INCH-POUND
MIL-G-17859D(SH)
30 September 1993
SUPERSEDING
MIL-G-17859C(SHIPS)
25 May 1967
(See 6.9)

MILITARY SPECIFICATION

GEAR ASSEMBLY, PROPULSION
(NAVAL SHIPBOARD USE)

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 reduction gears (including fittings, accessories and reports) for use in Naval submarine and surface ship main propulsion systems where such gears are not integral with or part of the prime mover.

1.2 *Classification*. Main propulsion reduction gears are of the following classes and arrangements as specified (see 6.2):

Classes.

Class A - For use in Naval submarines.
Class B - For use in Naval surface ships.

Arrangements.

1 - Twin input-dual torque path-tandem-articulated, double reduction, double helical (see figure 1).

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, SEA 03Q42, Naval Sea Systems Command, 2531 Jefferson Davis Hwy, Arlington, VA 22242-5160 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A FSC 3010

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

2 - Twin input-tandem-articulated, double reduction, double helical (see figure 2).
3 - Single reduction, one or more power inputs, double helical (see figure 3).

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-C-390	- Copper Alloy Castings (Including Cast Bar).
QQ-T-390	- Tin Alloy Ingots and Castings and Lead Alloy Ingots and Castings (Antifriction Metal) for Bearing Applications.

MILITARY

MIL-S-901	- Shock Tests, H.I. (High-Impact) Shipboard Machinery, Equipment, and Systems, Requirements for.
MIL-E-917	- Electric Power Equipment, Basic Requirements (Naval Shipboard Use).
MIL-G-1149	- Gasket Materials, Synthetic Rubber, 50 and 65 Durometer Hardness.
MIL-S-1222	- Studs, Bolts, Hex Cap Screws, Socket Head Cap Screws and Nuts.
MIL-C-2212	- Contactors and Controllers, Electric Motor AC or DC, and Associated Switching Devices.
MIL-G-2697	- Glasses, Portlight, Circular, Heat Treated.
MIL-G-2860	- Glasses, Sight-Flow, Clear, Borosilicate.
MIL-C-5015	- Connectors, Electrical, Circular Threaded, AN Type, General Specification for.
MIL-P-5510	- Packing, Preformed, Straight Thread Tube Fitting Boss, Type I Hydraulic (-65° to 160°F).
MIL-R-6855	- Rubber, Synthetic, Sheets, Strips, Molded or Extruded Shapes, General Specification for.
MIL-A-8625	- Anodic Coatings, for Aluminum and Aluminum Alloys.
MIL-I-8846	- Inserts, Screw-Thread, Helical Coil.
MIL-S-13165	- Shot Peening of Metal Parts.
MIL-T-16049	- Tachometers: Electrical; Self-Generating; Mechanical, Fixed Mounting and Hand Held; and Vibrating Reed.
MIL-S-16216	- Steel Plate, Alloy, Structural, High Yield Strength (HY-80 and HY-100).
MIL-M-17060	- Motors, 60-Hertz, Alternating Current, Integral-Horsepower, Shipboard Use.
MIL-I-17244	- Indicators, Temperature, Direct-Reading, Bimetallic, (3 and 5 Inch Dial).

MILITARY (Continued)

MIL-T-17286	- Turbines and Gears, Shipboard Propulsion and Auxiliary Steam; Packaging of.
MIL-C-18087	- Clutches for Propulsion Units and Auxiliary Machinery, Naval Shipboard.
MIL-F-18240	- Fastener Element, Self-Locking, Threaded Fastener, 250°F Maximum.
MIL-P-18547	- Pumps, Rotary, Power Driven, Naval Shipboard Main Lubricating Oil Service.
MIL-G-18997	- Gauge, Pressure, Dial Indicating.
MIL-C-19311	- Copper-Chromium-Alloy Forgings, Wrought Rod, Bar, and Strip (Copper Alloy Numbers 182, 184,and 185).
MIL-S-19434	- Steel Gear and Pinion Forgings, Carbon and Alloy, Heat Treated, Naval Shipboard Propulsion Unit and Auxiliary Turbine.
MIL-S-21952	- Steel (HY-80 and HY-100) Bars, Alloy.
MIL-S-22698	- Steel Plate, Shapes and Bars, Weldable Ordinary Strength and Higher Strength: Structural.
MIL-C-23233	- Couplings for Propulsion Units, Auxiliary Turbines and Line Shafts, Naval Shipboard.
MIL-S-23284	- Steel Forgings, Carbon and Alloy, for Shafts, Sleeves, Propeller Nuts, Couplings, and Stocks (Rudders and Diving Planes).
MIL-S-24093	- Steel Forgings, Carbon and Alloy Heat Treated.
MIL-T-24388	- Thermocouple and Resistance Temperature Detector Assemblies, General Specification for (Naval Shipboard).
DOD-B-24668	- Bearing Unit, Main Thrust, Submarine Propulsion System.
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-C-24707	- Castings, Ferrous, General Specification for.
MIL-C-24707/1	- Castings, Ferrous, for Machinery and Structural Applications.
MIL-G-24716	- Gaskets, Metallic-Flexible Graphite, Spiral Wound.
MIL-N-25027	- Nut, Self-Locking, 250°F, 450°F, and 800°F.
MIL-P-25732	- Packing, Preformed, Petroleum Hydraulic Fluid Resistant, Limited Service at 275°F (132°C).
MIL-P-43607	- Padlock, Key Operated, High Security, Shrouded Shackle.
MIL-S-45909	- Stud, Locked In, Ring Locked, Serrated, General Specification for.
MIL-I-45910	- Insert, Screw Thread-Locked In and Ring Locked, Serrated General Specification for.
MIL-I-45914	- Insert, Screw Thread-Locked In, Key Locked, General Specification for.
MIL-T-55164	- Terminal Boards, Molded, Barrier Screw and Stud Types, and Associated Accessories, General Specification for.

STANDARDS

FEDERAL

FED-STD-H28	- Screw-Thread Standards for Federal Services.

MILITARY

MIL-STD-167-1	- Mechanical Vibrations of Shipboard Equipment (Type I - Environmental and Type II - Internally Excited).
MIL-STD-167-2	- Mechanical Vibrations of Shipboard Equipment (Reciprocating Machinery and Propulsion System and Shafting) Types III, IV, and V.
MIL-STD-271	- Requirements for Nondestructive Testing Methods.
MIL-STD-278	- Welding and Casting Standard.
MIL-STD-438	- Schedule of Piping, Valves, Fittings, and Associated Piping Components for Submarines Service.
MIL-STD-461	- Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference.
MIL-STD-777	- Schedule of Piping, Valves, Fittings, and Associated Piping Components for Naval Surface Ships.
MIL-STD-792	- Identification Marking Requirements for Special Purpose Components.
DOD-STD-2183	- Bond Testing, Babbitt-Lined Bearings.
DOD-STD-2188	- Babbitting of Bearing Shells. (Metric)

(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.

DRAWINGS

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

NAVSHIPS 803-1385850	- Piping, Instrument, Pressure for All Service.
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)
0908-LP-000-3010 - Shock Design Criteria for Surface Ships.
342-0138 - The Making and Use of Plastic Hones and Lead Bars for Inspection of Gear Teeth.

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

SUPERVISOR OF SHIPBUILDING CONVERSION AND REPAIR, USN (SUPSHIP)
SUPSHIP 280-3 - Mathematical Modeling and Dynamic Shock Analysis Guide for Main Reduction Gear.

(Application for copies should be addressed to the Supervisor of Shipbuilding, Conversion and Repair, Portsmouth Detachment, USN, Attn: Code 280, Flushing and Washington Avenues, Brooklyn, NY 11251-9000.)

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

AMERICAN GEAR MANUFACTURERS ASSOCIATION, INC. (AGMA)
230.01 - Surface Temper Inspection Process.

(Application for copies should be addressed to the American Gear Manufacturers Association, 1500 King St., Suite 201, Alexandria, VA 22314.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)
A 27 - Standard Specification for Steel Castings, Carbon, for General Application. (DoD adopted)
A 105 - Standard Specification for Forgings, Carbon Steel, for Piping Components. (DoD adopted)
A 106 - Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service. (DoD adopted)
A 216 - Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service. (DoD adopted)
A 304 - Standard Specification for Steel Bars, Alloy, Subject to End-Quench Hardenability Requirements. (DoD adopted)
A 322 - Standard Specification for Steel Bars, Alloy, Standard Grades. (DoD adopted)
A 331 - Standard Specification for Steel Bars, Alloy, Cold-finished. (DoD adopted)
A 439 - Standard Specification for Austenitic Ductile Iron Castings.
A 515 - Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service. (DoD adopted)

ASTM (Continued)

A 516 - Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service. (DoD adopted)

A 524 - Standard Specification for Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures.

A 570 - Standard Specification for Steel, Sheet and Strip, Carbon, Hot-Rolled, Structural Quality. (DoD adopted)

A 576 - Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality. (DoD adopted)

A 607 - Standard Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Columbium or Vanadium, or Both, Hot-Rolled and Cold-Rolled. (DoD adopted)

A 668 - Standard Specification for Steel Forgings, Carbon and Alloy, for General Industrial Use. (DoD adopted)

A 675 - Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties. (DoD adopted)

A 686 - Standard Specification for Tool Steel, Carbon. (DoD adopted)

A 757 - Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing and Other Applications, for Low-Temperature Service.

B 62 - Standard Specification for Composition Bronze or Ounce Metal Castings.

E 8 - Standard Test Methods of Tension Testing of Metallic Materials. (DoD adopted)

E 140 - Standard Hardness Conversion Tables for Metals. (DoD adopted)

E 208 - Standard Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels.

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

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

B 4.1 - Preferred Limits and Fits for Cylindrical Parts. (DoD adopted)

B 16.5 - Pipe Flanges and Flanged Fittings. (DoD adopted)

B 40.1 - Gauges - Pressure Indicating Dial Type - Elastic Element. (DoD adopted)

B 46.1 - Surface Texture (Surface Roughness, Waviness, and Lay). (DoD adopted)

(Application for copies should be addressed to the American Society of Mechanical Engineers, 22 Law Drive, P.O. Box 2300 Fairfield NJ 07007.)

SOCIETY OF AUTOMOTIVE ENGINEERS, INC. (SAE)

AMS 5629 - Steel, Corrosion Resistant, Bars, Forgings, Rings, and Extrusions, 13Cr - 8.0Ni - 2.2Mo - 1.1Al Vacuum Induction Plus Consumable Electrode Melted Solution Heat Treated, Precipitation Hardenable. (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. DESIGN AND CONSTRUCTION REQUIREMENTS

3.1 General design concepts and basic criteria.

3.1.1 Main reduction gear design. Designs shall be based upon the concepts and requirements described in this specification.

3.1.2 Equipment required.

3.1.2.1 Gear units. Gear units required shall be as follows:

(a) Gear units shall be furnished to the requirements specified herein. If metric configuration is required it shall be specified (see 6.2).
(b) Arrangements shall be as specified in 1.2. If details of arrangements, such as the number of input pinions, location of first reduction with respect to the second reduction gear, and so forth, are pertinent, they shall be as specified (see 6.2). Where they are not specified, such details shall be left to the choice of the contractor.
(c) Limiting dimensions, limiting weight, interface requirements (e.g., sump oil level, see 3.2.2.5) and shaft rake shall be as specified (see 6.2 and 3.1.16).
(d) Rotation of the output shaft of the gear unit shall be as specified (see 6.2).

3.1.2.2 Equipment, fittings, and accessories. Equipment, fittings, and accessories shall be furnished with the gear unit by the contractor unless otherwise specified in this specification to meet the requirements of this specification.

3.1.3 Accessibility. Maximum accessibility to gear parts which require routine examination, maintenance and repairs shall be provided within space and weight limitations. Designs shall provide for minimum effort required to accomplish planned maintenance actions and repairs.

3.1.4 Design operating conditions. Shaft horsepowers, torques and speeds for the design operating conditions of shipboard main reduction gears shall be as specified (see 6.2), as applicable:

(a) Maximum steady state for ahead conditions.
(b) Maneuvering for ahead conditions.
(c) Emergency maneuvering for ahead conditions.
(d) Two and single prime mover operation per propulsion shaft for operating conditions (a), (b), and (c) above.
(e) Trailing shaft operation of single (i.e., ship in tow, unlocked) and multiple propulsion shaft ships for operating conditions (a), (b), and (c) above.
(f) Locked shaft operation of multiple propulsion shaft ships for operating conditions (a), (b), and (c) above.
(g) Quick reversals from ahead and astern.
(h) Astern conditions.
(i) Tolerances and other pertinent data.
(j) Gear tooth contact test conditions (see 4.14.1.2.1).

The reduction gear shall operate satisfactorily within specified design operating conditions without distress or other abnormalities.

3.1.5 Emission and susceptibility requirements of electrical components. Electrical components provided with the gear unit and electrical component installations shall comply with emission and susceptibility requirements of MIL-STD-461, part 5 for surface ships and part 6 for submarines.

3.1.6 Exceptions to specifications. Where the contractor believes that he can supply a gear unit of acceptable quality by proposing a substitution for any given requirement in this specification, he may do so, providing all of the following are satisfied:

(a) Substitution is approved by the contracting activity.
(b) Substitution does not compromise reliability or other criteria herein.
(c) Substitution does not increase the contract cost or result in the subsequent higher cost of maintaining the equipment in service.
(d) Substitution represents a sound engineering approach to the original specification requirements based upon either of the following:

    (1) Previous satisfactory experience in service (Naval or comparable service).
    (2) Test results acceptable to the contracting activity.

3.1.7 Identification.

3.1.7.1 Component identification. Components and component parts shall be marked so that they can be identified with the drawings from which they are manufactured. Components and component parts shall also be marked to aid in disassembly, assembly and inspection (see 30.2.3 of appendix A). Permanent marking shall be applied in areas of essentially no stress and shall be accomplished in accordance with MIL-STD-792, except that the depth of low stress stamp marking penetration shall not exceed 1/32 inch.

3.1.7.2 Identification and information plates. Identification plates and information plates shall be readily visible and attached to the part of the machinery or equipment which will not be replaced during ships service life. Stamped identification and information plates shall have a minimum thickness of 0.03 inch and shall be in accordance with the material requirements contained in table II. Markings shall be either stamped or cast on the plate surface and shall last the anticipated life of the equipment. Stamped characters shall have a minimum depth of 0.007 inch for corrosion resistant steel plates, 0.020 inch for aluminum alloy or brass plates, or 0.010 inch for stamped characters on the raised surface of cast plates. Stamped inscriptions shall be filled with black enamel paint or lacquer, except for those containing safety information or warnings which shall be filled with red enamel paint or lacquer. Cast plates shall have polished characters raised a minimum of 0.030 inch above a roughened or stippled plate surface except that stamped characters are permitted on raised pads provided for this purpose. All identification and information plates shall be securely fastened to the part or component. Where metal fasteners are not used, plates shall be secured with epoxy resin (see 3.1.11.4) provided they are not attached on a curved surface.

3.1.7.2.1 Gear unit identification. A gear unit identification plate shall be secured to the gear housing by the contractor and shall include the contractor name, unit model number, unit serial number, and any additional information as desired by the contractor.

3.1.7.2.2 Information plate applications. Information plates shall be provided by the contractor where necessary to minimize the possibility of injury to personnel or damage to the gear unit and associated equipment. Necessary operating instructions, maintenance requirements, warnings or system diagrams shall be included on information plates, as applicable.

3.1.8 Interchangeability. Components and parts should be interchangeable with design(s) previously furnished to the maximum extent practical with particular reference to repair parts. Components and parts shall be interchangeable with all units of a specific design. In no case shall parts within a main reduction gear (i.e., a unit of a specific design) be physically interchangeable or reversible unless such parts are also interchangeable or reversible with regard to function, performance and strength.

3.1.9 Life. Unless otherwise specified (see 6.2), main reduction gear design shall be based on a life expectancy of 150,000 hours of operation (this represents 30 years life at approximately 58 percent utilization per year). Life of associated equipment (see table II) shall be as stated above unless otherwise specified (see 6.2). The contractor shall establish the gear design and verify by analysis acceptable operation under all specified design operating conditions (see 3.1.4). When a life expectancy of 150,000 hours of operation applies, life shall be based on the following hours of operation.

For steam turbine driven gears:

(a) 15,000 hours at ahead maximum steady state propulsion torque (PT).
(b) 60,000 hours between 50 and 100 percent PT.
(c) 75,000 hours at less than 50 percent PT.

For gas turbine and diesel driven gears:
(a) 75,000 hours at ahead maximum steady state turbine torque (TT).
(b) 15,000 hours at PT.
(c) 37,500 hours between 50 and 100 percent TT.
(d) 22,500 hours at less than 50 percent TT.

3.1.10 Lifting attachments. All individual components and parts of components (e.g., gears, pinions, couplings, bearing parts, removable covers, all parts of all accessories) that weigh more than 35 pounds and may be lifted separately shall have provisions for lifting and hoisting equipment (see 30.2.4 of appendix A). When a threaded hole for conventional shouldered eyebolts is proposed on a curved surface, the contractor shall provide a flat or slight counterbore to the threaded lifting hole on the part being lifted. When using nylon slings on smooth surfaces, means shall be provided to prevent the slings from sliding relative to the part during a lifting operation (e.g., machined grooves). When nylon slings are used, at no time shall the nylon sling contact a sharp edge. Rigging with a shackle pin in binding is not permitted. Out of plane loading for conventional shouldered eyebolts and padeyes is not permitted. Hooks shall be safety latched to prevent the component from uncoupling during a lifting/handling operation. Standard lifting gear shall be provided by the lifting activity. Special lifting gear shall be provided by the contractor (see 3.2.17).

3.1.11 Materials. Unless otherwise indicated (see 30.1 and 30.2 of appendix B) materials proposed for principal parts shall be as listed in table I and as specified in the associated equipment specifications in table II. Materials shall be as specified in 3.1.11.1 through 3.1.11.8.

TABLE I. Materials of principal parts.

Part	Applicable documents	Material	Remarks
A. Bearing, antifriction metal (journal and thrust)	QQ-T-390, grade 2	Babbitt (tin base)	---
B. Bearing, thrust (pivoted shoe type):			
(1) Shoe (thrust pad)	QQ-C-390, type I or II, alloy nos. C95200, C95300, C95400 (as cast only), C95700, and C95800	Copper alloy casting	---
	ASTM A 515	Carbon steel plate	---

TABLE I. Materials of principal parts - Continued.

Part	Applicable documents	Material	Remarks
(1) Shoe (thrust pad) (Continued)	ASTM A 516	Carbon steel plate	---
	ASTM A 27, grade N-1, N-2, U-60-30, 60-30, and 65-35	Carbon steel casting	---
	ASTM A 576	Carbon steel bar	---
	ASTM A 668, class B	Carbon and alloy steel forging	---
	ASTM A 675	Carbon steel bar	---
	MIL-C-24707 and MIL-C-24707/1, grades A1Q and A2Q (ASTM A 757) and WCA, WCB, and WCC (ASTM A 216)	Steel casting	---
	MIL-S-24093, class H, type V	Carbon steel forging	---
(2) Shoe support (thrust pad support)	ASTM A 686, type W1-9 or W1-10	Carbon tool steel	---
	ASTM A 331, grade E52100	Alloy steel bar	---
(3) Leveling plates (leveling links)	ASTM A 304	Alloy steel bar	---
	ASTM A 322	Alloy steel bar	---
	ASTM A 331	Alloy steel bar	---
(4) Oil seal ring	ASTM A 106	Carbon steel pipe	Sealing surface shall be babbitted per part A above.

TABLE I. Materials of principal parts - Continued.

Part	Applicable documents	Material	Remarks
(4) Oil seal ring (Continued)	ASTM A 322 (AISI 4137, 4140, 4142)	Alloy steel bar	Sealing surface shall be babbitted per part A above.
	ASTM A 524	Carbon steel pipe	Sealing surface shall be babbitted per part A above.
(5) Removable thrust collar	MIL-S-24093	Steel forging	---
	ASTM A 515	Carbon steel plate	---
	ASTM A 516	Carbon steel plate	---
C. Bearing, journal (sleeve type) shells	ASTM A 27, grade N-1, N-2, U-60-30, 60-30, and 65-35	Carbon steel casting	---
	ASTM A 515	Carbon steel plate	---
	ASTM A 516	Carbon steel plate	---
	MIL-S-22698, grades A, B, and D	Carbon steel plate, shapes or bar	---
	MIL-C-24707/1, grades A1Q and A2Q (ASTM A 757) and WCA, WCB, and WCC (ASTM A 216)	Steel casting	---
D. Bearing, journal (pivoted-shoe type)			

TABLE I. Materials of principal parts - Continued.

