of the sleeve of the second member, and two steel end closures. Multiple blocks shall be used, equally spaced in a circle around the axis of rotation.

3.11.1.3 Elastomer bushing-type. The elastomer bushing-type coupling shall transmit torque between driver and driven members through hollow flexible bushings mounted at their inside diameters on pins in the hub of one member, and retained at their outside diameters under compression in sockets in the flange or sleeve of the second member. Each bushing may consist of a single elastomer annulus, or may be made up of alternating steel and elastomer annuli bonded together. Multiple bushings shall be distributed symmetrically around the axis of rotation.

3.11.2 Inert to lubricants. The elastomer elements shall not be affected by direct and prolonged contact with mineral oil or grease.

3.11.3 Heat dissipation. The elastomer elements shall be designed to provide for removal of the heat generated in the coupling by normal ventilation inside the coupling housing.

3.12 Type VIII connect or disconnect dental coupling.

3.12.1 Construction (type VIII). Type VIII couplings shall be arranged for single- or double-engagement as specified (see 6.2) and shall consist of externally toothed hubs and internally toothed sleeves which may be mechanically engaged and disengaged. One or both of the mating members of the mesh shall be able to move axially into the engaged or disengaged positions. Provision shall be made in the construction of the coupling to retain the members in the appropriate position (engaged or disengaged) during operation. Unless otherwise specified (see 6.2), type VIII couplings shall meet all the dental tooth, lubrication, and housing requirements of type I couplings (see 3.5.2 through 3.5.4). Hub and sleeve material, as well as tooth hardness, case hardening method, and minimum case depth shall be designated by class number (1 through 5), in the same manner as for type I couplings (see table I).

3.12.2 Disassembly. Construction shall be such that dental couplings can be disassembled without removing the connected shafts.

3.12.3 Disconnect. When required (see 6.2), couplings shall be constructed so that one coupling may be disconnected and operation resumed on remaining shafts. Target time required for disconnect is 15 minutes (see 6.3 and appendix C).

3.12.4 Locking device. When a disconnect coupling is required for a turbine drive, the contractor shall also furnish a device to lock the driving turbine as specified (see 6.2). Holding capacity of locking device shall be not less than 10 percent of turbine full power torque.

3.12.5 Housing ports. When constructed for a disconnect type coupling, housings shall be provided with access ports which permit use of both hands to manually disconnect the coupling and provide for simultaneous sighting of the work. Port covers shall be oiltight when secured.

3.13 Environment.

3.13.1 Trim, list, roll, and pitch. Couplings shall operate satisfactorily when the ship in which they are installed is operating in the condition shown in table III or as specified (see 6.2). Trim and list or roll and pitch can occur simultaneously. Pitch and roll time cycle data shall be recorded when the pitch and roll angles specified exceed those listed in table III.

TABLE III. Trim, list, roll, and pitch.

Condition	Surface ships (degrees)	Submarines (degrees)
Permanent trim, down bow or stern	5	30
Permanent list, port or starboard	15	15
Roll, port or starboard from even keel	45	60
Pitch, up or down from normal waterline	10	10

3.13.2 Lubricating oil temperature. Unless otherwise specified (see 6.2), oil inlet temperature to coupling under normal operating conditions shall be between 110 and 130 degrees Fahrenheit (°F). However, couplings shall be designed for start-up and unrestricted operation with oil inlet temperature as low as 90°F. Maximum rise between oil inlet and oil discharge temperatures from coupling shall be not greater than 50°F.

3.13.3 Ambient conditions. Depending on the ship type, ambient engineering space temperature will range up to 150°F. Under emergency conditions, (space abandoned) temperature may rise above 200°F until heat producing equipment can be shut down.

3.13.4 Atmospheric conditions. Couplings shall operate in an environment where the air will be salt laden (saltwater atmosphere) and humidity will be at or near the saturation point for long periods of time.

3.14 Special tools and equipment. Special tools and equipment as defined herein shall be furnished as specified (see 6.2). Special tools and equipment are defined as those items not listed in the Federal Supply Catalog (copies of this catalog may be consulted in the office of the Defense Contract Management Area Operations (DCMAO)) and not normally carried on board the applicable ship.

3.15 Variations.

3.15.1 Equipment variations. Couplings which do not conform to contractual requirements shall be processed regarding acceptance or rejection in accordance with contract provisions. Other variations not covered by contractual requirements, which result in conforming equipment but with parts which deviate from drawings or specifications, shall be processed in accordance with 3.15.1.1 (see 6.3 and appendix B).

3.15.1.1 Exceptions to specifications or drawings. Exceptions to specifications or drawings shall be subject to review and approval by the contracting activity.

3.15.2 Conditions for acceptance. Conditions for acceptance shall be as follows:

(a) The parts which deviate from drawings or specifications maintain specified safety factors and do not affect operations, equipment life and safety of personnel or equipment.
(b) Cost of replacement is not economically justified.
(c) For variations which result in nonstandard repair parts, twice the normal quantity of spares is provided by the contractor.
(d) Machinery variation drawings are provided by the contractor.

3.16 Workmanship. Parts shall be free of burrs, sharp edges, and damage that could make the part unsatisfactory for the purpose intended. Threaded parts and fasteners shall show no evidence of cross-threading, mutilation or burrs. Fasteners shall be torqued to prescribed limits (see 3.4.6.6).

4. QUALITY ASSURANCE PROVISIONS

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

4.1.1 Responsibility for compliance. All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system (see 6.3), or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of the manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, not does it commit the Government to accept defective material.

4.1.2 Mercury. Use of mercury is prohibited for shipboard inspections, examinations, or tests of equipment (see 3.2.3.1).

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 applicable examinations and tests designated in table IV for the type (and class when applicable) coupling.

TABLE IV. Examinations and tests.

Examination or test	Requirement	First article inspection	Quality conformance inspection
Workmanship	3.16	4.5.1	4.5.1
Material inspection	3.2 through 3.2.7	4.5.2	4.5.2
Welding, brazing, and allied processes	3.4.12	4.5.3	4.5.3
Castings	3.2.6	4.5.4	4.5.4
Critical fits	3.4.7.1, 3.5.2.2, 3.5.2.6, and 3.5.2.7	4.5.5	4.5.5
Tooth finish	3.5.2.3	4.5.6	4.5.6
Weight	3.4.15	4.5.7	-
Tooth contact	3.5.2.5	4.5.8	4.5.8
Magnetic permeability	3.8.2	4.5.9	-
Surface defects	3.2.4	4.6.1 through 4.6.1.2	4.6.1 through 4.6.1.2
Tooth hardness			
Through hardened	table I	4.6.1.3	4.6.1.3
Type II, class 1	table I	4.6.1.4	4.6.1.4
Case hardened	table I	4.6.1.5	4.6.1.5
Shock	3.4.10	4.6.2	-
Dynamic balance	3.4.11	4.6.3	4.6.3
Static (type IV)	3.8.3	4.6.4	-
Special tools and lifting gear	3.14	4.6.6	-
Special features (type VIII)	3.12.3 and 3.12.4	4.6.7	-
Solidification (type V)	3.9.5.3	4.6.8	-
Elastomer properties (type V)	3.9.5.1	4.6.9	-

4.4 Quality conformance inspection. Quality conformance inspection shall be performed on all coupling assemblies and parts, and shall consist of applicable examinations and tests specified in table IV (see 6.3).

4.5 Examinations.

4.5.1 General. Parts shall be examined to determine conformance to 3.16.

4.5.2 Materials inspection. Materials inspection shall consist of certification supported by verifying data that the materials listed in table I, used in fabricating the couplings specified herein, are in accordance with the applicable referenced specifications or requirements prior to such fabrication. Where substitute materials have been approved, inspection requirements of the applicable specification for the substitute material shall apply (see 6.8). Inspection of materials for parts not specified herein shall be to the manufacturer's specification or standard even though identification by Government or technical society specification is required. Unless otherwise specified in the contract or order (see 6.2), tensile strength, yield point, elongation, reduction of area, and bend tests are required for coupling forgings, except type II, class 1.