Part	Applicable documents	Material	Remarks
(1) Shoe	MIL-C-19311, alloy 182 or 184	Copper-chromium wrought alloy	---
	ASTM A 304 (4140H, 4142H, 4145H, 4147H, 4150H)	Alloy steel bar	---
	ASTM A 322 (AISI 4137, 4140, 4142)	Alloy steel bar	---
(2) Shoe support	SAE AMS 5629, condition H-950	Stainless steel bar (PH 13-8Mo)	---
(3) Aligning ring	ASTM A 304 (4140H, 4142H, 4145H, 4147H, 4150H)	Alloy steel bar	---
	ASTM A 322 (AISI 4137, 4140, 4142)	Alloy steel bar	---
(4) Oil seal ring	ASTM A 106	Carbon steel pipe	Sealing surface shall be babbitted per part A above.
	ASTM A 322 (AISI 4137, 4140, 4142)	Alloy steel bar	Sealing surface shall be babbitted per part A above.
	ASTM A 524	Carbon steel pipe	Sealing surface shall be babbitted per part A above.

TABLE I. Materials of principal parts - Continued.

Part	Applicable documents	Material	Remarks
E. Housing and covers and bearing seats and caps	ASTM A 27, grade N-1, N-2, U-60-30, 60-30, and 65-35	Carbon steel casting	---
	ASTM A 515	Carbon steel plate	---
	ASTM A 516	Carbon steel plate	---
	ASTM A 570	Carbon steel sheet and strip	---
	ASTM A 607	Low alloy steel sheet and strip	---
	MIL-S-21952 grade HY-80	Alloy steel bar	---
	MIL-S-22698, grades A, B, D, DH-36, and EH-36T	Steel plate, shapes or bar	---
	MIL-S-24093	Steel forging	---
	MIL-C-24707/1, grades A1Q and A2Q (ASTM A 757) and WCA, WCB, and WCC (ASTM A 216)	Steel casting	---
F. Rotating parts, main:			
(1) Pinion	MIL-S-19434, classes 2 through 6	Alloy steel forging	For through-hardening
	ASTM A 304	Alloy steel bar	For carburizing
	ASTM A 322	Alloy steel bar	For carburizing
	ASTM A 331	Alloy steel bar	For carburizing

TABLE I. Materials of principal parts - Continued.

Part	Applicable documents	Material	Remarks
(1) Pinion (Continued)	DOD-F-24669, DOD-F-24669/1, grade 1016, 4140, 4340, 4615, 8615	Alloy steel	For carburizing
(2) Gear tire (or rim)	MIL-S-19434, classes 2 through 6	Alloy steel forging	For through-hardening
	ASTM A 304	Alloy steel bar	For carbur-izing or nitriding
	ASTM A 322	Alloy steel bar	For carbur-izing
	ASTM A 331	Alloy steel bar	For carbur-izing
	DOD-F-24669/3	Nitriding steel	For nitriding
	DOD-F-24669/1	Alloy steel	For nitriding or carbur-izing
(3) Gear web or side-plates and web stiffeners	ASTM A 515	Carbon steel plate	---
	ASTM A 516	Carbon steel plate	---
	MIL-S-22698, grades A, B, and D	Carbon steel plate, shapes or bar	---
(4) Shafts (hub or connecting shaft)	MIL-S-23284	Carbon and alloy steel forging	---
	MIL-C-24707/1, grades A1Q and A2Q (ASTM A 757) and WCA, WCB, and WCC (ASTM A 216)	Steel casting	---

TABLE I. Materials of principal parts - Continued.

Part	Applicable documents	Material	Remarks
(4) Shafts (hub or connecting shaft) (Continued)	MIL-S-24093	Carbon and alloy steel forgings	---

TABLE II. Associated equipment specifications.

Equipment or accessory	Applicable documents	Material 1/	Remarks
A. Controller, turning gear motor	MIL-C-2212	---	See 3.2.8, appendix G
B. Connectors, electric "AN" type (RTE System)	MIL-C-5015	---	See 3.2.5.5
C. Couplings, flexible	MIL-C-23233	2/	See 3.2.1.3
D. Clutches	MIL-C-18087	3/	See 3.2.9
E. Dehumidifier	---	---	See 3.2.11
F. Gasket	MIL-G-1149, class 5	Rubber	---
	MIL-R-6855 class 1	Rubber	---
	MIL-P-5510	O-Rings, Buna-N, for instrumentation piping only	---
	MIL-G-24716	Spiral wound, metallic flexible graphite	---
	MIL-P-25732	O-rings, Buna-N, for union ends	---

See footnotes at end of table.

TABLE I. Materials of principal parts - Continued.

Part	Applicable documents	Material	Remarks
(1) Pinion (Continued)	DOD-F-24669, DOD-F-24669/1, grade 1016, 4140, 4340, 4615, 8615	Alloy steel	For carburizing
(2) Gear tire (or rim)	MIL-S-19434, classes 2 through 6	Alloy steel forging	For through-hardening
	ASTM A 304	Alloy steel bar	For carburizing or nitriding
	ASTM A 322	Alloy steel bar	For carburizing
	ASTM A 331	Alloy steel bar	For carburizing
	DOD-F-24669/3	Nitriding steel	For nitriding
	DOD-F-24669/1	Alloy steel	For nitriding or carburizing
(3) Gear web or side-plates and web stiffeners	ASTM A 515	Carbon steel plate	---
	ASTM A 516	Carbon steel plate	---
	MIL-S-22698, grades A, B, and D	Carbon steel plate, shapes or bar	---
(4) Shafts (hub or connecting shaft)	MIL-S-23284	Carbon and alloy steel forging	---
	MIL-C-24707/1, grades A1Q and A2Q (ASTM A 757) and WCA, WCB, and WCC (ASTM A 216)	Steel casting	---

TABLE I. Materials of principal parts - Continued.

Part	Applicable documents	Material	Remarks
(4) Shafts (hub or connecting shaft) (Continued)	MIL-S-24093	Carbon and alloy steel forgings	---

TABLE II. Associated equipment specifications.

Equipment or accessory	Applicable documents	Material 1/	Remarks
A. Controller, turning gear motor	MIL-C-2212	---	See 3.2.8, appendix G
B. Connectors, electric "AN" type (RTE System)	MIL-C-5015	---	See 3.2.5.5
C. Couplings, flexible	MIL-C-23233	2/	See 3.2.1.3
D. Clutches	MIL-C-18087	3/	See 3.2.9
E. Dehumidifier	---	---	See 3.2.11
F. Gasket	MIL-G-1149, class 5	Rubber	---
	MIL-R-6855 class 1	Rubber	---
	MIL-P-5510	O-Rings, Buna-N, for instrumentation piping only	---
	MIL-G-24716	Spiral wound, metallic flexible graphite	---
	MIL-P-25732	O-rings, Buna-N, for union ends	---

See footnotes at end of table.

TABLE II. Associated equipment specifications - Continued.

Equipment or accessory	Applicable documents	Material 1/	Remarks
G. Indicator gauge	MIL-G-18997	---	See 3.2.6.2.3 4A/
	ASME B 40.1	---	See 3.2.6.2.3 4B/
H. Indicator, thermometer	MIL-I-17244	---	See 3.2.6.2.7.1.1 5/
I. Motor, turning gear	MIL-M-17060	---	See 3.2.8, appendix G
J. Padlock and keys	MIL-P-43607	---	See 3.2.2.3.1
K. Piping, fittings and associated components (except gaskets) for:			
(1) Class A gear units	MIL-STD-438	---	See 3.2.6.2.2.1 Galvanized bolting is not required on lube oil piping.
(2) Class B gear units	MIL-STD-777	---	See 3.2.6.2.2.2 Galvanized bolting is not required on lube oil piping.
L. Plate, identification	---	Brass, bronze corrosion resisting steel or anodized aluminum alloy	See 3.1.7.2 6/

See footnotes at end of table.

TABLE II. Associated equipment specifications - Continued.

Equipment or accessory	Applicable documents	Material 1/	Remarks
M. Precipitator, vent fog	---	---	See 3.2.11
N. Pumps, rotary	MIL-P-18547	---	See 3.2.6.2.1 for attached lube oil pump
O. Sight-flow fitting:			See 3.2.6.2.7
(1) Housing	ASTM A 27	Carbon steel casting	---
	ASTM B 62, alloy C83600	Bronze casting	---
	QQ-C-390, alloy C83600	Copper alloy casting	---
	MIL-C-24707/1	Steel casting	---
(2) Glass	MIL-G-2860, type I	Borosilicate	Thermally tempered, 1/4 inch minimum thickness, impact resistant
	MIL-G-2697, type A	Borosilicate	Thermally tempered, 1/4 inch minimum thickness, breakage resistant
P. Temperature element, resistance (RTE)	MIL-T-24388	---	See 3.2.5.1
Q. Terminal board	MIL-T-55164	---	See 3.2.5.7

See footnotes at end of table.

TABLE II. Associated equipment specifications - Continued.

Equipment or accessory	Applicable documents	Material 1/	Remarks
R. Threaded fasteners, critical application			See 3.2.14 7/ 8/
(1) Bolts, studs, cap screws and nuts	MIL-S-1222	Carbon, alloy and corrosion resisting steel	9/
(2) Lock nuts	MIL-N-25027	Carbon and corrosion resisting steel	---
(3) Locked in studs	MIL-S-45909	Alloy and corrosion resisting steel	---
(4) Self-locking elements	MIL-F-18240	Nylon	---
(5) Threaded insert	MIL-I-8846	Corrosion resisting steel	---
	MIL-I-45910	Carbon, alloy and corrosion resisting steel	---
	MIL-I-45914	Alloy and corrosion resisting steel	---

1/ Materials shall be in accordance with the appropriate applicable document as modified by 3.1.11 of this specification.

2/ Coupling parts specified in tables I and II of MIL-C-23233 are considered principal parts as defined in 6.5.10.1 and shall meet the requirements of 3.1.11.

3/ Clutch parts specified in tables I and II of MIL-C-18087 are considered principal parts as defined in 6.5.10.1 and shall meet the requirements of 3.1.11.

4A/ Simplex, gauge pressure, 4-1/2 dial size, general application, no liquid fill, 0-100 psig.

4B/ Single, pressure gauge, 4-1/2 dial size, no liquid fill, 0-100 psig, accuracy grade 1A.

5/ Bimetallic, shock resistant indicator, direct reading (ITD), 3 inch dial size, 20 to 240°F temperature range, back or bottom connected, 2 or 4 inch stem length.

6/ Does not require documentation on list of preferred materials. Cast plates shall be brass or bronze. Stamped plates shall be brass, corrosion resisting steel or anodized aluminum alloy.
7/ Fasteners for critical and non-critical applications shall be in accordance with standard procurement specifications and shall meet the requirements of this specification.
8/ The contractor shall perform all nondestructive testing required by the applicable fastener specification. Where not otherwise specified, fasteners for critical applications require magnetic particle or liquid penetrant inspection (see 4.6).
9/ Use of grades of fasteners in MIL-S-1222 having a specified elongation as low as 8 percent is permitted.

3.1.11.1 Availability. The use of materials having low availability shall be kept to a minimum. Where there is a choice, the non-strategic material which represents the lowest overall cost considering initial cost, service life and future replacement/spare part procurement shall be selected.

3.1.11.2 Corrosion resisting metals. Metals shall be selected or processed and applied in a manner that provides corrosion resistance. Metal surfaces that are not inherently corrosion resistant shall be processed (treated, plated or painted) to provide corrosion resistance. The treatment and processing shall be selected so as not to adversely affect the part for the use intended. Fabricating operations such as welding, machining, drilling and tapping shall be accomplished prior to treating, coating, plating or painting. The internal main reduction gear metal surfaces exposed to oil and dehumidification system dry air are not required to be of a corrosion resistant material.

3.1.11.3 Electrolytic action between dissimilar metals. Contact between dissimilar metals shall be avoided wherever possible. Fastenings (e.g., bolts, nuts, studs, pins, springs, screws, capscrews) 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 in order to prevent deterioration due to corrosion. Aluminum alloy parts shall be anodized in accordance with MIL-A-8625.

3.1.11.4 Lubricants and compounds. Lubricants shall be as specified (see 6.2) for the following components:

(a) Main gear meshes and bearings.
(b) Turning gear and other accessory drives.
(c) Dental couplings for main couplings and accessory drives.
(d) Clutches.

Compounds (i.e., anti-galling, sealing, silicone, epoxy resin, locking and penetrating fluid) shall also be as specified (see 6.2).

3.1.11.5 Material examination. Material examination shall be as specified in 4.9.

3.1.11.6 Prohibited materials. Certain materials specified in 3.1.11.6.1 through 3.1.11.6.10, shall not be used for any part, including principal and non principal parts.

3.1.11.6.1 Aluminum alloy pipe, fittings, and valves. Aluminum alloy pipe, fittings and valves shall not be used in any piping system.

3.1.11.6.2 Asbestos. Asbestos and any material containing asbestos shall not be used.

3.1.11.6.3 Brittle materials. High transition temperature material or low ductility material, as specified in 3.1.11.6.3.1 and 3.1.11.6.3.2, shall not be used unless specified otherwise in this specification.

3.1.11.6.3.1 High transition temperature material. High transition temperature material is material having a nil-ductility transition temperature (NDTT) above plus 10°F as determined by the method described in ASTM E 208. This NDTT requirement only applies to part E of table I. This NDTT requirement does not apply to plate thickness less than 5/8 inch or more than 4 inches thick. This NDTT requirement also does not apply to bolts, nuts, studs, pipe and fittings, dowels, and pins. The use of impact tests may be substituted where there is sufficient statistical data to show correlation between nil-ductility properties and impact values. Drop weight testing to determine NDTT is not required for MIL-S-16216 (HY-80) material.

3.1.11.6.3.2 Low ductility material. Low ductility material is metallic material showing less than 10 percent elongation in a standard 2-inch gauge length tension test (see ASTM E 8).

3.1.11.6.4 Cadmium plating, zinc plating, and plastic coating. Cadmium plating, zinc plating, and plastic coating are not permitted on parts which during normal operation are exposed to lubricating oil, grease, or hydraulic fluid.

3.1.11.6.5 Cast iron and cast aluminum. Cast iron (nodular, gray, white, austenitic, alloy, malleable cast iron and close grain semi-steel) or cast aluminum parts are prohibited except as follows and as specified (see 6.2):

(a) Use of austenitic ductile iron (ASTM A 439) on the sliding surfaces of keyways and support pads.
(b) Use of ductile iron as specified in table XIII of MIL-M-17060.

3.1.11.6.6 Cork. Cork gasket material is prohibited.

3.1.11.6.7 Magnesium. Magnesium or magnesium base alloys shall not be used in shipboard equipment.

3.1.11.6.8 Mercury. Mercury in any form shall not be used in shipboard equipment, including materials and parts thereof. Mercury shall not be used in manufacturing and test processes (including test equipment such as mercury thermometers) applying to the basic equipment. Material furnished by the contractor shall not contain functional mercury in any form and shall be free from contamination by the presence of mercury.

3.1.11.6.9 Paint. Paint shall not be applied to any surface internal to a lubricating oil, grease, or hydraulic fluid system.

3.1.11.6.10 Polyvinyl chloride. Polyvinyl chloride material shall not be used.

3.1.11.7 Recovered materials. 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 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 specified (see 6.2).

3.1.11.8 Responsibility for material usage. Acceptance of any material by the contracting activity (see 30.1 and 30.2 of appendix B), does not absolve the contractor of the responsibility to assure that each material meets design strength and performance requirements and that fabrication practices such as heat treatment and welding are consistent with good engineering practice and in accordance with the applicable fabrication specifications.

3.1.12 Noise and vibration. The contractor shall meet the balance and vibration requirements specified in 3.1.12.1 and 3.1.12.2. For applications where radiated noise levels are critical (for example, class A gear units) requirements and goals shall be as specified (see 6.2).

3.1.12.1 Internally excited vibration. Balance and vibration requirements shall be in accordance with MIL-STD-167-1, type II internally excited vibration, except as specified in 3.1.12.1.1 and 3.1.12.1.2.

3.1.12.1.1 Balancing. Main rotating gears and pinions that operate at 150 revolutions per minute (r/min) and above shall be dynamically balanced while those gears and pinions operating up to 150 r/min shall be statically balanced, as a minimum. The teeth of gears and pinions shall be finish machined prior to balancing. Where feasible, balance shall be accomplished by removal of metal, preferably from welded-on balancing rings for fabricated gears. Welds shall not be cut into when balancing. Where balancing holes are drilled in pinion or gear rims, the distance from the outer surface of the holes from the root of any tooth shall be not less than 1-1/4 times the respective tooth whole depth and the remaining metal between holes shall be not less than one hole diameter. If the required level of residual unbalance in each plane of correction can not be accomplished by removal of metal alone, balance weights shall be used. Balance weights shall be threaded and be of the self locking type with a self-locking element or positively secured by disruption of the first thread of the balance hole by peening. All balance weights shall be torqued and bottomed in a blind hole (see 6.3 and 30.9 of appendix B). Welded weights shall not be added to correct for balance after teeth are cut.

3.1.12.1.2 Vibration limits. Gear unit vibration characteristics shall be observed during contractor performance acceptance testing (see 4.14.1.1 and 4.14.1.2) through the entire speed range from zero to overspeed. Measurement techniques and instrumentation shall be suitable for accurate measurement of the fundamental rotational frequency and any known or expected subharmonics. The contractor shall include provisions and instrumentation for measurement of vertical, athwartship and forward and aft vibration at journal bearing caps, the gear housing or gear housing covers adjacent to journal bearings. These vibration levels shall be within the maximum allowable vibration limits defined by paragraph 5.2.2.3 of MIL-STD-167-1, except that no reading shall exceed 2 mils peak to peak.

3.1.12.2 Vibration analyses. Unless otherwise specified (see 6.2), the shipbuilder will perform torsional, longitudinal and lateral vibration analyses of the propulsion system in accordance with MIL-STD-167-2 (see 30.3 of appendix B). The contractor is responsible for ensuring that the rotor dynamics of the gear unit rotating parts result in satisfactory vibration levels under internal excitation.

3.1.13 Reliability. Parts shall be designed and constructed such that replacement or repair is not required during the specified life (see 3.1.9).

3.1.14 Ship attitudes. In addition to performing satisfactorily when the ship in which the gear is installed is at normal even keel, equipment and machinery shall be designed and installed to operate satisfactorily, to maintain satisfactory lubrication, and to avoid loss of oil from machinery under the most unfavorable combination of trim, pitch, list, and roll. Trim and list angles, pitch and roll angles, number of cycles and cycle times shall be as specified (see 6.2).

3.1.15 Shock. If required (see 6.2), shock design of gear unit and associated equipment shall be in accordance with MIL-S-901, grade A, hull mounted equipment except for the dehumidifier, which shall be in accordance with MIL-S-901, grade B.

3.1.15.1 Static design method. Gear units and associated equipment shall be designed for shock loading based on static analysis methods. Shock factors (static "g" accelerations) shall be as specified (see 6.2). Gear units and associated equipment shall be capable of withstanding maximum shock loads at all design operating conditions (see 3.1.4) without exceeding allowable stresses or deflections. The contractor is responsible for ensuring that the gear unit and associated equipment meet the static shock requirements as specified herein.

3.1.15.1.1 Use of shock factors. Shock factors shall be used to determine shock loads due to the inertia of each element in accordance with the following formula:

Shock load = M x G x g

Where:

M = mass of element (concentrated or distributed)
G = shock factor (see 3.1.15.1).
g = acceleration due to gravity.

Shock loads shall be used to determine shock stresses which are to be calculated and analyzed separately for each of the principal directions of loading (vertical, athwartship, and forward and aft).

3.1.15.1.2 Allowable stresses. Allowable stresses, as evaluated at the corresponding operating temperature, shall be within the following limits:

For components where plastic deformation is not permissible,

$\sigma' \leq \sigma_y$ (In general, except bearing)

$\sigma_b' \leq 1.6\sigma_y$ (In bearing)

For components (i.e., non-alignment critical items) where minor plastic deformation is permissible,

$\sigma' \leq \sigma_y + F(\sigma_u - \sigma_y)$ (In general, except bearing)

$\sigma_b' \leq 1.6(\sigma_y + F(\sigma_u - \sigma_y))$ (In bearing)

For babbitted bearings,

$\sigma_b' \leq$ 20,000 pounds per square inch (lb/in^2)

Where:

σ' = Von Mises' equivalent stress (in general, except bearing).
σ_b' = Bearing stress.
σ_y = Yield strength (0.2 percent offset).
σ_u = Ultimate tensile strength.