4.5.3 Welding, brazing, and allied processes. Examinations and test procedures for welding, brazing, and allied processes shall conform to MIL-STD-278.

4.5.4 Castings. Castings shall be inspected in accordance with MIL-STD-278.

4.5.5 Critical fits. Critical fits shall be measured to ensure satisfactory installation.

4.5.6 Roughness height rating (RHR). Hub and sleeve tooth surfaces shall be inspected in accordance with ANSI B46.1 to ensure that they conform to tooth finish specifications.

4.5.7 Weight. The first article shall be weighed and actual weight recorded on assembly drawing. Any change of weight or center of gravity which produces more than a 5 percent increase in weight or change of center of gravity determined during design stage shall be reported to the contracting activity as soon as it is known to the contractor.

4.5.8 Tooth contact check. Dental type couplings shall be checked for tooth contact to determine conformance to the requirements specified in 3.5.2.5. Unless otherwise specified (see 6.2), this test may be waived for type II, class 1 couplings.

4.5.9 Magnetic permeability. Unless otherwise specified (see 6.2), magnetic permeability of type IV coupling assembly shall be measured on the first article to verify conformance to 3.8.2 (see 6.3 and appendix C).

4.6 Tests.

4.6.1 Nondestructive tests of metals.

4.6.1.1 Ultrasonic tests. Forgings for coupling sleeves, hubs, diaphragms, discs, and shafts shall be ultrasonic tested in accordance with MIL-STD-271. Testing shall be in both radial and longitudinal directions using either a shear or longitudinal wave depending on the geometry of the forging. NAVSEA approved specific standards of acceptance shall be established by the contractor. Unless otherwise specified (see 6.2), this test may be waived for type II, class 1 couplings.

4.6.1.2 Magnetic particle or liquid penetrant tests. Dental coupling teeth and all coupling shafts shall be inspected by the magnetic particle or liquid penetrant methods in accordance with MIL-STD-271. The inspection shall be made at the completion of all finishing operations and shall cover 100 percent of the surface of the parts. The magnetic particle method is preferred for magnetic materials. The liquid penetrant method shall be used for non-magnetic material. NAVSEA approved acceptance standards shall be established by the contractor. Unless otherwise specified (see 6.2), this test may be waived for type II, class 1 couplings.

4.6.1.2.1 Welded diaphragm connections. When elements of a diaphragm coupling are joined by welding, all such welds shall be 100 percent inspected for absence of flaws, cracks, or porosity, both ultrasonically and by the liquid penetrant method, in accordance with MIL-STD-271. The inspection shall be made after completion of all finishing operations. NAVSEA approved acceptance standards shall be established by the contractor.

4.6.1.2.2 Residual magnetism. Residual magnetism of magnetic parts after finish machining and demagnetization following magnetic particle inspection shall be not greater than 10 gauss.

4.6.1.3 Tooth hardness, through hardened material. Tooth hardness shall be determined on the finished blank after heat treatment but before machining teeth. At least three readings shall be taken on each end face of blank, equally spaced circumferentially. Readings shall be taken below root diameter when blank is for coupling hub and above root diameter when blank is for coupling sleeve.

4.6.1.4 Tooth hardness, type II class 1 couplings. Tooth hardness of type II class 1 couplings may be determined by the contractor's method in lieu of 4.6.1.3, but shall not cause damage or upset metal in teeth. Requirements of 4.6.1.3 shall apply to type II, class 2 couplings.

4.6.1.5 Tooth hardness, case hardened material. Tooth hardness of case hardened couplings shall be determined as specified in 4.6.1.5.1 and 4.6.1.5.2 (see 6.3 and appendix C).

4.6.1.5.1 Surface hardness and case depth. Tooth surface hardness and case depth shall be determined from a coupon piece or lug obtained from the same heat and lot as the actual coupling part. The coupon piece or lug shall have been processed together with the coupling part through the complete heat-treat cycle. Determination of tooth surface hardness and case depth shall take account of effects of final machining or other processes used to achieve the final tooth profile in the case hardened regions. No hardness measurements shall be taken on active surfaces of teeth.

4.6.1.5.2 Core hardness. Core hardness shall be determined on the actual coupling part. Readings shall be taken by contractor's method but shall not damage or upset metal in coupling teeth.

4.6.2 Shock test. A type A shock test in accordance with MIL-S-901 shall be conducted when required for parent equipment as specified in 3.4.10. During shock test, couplings shall be tested with parent equipment and shall be mounted in normal operating position (see 6.2). For examination and failure to pass examination, see 4.6.5.

4.6.3 Dynamic test. Couplings shall be tested with associated reduction gear, engine, or turbine to the same extent as required for the parent equipment or as specified (see 6.2). Type V couplings shall be tested at maximum misalignment permissible for continuous operation (see 3.9.2.2). During the dynamic test, a check shall be made of the couplings for the following:

(a) Quiet running.
(b) Freedom from vibration.
(c) Wearing of parts.
(d) Tightness of casing and piping connections.
(e) Adequacy of oil seals.

Evidence of probable unsatisfactory operation in service apparent from the dynamic test shall be considered cause for rejection of the coupling. For examination and failure to pass examination, see 4.6.5.

4.6.4 Static test (type IV only). The first article of each type IV coupling design shall be statically tested at 200 percent of rated torque for 1 minute to determine conformance to 3.8.3. For examination and failure to pass examination, see 4.6.5.

4.6.5 Examination after test. Couplings shall be examined after test for cracks, distortions, looseness or deformation of fasteners, broken or displaced snap rings, or other visible damage. In addition, toothed elements shall be examined for distress in accordance with NAVSEA 0901-LP-420-0007. Elastomer elements shall be examined for deformations, cracks or extrusions. Disc and diaphragm elements shall be examined for cracks, evidence of yielding, presence of pits 0.002 inch or deeper and, where applicable, elongation of fastener holes. Any of the foregoing or other defects which would adversely affect operation shall be cause for rejection.

4.6.6 Special tools and lifting gear, verification of suitability. Special tools and lifting gear provided for couplings shall be demonstrated on the first article to ensure that they are satisfactory for their intended purpose.

4.6.7 Special feature demonstration. Coupling special features (for example, disconnect and reconnect features) shall be demonstrated on the first article during dynamic test or under static conditions whichever is applicable.

4.6.8 Solidification. When solidification hardware to replace or bypass the elastomer elements in a type V coupling assembly is required (see 3.9.5.3.2), the instructions for on-site installation of this hardware (see 3.9.5.3) shall be verified on first article test.

4.6.9 Elastomer properties test. Unless otherwise specified (see 6.2), the mechanical, physical, and life properties of "as-cured" elastomer components used in type V couplings shall be established by test (see 6.3).

4.7 Acceptance trials. Couplings shall be examined for defects during in-port period after completion of first or prototype ship-full power and maneuvering acceptance trials, or as specified (see 6.2). Examination and failure to pass examination shall be as specified in 4.6.5.

4.8 Records. Records shall be retained by the contractor of all inspections, examinations, and tests. Records shall be available for review upon request by Government representatives.

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

5. PACKAGING

(The packaging requirements specified herein apply only for direct Government acquisition. For the extent of applicability of the packaging requirements of referenced documents listed in section 2, see 6.7.)

5.1 Preservation, packing, and marking.

5.1.1 Equipment. Couplings and stock components shall be preserved and packed as required by the parent equipment specifications (see 6.2). When such instructions are not otherwise provided, preservation and packing shall be in accordance with MIL-P-17286, to the following levels which are specified for the destination or intended use of the parts:

Destination	Preservation level	Packing level
On board	A	C
Stock	A	B
Immediate use	C	C

5.1.2 Lifting gear and tools. Unless used in sets, pairs, or quantities greater than one, or as specified (see 6.2), lifting gear and tools shall be individually preserved. When the unit is packaged as a set, assembly, or quantities greater than one, each item shall be wrapped or cushioned to prevent direct surface contact with surfaces of adjacent parts.

5.1.3 Talc or talcum. When used in the packaging process of items, talc or talcum shall be free of asbestos and asbestiform-like materials.

5.1.4 Marking. Marking for shipment and storage shall be in accordance with requirements of the parent equipment specification (see 6.2). When requirements are not otherwise provided, marking shall be in accordance with MIL-STD-129.

5.1.5 Depreservation. Depreservation instructions shall be provided for each container. These instructions shall also be provided when shipment is made.

5.1.6 Unpacking. Coupling containers shall be marked and unpacking instructions provided when normal unpacking procedures may damage the container contents. A sealed waterproof envelope prominently marked "UNPACKING INSTRUCTIONS" shall be firmly fixed to the outside of the container.

6. NOTES

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

6.1 Intended use. Equipment described by this specification will be a permanent installation on Naval ships and is used to transmit power from prime mover, electric motor or reduction gear (as applicable) for propulsion or from prime mover to driven equipment for auxiliaries.

6.2 Acquisition requirements. Acquisition documents must specify the following:

(a) Title, number, and date of this specification.
(b) Coupling required; cite type and class (when applicable) (see 1.2).
(c) 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).
(d) When first article inspection is required (see 3.1).
(e) Coupling materials if other than those of tables I and II (see 3.2).
(f) If cast iron parts can be used (see 3.2.2).
(g) Related parent equipment requirements (see 3.3.3, 3.3.4, 3.4.10, 3.4.11.2, and 4.6.2).
(h) Whether guards, casings, and shields will be furnished by equipment contractor or shipbuilder (see 3.4.2.1).
(i) When calculations are for other than specified torques (see 3.4.3).
(j) If unbalance limits require approval (see 3.4.11).
(k) If type I arrangement is other than double-engagement (see 3.5.1).
(l) For type I or when type I requirements are invoked in type II, class 2 (see 3.6.1.2), type IV (see 3.8.4 and 3.8.4.1), type V (see 3.9.3), or type VIII (see 3.12.1), cite:

    (1) If tooth crown is other than as specified (see 3.5.2.2).
    (2) If tooth contact is other than as specified (see 3.5.2.5).
    (3) If lube oil supply is other than from lube oil supply of main reduction gear or parent equipment (see 3.5.3.2).

(m) For type II, if arrangement is other than double-engagement (see 3.6.1).
(n) For type II, class 1, cite:

(1) If tooth hardness and surface finish are other than as specified (see 3.6.1.1).
(2) If tooth contact check is not waived (see 4.5.8).
(3) If ultrasonic test of forging is not waived (see 4.6.1.1).
(4) If magnetic particle or liquid penetrant test of forging is not waived (see 4.6.1.2).

(o) For type II, class 2, cite special material and hardness requirements, if any (see 3.6.1.2).
(p) For type III, if arrangement is for single- or double-engagement (see 3.7.1).
(q) For type IV, cite:

(1) Coupling components (see 3.8.1).
(2) If dental coupling is other than double-engagement (see 3.8.4).
(3) Whether lubricant is oil or grease (see 3.8.4.1).
(4) If magnetic permeability test is waived (see 4.5.9).

(r) For type V, cite:

(1) Coupling components and arrangements (see 3.9.1).
(2) If rated design torque is other than as specified (see 3.9.2.1).
(3) Normal misalignment (see 3.9.2.2).
(4) Maximum continuous misalignment (see 3.9.2.2).
(5) Maximum transient misalignment (see 3.9.2.2).
(6) Axial displacement (see 3.9.2.3).
(7) If operating life is other than as specified (see 3.9.2.4).
(8) Operation under maximum transient misalignment, number of occurrences, and duration (see 3.9.2.4(a)).
(9) Number of full-power operating hours under maximum continuous misalignment (see 3.9.2.4(b)).
(10) Coupling stiffness limits (see 3.9.2.5).
(11) If sighting arrangements are required for elastomer elements or lubrication sprays or jets (see 3.9.2.9.2).
(12) If oil sprays or jets shall be lubricated without lifting guard or cover (see 3.9.2.9.3).
(13) Dimensions and arrangement (see 3.9.2.10).
(14) Design loading for retaining rings and bolts (see 3.9.3.1).
(15) Relative axial velocity of floating member at impact with stop if other than 1 inch per second, and data for analysis of cyclic loading imposed on stop (see 3.9.3.1(a) and (b)).
(16) Capability of back-up drive for diaphragm elements (see 3.9.4.1.1).
(17) If Lubrication of dental teeth of back-up drive is other than as specified (see 3.9.4.1.2).

(18) Coefficients of friction of back-up dental coupling teeth if other than as specified (see 3.9.4.2).
(19) Back-up drive capability for elastomer coupling (see 3.9.5.2).
(20) If requirement for coupling design that permits on-site solidification is waived (see 3.9.5.3).
(21) Misalignment capability of coupling with elastomer elements solidified (see 3.9.5.3.1).
(22) If solidification hardware is required and quantity required (see 3.9.5.3.2).
(23) Activity responsible for review and approval of procedure for on-site solidification (see 3.9.5.3.2).

(s) For type VI, cite:

(1) If coupling is other than double-engagement (see 3.10.1).
(2) If back-up drive is required and capabilities of back-up drive (see 3.10.4).
(3) Other speed or exciting frequency (see 3.10.7(b)).

(t) Whether type VII arrangement is for single- or double-engagement (see 3.11.1).
(u) For type VIII cite:

(1) Whether arrangement is for single- or double-engagement (see 3.12.1).
(2) If dental tooth, lubrication, and housing requirements of type I may be waived (see 3.12.1).
(3) Whether couplings shall be constructed so that one coupling may be disconnected and operation resumed on remaining shafts (see 3.12.3).
(4) If provision to lock turbine drive is required (see 3.12.4).

(v) Trim, list, roll and pitch if other than table III values (see 3.13.1).
(w) Lubricating oil temperature ranges if other than as specified (see 3.13.2).
(x) Contractor furnished special tools and equipment (see 3.14).
(y) If tensile strength, yield point, elongation, reduction of area and bend tests on coupling forgings are waived (see 4.5.2).
(z) Parent equipment requirements apply for the following except when deleted or when substitute requirements are provided herein:

(1) Operating conditions (see 3.3).
(2) Horsepower, r/min, misalignment (where applicable) and other data required for coupling design (see 3.3.3).
(3) Life (endurance) (see 3.3.4).
(4) Safety objectives (guards, casings, or shields) furnished by the shipbuilder or parent equipment contractor unless otherwise indicated (see 3.4.2.1).
(5) Shock (see 3.4.10, 3.9.3.1, and 4.6.2).
(6) Low noise, vibration or in situ balancing (see 3.4.11.2).

(7) Dynamic test (see 4.6.3).
(8) Elastomer properties test (see 4.6.9).
(9) Examination after ship trials (see 4.7).
(10) Level of preservation and packing (see 5.1.1 and 5.1.2).
(11) Marking for shipment and storage (see 5.1.4).

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.

Reference Paragraph	DID Number	DID Title	Suggested Tailoring
3.3.1, 3.3.2, 3.4.3, 3.9.4.2, and appendix A	DI-GDRQ-80650	Design, data, and calculations	----
3.4.1.1	DI-MISC-80678	Certification/data report	10.3.1 does not apply
3.4.1.2, 3.4.11.2, 3.15.1, and appendix B	DI-DRPR-80651	Engineering drawings	----
3.4.2.1	DI-SAFT-80100	System safety program plan	----
3.12.3, 4.5.9, 4.6.1.5, and appendix C	DI-MISC-80653	Test reports	----
4.1.1	DI-QC-81110	Inspection and test plan	----
4.4	DI-NDTI-80809	Test/inspection reports	----
4.6.9	UDI-T-23732	Procedures, test	----

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 Technical manuals. The requirement for technical manuals should be considered when this specification is applied on a contract. If technical manuals are required, military specifications and standards that have been cleared and listed in DOD 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL) must be listed on a separate Contract Data Requirements List (DD Form 1423), which is included as an exhibit to the contract. The technical manuals must be acquired under separate contract line item in the contract. Technical content should include the requirements of appendix D, titled "Manual Technical Requirements".