F = a factor which takes into account the efficiency with which the material in a member is utilized and is dependent on the kind of loading and cross section of the member. The value of F is given by:

$$F = \frac{\text{Load to completely yield member}}{\text{Load to initiate yield of member}} - 1$$

F = 0, for a member in pure tension.
F = 0.5, for a rectangular section in pure bending.
F = 0, for low ductility materials (see 3.1.11.6.3.2) or where plastic deformation is not permissible.

3.1.15.2 Dynamic analysis. The type of dynamic analysis used (e.g., dynamic design and analysis method, transient dynamic shock analysis, underwater shock analysis) and additional analysis requirements shall be as specified (see 6.2). When the contractor is required to use the dynamic design and analysis method it shall be performed in accordance with NAVSEA 0908-LP-000-3010 and SUPSHIP 280-3. Items found deficient by the analysis used shall be identified and corrective action proposed (see 30.4 of appendix B).

3.1.15.3 Exceptions to shock requirements. Exceptions to shock design requirements of 3.1.15 through 3.1.15.2 and shock testing requirements of 4.14.1.5 are as follows:

(a) When the proposed design of a gear unit is identical to a design which has been previously shock tested and accepted by the contracting activity, such design shall be acceptable without further testing or analysis from a shock standpoint.

(b) When the proposed design of a gear unit is identical to a design which has been previously dynamically analyzed and the analysis has been accepted by the contracting activity such design shall be acceptable without further testing or analysis from a shock standpoint if the foundation and other equipment affecting the mathematical model are the same.

(c) When the proposed design of a gear unit is similar, but not identical, to a design which has been previously tested or dynamically analyzed and accepted by the contracting activity, the contractor may define areas of dissimilarity, including calculated shock factor capability in these areas, and propose to the contracting activity the acceptance of such design in lieu of the requirements in 3.1.15.1 through 3.1.15.2. If the contracting activity concurs that the similar design will provide equal or better shock capabilities in the intended application, extension acceptance will be granted and shock testing is not required.

(d) When an accessory component (e.g., oil pump, turning gear motor or clutch) has been shock qualified in accordance with MIL-S-901 and applicable equipment specifications (see table II), shock stress analysis and testing is required only for determination of the components effect upon the overall system (see (a), (b), and (c) above).

3.1.16 Weight and space. Weight and space shall meet the requirements of this specification (see 3.1.2.1). The specified weight limit is not to be exceeded (see 30.5 of appendix B). Definitions of weight control terminology are specified in 6.5.13.

3.1.17 Welding, brazing, and allied processes. Welding and allied processes shall be in accordance with MIL-STD-278. Alteration or repair of all fabrications, forgings, castings and welded pipe joints shall also be in accordance with MIL-STD-278. Brazing is prohibited for all applications other than dehumidification and vent system piping. Requirements for the fabrication of brazed piping joints shall be as determined by the contractor.

3.2 Specific reduction gear design and construction requirements.

3.2.1 Main rotating parts. Insofar as practical, rotating parts shall be designed for use in both port and starboard units.

3.2.1.1 Main gears and pinions. (See 30.2.5 of appendix A.)

3.2.1.1.1 Construction. Unless otherwise specifically approved by the contracting activity, main rotating pinions shall be of one-piece construction (that is, a solid forging) and gears which mate with pinions will be a fabrication of weldments. Where fabrications are used, strength welds shall be full penetration designed to allow 100 percent ultrasonic inspection. Non-strength welds (e.g., welds between balancing pads or balancing rings and web plates) need not be full penetration. For gear rim materials and high alloy shaft materials used in a fabrication of weldments, the contractor shall perform the tests as specified in 4.9.1 and 4.9.2. Consideration will be given to alternate construction (e.g., castings, shrink fit (keyed), and bolted (keyless)) provided drawings are approved by the contracting activity. This approval recommendation shall be supported by design engineering calculations and an acceptable experience record. For construction where the gear assembly is not integral with the shaft, the gear assembly shall be shrunk on the shaft against a shoulder and secured with a nut or shrink ring. Nuts shall be locked to prevent loosening. Interface with the shaft for this shrink fit design shall be keyed against rotation with respect to the shaft.

3.2.1.1.2 Tooth design.

3.2.1.1.2.1 Tooth form. The tooth form shall be of the involute shape in the transverse direction and shall blend smoothly with the root fillets.

3.2.1.1.2.2 Tooth modifications. Ends of pinion and gear teeth shall be chamfered to prevent breaking of unsupported edges. Chamfers at ends of pinion and gear teeth shall be 30 to 60 degrees from the vertical and extend to the pitch line or below. Corners formed by involute profiles at root radii, tooth end faces and tooth tips shall be chamfered or provided with a radius to avoid quench cracking and sharp edges.

3.2.1.1.2.3 Profile and lead modifications. Modified involute profiles (including tip and root relief), lead modifications and crowned teeth may be incorporated to compensate for tooth distortions which result from load and temperature differentials.

3.2.1.1.2.4 Helix angle. Double helical gears with a 25 degree minimum helix angle shall be used.

3.2.1.1.2.5 Design tooth stress. Unless otherwise specified (see 6.2), main pinion and gear tooth bending stress (S_k) calculated for helical gearing using the procedure on figure 4, sheets 1 through 5, shall not exceed the values shown on figures 5 through 7 at specified maneuvering conditions (see 3.1.4). The maximum K factor at specified maneuvering conditions shall be as specified (see 6.2).

3.2.1.1.2.6 Gear tooth scoring resistance. Main gear and pinion tooth scoring resistance shall be established by the contractor. Scoring risk shall be calculated for both cold scoring (slow speed) and hot scoring (high speed) for each main gear and pinion at worst case design operating conditions (see 3.1.4 and 30.2.6 of appendix A).

3.2.1.1.2.7 Heat treatment of main pinions or gears. Where a specific heat treatment process, for example, through hardening or case hardening, or combinations thereof, is required for the manufacture of a main pinion or gear, it shall be as specified (see 6.2). Through hardened and surface hardened tooth hardnesses shall meet the requirements of 4.10.1.1 through 4.10.1.3.2, as applicable.

3.2.1.1.2.8 Tooth finishing process. Through hardened teeth shall be finished by shaving or grinding. Surface hardened teeth shall be finished by grinding. Honing is permitted to improve tooth accuracy or surface finish. The meshing surfaces shall blend to form smooth surfaces free of sharp edges. Roots of teeth shall not be finish machined after surface hardening or shot peening. Tooth root fillets shall be finished by shot peening in accordance with MIL-S-13165 for through hardened and carburized pinions or gears. Nitrided pinions or gears shall not be shot peened. Tooth fillets are to be shot peened using hard steel shot of 55-65 Rockwell C hardness. Shot peening acquisition requirements, process parameters and liquid tracer system shall be determined by the contractor to ensure design requirements and all requirements of this specification are met. Complete shot peening coverage is to be verified as specified in 4.10.2. Tooth flanks subjected to shot peening shall be finish machined such that all evidence of the peening is removed from the finished surface (see 4.10.2).

3.2.1.1.2.9 Hand working on active tooth surfaces. Use of hand tools, filing, scraping or stoning on the active tooth surfaces shall not be permitted, except that a very limited amount of hand stoning or scraping is permitted by this specification for the removal of isolated local high spots which may become apparent after the normal finishing process. Such hand work shall not be permitted to remedy poor or inaccurate machining, errors in the cutters, or conditions which may arise from general or large hard spots in the metal. Teeth shall be free of machining tears and other surface detectable defects so that the accuracy and mating tooth contact pattern requirements are met.

3.2.1.1.3 Ratio of pinion total face width to pinion pitch diameter (F_t/d). Ratio of pinion total face width (F_t) (includes gap in double helical gearing) to pinion pitch diameter (d) shall not exceed the following:

(a) Through hardened tooth without lead correction: 2.50.
(b) Surface hardened tooth without lead correction: 1.75.
(c) Through hardened tooth with lead correction: 3.00.
(d) Surface hardened tooth with lead correction: 2.10.

3.2.1.1.4 Chrome content of main pinion or gear surfaces. The chrome content of main pinion or gear surfaces (e.g., journals and thrust collars) used with babbitted bearing surfaces or babbitted steel bearing end seals shall not exceed 2 percent.

3.2.1.1.5 Pinion and gear shoulder. A shoulder shall be machined on the rim at each end of each pinion and gear. The shoulder shall have an outside diameter approximately equal to but less than the root diameter and shall be at least 1/8 inch wide.

3.2.1.1.6 Accuracy. Unless otherwise specified (see 6.2), gear tooth and reference surface (e.g., journal surface) accuracy requirements shall be in accordance with appendix E. Gear tooth and reference surface accuracy shall be verified as specified in 4.10.3.

3.2.1.2 Shafting.

3.2.1.2.1 Shaft stresses. Main rotating part shaft stresses shall be calculated as specified in and meet all requirements of appendix D.

3.2.1.2.2 Shaft bores. The bore in each hollow pinion, gear or shaft shall be provided with natural drainage unless plugged. Drain holes shall not be located between teeth or between helices. Hollow output shafts shall be plugged except where the machinery design requires a passage through the shaft. Shaft bores which can not be plugged and which are exposed to the engine room shall be protected from corrosion (see 3.1.11.2).

3.2.1.2.3 Connecting shafts. Where connecting shafts (e.g., quill shafts or distance pieces) are used in the gear train they shall be as specified in appendix D.

3.2.1.2.4 Flanges. All flange faces between main rotating parts which can be disassembled shall be provided with fitted bolts and rabbets or spigots for centering. Rabbets or spigots shall provide a class LC1 locational clearance fit in accordance with ASME B 4.1. For low speed gear shaft flanges, fitted bolts may be used in lieu of rabbets or spigots, provided that the same centering is maintained at the locating diameters. A tighter fit than provided with class LC1 in accordance with ASME B 4.1 is permitted, if required for a specific application, up to a maximum interference of 0.0005 inch. Gear shaft flanges mating with propulsion shaft flanges shall also conform to Drawing 803-2145807. Rotating part flanges shall conform to the accuracy requirements specified in 3.2.1.2.5. Connection to the prime mover(s) shall be as specified (see 6.2). Unless otherwise specified (see 6.2), the shipbuilder will provide the fasteners connecting the gear unit to the prime mover(s) and the gear unit to the lineshaft.

3.2.1.2.5 Shaft flange face, thrust collar, and spigot/rabbet runout. Flange faces to which flexible couplings bolt, thrust collars, and spigot/rabbet runouts shall not exceed 0.001 inch TIR for individual components in the intermediate and low speed gear assemblies. Flange faces to which flexible couplings bolt, thrust collars, and spigot/rabbet runouts for individual components in the high speed pinion assemblies shall not exceed 0.0005 inch TIR. The total indicated runout for flange faces which do not bolt to flexible couplings shall be less than $(1.5D \times 10^{-5}) + (2 \times 10^{-4})$ inch where D equals the diameter of the flange where indicated. For flange face runout, measurements shall be made near the outer diameter of the flange and be normal to the journals of pinions and gears and to the centerline axis of other shafts to the extent noted above. For flange faces (including contacting flange faces of spigots or rabbets) and thrust collars, the TIR shall be determined by perpendicularity measurements with the journal centerline as the datum axis. For locating diameters (i.e., spigots and rabbets), the TIR shall be established by concentricity measurements with the journal centerline as the datum axis. Shaft flange face, thrust collar, and spigot/rabbet runout shall be verified as specified in 4.10.4.

3.2.1.3 Flexible couplings for main rotating parts.

3.2.1.3.1 High speed coupling. Unless otherwise specified (see 6.2), the contractor shall furnish flexible coupling(s) for connecting each prime mover output shaft to each gear unit input shaft in accordance with type I, class 3 or 5, or type VI of MIL-C-23233.

3.2.1.3.2 High speed coupling quick disconnect. When specified (see 6.2), the coupling shall provide means for disconnection within 15 minutes from the prime mover. The 15 minute time period shall begin with opening of the access cover (already unlocked) and end with verification of disconnection and closing of the access cover. High speed coupling quick disconnect within 15 minutes shall be verified as specified in 4.14.1.4. This test shall be conducted after operation (i.e., with gear unit hot after system shut down) in accordance with test conditions and time after shut down as mutually determined by the contractor and contracting activity.

3.2.1.3.3 Intermediate speed coupling. Intermediate speed main rotating part assemblies shall be connected at one or both ends by flexible coupling(s) in accordance with type I, class 3 or 5, or type VI of MIL-C-23233.

3.2.1.3.4 Low speed coupling. When specified (see 6.2), the gear unit shall connect to the propulsion shaft through flexible coupling(s) in accordance with type V of MIL-C-23233 provided by the contractor.

3.2.2 Housing.

3.2.2.1 Construction. Housings shall be rugged and shall absorb all imposed stresses under specified operating conditions (see 3.1.4), including shock (see 3.1.15), such that tooth contact of meshing pinions and gears will not be adversely influenced. Forged, rolled, and cast materials, or combinations thereof, shall be used. Thrust and journal bearings shall be directly mounted on or within the gear housing. Bearing bores shall be properly machined as necessary, to ensure correct alignment. Housing covers and bearing caps shall be designed and arranged for accessibility (see 3.1.3) of main rotating parts, bearings, and other maintainable parts. Clearance between the rotating parts and gear housing shall be provided under conditions of maximum thermal expansion. Class B gear units shall incorporate means for readily measuring the static vertical plane and horizontal plane reactions, as applicable of the low speed gear journals by use of a hydraulic jack and calibrated load cell (see 3.2.15.3). The jack and load cell shall be located as near as practicable to the journal bearing whose reaction is being measured. Adequate space for each reaction position shall be provided to accommodate a hydraulic jack and a load cell each sized to carry approximately twice the maximum calculated static design load of the bearing under cold plant condition. For all classes, the gear housing shall facilitate removal of all bearings by providing provisions for vertical and horizontal jacking or lifting of all rotating parts. The hydraulic jacks and load cells shall be provided by the activity performing the shaft alignment check or bearing removal. Special tools, if required for alignment or bearing removal, shall be provided by the contractor (see 3.2.17). The design shall prevent galling of bearing cap outer bolting surfaces from tightening of nuts.

3.2.2.2 Mesh inspection and other access opening covers.

3.2.2.2.1 Mesh inspection opening covers. Mesh inspection openings shall be provided over the areas of mesh of main pinions and gears (see 30.2.7 of appendix A). Openings shall enable a detailed, close-up inspection of the entire face width of each pinion and gear; provide sufficient room to facilitate uniform dykem application and evaluation of tooth contact patterns over the entire face width; and provide for observation of the oil spray pattern. For inspection covers whose orientation/arrangement is such that they could inadvertently slam shut during inspections or can not be completely opened, means shall be provided to mechanically hold each of these inspection covers in the open position. Each inspection opening shall be provided with a closure secured to the gear housing by a hinge pin on one end and a clevis on the other, or similar arrangement. Hinge pins shall be positively secured mechanically (e.g., peening over the end of hinge pin). A strongback or "Y" shall connect the hinge pin and clevis with the cover plate secured to the "Y" at the center by a bolt which may be tightened to prevent oil leakage around the cover. Center bolts shall be positively secured to prevent backing off. All cover parts shall be secured such that they can not fall into the gear housing during inspection. Each inspection cover shall be secured to the gear housing by a padlock (see 3.2.2.3.1). Each padlock shall also be provided with a chain securely fastened to the gear housing or housing main cover. Where more than one strongback or "Y" is installed on one inspection cover, each strongback or "Y" shall be locked. Foreign material shall not enter the inspection opening and oil shall not leak from the opening when the closure is secured. All inspection openings shall have a coaming around the edge of the opening which is at least 1 inch high to prevent entry of foreign material into the gear housing when the cover is lifted.

3.2.2.2.2 Other access opening covers. Unless otherwise specified in this specification, access openings other than mesh inspection openings shall be provided with hinged covers or covers secured by bolting. When hinged covers are used, 3.2.2.2.1 applies. Hinged covers as specified in 3.2.2.2.1 shall be provided to gain access to the high speed coupling quick disconnect (see 3.2.1.3.2) and attached oil pump drive train quick disconnect (see 3.2.6.2.1.2). When access opening covers are secured by 12 bolts or less, they shall be provided with locking devices to prevent unauthorized entry into the gear housing as specified in 3.2.2.3.2.

3.2.2.3 Security provisions. (See 30.2.8 of appendix A.)

3.2.2.3.1 Padlocks. Padlocks shall meet the requirements of MIL-P-43607 except that shrouded shackles are not required. Approved padlocks are Sargent and Greenleaf (S&G), model 826A or equivalent. Keys shall open the locks on only one gear assembly. For one gear assembly a single design of key shall fit all locks. Lock openings for keys shall hang in the downward position to reduce chance of dirt entry. All locks, two access keys and one control key, shall be furnished by the contractor.

3.2.2.3.2 Locking devices. Unless otherwise specified in this specification, lube oil spray installations, vent openings, cover plates, piping flanges, or sight flow indicators which allow direct entry into the gear housing and are secured by twelve or fewer threaded fasteners shall be secured by one of the following means to prevent unauthorized or inadvertent entry into the gear housing:

(a) Epoxy-filled caps. Details of the epoxy-filled caps method shall be as specified (see 6.2). Hardware shall be provided and installed by the contractor without epoxy applied. Epoxy will be provided and installed by the shipbuilder (see 3.1.11.4).
(b) A padlock (see 3.2.2.3.1).
(c) A padlocked bar (see 3.2.2.3.1).

3.2.2.4 Housing vent opening. One or more vent openings shall be provided in the gear housing (see 3.2.11).

3.2.2.5 Oil excluding pan or shield. For those installations where the oil in the sump tank may reach a main gear or pinion when the ship is not at even keel (see 3.1.14) an oil excluding pan or shield shall be provided by the contractor to prevent excessive churning and aeration of the oil. The determination as to whether the oil level will contact a gear or pinion during trim, pitch, list or roll is dependent upon the type of sump tank and oil system.

3.2.2.6 Attachment to ship's foundation. When directly mounted to ship foundations, gear housing mounting flanges shall be machined and drilled by the contractor. These contractor drilled holes will be reamed for fitted bolts by the shipbuilder during installation. Housing mounting flanges shall be tapped for an adequate number of jacking bolts to facilitate alignment. Bolting, chocks and jacking bolts will be provided and installed by the shipbuilder. If special mounting is required, it shall be as specified (see 6.2).

3.2.2.7 Disassembly design features. Housing or cover flanges and removable bearing caps shall be provided with tapped holes for forcing bolts or other features to facilitate disassembly. Low speed gear bearing caps shall be removable without lifting gear main covers. Also see 3.1.10 and 3.2.2.1 for additional lifting requirements.

3.2.3 Journal bearings.

3.2.3.1 Detail requirements. Sliding surface journal bearings which support main rotating parts shall be of the sleeve type (i.e., cylindrical, elliptical or lobe) or pivoted-shoe type or combinations of such types. Sliding surface journal bearings shall be in halves except for lobe bearings which shall be divided into three segments. For bearings with sight flow indicators, bearing design shall ensure sight flow indicator flow is maintained during all design ranges, temperatures and ship attitudes.

3.2.3.2 Interchangeability. Each journal bearing supporting a main pinion or gear shall be the same with respect to general dimensions. Bearings for port and starboard gear units of the same general design shall, where practicable, be interchangeable.

3.2.3.3 Anti-friction metal. Bearing surfaces of sliding surface journal bearings and steel bearing end seals shall be lined with anti-friction metal as specified in table I, babbitted in accordance with DOD-STD-2188. Grooves or holes in shoes or shells to anchor the babbitt will not be permitted. Following application, the anti-friction metal of sleeve type journal bearings shall be chamfered where the bearing segments meet. The anti-friction metal of sleeve type journal bearings shall blend in smoothly at oil spreader grooves. Bond tests shall be in accordance with 4.11.

3.2.3.4 Surface finish. Shoe and seal anti-friction metal surfaces shall be finished to 32 Ra or better.

3.2.3.5 Locating provisions. Provisions for properly locating bearing parts with respect to each other and with respect to the bearing housing shall be provided (e.g., doweling, bolts, marking, etc.). These provisions shall ensure bearing parts can not be inadvertently assembled incorrectly with respect to each other or with respect to the bearing housing.

3.2.3.6 Anti-rotation provisions. Anti-rotation provisions shall be provided to prevent bearings from rotating in their housings. Anti-rotation provisions shall also be provided for bearing end seals.

3.2.3.7 Oil spreader grooves. When used, oil spreader grooves shall not be placed in the areas of normal steady state journal action (see 3.1.4). The oil grooves and chamfers shall be sized to ensure that the oil flow to the bearing is sufficient to maintain a full oil film and meet the babbitt temperature and oil temperature rise limitations specified in this specification.