6.5 First article. When first article inspection is required, the contracting officer should provide specific guidance whether the item(s) should be a first article sample, a first production item, a sample selected from the first productions items, a standard production item from the contractor's current inventory (see 3.1), and the number of items to be tested as specified in 4.3. The contracting officer should also 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 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. Bidders should not submit alternate bids unless specifically requested to do so in the solicitation.

6.6 Provisioning. Provisioning Technical Documentation (PTD), spare parts, and repair parts should be furnished as specified in the contract.

6.6.1 When ordering spare parts or repair parts for the equipment covered by this specification, the contract should state that such spare parts and repair parts should meet the same requirements and quality assurance provisions as the parts used in the manufacture of the equipment. Packaging for such parts should also be specified.

6.7 Subcontracted material and parts. The packaging requirements of referenced documents listed in section 2 do not apply when material and parts are acquired by the contractor for incorporation into the equipment and lose their separate identity when the equipment is shipped.

6.8 Substitute materials approval. Contractors who anticipate bidding to this specification may obtain from the Command or agency concerned "across-the-board" approval of commercial or contractor specification materials, including test and examination requirements, to be used in lieu of the Government specification requirements referred to herein. The approval of substitute material must represent no present or predicted cost increase to the contracting activity.

6.8.1 Substitute materials when bidding. Contractors who anticipate using substitute materials should indicate these materials as alternatives in the bid proposal. Prior approval in accordance with 6.8 should be indicated, where applicable, by citing approval letters. The material substitutions must be approved or not approved in whole or in part by the contracting activity. Such approval applies only to a specific purchase or contract.

6.9 Nonspecified materials. Where, for the applications of tables I and II, materials or material properties are not specified, approval by the contracting activity or Government technical approval command as designated in the contract or order is required.

6.10 Subject term (key word) listing.

Dental tooth couplings
Diaphragm couplings
Elastomer
Housing (guards)
Life (endurance)

6.11 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issues due to the extensiveness of the changes.

Preparing activity:
Navy - SH
(Project 2010-N019)

APPENDIX A

DESIGN DATA AND CALCULATIONS TECHNICAL CONTENT REQUIREMENTS

10. SCOPE

10.1 Scope. This appendix covers technical requirements that shall be included in calculations and stress diagrams when required by the contract or order. This appendix is mandatory only when data item description DI-GDRQ-80650 is cited on the DD form 1423.

20. APPLICABLE DOCUMENTS

This section in not applicable to this appendix.

30. DESIGN DATA AND CALCULATIONS

30.1 Design data and calculation. When required by the contract or order, design data and calculations shall contain the following information:

(a) Calculations made as required in 3.4.3, 3.4.3.1, 3.4.3.2, 3.4.3.3, and 3.9.4.2 shall be furnished. Allowable limits, when not specified in the specification or in the contract or order shall be proposed with supporting justification by the contractor for approval by the contracting activity. Calculation shall be provided in sufficient detail for review by the contracting activity.

(b) Coupling data shall be provided with parent equipment data to activities performing vibration calculations as designated by the parent equipment requirements (see 3.3.1).

(c) Data, including drawings, for the purposes of 3.3.2 shall be provided to the extent required by the driven and driving machinery contractors.

(d) Where the coupling contractor does not hold requirements and specifications for machinery or components referred to in specification or when required information is not in parent equipment specifications, this documentation and information will be provided by the contracting activity. Coupling contractor shall identify misalignment capability of furnished coupling and verify that this capability is not less than that specified by the contracting activity.

APPENDIX B

ENGINEERING DRAWINGS TECHNICAL CONTENT REQUIREMENTS

10. SCOPE

10.1 Scope. This appendix covers technical requirements that shall be included or engineering drawings when required by the contract or order. This appendix is mandatory only when data item description DI-DRPR-80651 is cited on the DD Form 1423.

20. APPLICABLE DOCUMENTS

20.1 Government documents.

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

SPECIFICATIONS

MILITARY

MIL-T-31000 - Technical Data Packages, General Specification for.

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

30. DRAWING CONTENT

30.1 Drawing content. When required by the contract or order, engineering drawings shall include the following:

(a) Location where metal may be removed during in-situ balancing shall be identified in the coupling drawings (see 3.4.11.2).

(b) Instruction for packaging and delivery of drawings shall be provided by the specification for the parent equipment. When requirements are not otherwise provided, packaging and delivery shall be in accordance with MIL-T-31000 for drawings.

APPENDIX C

TEST REPORT TECHNICAL CONTENT REQUIREMENTS

10. SCOPE

10.1 Scope. This appendix covers the technical requirements that shall be included on first article inspection 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. REPORT CONTENT

30.1 Report content. When required by the contract or order, first article inspection reports shall contain the following information in addition to the results of the tests specified in table IV herein:

(a) Disconnect coupling time requirements. Actual time required, determined on first article, shall be furnished to activity concerned (see 3.12.3).

(b) Magnetic permeability. The results of any magnetic permeability measurement required (see 4.5.9) shall be reported as soon as possible.

(c) Tooth hardness, case hardened material. Contractor shall provide tooth hardness data when requested by the Government inspector or contracting activity in accordance with data ordering document (see 4.6.1.5).

APPENDIX D

MANUAL TECHNICAL CONTENT REQUIREMENTS

10. SCOPE

10.1 Scope. This appendix covers technical requirements that shall be included in the manuals when required by the contract or order. This appendix is not a mandatory part of the specification unless invoked by the contract or order. When invoked, the information contained herein is intended for compliance.

20. APPLICABLE DOCUMENTS

20.1 Government documents.

20.1.1 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

MIL-M-15071 - Manuals, Technical: Equipments and Systems Content Requirements for.

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

30. MANUALS

30.1 Manuals. When required by the contract or order, manuals shall contain the following information:

(a) Contractor shall indicate specific schedule for each maintenance action required and shall list in the technical manual periodic maintenance requirements.

(b) Actual time required to disconnect the coupling, determined on first article, shall be incorporated in the technical manual (see 3.12.3).

(c) Instruction for packaging and delivery of technical manuals will be provided by the specification for the parent equipment. When requirements are not otherwise provided, packaging and delivery shall be in accordance with MIL-M-15071 for manuals.

APPENDIX E

TYPE V COUPLING DISTANCE PIECE DESIGN

10. SCOPE

10.1 Scope. This appendix covers information to be used in design of the type V lineshaft noise attenuating coupling distance piece of all Naval ships. This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

20. APPLICABLE DOCUMENTS

20.1 Government documents.

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

SPECIFICATIONS

FEDERAL

QQ-N-281 - Nickel-Copper Alloy Bar, Rod, Plate, Sheet, Strip, Wire, Forgings, and Structural and Special Shaped Sections.

QQ-N-286 - Nickel-Copper-Aluminum Alloy, Wrought (UNS N05500).

MILITARY

MIL-S-23284 - Steel Forgings, Carbon and Alloy, for Shafts, Sleeves, Propeller Nuts, Couplings, and Stocks (Rudders and Diving Planes).

STANDARD

MILITARY

MIL-STD-167-2 - Mechanical Vibrations of Shipboard Equipment (Reciprocating Machinery and Propulsion System and Shafting) Types III, IV, and V.

(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.)

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

DRAWING

NAVAL SEA SYSTEMS COMMAND (NAVSEA)
NAVSHIPS 803-2145807 - Propulsion Shafting and Components.

(Application for copies should be addressed to: Commander, Portsmouth Naval Shipyard, Code 202.2, Portsmouth, NH 03801.)

PUBLICATIONS

NAVAL SEA SYSTEMS COMMAND (NAVSEA)
0900-LP-090-3020 - Guidelines to MIL-STD-167-2 Ship Mechanical Vibrations of Shipboard Equipment.

(Application for copies should be addressed to the Standardization Documents Order Desk, BLDG. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

NAVAL SURFACE WARFARE CENTER ANNAPOLIS (was DTRC)
A. Zaloumis and G. P. Antonides - Recent Developments in Longitudinal Vibrations of Surface Ship Propulsion Systems. NSRDC (now DTRC) Report 3358, September 1970.