3.2.3.8 Oil film thickness and unit load. (See 30.2.9 of appendix A.) The minimum oil film thickness of journal bearings shall be not less than 0.001 inch under all ahead steady state design operating conditions (see 3.1.4). Low speed gear journal bearing unit load shall be not greater than 250 lb/in^2 and all other journal bearing unit loads shall be not greater than 350 lb/in^2 under all ahead steady state design operating conditions (see 3.1.4). Bearing design for the low speed gear shall include loads imposed from the low speed coupling assembly.

3.2.3.9 Bearing temperature limits. Maximum allowable operating temperature as read by the bearing RTEs installed as specified in 3.2.5 shall be 230 degrees Fahrenheit (°F) for all journal bearings. Alarm settings shall initially be set at maximum limits; however, final alarm settings will be 20°F higher than the maximum value observed during sea trials. The maximum temperature rise of oil, as measured by thermometer or resistance temperature element (RTE) in bearing drains or sight flow fittings, shall be not greater than 50°F.

3.2.3.10 Rolling out bearings. All bearing parts for each main rotating pinion and gear shall be removable without removing the main pinion or gear (see 3.2.2.1).

3.2.3.11 Bearing reference surfaces. Each sleeve type journal bearing shall be provided with a pair of concentric reference shoulders (one at each end) to be used for boring and crown thickness measurements. Unless otherwise marked on the bearing detail drawing, the outside diameter of the shell shall be the reference shoulder.

3.2.3.12 Bearing thickness measurement. The bearing thicknesses which establish the journal location shall be measured by the crown thickness method or equivalent.

3.2.3.12.1 Bearing thickness measurements for cylindrical and elliptical bearing. Crown thickness constants are the radial distances between the inner babbitted surface and the concentric circumferential reference surface (see 3.2.3.11). Each cylindrical or elliptical bearing shall be marked to indicate points of measurement of the shell thickness. Marking shall consist of radial lines on the face of each end. The ahead loaded arc shall have a pair of lines at the angular center plane and two pairs at approximately 45 degrees from the center plane. The ahead non-loaded arc shall have one pair of lines at the angular center plane. The as delivered crown thickness constants shall be measured by the contractor at each scribe line location at each end of the bearing and marked adjacent to the scribe lines (see 30.6 of appendix B).

3.2.3.12.2 Bearing thickness measurements for lobe type bearing. Crown thickness constants are the radial distances between the inner babbitted surface and the concentric circumferential reference surface (see 3.2.3.11). Each lobe bearing shall be marked to indicate points of measurement of the shell thickness. Marking shall consist of radial lines on the face of each end. Each lobe shall have a pair of scribed lines at the angular center plane and two pairs at approximately 45 degrees from the center plane. The as delivered crown thickness constants shall be measured by the contractor at each scribe line location at each end of the bearing and marked adjacent to the scribe lines (see 30.6 of appendix B).

3.2.3.12.3 Bearing thickness measurements for pivoted-shoe type bearing. Each pivoted-shoe type journal bearing shall have provisions for measuring crown thickness or equivalent (e.g., "stackup" of pad, shim, etc.). The crown thickness measurement method (see 30.7 of appendix B) shall consider the "stack-up" of bearing components which establishes the journal location. Bearing parts shall be marked to ensure each part is reassembled in identical locations after disassembly. Also pads, shims, and so forth used to adjust or establish the journal location shall be measured and marked by the contractor with the as delivered thickness(es) (see 30.6 of appendix B).

3.2.4 Thrust bearings.

3.2.4.1 Detail requirements. Thrust bearings shall position the propulsion shafting and/or position the low speed gear in the forward and after directions. Pivoted segmental shoe type thrust bearing(s) shall be used which transmit load from a shaft thrust collar or thrust surface. The propulsion and positioning thrust bearing(s) shall absorb thrust in the forward and after directions as well as in both directions of shaft rotation. Thrust bearing shoes shall not be attached to or derive support from a journal bearing. Each thrust bearing shall have two sets (ahead and astern) of thrust bearing elements each consisting of babbitted thrust pads mounted to equally transmit thrust (e.g., mounted on leveling or equalizing plates) to the thrust bearing base ring and gear housing. For a class A gear unit, separate positioning and propulsion thrust bearings are required; with the propulsion thrust bearing provided by the contractor in accordance with DOD-B-24668 when specified (see 6.2) and the positioning thrust bearing provided by the contractor in accordance with the requirements of this specification. For a class B gear unit, positioning and propulsion thrust bearings shall be separate or combined as specified (see 6.2) and in accordance with the requirements of this specification. For bearings with sight flow indicators, bearing design shall ensure sight flow indicator flow is maintained during all design ranges, temperatures and ship attitudes.

3.2.4.2 Major bearing parts.

3.2.4.2.1 Thrust collar. Except for class A gear unit propulsion thrust collars, thrust collars shall be separate and removable; forged integral with a gear shaft; or forged integral with a stub shaft bolted to a gear shaft. Class A gear unit propulsion thrust collars shall be in accordance with DOD-B-24668. Separate, removable collars shall be keyed or otherwise secured from rotation and a locked nut (see 3.2.14.1.7.1) shall be used to secure the collar against a shoulder on the shaft. Wrenching space shall be provided to permit tightening the locking nut. Removable thrust faces may be used on integral collars. Stub-shaft arrangements shall be positioned concentric to shafting by rabbet/spigot fits (see 3.2.1.2.5) and bolted thereto by a locked bolting arrangement (see 3.2.14.1.7.1). Removable thrust faces shall be positively located on the integral collar and bolted thereto by a locked bolting arrangement (see 3.2.14.1.7.1).

3.2.4.2.2 Thrust shoes. Each shoe shall be equipped with a hardened steel button on its back face to transmit load to the load equalizing system. The button shall extend sufficiently beyond the back of the shoe to allow the shoe full freedom to tilt within the thrust bearing clearance. The face of the button shall have a spherical crown to mate with flat surface on leveling link. Thrust shoes shall be supplied in sets which shall be installed together.

3.2.4.2.3 Load equalizing links. Each link in direct contact with a shoe shall be provided with a hardened steel insert positioned to provide the design pivot point for the shoe. The spherical crown radius in the buttons of the thrust shoes, as well as the radii in the contacts between links and base ring, shall be chosen such that plastic deformation of the surfaces does not occur under worst case conditions (see 3.2.4.8).

3.2.4.2.4 Base ring. The base ring shall be designed to contain the load equalizing mechanism and to position the crowned pivots at the proper point on the shoe button so as to prevent sliding motion between load equalizing mechanism and base ring and between shoes and base ring. The base ring shall restrain and position the links of the load equalizing system and the shoes of the thrust bearing.

3.2.4.2.5 Spacer or filler plates. Forward and aft location of thrust elements within limits of the housing shall be made by use of spacer or filler plates inserted between housing and base ring. These plates shall mate with flat finished surfaces in the thrust housing. Stacking of plates shall not be permitted and plates shall neither be attached to nor derive support from the journal bearing.

3.2.4.2.6 Oil Seals. Restraints shall be employed to prevent the ring seals from becoming locked either on the shaft or the housing as a result of axial motion of the shaft. End seals shall be of a design which permits repair or renewal.

3.2.4.3 Interchangeability. Similar thrust bearing elements shall be interchangeable. Bearings for port and starboard gear units of the same general design shall, where practicable, be interchangeable.

3.2.4.4 Anti-friction metal. Bearing surfaces of thrust shoes and steel bearing end seals shall be lined with anti-friction metal as specified in table I, babbitted in accordance with DOD-STD-2188. Grooves or holes in shoes to anchor the babbitt will not be permitted. Bond tests shall be as specified in 4.11.

3.2.4.5 Contact areas and bearing surfaces. Friction and contact surfaces shall be smoothly and accurately finished. Surface finish and Brinell hardness (Bhn) requirements shall be as follows:

(a) Collar - 16 Ra or better.
(b) Leveling plate contact areas - 32 Ra or better on surfaces in contact with shoes or base ring pivot surface (525 ± 25 Bhn) and 63 Ra or better on leveling link surfaces bearing on mating links (550 ± 50 Bhn).
(c) Buttons - 32 Ra or better (550 ± 50 Bhn).
(d) Base ring contact areas (or hardened inserts, where used) - 63 Ra or better (525 ± 25 Bhn).
(e) Shoe and seal babbitted surface - 32 Ra or better.
(f) For case hardened surfaces, nitriding is not permitted. Case depth shall be 0.090 inch minimum.

3.2.4.6 Locating provisions. Provisions for properly locating bearing parts with respect to each other and with respect to the bearing housing shall be provided (e.g., doweling, bolts, marking, etc.). These provisions shall ensure bearing parts can not be inadvertently assembled incorrectly with respect to each other or with respect to the bearing housing.

3.2.4.7 Anti-rotation provisions. Anti-rotation provisions shall be provided to prevent bearings from rotating in their housings. Anti-rotation provisions shall also be provided for bearing end seals.

3.2.4.8 Oil film thickness and unit load. The minimum oil film thickness of thrust bearings shall be not less than 0.001 inch under all ahead steady state design operating conditions (see 3.1.4). Propulsion thrust bearings not combined with positioning thrust bearings shall be as specified in 3.2.4.8.1. Positioning thrust bearings not combined with propulsion thrust bearings shall be as specified in 3.2.4.8.2. Combined thrust bearings shall be as specified in 3.2.4.8.1 and 3.2.4.8.2. Maximum unit load during continuous operation including maneuvering conditions (see 3.1.4) for any thrust bearing shall be not greater than 500 lb/in^2.

3.2.4.8.1 Propulsion thrust load. For class B gear units, propulsion thrust bearings shall absorb any thrust loads which may be developed during all specified design operating conditions (see 3.1.4). Simultaneous worst case operating and shock conditions (see 3.1.15) and worst case trim and list (see 3.1.14) shall be considered. Contact stresses and factor of safeties for both babbitt and thrust shoe materials shall be analyzed. Design propulsion thrust load shall be as specified (see 6.2).

3.2.4.8.2 Positioning thrust load. The main gear unit positioning thrust bearing(s) shall absorb loads due to weight and coupling forces and moments resulting from maximum transient misalignment, thermal effects, and elastic effects. Simultaneous worst case operating and shock conditions (see 3.1.15) and worst case trim and list (see 3.1.14) shall be considered. Contact stresses and factor of safeties for both babbitt and thrust shoe materials shall be analyzed.

3.2.4.9 Bearing temperature limits. Maximum allowable operating temperature as read by the bearing RTEs installed as specified in 3.2.5 shall be 230°F for all thrust bearings. Alarm settings shall initially be set at maximum limits; however, final alarm settings will be 20°F higher than the maximum value observed during sea trials. The maximum temperature rise of oil, as measured by thermometer or resistance temperature element in bearing drains or sight flow fittings, shall be not greater than 50°F.

3.2.4.10 Rolling out bearings. All bearing parts, excluding thrust collars or thrust surfaces, for each pinion or gear shall be removable without removing the pinion or gear.

3.2.4.11 Measurement of wear of thrust bearings. For class B gear units, the oil clearance or end float of the propulsion thrust bearing of each gear assembly shall be readily measured by using a standard depth gauge or dial indicator.

3.2.4.12 Thrust meter. For class B gear units, the first gear unit of a new design shall include an electronic thrust meter on propulsion thrust bearings provided by the contractor. An electronic thrust meter consists of a complete set of ahead and astern thrust pads or leveling links with strain gage type load cells, housing wall "AN" type connector(s), a terminal box, and associated wiring. When an electronic thrust meter design is provided with a gear unit, a complete set of non-instrumented thrust pads or leveling links shall also be provided by the contractor for replacement of instrumented thrust pads or leveling links after completion of standardization trials. Cover plates, gaskets, fasteners etc. shall be provided to replace "AN" type connector(s) at housing penetration points. It is intended that all thrust meter components be removed from the first gear unit and reused on follow-on gear units. Follow-on gear units shall include identical provisions to the first unit to permit installation of the entire electronic thrust meter system (see 30.2.10 of appendix A).

3.2.5 Bearing temperature sensing elements. An RTE system shall be furnished as specified in 3.2.5.1 through 3.2.5.10 when specified (see 6.2). The RTE system is considered to encompass all aspects of the metal temperature indication system from RTE locations in bearings to terminal box terminal board shipbuilder interface locations (see 30.2.11 of appendix A). RTE system components shall be of the three wire type and, to the maximum extent practical, be repairable without lifting main gear housing covers. For the main pinions and gears, there shall be two RTEs in one shoe or shell of each journal bearing and one RTE in two shoes on each side of the thrust collar(s) for each thrust bearing, unless otherwise specified (see 6.2).

3.2.5.1 Bearing RTE. The RTE (including wire and insulation) shall be physically and electrically qualified to MIL-T-24388 (embedded type). RTE sensing elements shall be either platinum or nickel as specified (see 6.2) and element wire leads shall not be provided with shielding (e.g., stainless steel braid) and wire insulation shall bond with epoxy to form a hermetic seal.

3.2.5.2 RTE installation. (See 30.2.11 of appendix A.) Each RTE shall be either fusion bonded to surrounding bearing babbitt (see figure 8) or installed from the backside of the bearing (see figure 9). For backside type RTE installations, the hole depth and proper seating of the RTE shall be controlled (see figure 9).

3.2.5.2.1 RTE installation in journal bearings. The RTEs in each journal bearing shall be axially in line at the calculated ahead maximum steady state operating condition (see 3.1.4) hot spot. The hot spot for pivoted-shoe type journal bearings is close to the trailing edge (when operating in the ahead direction) of the hottest loaded journal pad.

3.2.5.2.2 RTE installation in thrust bearings. The RTEs in each thrust bearing shall be close to the trailing edge (when operating in the ahead direction) and outer diameter of the instrumented shoes at the calculated ahead maximum steady state operating condition (see 3.1.4) hot spot. Two shoes on each side of the thrust collar closest to the housing joint shall each be fitted with an RTE to facilitate disassembly when shoes are removed for inspection and replacement.

3.2.5.3 RTE lead wire routing and connection blocks. All RTE lead wire holes, slots and grooves shall be free of sharp edges and of sufficient size and depth to prevent damage to wires. Connection blocks shall be in accordance with figure 10. Connection blocks shall be located close to the bearing housing part line to facilitate disassembly, and recessed deep enough to ensure that the solder connections will not contact the housing bore or cover plate. The wires attached to the RTE shall be routed to the side of the connection block terminal furthest from the housing joint. Unless otherwise specified herein, an air hardening epoxy-resin (see 3.1.11.4) shall be applied in grooves and holes to protect the RTE lead wires and shall stop short of the connection block by approximately 0.5 inch. Wire splicing between the RTE and connection block is not permitted. Wiring instructions shall be as specified on figure 11.

3.2.5.3.1 Sleeve type journal bearing RTE lead wire routing and connection blocks. The three wires attached to the RTE shall be brought out through a radially drilled hole and channeled into a groove leading to the connection block. The connection block shall be recessed in the shell outer periphery and protected by bearing bore or cover plate.

3.2.5.3.2 Pivoted-shoe type journal bearing RTE lead wire routing and connection blocks. The three wires attached to the RTE shall be brought out of the shoe through a radially drilled hole and led to a radially drilled hole or slot in the bearing aligning ring. After exiting the aligning ring, the RTE lead wires shall be channeled into a groove leading to the connection block. The connection block shall be recessed in the aligning ring outer periphery and protected by bearing bore or cover plate. The lead wire between the back of the bearing pad and outer diameter of aligning ring need not be potted (to accommodate shoe movement); but shall be arranged such that it will not be pinched, rubbed or pulled during assembly or operation. To alleviate wire strain where the wires exit/enter epoxied grooves, the unpotted wires shall be sleeved with heat skrinkable insulation of 0.020 inch minimum thickness. For bearings without an aligning ring, the connection block shall be placed on the back of the bearing shoe. The connection block shall be accessible without bearing disassembly. For a shoe mounted connection block arrangement, the three wires attached to the RTE shall be brought to the shoe outer periphery through a radially drilled hole and channeled into a groove on the back of the shoe to the connection block.

3.2.5.3.3 Thrust bearing RTE lead wire routing and connection blocks. Wire routing and connection block arrangement shall be as specified on figure 12.

3.2.5.4 Wiring between connection block and housing wall "AN" connector. Wiring shall be sheathed in a braided stainless steel flexible cover with a teflon outer jacket which protects the three teflon insulated wires. Wiring shall be recessed in grooves, in holes and/or in pipe conduit in a manner that provides support and prevents chafing of the wire insulation due to vibration. Internal wire in bearing grooves and pipe conduit shall remain unpotted. Internal wire in exposed housing grooves shall be potted with an air hardening epoxy-resin (see 3.1.11.4); while internal wire in covered (e.g., secured by bearing cap) housing grooves shall be potted in nonoil soluble silicone rubber (RTV) (see 3.1.11.4). All internal wire holes, slots, grooves and conduit shall be free of sharp edges and of sufficient size and depth to prevent damage to wires. Provision shall be made, at the connection block and "AN" type connector, for storage of excess wire sufficient to accommodate two field repairs in the event that the wires are damaged or have to be clipped during disassembly. Wire splicing between the connection block and "AN" type connector is not permitted. Wiring instructions shall be as specified on figures 11 and 13. The minimum insulation wall thickness for heat shrink tubing shall be 0.020 inch.

3.2.5.5 Housing wall "AN" type connector. The design shall provide "AN" type connectors in the housing wall to connect internal wiring with external wiring. "AN" type connectors shall conform to class H of MIL-C-5015 (hermetically sealed). Location or protection of "AN" type connectors shall minimize possibility of damage to the connectors and cables attaching thereto. Location of "AN" type connectors shall permit external accessibility for connection/disconnection of external wiring. The interface between the connector and housing wall shall be oil tight.

3.2.5.6 External RTE wiring. From the housing wall "AN" type connector, RTE wiring shall be routed to a terminal box or boxes. The external wiring shall be consolidated, protected and firmly supported; and utilize rigid or flexible liquidtight steel conduit. Protection shall be suitable for an industrial environment. The flexible liquidtight conduit outer jacket shall be zero halogen or low halogen producing. Wire markers at both ends of the external RTE wiring shall be provided to ensure that cables will be accurately connected. External RTE wiring shall be 20 AWG or larger. The wires shall be connected to the "AN" type connectors and terminal box terminal boards.

3.2.5.7 Terminal box. Terminal box(es), with internally mounted terminal boards, shall be provided. The terminal box(es) shall be arranged or protected to minimize the possibility of damage. Terminal boards shall be in accordance with MIL-T-55164. All RTEs shall be routed to the terminal boards. Associated equipment instrumentation and control electrical wiring shall also be routed to the terminal boards.

3.2.5.8 Electrical bearing temperature monitor. Electrical bearing temperature monitors will be provided by the shipbuilder.

3.2.5.9 Warning plate. Warning plates (see 3.1.7) shall be permanently affixed to the external housing covers or external bearing caps stating that the RTE wires to the bearings must be disconnected before rolling out the bearing.

3.2.5.10 Wiring checks. Electrical continuity checks and resistance checks shall be performed as specified in 4.12.

3.2.6 Lubrication. Unless otherwise specified (see 6.2), the gear unit will be pressure lubricated by a shipbuilder supplied lubricating oil system. The shipbuilder will supply fasteners and gaskets at lubricating oil system to gear unit interface locations. The gear unit shall have provisions for oil supply lines, drain lines, instrumentation connections and control connections (see 30.2.12 of appendix A). Early in design, the contractor shall determine oil flow rate, pressures and heat rejection rate at 60, 90, 120, and 130°F (see 3.2.6.1.1) oil inlet temperature for all components including bearings, mesh oil nozzles, couplings, clutches, attached oil pump and components requiring control oil (see 30.8 of appendix B). Oil supply pressure at shipbuilder to contractor interfaces shall be as specified (see 6.2). Oil flow rate, temperature, and pressure shall be adequate for lubrication and cooling of all components under all design operating conditions (see 3.1.4) and ship attitudes (see 3.1.14). Accessory drive lubrication shall be as specified in 3.2.7. Motor lubrication shall be in accordance with the applicable motor specification. Components shall be designed, to the maximum extent practicable, to facilitate cleaning. Piping sections shall be arranged to the maximum extent practicable to permit removal and cleaning without requiring disassembly of the gear unit or associated equipment.

3.2.6.1 System characteristics.

3.2.6.1.1 Oil inlet temperature. Under emergency conditions, gear units shall be capable of operation with 60°F lubricating oil at the unit inlet. For all other design operating conditions (see 3.1.4) gear units shall operate satisfactorily with 90 to 130°F oil at the unit inlet. The normal oil inlet operating temperature will be approximately 120°F and will not exceed 130°F.

3.2.6.1.2 Oil flow rate. The oil flow rate as determined by the contractor (see 3.2.6) shall be met during contractor performance acceptance testing (see 4.14.1). Orifice sizes shall be adjusted, if required, to ensure the design oil flow rate is met (see 3.2.6.2.4).

3.2.6.1.3 Oil filtration. Unless otherwise specified (see 6.2), lubricating oil supplied to the main reduction gear will be subject to 25 micrometer absolute filtration. Oil filtration is the responsibility of the shipbuilder.

3.2.6.2 Contractor lubrication provisions. Oil supplied to each component (e.g., bearings, mesh oil nozzles, couplings) shall not be used to lubricate or cool any other component (other than the attached oil pump rotating elements). Used oil shall drain back to the sump. The gear unit shall include provisions for oil drainage from all areas within the gear housing. Contractor lubrication requirements shall be as specified in 3.2.6.2.1 through 3.2.6.2.7.1.2.

3.2.6.2.1 Attached oil pumps. When specified (see 6.2), the gear unit shall incorporate an attached oil pump driven by an accessory drive (see 3.2.7). Attached oil pumps shall be of the rotary, positive displacement type, in accordance with type II, III, IV, or VI of MIL-P-18547. The attached pump shall be mounted on the gear housing. When the lubricating oil system is provided by the shipbuilder, the contractor shall work with the shipbuilder to establish the attached oil pump location and interface requirements. The shipbuilder supplied lubricating oil system will include provisions for lubrication of the attached pump during astern operation.

3.2.6.2.1.1 Pump rating. Pumps shall be designed to include a 40 percent (+0, -5 percent) excess flow capacity over system demand at the maximum steady state ahead operating condition (see 3.1.4). This oil flow rate, as established by the contractor (see 3.2.6), shall be met during contractor performance acceptance testing (see 4.14.1.2.1(e)). Rated pump discharge pressure shall be as specified (see 6.2). Suction velocity in oil suction lines from sump tanks to oil pumps shall be not greater than 4 feet per second. The attached oil pump shall supply other systems not provided by the contractor (e.g., prime movers) when and as specified (see 6.2).

3.2.6.2.1.2 Attached pump drive train quick disconnect. Means shall be provided for a rapid and complete disconnect of the attached oil pump and drive train. The disconnect shall be located just prior to the connection to the main pinion or gear, and shall be designed to permit operation of the gear unit immediately following completion of the disconnect. Provisions shall be included to ensure broken or loose parts associated with the disconnect can not damage any other component and can be removed without requiring disassembly of the gear unit or associated equipment to the maximum extent practicable. The disconnect shall be accomplished by one of the following methods:

(a) Provision of a weak link in the attached pump drive assembly which, upon failure, disconnects the drive train from the main pinion or gear. Access to the weak link shall be provided through a bolted on cover (see 3.2.2.2.2).
(b) Disassembly and removal of a drive train part. Access for removal of the drive train part shall be provided through a hinged and padlocked cover (see 3.2.2.2.1). The time required to disassemble and remove the part shall be not greater than 15 minutes.
(c) Provision of a disconnect mechanism. Access to the disconnect mechanism shall be provided through a hinged and padlocked cover (see 3.2.2.2.1). The time required to complete the disconnection shall be not greater than 15 minutes.

3.2.6.2.2 Piping. Unless otherwise specified (see 6.2), piping, fittings, and associated piping components shall be as specified in 3.2.6.2.2.1 or 3.2.6.2.2.2.

3.2.6.2.2.1 Class A gear piping. Piping, fittings, and associated piping components for class A gears shall be in accordance with MIL-STD-438 except as modified by this specification. For lubrication service at a rated gauge pressure of 150 lb/in^2 and rated temperature of 200°F, fillet reinforced, single bevel welded slip-on flanges of carbon steel (ASTM A 105) in accordance with ASME B 16.5, class 150, are acceptable. The use of double fillet welded slip-on flanges is prohibited. The carbon content of welded steel valves, pipe fittings and pipe flanges shall be not greater than 0.35 percent. Gaskets shall be as specified in table II.

3.2.6.2.2.2 Class B gear piping. Piping, fittings, and associated piping components for class B gears shall be in accordance with MIL-STD-777 except as modified by this specification. Groups applicable to hydraulic systems in category G of MIL-STD-777 are acceptable for lubrication purposes provided the rated temperature and pressure are consistent with the application. For lubrication service at a rated gauge pressure of 150 lb/in^2 and a rated temperature of 200°F, fillet reinforced, single bevel welded slip-on flanges of carbon steel (ASTM A 105) in accordance with ASME B 16.5, class 150 are acceptable. The use of double fillet welded slip-on flanges is prohibited. The carbon content of welded steel valves, pipe fittings and pipe flanges shall not exceed 0.35 percent. Gaskets shall be as specified in table II.

3.2.6.2.2.3 Gauge piping. When specified (see 6.2), a connection for sensing pressure of the hydraulically most remote bearing shall be provided. Gauge piping shall be in accordance with Drawing 803-1385850.

3.2.6.2.3 Pressure gauges. When specified (see 6.2), pressure gauges shall be provided by the contractor as specified in table II.

3.2.6.2.4 Flow-limiting orifices. Orifices shall be provided in the gear unit lubricating oil system (e.g., inlet or discharge to bearings, sight-flow indicators, etc.). Orifices shall be designed to permit adjustment of oil flow to ensure design oil flow rate is met. Orifice openings shall not have sharp edges and orifice diameter shall be not less than 3/32 inch.

3.2.6.2.5 Mesh oil nozzles. Mesh oil nozzles shall be mounted on the gear housing or gear housing covers so that they are accessible for inspection, cleaning, and removal without lifting gear housing covers. For each gear mesh, the oil spray pattern and trajectory from the nozzles shall provide sufficient lubrication and cooling at all design operating conditions (see 3.1.4).

3.2.6.2.6 Oil seals and oil deflectors. Oil seals and oil deflectors shall be provided where shafts penetrate the gear housing. The seal design shall permit installation and removal without requiring disassembly of the gear unit or associated equipment to the maximum extent practicable. Unless otherwise specified (see 6.2), zero leakage is required at shaft penetrations for all ship attitudes (see 3.1.14).

3.2.6.2.7 Sight-flow. Each sliding surface journal bearing, positioning thrust bearing and class B gear unit propulsion thrust bearing (when provided) shall be fitted with a sight-flow. Sight-flows shall provide visual indication of oil discharge from the bearing at all design operating conditions (see 3.1.4). Under maximum steady state conditions, oil passing through the sight-flows shall be discharged from the loaded area of the bearing when practicable. Sight-flow fittings and windows shall be as specified in table II. Full flow sight-flows are permitted in the drain line of thrust bearings.

3.2.6.2.7.1 Sight-flow temperature indicator. As specified (see 6.2), the contractor shall provide thermometers or RTEs to measure the temperature of the oil passing through sight-flow fittings.

3.2.6.2.7.1.1 Sight-flow thermometers. Thermometers, when provided, shall be as specified in table II. The contractor shall work with the shipbuilder to assure thermometers are located such that they can be read from nearby engineroom deck passages and are readily accessible for maintenance.

3.2.6.2.7.1.2 Sight-flow RTEs. RTEs, when provided, shall be physically and electrically qualified to MIL-T-24388 (thermowell type). RTE sensing elements shall be either nickel or platinum, as specified (see 6.2). RTE system components shall be of the three wire type. RTE lead wire connection shall be in accordance with MIL-C-5015. External RTE wiring, terminal box(es), electrical bearing temperature monitor, and wiring checks shall be as specified in 3.2.5.6, 3.2.5.7, 3.2.5.8, and 3.2.5.10, respectively.

3.2.7 Accessory drives. Accessory drives (drives for oil pump, turning gear, tachometer generator, and so forth) shall be designed, constructed, and rated as specified (see 6.2). Bevel gears shall not be used in accessory drives.

3.2.8 Turning (jacking) gear assembly. A turning gear assembly including motor, auxiliary gear drive, engagement/disengagement device, propulsion shaft locking device, splined drive coupling, and limit switches shall be provided by the contractor. The turning gear motor controller shall be provided by the contractor when specified (see 6.2). Cabling from turning gear motor controller to turning gear motor and to limit switches will be provided by the shipbuilder. Turning gear assembly requirements shall be as specified in appendix G unless otherwise specified (see 6.2).

3.2.9 Clutches. When and as specified (see 6.2), clutches, as specified in table II, shall be provided between the prime mover(s) and gear unit. The design of the clutch housing and gear housing shall, to the maximum extent practicable, ensure that broken or loose clutch parts are readily removable and can not cause damage to the gear unit or associated equipment. The arrangement shall permit installation and removal of the clutch without requiring disassembly of the gear unit or associated equipment, to the maximum extent practicable. Clutches shall be mounted on the ends of shafts, where practicable. Unless otherwise specified (see 6.2), clutch design shall incorporate a remote control lockout device. Clutches for accessory drives shall be as specified in 3.2.7.

3.2.10 Brakes. When and as specified (see 6.2), brakes shall be provided in gear arrangements to stop rotation of a turbine rotor and/or propulsion shaft. Brake application and duty cycle shall be as specified (see 6.2).

3.2.11 Dehumidification and vent system. A dehumidification and vent system including dehumidifier, associated piping, vent fog precipitators, valves and flame arrestors shall be provided by the contractor. Dehumidification and vent system requirements shall be as specified (see 6.2).

3.2.12 Tachometer systems. When provided, tachometer systems shall be in accordance with type IC/EFB, IC/EFC, or IC/EFD of MIL-T-16049. Main pinion or gear teeth shall not be used for speed sensing.

3.2.13 Revolution indicating transmitter. When and as specified (see 6.2), each class B gear unit shall contain provisions for mounting a revolution indicating transmitter driven at exactly two times the propulsion shaft r/min. When required, the coupling between the gear unit output drive shaft, the transmitter input shaft, and mounting bracket shall be furnished by the contractor. Transmitter will be furnished by the shipbuilder.

3.2.13.1 Location of transmitter. The transmitter shall be mounted so that it is accessible for maintenance and for reading total revolutions.

3.2.13.2 Transmitter drive train. The transmitter drive gear train shall be arranged so that it is not affected by normal displacements of main pinions and gears and so that parts, if broken from the transmitter drive train, can not enter the main gear housing. The drive train shall be as specified in 3.2.7.

3.2.14 Fasteners.

3.2.14.1 Threaded fasteners. Threaded fasteners for gear units and associated equipment shall be as specified in 3.1.11 and 3.2.14.1.1 through 3.2.14.1.10.2 of this specification and in accordance with FED-STD-H28 except that associated motors, controllers, and electrical equipment shall be in accordance with MIL-E-917 and applicable component specifications.

3.2.14.1.1 Types of fasteners. Wherever practicable, threaded fasteners shall be through-bolts or two-nut type through-studs. Through-bolting shall be employed for all rotating parts in the torque transmission path. Where through-bolting of rotating parts in the torque transmission path is not possible, the fastener design shall be submitted to the contracting activity for approval. For non-torque path applications where it is impracticable to use through-bolts or two-nut type through-studs, the use of one-nut bottoming studs, shoulder studs, or tap bolts is acceptable. Tap bolts shall not be used on housing joints.

3.2.14.1.2 Class of fit. Class 2A-2B fits shall be employed for all gear unit and associated equipment fastener applications except that class 3A-3B fits are permitted where the necessity for accuracy of lead and angle of thread can be justified, where the applicable fastener specification requires a class 3A-3B fit, or as otherwise specified herein. Class 1A-1B and class 5 interference fit threads shall not be used on the gear unit or associated equipment.

3.2.14.1.3 Unified thread series. Screw threads shall be of the unified thread series.

3.2.14.1.3.1 Course versus fine thread series. The course thread series shall be used unless the component design indicates a necessity for the use of the fine thread series.

3.2.14.1.3.2 Eight-thread series. Where practicable, the eight-thread series shall be used for fasteners 1 inch in diameter and larger.

3.2.14.1.3.3 Extra-fine thread series. Where the component design requires thread pitches finer than 16 threads per inch, the number of threads per inch shall be 18, 20, 28, 36, 44, or 56.

3.2.14.1.4 Thread engagement. The minimum acceptable thread engagement for the setting end of a stud or tap-bolt shall be the larger of the following values:

(a) The length of thread engagement that will develop maximum strength of the assembly as calculated by formulas in FED-STD-H28.
(b) One nominal diameter.

3.2.14.1.5 Thread protrusion. Threads on externally threaded fasteners, when nuts are installed and tightened, shall protrude the distance of at least one thread beyond the nut or plastic locking element. Excessive protrusion shall be avoided particularly where necessary clearances, accessibility, and safety are important. Where practicable, the number of threads protruding shall not exceed five. In no case shall thread protrusion be greater than 10 threads. Washers shall not be used for the sole purpose of lessening thread protrusion.

3.2.14.1.6 Internal fasteners and fasteners on rotating parts. Use of threaded fasteners inside the gear housing shall be avoided where practicable. Threaded fasteners used inside the gear housing and threaded fasteners used on rotating parts shall be of the self-locking type or secured such that they can not enter into a gear mesh (see 3.2.14.1.7.1, 6.3 and 30.9 of appendix B). The use of locking wire to secure internal fasteners and fasteners used on rotating parts is prohibited. Where internal fasteners must be removed prior to separating housing halves or housing covers, a warning plate so stating shall be permanently attached on the housing or housing covers (see 3.1.7.2).

3.2.14.1.7 Securing of fasteners.

3.2.14.1.7.1 Self-locking threaded fasteners. (See 30.1.4.6 of appendix A and 30.10 of appendix B and 6.3.) Self-locking bolts, studs, and nuts shall be in accordance with the applicable documents listed in table II. The use of locked-in studs as specified in table II constitutes an acceptable self-locking feature. One-nut bottoming and shoulder studs, when installed as specified in 3.2.14.1.7.2, are considered to be locked provided the nut is of the self-locking type. Self-locking threaded fasteners shall have a torque capability greater than or equal to the minimum breakaway or rotational resistance torque specified in the applicable table II documents. Threaded inserts shall be as specified in table II and shall be secured in place to prevent rotation and backing out. Except as specified herein, the use of anaerobic locking compounds does not qualify as a self-locking feature.

3.2.14.1.7.2 Threaded fasteners without self-locking feature. Bolts, studs, and nuts without a self-locking feature shall be installed using an appropriate installation torque (see 3.2.14.1.8). Shoulder studs and bottoming studs shall employ a class 3A-3B fit and shall be installed with a retaining anaerobic locking compound applied to the set end of the stud and its mating hole (see 6.3, 30.1.4.6 of appendix A, and 30.10 of appendix B).

3.2.14.1.8 Fastener torque. Installation torque limits and the necessity for the use of thread lubricant shall be determined by the contractor (see 30.1.4.6 of appendix A) for all threaded fasteners. Thread lubricants shall be as specified (see 6.2). The lower limit of installation torque shall be sufficient to prevent joint separation under all design operating conditions (see 3.1.4), ship attitudes (see 3.1.14) and, when required, shock conditions (see 3.1.15). Preloaded through-bolts shall be tightened by torquing the nut and not the bolt. Where not otherwise specified in applicable fastener specifications, the following requirements shall be met:

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

3.2.14.1.9 Fitted (body-bound) fasteners. Fasteners stressed in shear or used for positioning or shaft flange centering shall be fitted. The holes for fitted fasteners shall be reamed with the coupled parts in position in order to assure a tight fit. The mating surfaces of the fastener and hole shall have a surface finish of 63 Ra or smoother. The tolerances shown in table III shall apply to fitted fasteners.

TABLE III. Tolerances for fitted fasteners.

Nominal fastener size (inches)			Tolerances (inches)		
Over		To	Maximum clearance-body of fastener and hole (plus)	Diameter of hole (plus)	Body of fastener (minus)
0	-	0.12	0.0010	0.0006	0.0004
0.12	-	0.24	0.0012	0.0007	0.0005
0.24	-	0.40	0.0015	0.0009	0.0006
0.40	-	0.71	0.0017	0.0010	0.0007
0.71	-	1.19	0.0020	0.0012	0.0008
1.19	-	1.97	0.0026	0.0016	0.0010
1.97	-	3.15	0.0030	0.0018	0.0012
3.15	-	4.73	0.0036	0.0022	0.0014
4.73	-	7.09	0.0041	0.0025	0.0016

3.2.14.1.10 Fasteners securing aluminum or aluminum alloy parts.

3.2.14.1.10.1 Corrosion protection. In order to prevent deterioration due to corrosion, materials for fasteners used to secure aluminum or aluminum alloy parts shall be as specified in 3.1.11.2 and 3.1.11.3.

3.2.14.1.10.2 Fastener installation. Wherever practicable, through-bolts or two-nut type through-studs shall be used for the assembly of aluminum or aluminum alloy parts. Where the use of through-bolts or two-nut type through-studs is not possible, fasteners shall be threaded into corrosion resistant steel inserts cast or screwed into the aluminum or aluminum alloy part. Corrosion resistant steel inserts shall be in accordance with table II and shall be locked in place to prevent their backing out. Steel washers shall be fitted on the load bearing surface of nuts and bolt heads adjoining aluminum or aluminum alloy parts.

3.2.14.2 Unthreaded fasteners. Tapered pins and dowels shall be secured from backing out by staking or other locking device; welding is permitted where the dowel or pin becomes a permanent part of the assembly. Tapered pins and dowels shall be provided with means for removal such as tapped holes, external wrenching or pulling heads, or shouldered shanks.

3.2.15 Alignment.

3.2.15.1 Alignment and gear unit assembly. The contractor shall determine assembly requirements which detail the gear unit erection sequence, internal alignment requirements and associated limits including field tolerances for establishing main reduction gear internal alignment (see 30.2.13 of appendix A and 30.6 of appendix B).

3.2.15.2 Alignment criteria. Criteria including field tolerances for vertical, horizontal and axial alignment between the gear unit and the propulsion shaft and the gear unit and prime mover(s) shall be mutually determined by the contractor and the shipbuilder (see 30.2.13 of appendix A). Unless otherwise specified (see 6.2), the contractor shall perform the necessary design studies and determine detailed alignment criteria including field tolerances applicable to installation of the gear unit in specific ships. Requirements for alignment between the gear unit and other components (e.g., auxiliary gear drive) shall be as specified (see 6.2).

3.2.15.3 Line shaft to low speed gear alignment. The allowable class B gear unit low speed gear bearing load differential (horizontal and vertical) shall be mutually determined by the contractor and the shipbuilder (see 30.2.13 of appendix A). Class B gear units shall incorporate means for readily measuring the static reactions at the journals of the low speed gear by use of a hydraulic jack and calibrated load cell (see 3.2.2.1). Locations shall be mutually determined by the contractor and shipbuilder. Provisions for measurement of horizontal reactions are required if the low speed gear has a horizontal offset alignment at the lineshaft coupling flange. The shipbuilder will verify alignment by the bearing reaction method with the ship afloat.

3.2.16 Tooth hone check. The contractor shall provide hones for checking all main gears and pinions. Hones shall be in accordance with NAVSEA 342-0138.

3.2.17 Special tools. A complete set of special tools (i.e., non-standard tools; not readily available in a shipyard) required for operation, disassembly, maintenance, replacement of parts, lifting and handling operations, and alignment shall be furnished by the contractor. A set of special tools for removing journal bearings shall consist of the necessary jacks or other devices for lifting and supporting pinions and gears from their journal bearings to facilitate removal of the bearings (see 3.2.2.1). This set shall be sufficient to permit having all bearings removed from each gear unit at the same time (see 6.6).

3.3 Equipment variations. Equipment which does not conform to contractual requirements shall be handled in accordance with the provisions of the contract (see 6.7). Other variations, which result in conforming equipment but constitute deviations from the approved configuration, materials or processes, shall be handled in accordance with the procedures set forth hereinafter (see 6.3 and appendix A, and 30.2.14 of appendix A). Specific examples of these are as follows:

(a) Manufacturing errors which necessitate special repair procedures or use of non-standard repair parts.
(b) An improperly applied process procedure or a substitute process which does not adversely affect the end use of the part or assembly involved.
(c) Use of materials with chemical or mechanical properties outside of specification limits where factor of safeties are met and welding properties are not adversely affected.

3.3.1 Disposition of equipment variations. Variations which affect installation, operation, performance, maintainability, stock repair parts (onboard and ashore) or interchangeability of repairable and/or replaceable parts require approval by the contracting activity.