(Application for copies should be addressed to the Standardization Documents Order Desk, BLDG. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)
B 138 - Standard Specification for Manganese Bronze Rod, Bar, and Shapes. (DoD adopted)
B 150 - Standard Specification for Aluminum Bronze Rod, Bar, and Shapes. (DoD adopted)

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

Peterson, R. E., Stress Concentration Factors, John Wiley and Sons, New York; 1974.

(Application for copies should be addressed to the publisher. A copy may be consulted in the technical library of the Naval Sea Systems Command.)

(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.)

30. DEFINITIONS

30.1 Usual meanings. Unless otherwise defined herein, the terms used have their usual dictionary meanings appropriate to the context.

30.2 Abbreviations and symbols. Abbreviations and symbols used in this document are listed here for convenient reference. On occasion, the same symbol is used with a different intended meaning from that listed. In that event the symbol is specially annotated to make its meaning clear in the particular application.

Symbol	Meaning	Units
A	Cross-sectional area of shaft	$inch^2$
B_e	Effective length of key	inch
b_1	Contact depth of keyway	inch
C_h	Key Chamfer	inch
Cr	Chromium	
D_b	Diameter of bolt	inch
D_{bc}	Bolt circle diameter	inch
D_f	Outside diameter of flange	inch
D_k	Diameter at midpoint of contact depth (b_1) at midlength of B_e	inch
D_m	Diameter of shaft taper at midlength of B_e	inch
d	Propeller shaft reduced bore diameter	inch
E	Shaft modulus of elasticity	psi
EHP	Effective horsepower	hp
FL	Fatigue limit	psi
FS	Factor of safety	
G	Shaft shear modulus	psi
H	Depth of keyway at midlength of B_e (straight side plus corner radius)	inch
I	Area moment of inertia of shaft	$inch^4$
ID	Shaft inside diameter	inch
J	Polar moment of inertia of shaft	$inch^4$
K_b	Stress concentration factor in bending	
K_t	Stress concentration factor in torsion	
L_t	Length of shaft taper	inch
M_g	Gravity bending moment at any shaft location	in-lb

Symbol	Meaning	Units
Min	Minimum	
Mo	Molybdenum	
M_p	Gravity bending moment at aftermost bearing support point	in-lb
M_T	Total bending moment (sum of M_g and M_{oc})	in-lb
N_b	Number of bolts (in shaft coupling)	
N_1	Number of keys	
Ni	Nickel	
OD	Outside diameter of shaft	inch
PC	Propulsive coefficient	
Q	Mean or steady torque	in-lb
Q_T	Total torque including all increases required	in-lb
RPM	Propeller rotational speed	r/min
r_f	Radius of flange fillet	inch
r_g	Radius of sleeve groove fillet	inch
r_k	Radius of keyway fillet	inch
S_{ar}	Resultant alternating stress	psi
S_{as}	Alternating torsional shear stress	psi
S_b	Alternating bending stress	psi
S_{bt}	Shear stress of shaft coupling bolts	psi
S_c	Steady compressive stress	psi
S_{ck}	Allowable compressive stress of key	psi
SHP	Shaft horsepower	hp
S_s	Steady shear stress	psi
S_{sk}	Allowable shearing stress of key	psi
S_{sr}	Resultant steady stress	psi
T	Propeller full power thrust	pound
T_T	Total thrust	pound
t	Thrust deduction factor	pound
t_c	Shaft taper at inboard coupling	in/ft
UT	Ultimate tensile strength	psi
V	Ship speed at full power	knot
W	Width of key	inch
W_{ic}	Weight of shaft bore internal components	pound
w	Weight per unit length of shaft	lb/in
YP	Yield point of material	psi
ρ_{stl}	Density of steel material	lb/in^3

30.3 System of units. Unless otherwise stated or demanded by context, the U.S. conventional gravitational system of units, commonly called the foot-pound-second system (or inch-pound system) is used throughout this appendix.

40. GENERAL REQUIREMENTS

40.1 Design requirements. Unless otherwise specifically approved, the design of the main propulsion coupling distance piece (shafting) shall be in accordance with the methods and criteria described herein and in Drawing 803-2145807, except that material selection shall be in accordance with MIL-C-23233.

40.2 Material selection. Shafting materials shall be selected on the main considerations of fatigue characteristics and strength.

40.3 *Solid or hollow shafts*. Unless otherwise specified, shafts with an outside diameter (OD) less than 6 inches shall be solid. Shafting 6 inches in diameter and above shall be bored hollow.

40.4 Hollow (bored) shafting. The inside diameter (ID) of low speed gear shafting shall be 0.65 times the shaft nominal outside diameter (OD), unless specifically approved otherwise by NAVSEA. Where more than one design outside diameter exists within a shaft section, the 0.65 rule shall be based on the smaller outside diameter. Rounding off the inside diameter dimension to the nearest 1/8 inch is permitted. For controllable pitch propeller systems, the inside diameter shall not be decreased from forward to aft.

40.5 Design nominal outside diameter of shafting. The designed nominal outside diameter (OD) of shafting is the minimum diameter which is determined by calculations using the methods described herein meeting all the criteria specified.

40.6 Nominal outside diameter. The nominal outside diameter (OD) of the shafting shall be determined on the basis of the maximum combined stresses. Stresses and factors of safety shall be calculated at all fillets, keyways, splines, and other discontinuity points; at bearing support points; and at locations of maximum moment. Stress concentration factors (K_b & K_t) shall be applied as required to determine the point of maximum stress. Shaft sizes determined by these calculations shall meet the minimum factor of safety criteria specified herein.

40.7 Bearing support points. For shaft design purposes, the bearings shall each be considered to act as a point support at the bearing center.

40.8 Design torque. Propulsion coupling shafting design shall allow for maximum nominal steady state operation plus an additional torque imposed by the slowing of the propeller when the ship makes a turn. Design steady torque (Q) shall be based on the normal operating mode, either full plant or split plant, resulting in the highest torque in the shaft being analyzed, and shall include other possible increases in steady torque that the propulsion shafting system may experience, such as those caused by allowable variations in full power shaft RPM as specified for the propeller or prime mover in a particular shipbuilding specification. The additional torque allowed for a ship making a turn shall be 20 percent of design steady torque for both single and multi-propeller ships, except that for ships with geared diesel engine propulsion, 10 percent (instead of

20 percent) additional torque shall be used. In addition, the design of shafting for ships driven by reciprocating engines shall be checked in accordance with MIL-STD-167-2 and NAVSEA 0900-LP-090-3020 for the torsional critical rotational speed at which vibratory stresses are greatest.

40.9 Steady and alternating stresses. In calculating stresses, the steady stresses and the alternating stresses shall be calculated separately. The resultant steady stress (S_{sr}) is due to the steady torque and thrust. The resultant alternating stress (S_{ar}) is due to the alternating torque and bending . The effects from other sources of bending in a particular shafting design, such as couplings, shall also be included in the calculations. Stress concentration factors (K_b & K_t), where they exist, shall be applied to the alternating torsional shear (S_{as}) and bending stresses (S_b).

40.10 High localized stresses. High localized stresses shall be avoided by use of generous fillets and by avoiding the drilling of holes into the shafting to secure such items as keys, sleeves, and oil baffles. Inasmuch as only alternating stresses are multiplied by stress concentration factors, prevention of regions of high localization of stress is especially important where alternating stresses are large.

40.11 Alternating (vibratory) torsional shear stresses. Caution shall be used in computation of alternating torsional shear stresses (S_{as}), particularly those that are engine excited, as by diesel or reciprocating steam engines. For these stresses, a more elaborate torsional analysis may be required. The maximum torsional vibratory stresses determined from the vibratory analysis required by MIL-STD-167-2 shall be compared with the alternating torsional shear stress estimated by (Eq-12). If greater than the latter, they shall be incorporated into a reiteration of the shafting design calculations.

40.12 Shaft bore components. Determination of gravity moments (M_g) in shafting shall take into account the weight distribution of internal components in the bore. These components include, as applicable, such items as piping, control rods, and oil.

40.13 Factors of safety. Propulsion coupling shafting designs shall meet the factors of safety tabulated in table VI.

40.14 Clad weld inlays shall not be used on main propulsion coupling shafts.

TABLE II. Bending moments for surface ships and submarines.[1/]

	Surface ships		Submarines
	Strut-supported shafting	Nonstrut-supported shafting	
Total moment at any point of coupling (M_T) shafting	M_g	M_g	M_g

[1/] Where applicable, the total moment (M_T) shall also include bending moments due to other sources, such as dental couplings or sound isolation couplings.

TABLE VI. Factors of safety for main propulsion coupling shafting.

	Type of ship		
	Surface ships other than icebreakers	Icebreakers	Submarines
Coupling shafting	1.75	2.25	2.00

50. DETAILED REQUIREMENTS

50.1 Design loads. Propulsion coupling shafting is subjected to a variety of steady and alternating loads that include torsional shear, axial thrust, and bending. In the detail shaft design analysis, stresses shall be calculated at all bearing support points, shafting discontinuities, flange fillets, keyways, moment peaks, and all other areas where high stresses may occur.

50.2 Stresses. Steady and alternating stresses shall be analyzed separately, then combined using equations based on the Soderberg diagram to determine factors of safety. For proper shaft inside diameter to use in equations, see 40.4.

50.3 Shafting design equations.

50.3.1 Steady stresses.

50.3.1.1 Torsional load. The torsional load in the shafting, which results in steady torsional stresses, is calculated from the shaft horsepower (SHP) and propeller rotational speed (RPM) as follows:

$$Q = \frac{63,025 \times SHP}{RPM} \qquad \text{(Eq-1)}$$

where horsepower and RPM are chosen in accordance with the guidance in paragraph 40.8

50.3.1.1.1 Additional torque for turns. Additional torque shall be required for turns (see 40.8).

(a) For turbine-driven ships, whether single- or multishaft:

$$Q_T = 1.2 \times Q \qquad \text{(Eq-2a)}$$

(b) For reciprocating-engine-driven shafts, whether diesel or steam, single-or multishaft:

$$Q_T = 1.1 \times Q \qquad \text{(Eq-2b)}$$

50.3.1.2 Steady shear stress. (Eq-3a) through (Eq-3c) apply for the calculation of steady shear stress.

$$S_s = \frac{Q_T \times OD}{2 \times J} \qquad \text{(Eq-3a)}$$

$$S_s = \frac{5.1 \times Q_T \times OD}{OD^4 - ID^4} \qquad \text{(Hollow shaft)} \qquad \text{(Eq-3b)}$$

$$S_s = \frac{5.1 \times Q_T}{OD^3} \qquad \text{(Solid shaft)} \qquad \text{(Eq-3c)}$$

50.3.1.3 Thrust load. Thrust loads, T_t, shall be as specified.

50.3.1.4 Steady compressive stress. (Eq-8) applies for calculation of the steady compressive stress due to thrust.

$$S_c = \frac{T_T}{A} = \frac{1.273 \times T_T}{OD^2 - ID^2} \qquad \text{(Eq-8)}$$

50.3.1.5 Resultant steady stress. (Eq-9) applies for calculation of the resultant steady stress.

$$S_{sr} = [S_c^2 + (2 \times S_s)^2]^{1/2} \qquad \text{(Eq-9)}$$

50.3.2 Alternating stresses.

50.3.2.1 Bending moments.

50.3.2.1.1 Gravity bending moments.

(a) Not used
(b) The shaft alignment analysis shall be used to determine the maximum gravity bending moment that exists at each point of the bull gear shaft for the following conditions:

(1) Straight line in air.
(2) Aligned waterborne with machinery cold.
(3) Aligned waterborne with machinery cold and with collective weardown of water lubricated bearings.
(4) Aligned waterborne with machinery at operating temperature.
(5) Aligned waterborne with machinery at operating temperature and with collective weardown of water lubricated bearings.
(6) Aligned waterborne with allowable variations of bearings loads for conditions (2) through (5) above.
(7) For submarines only, hull deflections due to diving, rising, sea slap, and submergence pressure shall be analyzed in combination with conditions (2) through (6) above.
(8) For surface ships only, hull deflections that affect shaft alignment shall be analyzed in combination with conditions (2) through (6) above. These hull deflections are usually the result of large changes in ballast such as those seen on fleet oilers, amphibious-force ships, or supply ships. Hull deflections due to sea state and steering turns need not be analyzed.

50.3.2.1.2 Other moments. Analysis of gear tooth loads and flexible coupling loads shall be used to find additional moments applied to the coupling shaft.

50.3.2.2 Stress concentration factors. The principal points of stress concentration in shafting occur at the corners of keyways, at flange fillets, and at holes (where specifically approved) drilled in the shaft. These points of stress concentration shall be treated as specified in 50.3.2.2.1 and 50.3.2.2.2

50.3.2.2.1 Stress concentration at keyway fillets. The stress concentration factor for torsional stress (K_t) at keyway fillets is a function of the ratio of the fillet radius in the corner of the keyway (r_k) to the depth of the keyway at midlength (H). Values of K_t shall be taken from figure 1. The fillet radius shall be in accordance with Drawing 803-2145807. The stress concentration factor in bending due to a keyway is unity, and the stress concentration can be neglected at the key end provided that the ends of the keyway are properly faired into the shaft in accordance with Drawing 803-2145807.

50.3.2.2.2 Stress concentration at flange fillets. The stress concentration factors for alternating torsional and bending stresses (K_t and K_b, respectively) at the fillet of a coupling flange depend on the fillet radius (r_f), the shaft outside diameter (OD), and the flange outside diameter (D_f). Values for K_t and K_b shall be taken from figures 2 and 3 respectively.

50.3.2.2.3 Oil holes in shafting. Oil holes drilled normal to the surface of a shaft usually have a diameter that is small with respect to the shaft diameter. A stress concentration factor of three for the bending stress shall be used. Note that the drilling of these types of holes in propulsion shafting is prohibited except where specifically approved by NAVSEA.

50.3.2.3 Bending stress. (Eq-11a) through (Eq-11c) apply for the calculation of bending stress due to bending moment.

$$S_b = \frac{M_T \times OD}{2 \times I} \qquad \text{(Eq-11a)}$$

$$S_b = \frac{10.2 \times M_T \times OD}{(OD^4 - ID^4)} \qquad \text{(Hollow shaft)} \qquad \text{(Eq-11b)}$$

$$S_b = \frac{10.2 \times M_T}{OD^3} \qquad \text{(Solid shaft)} \qquad \text{(Eq-11c)}$$

50.3.2.4 Alternating (vibratory) torsional shear stress. Alternating torsional shear stresses in the shaft are generated by the propeller and occur predominantly at blade frequency, except for diesel propulsion plants, where the cyclic engine torque is significant also. Initially the alternating torsional shear stress may be approximated as follows:

$$S_{as} = 0.05 \times S_s \qquad \text{(Eq-12)}$$

Where:

S_s = steady shear stress as derived from (Eq-3b) or (Eq-3c).

Instead of the above, the values determined by the detailed propulsion system vibration analysis shall be substituted in the design calculations if they are larger at the corresponding shaft RPM than the approximation given by (Eq-12).

50.3.2.5 Resultant alternating stress. The resultant alternating stress shall be found, first by multiplying the bending and torsional stress components each by the appropriate stress concentration factor, and then by combining them as prescribed in the maximum shear theory as follows:

$$S_{ar} = [(K_b \times S_b)^2 + (2 \times K_t \times S_{as})^2]^{1/2} \qquad \text{(Eq-13)}$$

Where:

K_b and K_t are stress concentration factors for bending and torsion (see figures 1, 2, and 3) at shafting discontinuities such as flange fillets and keyways (see 50.4.2.2).

50.3.3 Factor of safety. The resultant steady stress (S_{sr}) and the resultant alternating stress (S_{ar}) are used to obtain the factor of safety as follows:

$$\frac{1}{FS} = \frac{S_{sr}}{YP} + \frac{S_{ar}}{FL} \qquad \text{(Eq-14a)}$$

-or-

$$FS = \frac{1}{\frac{S_{sr}}{YP} + \frac{S_{ar}}{FL}} \qquad \text{(Eq-14b)}$$

Values for YP and FL shall be the minimum allowed by the appropriate material specification.