3.3.2 Conditions for acceptance of parts having variations. Variations will be approved when all conditions listed are satisfied:

(a) Effect of the variation either as-is or with the part modified is technically acceptable to the contracting activity.
(b) Nature of the part involved is such that replacement is not economically justified.
(c) Verification that resultant special parts will be furnished.
(d) All variations are identified on the machinery variation summation drawing when required by the contract or order (see 30.2.14 of appendix A).
(e) Verification that repair parts will be furnished if the variation affects interchangeability (see 6.3 and 6.6).

3.4 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 as defined by the contractor (see 3.2.14.1.8).

3.5 Nonsignificant and noncritical deviations. Machining errors and equipment variations which are not covered in 3.3 (such as nonsignificant and noncritical deviations from drawing dimensions or tolerances for castings, forgings, weldments, connections, or machine-processed parts) do not require approval by either the contracting activity or Government inspector; however, each such deviation shall be documented. If the Government inspector considers that the deviation involves contractual requirements or meets criteria in 3.3, the contracting activity and the contractor shall be notified.

4. QUALITY ASSURANCE PROVISIONS

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

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

4.2 Quality. All contractor and subcontractor gear unit and associated equipment shall be subjected to quality program requirements when and as specified in the contract or purchase order (see 6.3 and appendices A, B, and C, and 30.11 of appendix B).

4.3 Classification of inspections. Inspection requirements of associated equipment shall be in accordance with the appropriate specification listed in table II. The inspection requirements specified herein are classified as follows:

(a) First article inspection (see 4.4).
(b) Quality conformance inspection (see 4.5).

4.4 First article inspection. First article inspection shall consist of the examinations and tests as specified in table IV. First article inspection is required for the first unit of a new gear design (see 6.4).

4.5 Quality conformance inspection. Quality conformance inspection shall consist of the examinations and tests as specified in table IV. Quality conformance inspection is required for all follow-on units of a gear design.

TABLE IV. First article and quality conformance inspections.

Examination or test	Requirement	Test method	First article	Quality conformance
Nondestructive testing (NDT) of metals	-	4.6	X	X
Inspection of fabrications, forgings, and castings	-	4.7	X	X
Material inspection	3.1.11.5	4.9	X	X
Fabricated gear qualification test assembly	3.2.1.1.1	4.9.1	X	
Tensile test of heat treated material	3.2.1.1.1	4.9.2	X	X
Tooth hardness inspection:				
Through-hardened	3.2.1.1.2.7	4.10.1.1	X	X
Carburized		4.10.1.2	X	X
Nitrided		4.10.1.3	X	X
Inspection of shot peening coverage	3.2.1.1.2.8	4.10.2	X	X
Accuracy inspection on main pinions and gears	3.2.1.1.6	4.10.3	X	X
Shaft flange face, thrust collar and spigot/rabbet runout	3.2.1.2.5	4.10.4	X	X
Residual magnetism inspection	-	4.10.5	X	X
Bond testing of bearings and seals	3.2.3.3 3.2.4.4	4.11	X	X
RTE wiring inspection	3.2.5.10	4.12	X	X

TABLE IV. First article and quality conformance inspections - Continued.

Examination or test	Requirement	Test method	First article	Quality conformance
Static tooth contact inspection	-	4.13.1	X	X
Performance tests:	-			
Spin		4.14.1.1	X	X
Load		4.14.1.2	X	X
Noise		4.14.1.3	X	X
Quick disconnect		4.14.1.4	X	X
Shock		4.14.1.5	X	

4.6 Nondestructive testing of metals. Methods for the nondestructive testing of metals shall be accomplished in accordance with MIL-STD-271.

4.7 Inspection of fabrications, forgings, castings and piping. Inspection of fabrications, forgings, castings and welded pipe system joints shall be accomplished in accordance with MIL-STD-278 and applicable material specifications unless otherwise specified (see 6.2). Requirements for the inspection of brazed piping joints shall be as determined by the contractor.

4.8 Surface texture. Surface texture (i.e., surface roughness, waviness, and lay) shall be in accordance with ASME B 46.1.

4.9 Material inspection. Inspection of materials for parts and associated equipment not specified in tables I and II shall be to the contractor's specification or standard. Where an unspecified material has been approved, inspection requirements of the unspecified material specification shall apply.

4.9.1 Fabricated gear qualification test assembly. When specified (see 6.2), the contractor shall determine the effects of the complete manufacturing cycle on the weld metal and base material properties for fabricated gear assemblies for each new design and for any changes (e.g., change of materials, heat treatment, welding methods, etc.) made to an existing design. The contractor shall perform a final qualification of the composite assembly weld which represents the materials and full heat treatments to be employed. Conformance to acceptance criteria for mechanical properties after all heat treatments (including nitriding, carburizing, or through-hardening) shall be demonstrated (see 30.12 of appendix B).

4.9.2 Heat treated material properties. For all parts made of material whose mechanical properties can be altered by heat treatment and for castings where weld repair and subsequent stress relief is performed, sample material from each lot of material shall be subjected to tensile test in the final heat-treated condition for the part. As a minimum, the tensile tests shall determine ultimate strength, yield strength, percent reduction in area and percent elongation. Tensile test samples shall have been subjected to the same heat treatment as the part made from the material. Acceptance criteria for the mechanical properties shall be in accordance with the material specification where specified therein or as approved by the contracting activity. For fabricated gear shaft and rim materials whose mechanical properties can be altered by heat treatment, the test samples shall be of equivalent thickness and accompany each gear assembly through all stress relief and either nitriding, carburizing, or through-hardening heat treatment cycles.

4.10 Main rotating parts.

4.10.1 Tooth hardness inspection.

4.10.1.1 Tooth hardness inspection on through-hardened pinions and gears. Tooth hardness inspection on through-hardened pinions and gears shall be accomplished in accordance with MIL-S-19434 except that hardness inspections on pinions may be taken at four points on the end face of the base end of each helix, approximately 90 degrees apart and slightly below the root diameter of the teeth. Checks on pinions and gears shall be accomplished after final heat treatment.

4.10.1.2 Tooth hardness inspection on carburized pinions and gears.

4.10.1.2.1 Test coupon. The contractor shall prepare test coupons selected to be representative of the actual pinions and gears (see 30.2.5 of appendix A). To ensure that test coupons are representative of the actual pinions and gears, each coupon material shall be from the same heat and shaped to be representative of the geometry of the teeth of the actual pinion or gear (e.g., same diametral pitch as part being carburized). Test coupon material shall accompany their respective pinion or gear through all heat treatments, tempers, and subcooling. Test coupons for each pinion or gear shall be used as follows (see appendix C and 30.13 of appendix B):

(a) Surface hardnesses, core hardnesses, and full profile microhardness surveys to the core shall be taken from these coupons and used to verify that test results meet contractor acceptance criteria and conform with the following:

(1) The minimum acceptable case depth (t) at the pitch diameter, as measured to the 50 Rockwell C point after compensation for maximum grinding stock removal, shall be a function of normal diametral pitch (P_N) as follows:

P_N	t (inches)
2	0.070 to 0.125
3	0.050 to 0.080
4	0.040 to 0.060
5	0.035 to 0.050

(2) Minimum core hardness shall be 280 Brinell.

(b) A maximum of 20 percent retained austenite, evenly dispersed throughout the structure, is permissible when examined by microscope or X-ray diffraction inspection.

(c) The case, under metallographic examination, shall not contain globular carbides or carbides precipitated along grain boundaries (i.e., a continuous or semi-continuous grain boundary network is not permitted).

4.10.1.2.2 Pinion and gear. (See appendix C and 30.13 of appendix B.)

(a) The average hardness as measured after grinding shall be Rockwell C 58 to 62 and in no case shall any single value be less than Rockwell C 55.

Surface hardness checks shall be taken after tooth grinding at the pitch diameter on the tooth flanks of all helices when tooth size permits. A minimum of four hardness readings shall be taken on each helix at locations 90 degrees apart. They shall be taken on the ahead and astern tooth flanks as close to mid-length position as possible. Additional readings shall be made as required at locations of maximum grinding.

If tooth size does not permit measurement on tooth flanks, surface hardness checks shall be taken on the tooth top lands at the ends and mid-length. Measurements shall be taken on each helix at locations 90 degrees apart. The top lands shall be ground to represent the amount of material removed from the tooth flanks. The amount of material removed from tooth flanks and tooth top lands shall be compared.

The hardness shall be measured using a Superficial Rockwell or Vickers Hardness Tester with measured values converted to the equivalent Rockwell C value. Acceptable Superficial Rockwell Hardness Test scales are Rockwell 15-N, 30-N, and 45-N. Conversion shall be in accordance with ASTM E 140.

(b) The same teeth specified in (a) above shall be subjected to grinding burn inspection in accordance with AGMA 230.01. The maximum amount of tempering shall be in accordance with AGMA 230.01, class B, "Light Tempering", with no reduction in hardness.

4.10.1.3 Tooth hardness inspection on nitrided pinions and gears.

4.10.1.3.1 Test coupon. The contractor shall prepare test coupons selected to be representative of the actual pinions and gears (see 30.2.5 of appendix A). To ensure that test coupons are representative of the actual pinions and gears, each coupon shall be from the same heat of material. Test coupons shall accompany their respective pinion or gear through all heat treatments, including nitriding. Test coupons for each pinion or gear shall be used as follows (see appendix C and 30.13 of appendix B):

(a) Surface hardnesses, core hardnesses, and full profile microhardness surveys to the core shall be taken from these coupons and used to verify that contractor acceptance criteria and requirements of this specification have been met. The required minimum surface hardness and minimum case depth to Rockwell C 40 after compensation for maximum grinding stock removal (of the part at the gear tooth pitch diameter) shall be established by the contractor. If case depth measured to Rockwell C 40 runs into the core, the contractor, as an alternative, shall measure case depth to 110 percent of core hardness. Minimum core hardness shall be 302 Brinell.

(b) Tests shall be performed on coupons to identify white layer thickness. A maximum thickness of 0.0008 inch is allowed on tooth flanks.

4.10.1.3.2 Pinion and gear. (See appendix C and 30.13 of appendix B.) The minimum hardness as measured after grinding shall be established by the contractor. Hardness readings shall be taken on each helix at locations 90 degrees apart. They shall be taken on the tooth top lands at the ends and mid-length or on the end face of the rim and on the tooth top land at the mid-helix position. The top lands and end face of the rim shall be ground to represent the amount of material removed from the tooth flanks. The amount of material removed from tooth flanks, tooth top lands and end face of the rim shall be compared. The hardness shall be measured using a Superficial Rockwell or Vickers Hardness Tester with measured values converted to the equivalent Rockwell C value. Acceptable Superficial Rockwell Hardness Test scales are Rockwell 15-N, 30-N, and 45-N. Conversion shall be in accordance with ASTM E 140.

4.10.2 Shot peening inspection. Complete coverage of the shot peening of tooth root fillets shall be verified by a visual inspection using a ten power magnifying glass and liquid tracer system in accordance with MIL-S-13165, complete visual coverage examination (method b). After gear tooth finish machining operations are complete, the contractor shall verify that all evidence of the shot peening operation has been removed from the active tooth surfaces.

4.10.3 Accuracy inspections on pinions and gears. Unless otherwise specified (see 6.2), accuracy requirements for measurement systems (i.e., measurement system calibration and certification requirements) used to determine the accuracy of main pinions and gears shall be accomplished as specified in appendix E. Unless otherwise specified (see 6.2), error limits and requirements for measurement of main pinions and gears shall be accomplished as specified in appendix E.

4.10.4 Shaft flange face, thrust collar, and spigot/rabbet runout. Flange face, thrust collar, and spigot/rabbet runouts shall be measured for at least one revolution as specified in 3.2.1.2.5.

4.10.5 Residual magnetism inspection on main pinions and gears. The level of residual magnetism remaining in main pinions and gears shall be such that adherence of magnetic particles will not occur; therefore, the maximum acceptable strength level of the magnetic field of a main pinion or gear shall not exceed 0.001 tesla (10 gauss) when measured by meter, such as Magnaflux Corporation, type 105645 Calibrated Field Indicator (or equivalent), with the meter resting on the part being inspected.

4.11 Bond testing of babbitted bearings and end seals. Tests, sampling for tests and acceptance criteria for tests, of babbitt lined journal and thrust bearings, and bearing end seals shall be accomplished in accordance with DOD-STD-2183.

4.12 RTE wiring. RTE wiring continuity inspections using a solid state volt-ohm meter shall be performed to confirm that wiring has been assembled in accordance with the wiring diagrams (see 30.2.11 of appendix A). RTE wiring resistance inspections using a solid state volt-ohm meter shall be performed to confirm the following:

(a) That the RTE resistance is within tolerance for ambient temperature.
(b) That each wire lead resistance to bearing metal is greater than 10 megohms.

4.13 Tooth contact inspections.

4.13.1 Static tooth contact inspection. Design tooth contact patterns of main pinions and gears in their respective casings and bearings shall be verified (see 30.2.5(k) of appendix A and 30.14 of appendix B) prior to factory load test at a minimum of 25 percent ahead maximum steady state torque and a minimum of 50 percent astern torque conditions (see 3.1.4). For these purposes, a static tooth contact inspection shall be accomplished in the gear housing with the main pinions and gears placed in the bearing reaction positions corresponding to the applied torque by the brake method, sling and strap method, or special hydraulic torquing device.

4.13.2 Running tooth contact inspection. Mating teeth shall have a contact pattern in accordance with the appropriate drawings (see 30.2.5(k) of appendix A and appendix C). For the 100 percent ahead maximum steady state torque condition, the contact band shall be at least 75 percent of the working depth (including areas of relief) with 85 percent total contact distributed across 100 percent of the effective face width (including areas of relief) as shown by a wear pattern on layout lacquer. Layout lacquer shall be applied as specified in appendix F.

4.14 Assembled gear unit and associated equipment tests.

4.14.1 Contractor's performance acceptance testing. Gear units and associated equipment shall be tested as specified in 4.14.1.1 through 4.14.1.5 (see appendix C). Emphasis shall be placed upon achieving and maintaining requisite cleanliness in and around the testing area. Particular attention shall be given to providing clean, filtered oil to the units under test within the design range of the tactical lube oil system temperature, pressure and flow (see 3.2.6). During the spin test and load test, lubricating oil shall be as specified in 3.1.11.4.

4.14.1.1 Spin test. Gear units and associated equipment shall be assembled and spin tested, without load applied, by the contractor to verify the general mechanical integrity prior to load tests. Rotating parts and accessories shall be installed to the maximum extent practical. If included in the design, the attached oil pump shall be installed and connected as required to demonstrate capacity and proper operation. Prior to performance of the spin test, the contractor shall ensure that all settings and adjustments are within appropriate limits. Pretest hot oil washing (i.e., unit flushing) shall be complete prior to spin testing to ensure the assembly is clean and free of foreign materials.

4.14.1.1.1 Tests to be performed during spin testing. The following shall be accomplished for the spin test.

(a) Ensure correct mesh spray patterns and flow of oil at the sight-flow assemblies. Check for leakage at flange joints and shaft seals.

(b) Operate turning gear (see appendix G) while engaged in both ahead and astern directions for a length of time to complete at least one revolution of the low speed gear. Additionally, the following turning gear attributes shall be verified:

(1) Engagement/disengagement device operates properly.
(2) Propulsion shaft locking device operates properly.
(3) All limit switches and indicating lights actuate and indicate.
(4) All modes of operation including continuous and breakaway conditions are within design requirements.

(c) The first gear unit shall undergo an extended spin test operating astern continuously for 2 hours at maximum steady state astern speed and no load. Follow-on gear units shall undergo this test for 30 minutes.

(d) The first gear unit shall undergo an extended spin test operating ahead continuously for 2 hours at maximum steady state ahead speed and no load. Follow-on gear units shall undergo this test for 30 minutes.

(e) Following completion of test (d) above, operate ahead continuously at 120 percent of the maximum steady state ahead speed and no load for 30 minutes.

(f) Check vibration of the gear unit during tests (c), (d) and (e) above to verify that vibration levels are below those specified in 3.1.12.1.2.

4.14.1.1.2 Examination following spin test. Upon satisfactory completion of the spin test, the contractor shall verify that all systems have functioned within prescribed limits. The contractor shall also visually inspect external and internal exposed parts of the gear unit and auxiliary equipment via all access and inspection covers for signs of abnormal conditions, wear, tooth contact or tooth damage. If a load test is not to be performed by the contractor, all main bearings (journal and thrust), journal surfaces and thrust surfaces shall be inspected for wear or distress of any kind.

4.14.1.1.3 Cause for rejection. Any unsatisfactory condition on the test specified in 4.14.1.1 shall be considered cause for rejection.

4.14.1.2 Load test.

4.14.1.2.1 Tests to be performed during load testing. Unless otherwise specified (see 6.2), each gear unit and associated equipment shall be tested by the contractor as follows:

(a) Each gear unit shall be operated at 25, 50, 75, and 100 percent maximum steady state torque and the corresponding speed as specified in 3.1.4 in the ahead direction and 100 percent maximum steady state torque and the corresponding speed as specified in 3.1.4 in the astern direction. The contractor shall verify acceptable internal gear alignment as specified in 4.13.2. After each torque test, the contractor shall inspect teeth markings and record results of visual observations. Layout lacquer shall be reapplied after each torque test. Oil temperatures, bearing metal temperatures, flow at sight-flow indicators, and oil pressures shall be recorded. Flange joints and shaft seals shall be checked for leakage. Time at each torque test shall be determined by the contractor to obtain a readable wear pattern. Vibration levels shall be monitored during each torque test. One prime mover operation is required when this is a normal non-emergency operating mode (i.e., both prime movers, one at a time); otherwise two prime mover operation shall be used.

(b) The first gear unit of each design shall be operated for 24 hours at ahead maneuvering for two prime mover operation to verify proper operation, tooth contact (see 4.13.2), bearing operation, and vibration.

(c) The first gear unit of each design shall be operated for 24 hours at ahead maneuvering for one prime mover operation when this operating condition is a normal non-emergency operating mode (i.e., both prime movers, one at a time, each tested for 24 hours) to verify proper operation, tooth contact (see 4.13.2), bearing operation and vibration.

(d) The first gear unit of each design shall be operated for 30 minutes at emergency maneuvering ahead operation to verify proper operation, tooth contact (see 4.13.2), bearing operation and vibration. One prime mover operation is required when this is a normal non-emergency operating mode (i.e., both prime movers, one at a time, each for 30 minutes); otherwise two prime mover operation shall be used.

(e) When provided, the attached oil pump capacity and system demand shall be verified for each gear unit. Measurement of the oil flow out of the pump and into the gear at various power and speed conditions shall be used to establish the speed at which the pump is self sufficient. This test shall be performed with 130°F oil inlet temperature and at design oil pressure.

(f) Follow-on units shall be operated for four hours at ahead maneuvering for two prime mover operation with same requirements as (b) above.

(g) Follow-on units shall be operated for 4 hours at ahead maneuvering for one prime mover operation with same requirements as (c) above.

(h) Follow-on units shall be operated for 5 minutes at emergency maneuvering ahead operation with same requirements as (d) above.

attached oil pump shall be installed and connected as required to demonstrate capacity and proper operation. Prior to performance of the spin test, the contractor shall ensure that all settings and adjustments are within appropriate limits. Pretest hot oil washing (i.e., unit flushing) shall be complete prior to spin testing to ensure the assembly is clean and free of foreign materials.

4.14.1.1.1 Tests to be performed during spin testing. The following shall be accomplished for the spin test.

(a) Ensure correct mesh spray patterns and flow of oil at the sight-flow assemblies. Check for leakage at flange joints and shaft seals.
(b) Operate turning gear (see appendix G) while engaged in both ahead and astern directions for a length of time to complete at least one revolution of the low speed gear. Additionally, the following turning gear attributes shall be verified:

    (1) Engagement/disengagement device operates properly.
    (2) Propulsion shaft locking device operates properly.
    (3) All limit switches and indicating lights actuate and indicate.
    (4) All modes of operation including continuous and breakaway conditions are within design requirements.

(c) The first gear unit shall undergo an extended spin test operating astern continuously for 2 hours at maximum steady state astern speed and no load. Follow-on gear units shall undergo this test for 30 minutes.
(d) The first gear unit shall undergo an extended spin test operating ahead continuously for 2 hours at maximum steady state ahead speed and no load. Follow-on gear units shall undergo this test for 30 minutes.
(e) Following completion of test (d) above, operate ahead continuously at 120 percent of the maximum steady state ahead speed and no load for 30 minutes.
(f) Check vibration of the gear unit during tests (c), (d) and (e) above to verify that vibration levels are below those specified in 3.1.12.1.2.

4.14.1.1.2 Examination following spin test. Upon satisfactory completion of the spin test, the contractor shall verify that all systems have functioned within prescribed limits. The contractor shall also visually inspect external and internal exposed parts of the gear unit and auxiliary equipment via all access and inspection covers for signs of abnormal conditions, wear, tooth contact or tooth damage. If a load test is not to be performed by the contractor, all main bearings (journal and thrust), journal surfaces and thrust surfaces shall be inspected for wear or distress of any kind.