50.4 Shafting components. Shafting components shall be as specified in 50.4.1 through 50.4.1.2.

50.4.1 Key and keyway design. The allowable design key stresses (S_{sk} and S_{ck}) are based, respectively, on the yield strength in shear and ultimate compressive strength of the key material, and on a factor of safety of five. Values for S_{sk} and S_{ck} to be used in (Eq-30) and (Eq-31) are given in table VII and VIII respectively.

50.4.1.1 Nomenclature. Symbols of special use in key and keyway design are listed here with their intended meanings:

Symbol	Meaning	Units
B_e	- Effective length of key	inches
b_1	- Contact depth of keyway [depth of keyway (H) minus key chamfer (C_h)]	inches
D_k	- Diameter at midpoint of contact depth (b_1) at midlength of B_e	inches
D_m	- Diameter of shaft taper at midlength of B_e	inches
H	- Depth of keyway at midlength of B_e (straight side plus corner radius)	inches
L_t	- Length of shaft taper	inches
N_1	- Number of keys	
S_{ck}	- Allowable compressive stress of key	psi
S_{sk}	- Allowable shearing stress of key	psi
W	- Width of key (minimum)	inches

50.4.1.2 Design formulas. (See (Eq-29a) through (Eq-31).)

$$W = \frac{2 \times Q_T}{N_1 \times B_e \times D_m \times S_{sk}} \qquad \text{(Eq-30)}$$

$$b_1 = \frac{2 \times Q_T}{N_1 \times B_e \times D_k \times S_{ck}} \qquad \text{(Eq-31)}$$

TABLE VII. Allowable shearing stress for key materials.

Material	Applicable document	S_{sk} Allowable shearing stress, (psi)	
		1 key	2 or more keys
Steel			
class 1	MIL-S-23284	11,250	7,500
class 2	MIL-S-23284	8,250	5,500
class 3	MIL-S-23284	6,750	4,500
class 4	MIL-S-23284	5,250	3,500
Ni-Cu (monel)	QQ-N-281	7,800	5,200
Ni-Cu-Al (K-monel)	QQ-N-286	15,000	10,000
Nickel aluminum bronze	ASTM B150 Alloy C63000	6,000	4,000
Manganese bronze half-hard, rolled	ASTM B 138	5,250	3,500
Steel, class C type I or II	MIL-S-24093	15,000	10,000

TABLE VIII. Allowable compressive stress for key materials.

Material	Applicable document	S_{ck} Allowable compressive stress, (psi)	
		1 key	2 or more keys
Steel			
class 1	MIL-S-23284	28,500	19,000
class 2	MIL-S-23284	24,000	16,000
class 3	MIL-S-23284	22,500	15,000
class 4	MIL-S-23284	18,000	12,000
Ni-Cu (monel)	QQ-N-281	27,000	18,000
Ni-Cu-Al (K-monel)	QQ-N-286	42,000	28,000
Nickel aluminum bronze	ASTM B150 Alloy C63000	24,000	16,000
Manganese bronze half-hard, rolled	ASTM B 138	19,500	13,000
Steel, class C type I or II	MIL-S-24093	36,000	24,000

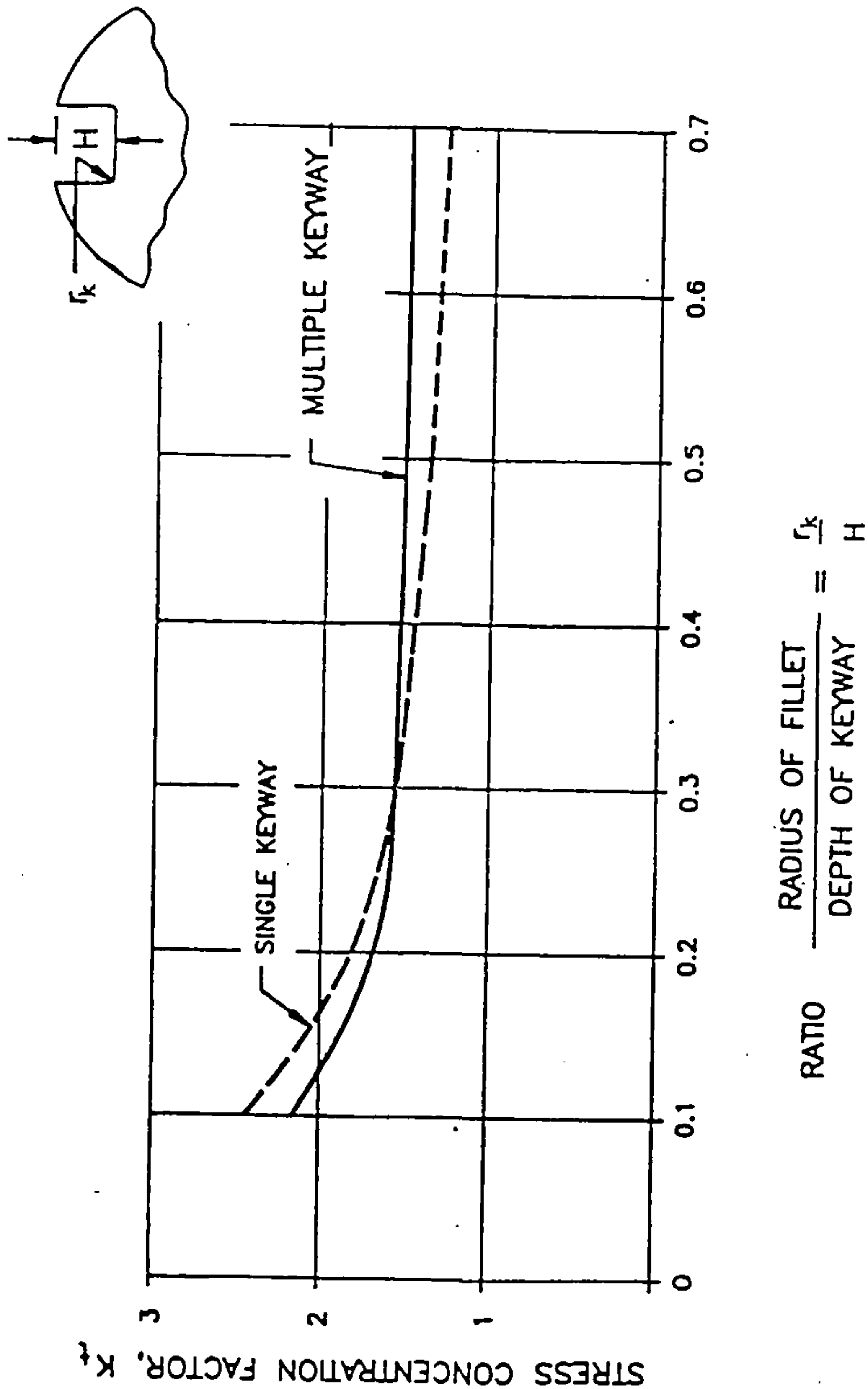

FIGURE 1. Stress concentration factors at keyway fillets, in torsion.