4.14.1.1.3 Cause for rejection. Any unsatisfactory condition on the test specified in 4.14.1.1 shall be considered cause for rejection.

4.14.1.2 Load test.

4.14.1.2.1 Tests to be performed during load testing. Unless otherwise specified (see 6.2), each gear unit and associated equipment shall be tested by the contractor as follows:

(a) Each gear unit shall be operated at 25, 50, 75, and 100 percent maximum steady state torque and the corresponding speed as specified in 3.1.4 in the ahead direction and 100 percent maximum steady state torque and the corresponding speed as specified in 3.1.4 in the astern direction. The contractor shall verify acceptable internal gear alignment as specified in 4.13.2. After each torque test, the contractor shall inspect teeth markings and record results of visual observations. Layout lacquer shall be reapplied after each torque test. Oil temperatures, bearing metal temperatures, flow at sight-flow indicators, and oil pressures shall be recorded. Flange joints and shaft seals shall be checked for leakage. Time at each torque test shall be determined by the contractor to obtain a readable wear pattern. Vibration levels shall be monitored during each torque test. One prime mover operation is required when this is a normal non-emergency operating mode (i.e., both prime movers, one at a time); otherwise two prime mover operation shall be used.

(b) The first gear unit of each design shall be operated for 24 hours at ahead maneuvering for two prime mover operation to verify proper operation, tooth contact (see 4.13.2), bearing operation, and vibration.

(c) The first gear unit of each design shall be operated for 24 hours at ahead maneuvering for one prime mover operation when this operating condition is a normal non-emergency operating mode (i.e., both prime movers, one at a time, each tested for 24 hours) to verify proper operation, tooth contact (see 4.13.2), bearing operation and vibration.

(d) The first gear unit of each design shall be operated for 30 minutes at emergency maneuvering ahead operation to verify proper operation, tooth contact (see 4.13.2), bearing operation and vibration. One prime mover operation is required when this is a normal non-emergency operating mode (i.e., both prime movers, one at a time, each for 30 minutes); otherwise two prime mover operation shall be used.

(e) When provided, the attached oil pump capacity and system demand shall be verified for each gear unit. Measurement of the oil flow out of the pump and into the gear at various power and speed conditions shall be used to establish the speed at which the pump is self sufficient. This test shall be performed with 130°F oil inlet temperature and at design oil pressure.

(f) Follow-on units shall be operated for four hours at ahead maneuvering for two prime mover operation with same requirements as (b) above.

(g) Follow-on units shall be operated for 4 hours at ahead maneuvering for one prime mover operation with same requirements as (c) above.

(h) Follow-on units shall be operated for 5 minutes at emergency maneuvering ahead operation with same requirements as (d) above.

(i) For gear units driven by steam turbines, each gear unit shall be operated in the astern direction at the specified maximum transient astern speed and torque conditions (see 3.1.4) for 5 minutes or for a period of time as limited by the driving engines, whichever is shorter.

Tests shall be conducted in a four-square torque arrangement or by means of two prime movers and a load absorption dynamometer. Special features of items such as attached oil pumps, clutches, brakes, interlocks, and so forth shall be demonstrated for adequacy during the test. Gear unit associated equipment (see table II) shall have a functional test.

4.14.1.2.2 Examination following load test. Upon satisfactory completion of the load test, the contractor shall verify that all systems have functioned within prescribed limits. The contractor shall also visually inspect external and internal exposed parts of the gear unit and auxiliary equipment via all access and inspection covers for signs of abnormal conditions, wear, tooth contact, or tooth damage. Main bearings (journal and thrust), journal surfaces and thrust surfaces shall be inspected for wear or distress of any kind. Main element tooth contact shall be recorded; criteria for acceptable contact pattern is specified in 4.8.4.3.

4.14.1.2.3 Cause for rejection. Any unsatisfactory condition on the test specified in 4.14.1.2 shall be considered cause for rejection.

4.14.1.3 Noise test. When and as specified (see 6.2), gear unit noise tests shall be performed by the contractor.

4.14.1.4 High speed coupling and attached oil pump quick disconnect. Quick disconnect within 15 minutes of the high speed coupling (see 3.2.1.3.2) and attached oil pump (see 3.2.6.2.1) shall be verified by the contractor.

4.14.1.5 Shock test. When and as specified (see 6.2), the first gear unit (with associated equipment installed) of each design which is capable of being tested, by reason of its weight and size not exceeding the capacity of available test facilities, shall be shock tested by the contractor in accordance with MIL-S-901 (see 6.3).

4.14.2 Shipbuilder's trials.

4.14.2.1 Dock trials. Gear unit will be examined for unusual conditions, such as rust, dirt, cracks and so forth via access and inspection covers, and the information recorded. Prior to sea trials, propulsion machinery will be operated dockside to the maximum practicable power allowable. Tooth contact checks will be made and acceptable contacts achieved before sea trials. Acceptable tooth contacts are in accordance with gear contractor acceptable tooth contact diagrams (see 30.2.5(k) of appendix A).

4.14.2.2 Sea trials. Unless otherwise specified in this paragraph, each gear unit aboard a ship will operate in its normal operating mode during sea trials (i.e., single or twin prime mover). If single prime mover operation per gear unit is a normal (i.e., non-emergency) operating mode, multiple tests, for each test listed below, will be performed to ensure both prime movers will independently drive its gear unit. Propulsion system sea trial operational tests will include the following:

(a) Operate for a minimum of 2 hours at 50 percent maximum steady state ahead power conditions and verify acceptable tooth contact patterns (see 30.2.5(k) of appendix A).
(b) Repeat test (a) above at 100 percent maximum steady state ahead power conditions.
(c) A maximum of 1 hour at steady state astern speed or power, whichever occurs first. Steady state astern may also be limited to the maximum r/min permitted by controllability of ship or rudder.
(d) Quick reversals from 100 percent maximum steady state power ahead to maximum power astern and from maximum power astern to 100 percent maximum steady state power ahead.
(e) For class B gear units on multiple shaft ships, locked shaft test (each gear unit and prime mover).
(f) For class B gear units on multiple shaft ships, trail shaft test (each gear unit and prime mover).
(g) Brake test (each brake where brakes are installed).
(h) Clutch-declutch tests to operate in prescribed modes (each prime mover to gear unit clutch where installed).

4.14.2.2.1 Information obtained during sea trials. The following information will be obtained during sea trials or as a result thereof:

(a) Inlet oil temperature and oil pressure to the gear unit(s).
(b) Babbitt metal temperature and drain temperature of each journal and thrust bearing.
(c) Visual inspection results of gear unit internals and tooth contact patterns.
(d) Satisfactory operation without distress or other abnormalities.

4.15 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 in 5.1 apply only to preservation, packing, and marking of the gear unit/auxiliaries for shipment by contractor to shipbuilder. The packaging requirements of referenced documents listed in section 2 do not apply when material and parts are acquired by the contractor.)

5.1 Packaging requirements. (See 6.3 and appendix A, and 30.2.18 of appendix A.) Preservation, packing, and marking requirements shall be in accordance with MIL-T-17286 and as specified (see 6.2). The gear unit and associated equipment shall be level A for preservation and level C for packing. Specific packaging acquisition requirements shall be as specified (see 6.2).

6. NOTES

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

6.1 Intended use. This specification is intended to be applied to high quality propulsion reduction gears where such gears are not integral with or part of the prime mover for surface ships and submarines of the U.S. Navy. The intended arrangements and details are those of conventional design (similar units having been built previously and installed on board Navy ships or comparable commercial ships).

6.2 Acquisition requirements. Acquisition documents must specify the following:

(a) Title, number, and date of this specification.
(b) Class and arrangement (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 metric configuration is required (see 3.1.2.1(a)).
(e) Limiting dimensions, limiting weight, interface requirements, shaft rake, output shaft rotation, and details of arrangements (see 3.1.2.1(b), 3.1.2.1(c), and 3.1.2.1(d)).
(f) Design operating conditions (see 3.1.4).
(g) Life requirements if other than as specified (see 3.1.9).
(h) Lubricants and compounds (see 3.1.11.4, 3.2.14.1.8).
(i) Cast iron and cast aluminum on parts if other than as specified (see 3.1.11.6.5).
(j) Used or rebuilt products if other than as specified (see 3.1.11.7).
(k) When radiated noise level requirements and goals are required (see 3.1.12).
(l) Torsional and longitudinal vibration analyses if other than as specified (see 3.1.12.2).
(m) Ship attitudes (see 3.1.14).
(n) When shock design is required (see 3.1.15).
(o) Shock factors (see 3.1.15.1).
(p) Type of dynamic analysis and additional analysis requirements (see 3.1.15.2).
(q) Allowable tooth bending stress if other than as specified (see 3.2.1.1.2.5).
(r) K factor (see 3.2.1.1.2.5).
(s) When a specific process, or combinations thereof, are required for the heat treatment of a main element (see 3.2.1.1.2.7).
(t) Gear tooth and reference surface accuracy if other than as specified (see 3.2.1.1.6).
(u) Connection to prime mover(s) (see 3.2.1.2.4).
(v) Fasteners connecting prime mover(s) to gear unit and lineshaft to gear unit if other than as specified (see 3.2.1.2.4).
(w) High speed couplings if other than as specified (see 3.2.1.3.1).
(x) When high speed coupling quick disconnect is required (see 3.2.1.3.2).
(y) When low speed coupling(s) is required (see 3.2.1.3.4).

(z) Epoxy-filled caps (see 3.2.2.3.2).
(aa) When special mounting is required (see 3.2.2.6).
(bb) When submarine propulsion thrust bearing is required (see 3.2.4.1).
(cc) Separate or combined surface ship thrust bearing (see 3.2.4.1).
(dd) Propulsion thrust design (see 3.2.4.8.1, 50.1.2 of appendix D).
(ee) When RTE system is required (see 3.2.5).
(ff) Quantity of RTEs if other than as specified (see 3.2.5).
(gg) Platinum or nickel RTE sensing element (see 3.2.5.1, 3.2.6.2.7.1.2).
(hh) Lubricating oil system (see 3.2.6).
(ii) Lubricating oil supply pressure (see 3.2.6).
(jj) Oil filtration if other than as specified (see 3.2.6.1.3).
(kk) When attached oil pump is required (see 3.2.6.2.1).
(ll) Attached oil pump rated discharge pressure (see 3.2.6.2.1.1).
(mm) When attached oil pump is required to supply other systems (see 3.2.6.2.1.1).
(nn) Piping, fittings, and associated piping components if other than as specified (see 3.2.6.2.2).
(oo) When a connection for sensing pressure of the hydraulically most remote bearing is required (see 3.2.6.2.2.3).
(pp) When pressure gauges are required (see 3.2.6.2.3).
(qq) Leakage at shaft penetrations if other than as specified (see 3.2.6.2.6).
(rr) Thermometers or RTEs at sight-flow indicators (see 3.2.6.2.7.1).
(ss) Accessory drives (see 3.2.7).
(tt) When turning gear motor controller is required (see 3.2.8).
(uu) Turning gear assembly requirements if other than as specified (see 3.2.8).
(vv) When clutches are required (see 3.2.9).
(ww) Clutch design if other than as specified (see 3.2.9).
(xx) When brakes are required (see 3.2.10).
(yy) Brake application and duty cycle (see 3.2.10).
(zz) Dehumidification and vent system (see 3.2.11).
(aaa) When provisions for revolution indicating transmitter are required (see 3.2.13).
(bbb) Alignment procedures and criteria if other than as specified (see 3.2.15.2).
(ccc) Alignment between gear unit and other components (see 3.2.15.2).
(ddd) Inspection of fabrications, forgings, castings, and piping if other than as specified (see 4.7).
(eee) When fabricated gear element qualification test assembly is required (see 4.9.1).
(fff) Accuracy of main pinions and gears if other than as specified (see 4.10.3).
(ggg) Load test if other than as specified (see 4.14.1.2.1).
(hhh) When noise testing is required (see 4.14.1.3).
(iii) When shock testing is required (see 4.14.1.5).
(jjj) Packaging requirements (see 5.1).
(kkk) Bearing reaction diagram design operating condition(s) (see 30.2.9 of appendix A).
(lll) Holes in gear unit shaft(s) if other than as specified (see 50.2.2.2.3 of appendix D).

(mmm) Calculation of alternating torsional shear stress if other than as specified (see 50.2.2.4 of appendix D).
(nnn) Accuracy classification (see 10.2 of appendix E).
(ooo) When certification of accuracy measurement systems are required (see 30.3 of appendix E).
(ppp) Certification facility (see 30.3 of appendix E).
(qqq) Gear accuracy measurement charts and numerical printouts if other than as specified (see 30.4.1.1 of appendix E).
(rrr) When turning gear interlocks are required (see 30.1 of appendix G).
(sss) Breakaway and running torque for line shaft components (see 30.1 of appendix G).
(ttt) Torque for turning gear locking mechanism if other than as specified (see 30.3 of appendix G).
(uuu) When a turning gear motor controller is required (see 30.5 of appendix G).

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
3.1.7.1, 3.1.10, 3.2.1.1, 3.2.1.1.2.6,	DI-DRPR-81000	Product drawings and associated lists	----
3.2.2.2.1, 3.2.2.3, 3.2.3.8,	DI-DRPR-81001	Conceptual design drawings and associated lists	
3.2.4.12, 3.2.5, 3.2.5.2, 3.2.6, 3.2.14.1.7.1,	DI-DRPR-81002	Developmental design drawings and associated lists	
3.2.14.1.7.2, 3.2.14.1.8, 3.2.15.1, 3.2.15.2, 3.2.15.3, 3.3, 3.3.2, 4.10.1.2.1, 4.10.1.3.1, 4.12, 4.13.1, 4.13.2, 5.1, appendix A, and 30.2.1 of appendix G	DI-DRPR-80651	Engineering drawings	

Reference Paragraph	DID Number	DID Title	Suggested Tailoring
3.3.2	DI-MISC-80678	Certification/data report	10.3.1 does not apply
3.1.11, 3.1.11.8, 3.1.12.1.1, 3.1.12.2, 3.1.15.2, 3.1.16, 3.2.3.12.1, 3.2.3.12.2, 3.2.3.12.3, 3.2.15.1, 3.2.6, 3.2.14.1.6, 3.2.14.1.7.1, 3.2.14.1.7.2, 4.2, 4.9.1, 4.10.1.2, 4.10.1.3, 4.13.1, appendix B, and 30.3.1.2 and 30.4.1.1 of appendix D	DI-MISC-80652	Technical information report	----
3.3	UDI-E-23216	Report, variation transmittal/ referral letter	----
3.3.2	DI-MISC-80678	Certification/data report	10.3.1 does not apply
4.1.2	DI-QCIC-80562	Assembly and subassembly manufacturing quality report	----
4.10.1.2.1, 4.10.1.2.2, 4.10.1.3.1, 4.10.1.3.2, 4.14.1 and appendix C	DI-MISC-80653	Test reports	----
4.14.1.5	DI-ENVR-80708	Shock test report	----

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

6.4 First article. The contracting officer will include specific instructions in acquisition documents regarding arrangements for examinations, approval of first article test results, and disposition of first articles. Invitations for bids will 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.

6.5 Definitions.

6.5.1 Accessory drive train. An accessory drive train is any mechanical transmission path which drives or is driven by the gear unit.

6.5.2 Articulated gear unit. An articulated gear unit is a double reduction gear unit having the first reduction main gear and the second reduction main pinion each mounted on a pair of bearings and the two connected by a connecting shaft and one or two flexible couplings.

6.5.3 Bolt. A bolt is a fastener with a head on one end and the body threaded as required. It is a "through-bolt" where a nut is used on the threaded portion, or a "tap-bolt" (or screw) where the threaded portion is turned into a tapped hole other than a nut.

6.5.4 Contracting activity. The contracting activity is the agency which issues the contract or order with the gear contractor (e.g., NAVSEA or the shipbuilder).

6.5.5 Contractor. The contractor is the gear manufacturer through which the contracting activity orders a gear unit in accordance with this specification.

6.5.6 Critical application threaded fasteners. Critical application threaded fasteners include bolts, studs, nuts and other threaded fasteners used on parts internal to the gear housing, fasteners used on rotating parts, or fasteners subject to normal operating stress levels greater than 2/3 of the fastener yield strength.

6.5.7 Gear nomenclature. Unless otherwise defined in this specification, nomenclature for gearing is in accordance with AGMA publications.

6.5.8 Gear unit. A gear unit is the assembly transmitting power from one or more prime movers to a propulsion shaft.

6.5.9 Main rotating part. A main rotating part is any component which exists in a gear unit for the purpose of transmitting torque from the prime mover(s) to an output flange or fitting which drives a propulsion shaft.

6.5.10 Material terminology.

6.5.10.1 Principal part. A principal part is a part listed in table I (materials of principal parts) or referenced by documents listed in table II (associated equipment specifications).

6.5.10.2 Standard material. A standard material is a material of a type, class, form, and grade which is readily available from normal sources of supply without the necessity for additional treatment or processing other than that which is normal to the material or readily supplied by the industry.

6.5.10.3 Special material. A special material is any material which is not a standard material.

6.5.10.4 Specified material. A specified material is a material in accordance with an "applicable document" listed in table I (materials of principal parts) or referenced by documents listed in table II (associated equipment specifications).

6.5.10.5 Unspecified material. An unspecified material is a material not in accordance with any applicable document listed in table I (materials of principal parts) or referenced by documents listed in table II (associated equipment specifications).

6.5.10.6 Nonpreferred part. A nonpreferred part is a part which uses an unspecified material and is part of electronic/electrical equipment which may require spare or repair parts.

6.5.11 Prime mover. Prime mover(s) is the main driving assembly (e.g., turbine, diesel engine) providing power to a propulsion shaft through a gear unit.

6.5.12 Stud. A stud is a fastener which is threaded on each end or throughout its length. "Through-studs" are used with a nut on each end while "bottoming studs" and "shoulder studs" use a nut on one end and are set into a tapped hole in a part or component on the other end (i.e., set end). "Bottoming studs" have an unthreaded extension on the set end which, as the stud is threaded into the tapped hole, compresses against the bottom of the hole and forces the stud threads to engage the underside of the female threads. "Shoulder studs" have an enlarged diameter (i.e., shoulder) which, as the stud is threaded into the tapped hole, compresses against the surface of the part or component and forces the stud threads to engage the underside of the female threads.

6.5.13 Weight control terminology.

6.5.13.1 Dry weight. Dry weight is the weight of the part or component without fluids.

6.5.13.2 Fluid weight. Fluid weight is the weight of fluids contained in a component under operating conditions.

6.5.13.3 Wet weight. Wet weight is the sum of dry and fluid weight (see 6.5.12.1 and 6.5.12.2).

6.5.13.4 Estimated weight. Estimated weight is an estimate, as close as possible, based on similar design or preliminary sketches, for the completed weight of the component.

6.5.13.5 Calculated weight. Calculated weight is the weight of the completed design, calculated from detailed working drawings.

6.5.13.6 Weighed weight. Weighed weight is the actual weight of the part or component, using a certified weighing device.

6.5.13.7 Center of gravity. Center of gravity is the point at which the component can be statically balanced.

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 Procedure for equipment variation submittals. The procedure for submittal and approval of equipment variations will be specified in the contract (see 3.3).

6.8 Subject term (key word) listing.

Drive train
Prime mover
Reduction gears

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

Preparing activity:
Navy - SH
(Project 3010-N011)

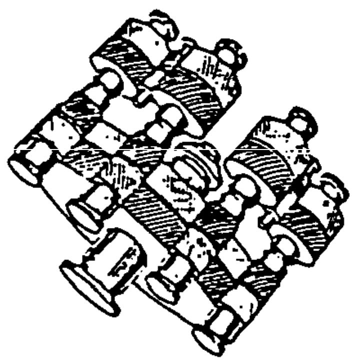

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FIGURE 1. Arrangement 1.

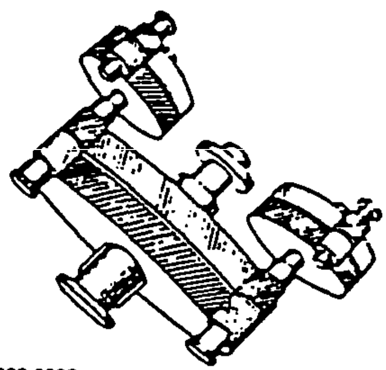

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FIGURE 2. Arrangement 2.