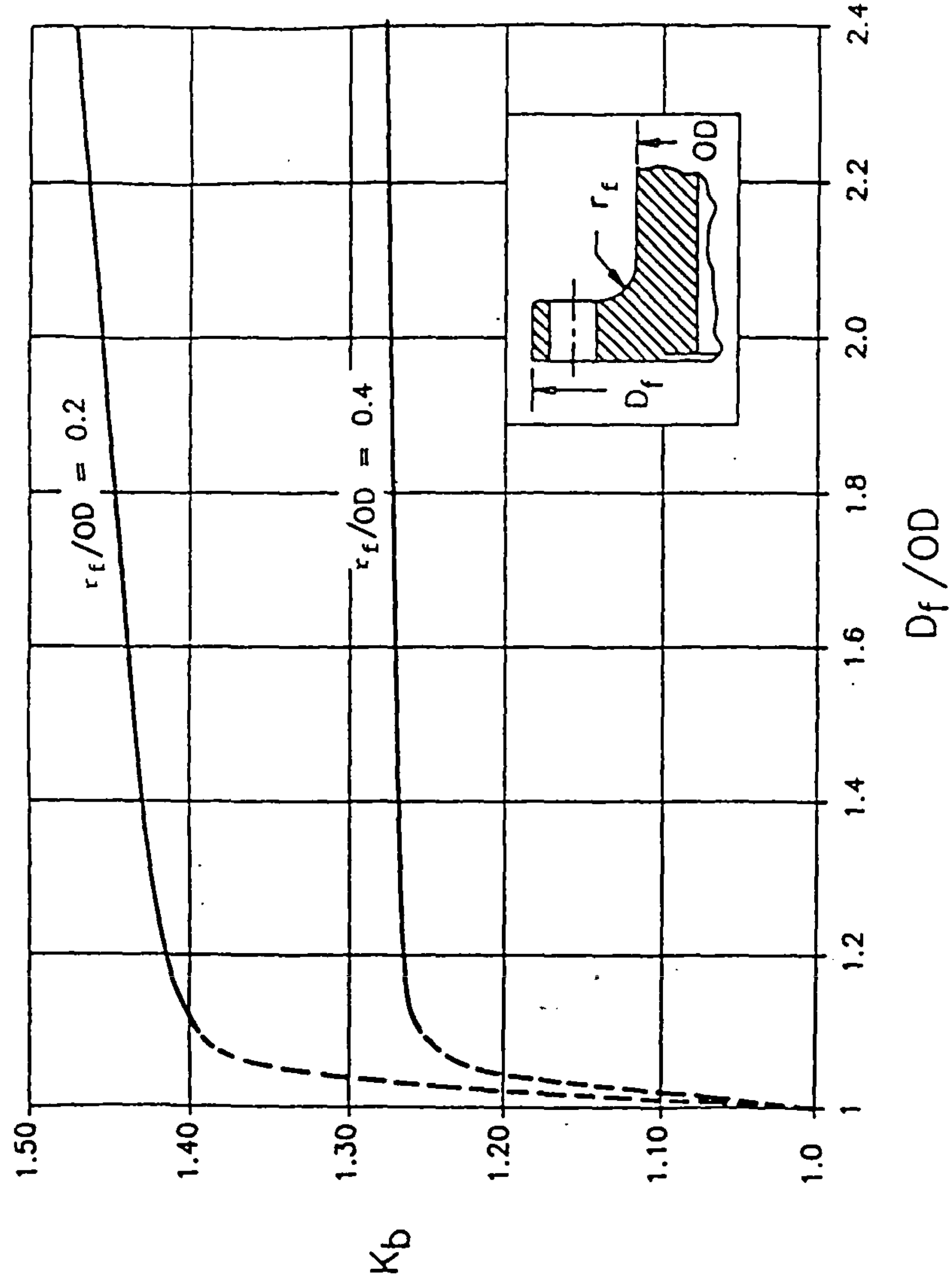

FIGURE 2. Stress concentration factor, K_b, for bending at flange fillet.

Source: R.E. Peterson
"Stress Concentration Factors"
John Wiley & Sons 1974

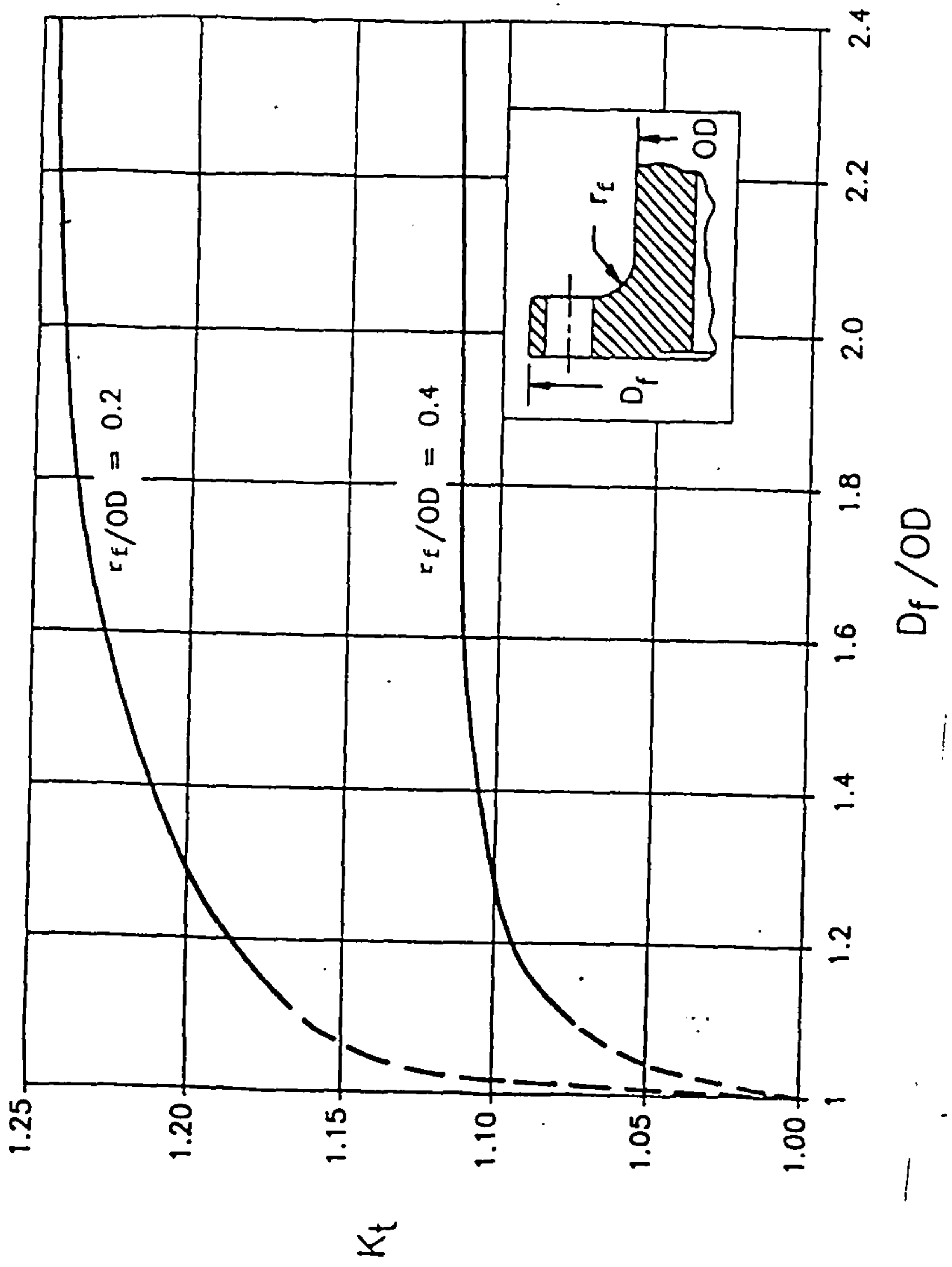

FIGURE 3. Stress concentration factor, K_t, for torsion at flange fillet.

Source: R.E. Peterson
"Stress Concentration Factors"
John Wiley & Sons 1974

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
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I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER MIL-C-23233A(SH)	2. DOCUMENT DATE *(YYMMDD)* 1992 November 25

3. DOCUMENT TITLE
COUPLINGS FOR PROPULSION UNITS, AUXILIARY TURBINES AND LINE SHAFTS, NAVAL SHIPBOARD

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*	b. ORGANIZATION	
c. ADDRESS *(Include Zip Code)*	d. TELEPHONE *(Include Area Code)* (1) Commercial (2) AUTOVON *(If applicable)*	7. DATE SUBMITTED *(YYMMDD)*

8. PREPARING ACTIVITY

a. NAME TECHNICAL ENGINEER: Mr. Bart Mancini, NAVSEA 05X44	b. TELEPHONE *(Include Area Code)* (1) Commercial (703) 602-1596 (2) AUTOVON 8-332-1596
c. ADDRESS *(Include Zip Code)* Commander, Naval Sea Systems Command ATTN: SEA 05Q42, 2531 National Ctr. Bldg 3 Washington, DC 20362-5160	IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403, Falls Church, VA 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340