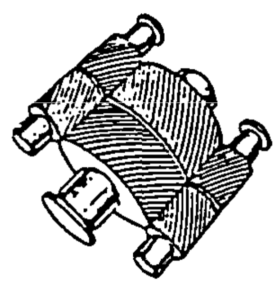

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FIGURE 3. Arrangement 3.

NOMENCLATURE 1/

- a_g, a_p - ADDENDUM, GEAR, PINION
- b_g, b_p - DEDENDUM, GEAR, PINION
- C - CENTER DISTANCE
- c_g - CLEARANCE BETWEEN ROOT OF GEAR AND TIP OF PINION
- c_p - CLEARANCE BETWEEN ROOT OF PINION AND TIP OF GEAR
- D, d - PITCH DIAMETER, GEAR, PINION
- D_b, d_b - BASE DIAMETER, GEAR, PINION
- D_i, d_i - ROOT DIAMETER, GEAR, PINION
- D_o, d_o - OUTSIDE DIAMETER, GEAR, PINION
- E_g, E_p - MODULUS OF ELASTICITY, GEAR, PINION
- F_e - EFFECTIVE TOOTH FACE WIDTH
- F_t - TOTAL TOOTH FACE WIDTH
- h - HEIGHT OF LOAD ABOVE "MIN. STRENGTH SECTION"
- h_k - WORKING DEPTH
- h_{tg}, h_{tp} - WHOLE DEPTH, GEAR, PINION
- HP - HORSEPOWER
- K - K FACTOR (PSI)
- K_f - STRESS CONCENTRATION FACTOR
- LA - LINE OF ACTION
- L_{avg} - AVERAGE LENGTH OF CONTACT LINES
- M_F - AXIAL CONTACT RATIO
- M_P - PROFILE CONTACT RATIO
- M_G - REDUCTION RATIO
- N_g, N_p - NUMBER OF TEETH, GEAR, PINION
- P - DIAMETRAL PITCH, TRANSVERSE
- P_N - DIAMETRAL PITCH, NORMAL
- p_n - CIRCULAR PITCH, NORMAL
- p_t - CIRCULAR PITCH, TRANSVERSE
- p_x - AXIAL PITCH
- p_b - BASE PITCH, TRANSVERSE
- p_{bN} - BASE PITCH, NORMAL
- ψ - HELIX ANGLE AT PITCH DIAMETER (DEGREES)
- ψ_b - BASE HELIX ANGLE (DEGREES)
- ϕ_n - NORMAL PRESSURE ANGLE (DEGREES)
- ϕ_t - TRANSVERSE PRESSURE ANGLE (DEGREES)
- ϕ_L - ANGLE BETWEEN LA AND THE NORMAL TO TOOTH CENTERLINE (DEGREES)
- r_f - MINIMUM TOOTH FILLET RADIUS OF CURVATURE AT INTERSECTION WITH ROOT CIRCLE
- ρ_{pt} - RADIUS OF CURVATURE, PINION TOOTH TIP
- ρ_{gt} - RADIUS OF CURVATURE, GEAR TOOTH TIP
- ρ_p - RADIUS OF CURVATURE, PINION AT PITCH DIAMETER
- ρ_g - RADIUS OF CURVATURE, GEAR AT PITCH DIAMETER
- RPM_p - PINION SPEED
- RPM_g - GEAR SPEED
- S_b - BEAM STRESS (PSI)
- S_k - TOTAL BEAM STRESS INCLUDES STRESS CONCENTRATION FACTOR (K_f) (PSI)
- S_{cp} - COMPRESSIVE STRESS AT PITCH LINE (PSI)
- S_s - SUBSURFACE SHEAR STRESS (PSI)
- t - TOOTH THICKNESS THRU "MIN. STRENGTH SECTION"
- W_t - TANGENTIAL TOOTH LOAD, TRANSVERSE PLANE (lbf)
- W_T - TOTAL TOOTH LOAD, TRANSVERSE PLANE (lbf)
- W_n - TANGENTIAL TOOTH LOAD, NORMAL PLANE (lbf)
- W_N - TOTAL LOAD NORMAL TO TOOTH SURFACE, NORMAL PLANE (lbf)
- X - TOOTH STRENGTH FACTOR
- Y - DEPTH OF MAXIMUM SHEARING STRESS
- Z - LENGTH OF LINE OF ACTION

NOTE: 1/ Dimensions are in inches unless otherwise noted.

FIGURE 4. Tooth stress formulas for helical gearing (sheet 1 of 5).

GENERAL RELATIONSHIP

1. TOOTH LOAD

a. TANGENTIAL TOOTH LOAD, TRANSVERSE PLANE

$$W_t = \frac{126050HP}{RPM_p \cdot d} = \frac{126050HP}{RPM_g \cdot D}$$

b. TOTAL TOOTH LOAD, TRANSVERSE PLANE

$$W_T = \frac{W_t}{COS\Phi_t}$$

c. TANGENTIAL TOOTH LOAD, NORMAL PLANE

$$W_n = \frac{W_t}{COS\Psi}$$

d. TOTAL TOOTH LOAD NORMAL TO TOOTH SURFACE, NORMAL PLANE

$$W_N = \frac{W_t}{COS\Phi_n \cdot COS\Psi} = \frac{W_t}{COS\Phi_t \cdot COS\Psi_b}$$

2. ANGLES

a. TRANSVERSE PRESSURE ANGLE

$$\Phi_t = TAN^{-1}\left[\frac{TAN\Phi_n}{COS\Psi}\right]$$

b. BASE HELIX ANGLE

$$\Psi_b = TAN^{-1}\left[\frac{P_b}{P_x}\right] = TAN^{-1}(TAN\Psi \cdot COS\Phi_t)$$

3. PITCH

a. CIRCULAR PITCH - TRANSVERSE

$$P_t = \frac{\pi}{P} = \frac{\pi D}{N_g} = \frac{\pi d}{N_p}$$

b. CIRCULAR PITCH - NORMAL

$$P_n = \frac{\pi}{P_N} = P_t \cdot COS\Psi$$

c. AXIAL PITCH

$$P_x = P_t \cdot COT\Psi$$

d. BASE PITCH - TRANSVERSE

$$P_b = P_t \cdot COS\Phi_t$$

e. BASE PITCH - NORMAL

$$P_{bN} = \frac{P_b \cdot P_x}{\sqrt{(P_b)^2 + (P_x)^2}} = P_t \cdot COS\Psi \cdot COS\Phi_n = P_t COS\Phi_t \cdot COS\Psi_b$$

f. DIAMETRAL PITCH - TRANSVERSE

$$P = \frac{N_g}{D} = \frac{N_p}{d}$$

g. DIAMETRAL PITCH - NORMAL

$$P_N = \frac{P}{COS\Psi}$$

4. RADIUS OF CURVATURE

a. RADIUS OF CURVATURE AT TOOTH TIP - GEAR, PINION

$$\varrho_{gt} = 1/2\sqrt{D_o^2 - D_b^2}$$

$$\varrho_{pt} = 1/2\sqrt{d_o^2 - d_b^2}$$

b. RADIUS OF CURVATURE AT PITCH DIAMETER - GEAR, PINION

$$\varrho_g = \frac{D}{2} SIN\Phi_t$$

$$\varrho_p = \frac{d}{2} SIN\Phi_t$$

5. LENGTH OF LINE OF ACTION

$$Z = \varrho_{gt} + \varrho_{pt} - (C \cdot SIN\Phi_t)$$

6. CONTACT RATIOS

a. AXIAL CONTACT RATIO (AVERAGE NUMBER OF TEETH IN CONTACT-AXIAL PLANE)

$$M_F = \frac{F_e}{P_x}$$

b. PROFILE CONTACT RATIO (AVERAGE NUMBER OF TEETH IN CONTACT-TRANSVERSE PLANE)

$$M_p = \frac{Z}{P_b} = \frac{Z}{P_t \cdot COS\Phi_t}$$

7. AVERAGE LENGTH OF CONTACT LINES

$$L_{avg} = \frac{F_e \cdot Z}{P_{bN}}$$

FIGURE 4. Tooth stress formulas for helical gearing (sheet 2 of 5).

GENERAL RELATIONSHIP (Cont'd)

8. CLEARANCE

a. CLEARANCE BETWEEN ROOT OF GEAR & TIP OF PINION

$$c_g = b_g - a_p$$

b. CLEARANCE BETWEEN ROOT OF PINION & TIP OF GEAR

$$c_p = b_p - a_g$$

9. DIAMETERS

a. OUTSIDE DIAMETER, GEAR, PINION

$$D_o = D + 2a_g$$

$$d_o = d + 2a_p$$

b. ROOT DIAMETER, GEAR, PINION

$$D_i = D - 2b_g$$

$$d_i = d - 2b_p$$

c. BASE DIAMETER, GEAR, PINION

$$D_b = D \cdot \mathrm{COS}\Phi_t$$

$$d_b = d \cdot \mathrm{COS}\Phi_t$$

10. ADDENDUM, GEAR, PINION

$$a_g = (D_o - D)/2$$

$$a_p = (d_o - d)/2$$

11. DEDENDUM, GEAR, PINION

$$b_g = (D - D_i)/2$$

$$b_p = (d - d_i)/2$$

12. WORKING DEPTH

$$h_k = a_g + a_p$$

13. WHOLE DEPTH

$$h_{tg} = a_g + b_g$$

$$h_{tp} = a_p + b_p$$

14. REDUCTION RATIO ($M_G > 1$)

$$M_G = N_g/N_p = D/d = RPM_p/RPM_g$$

15. K FACTOR

$$K = \frac{W_t}{F_e \cdot d}\left(\frac{M_G + 1}{M_G}\right)$$

FIGURE 4. Tooth stress formulas for helical gearing (sheet 3 of 5).

SUBSURFACE SHEAR STRESS

1. SUBSURFACE SHEAR STRESS AT PITCH LINE

$$S_s = 0.127 \cdot \sqrt{\frac{(W_t)\cdot(E)\cdot(\varrho_p + \varrho_g)}{(L_{avg})\cdot(\varrho_p)\cdot(\varrho_g)}}$$

2. DEPTH OF MAXIMUM SHEARING STRESS

$$Y = 1.186 \cdot \sqrt{\frac{W_t\cdot(\varrho_p)\cdot(\varrho_g)}{(L_{avg})\cdot(E)\cdot(\varrho_p + \varrho_g)}}$$

(NOTE: For pinion or gear, "E" is used in this formula for "E_p" or "E_g" respectively)

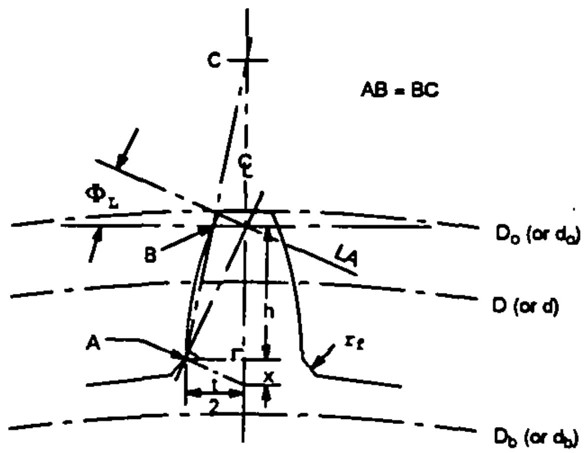
COMPRESSIVE STRESS

1. COMPRESSIVE STRESS AT PITCH DIAMETER

$$S_{cp} = \sqrt{\frac{0.70 \cdot COS^2\,\Psi}{(1/E_p + 1/E_g)\cdot COS\Phi_n \cdot SIN\Phi_n \cdot M_p}} \cdot \sqrt{\frac{W_t}{F_e \cdot d}\left(\frac{M_G + 1}{M_G}\right)}$$

FIGURE 4. Tooth stress formulas for helical gearing (sheet 4 of 5).

TOOTH BENDING STRESS



SECTION THRU TOOTH IN NORMAL PLANE

BEAM STRESS - DOLAN & BROGHAMER

$$S_b = \frac{6 \cdot W_n \cdot h}{t^2 \cdot L_{AVG}} - \frac{W_n \cdot TAN\Phi_L}{t \cdot L_{AVG}}$$

STRESS CONCENTRATION FACTOR - DOLAN & BROGHAMER

$$K_f = H + \left(\frac{t}{r_f}\right)^J \cdot \left(\frac{t}{h}\right)^L$$

Values of H, J, and L are obtained from the following table.

Values of H, J, and L for other pressure angles can be obtained by interpolation or extrapolation.

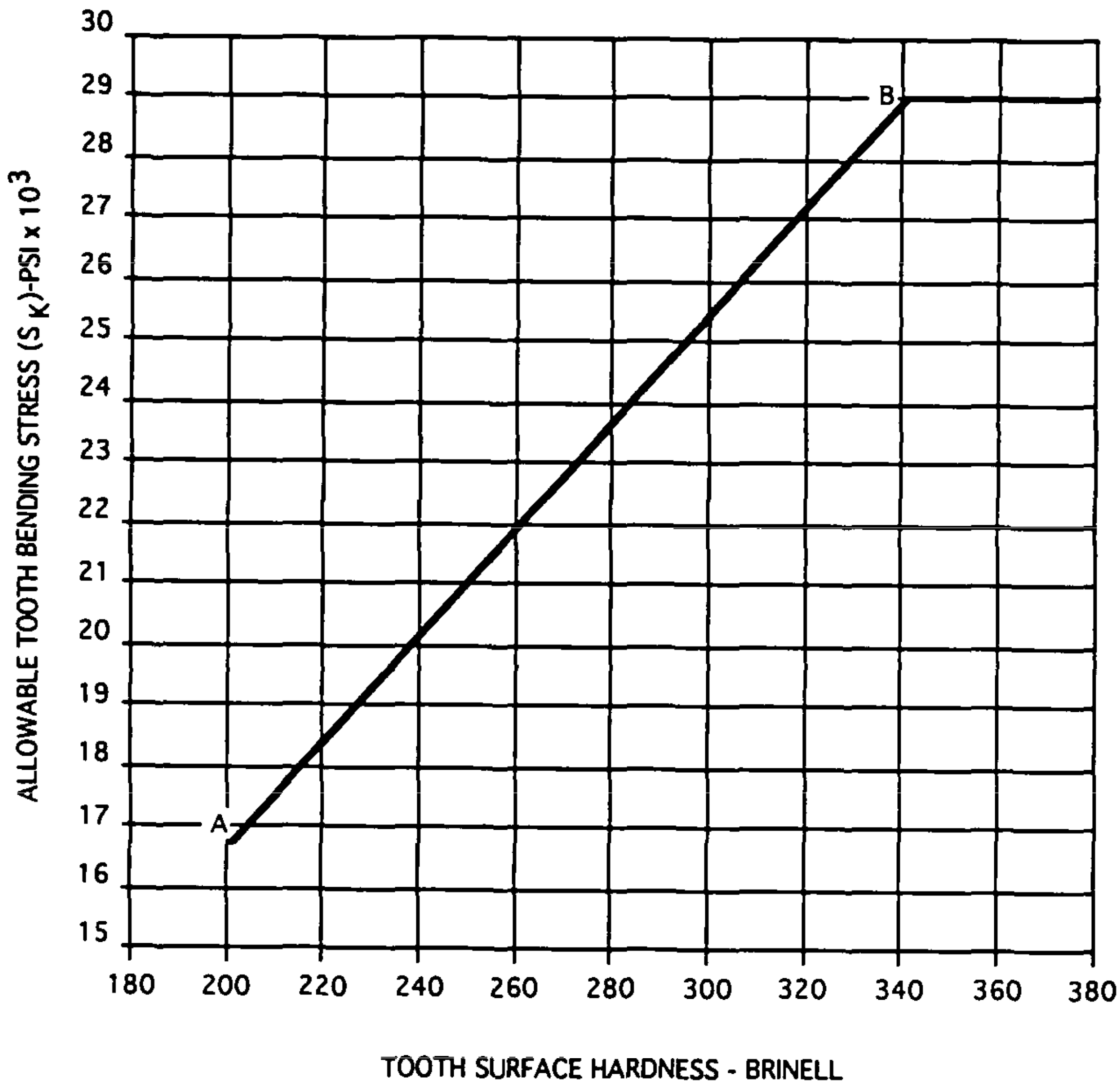
Values of t, h, r_f, and Φ_L are for tooth (gear or pinion) under investigation.

(Φ_n)PRESSURE ANGLE	H	J	L
14 1/2°	0.220	0.200	0.400
20°	0.180	0.150	0.450
25°	0.140	0.110	0.500

TOTAL BEAM STRESS

$S_t = K_f \cdot S_b$

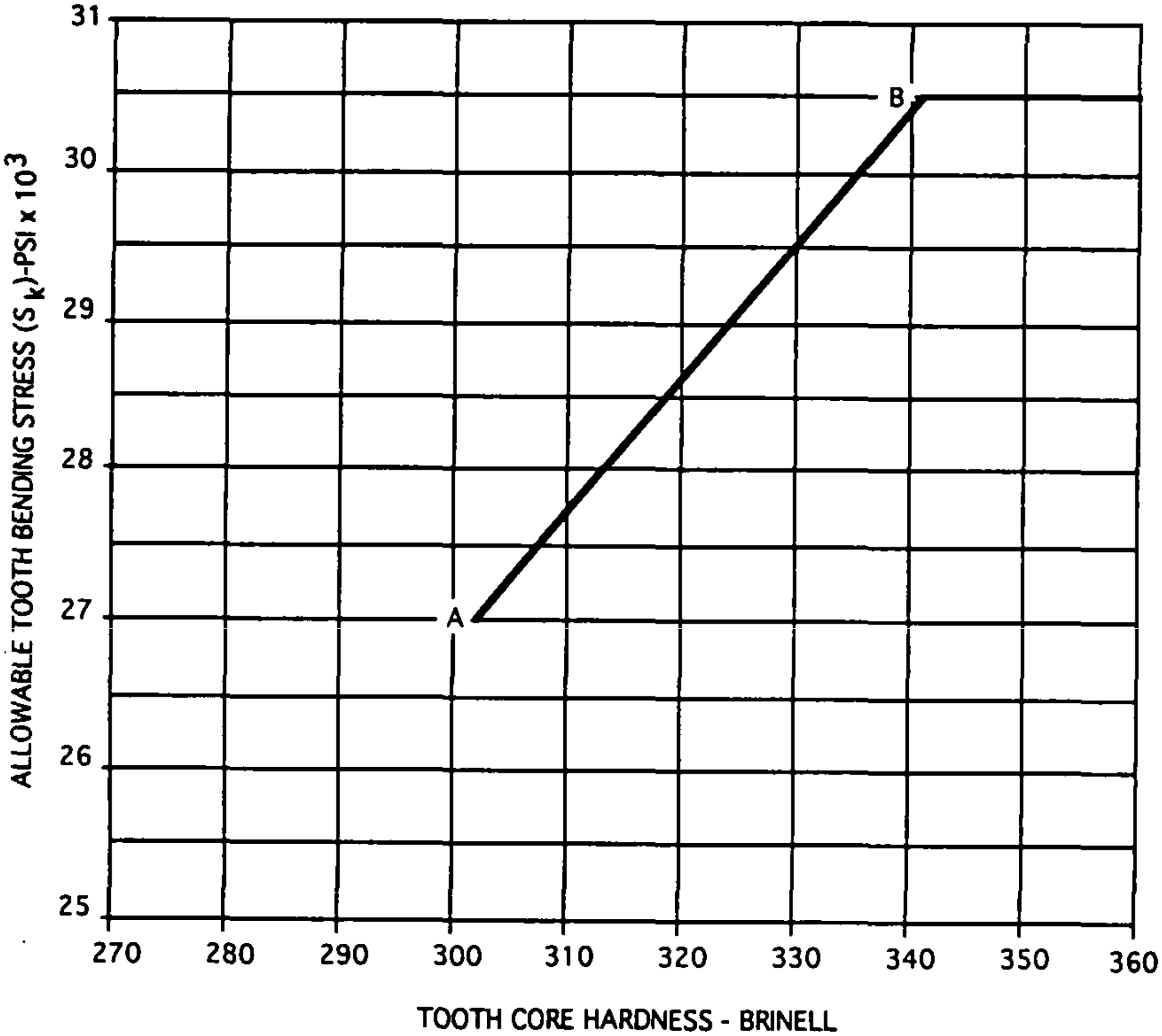
FIGURE 4. Tooth stress formulas for helical gearing (sheet 5 of 5).



NOTES:

1. This curve applies where 100 percent of effective tooth width is used and where root fillets are shot peened.
2. Allowable tooth bending for Diesel engine gears shall be limited to 75 percent of the curve value.
3. Curve applies to main propulsion reduction gears, conventional design, helical tooth, when calculated as specified on figure 4.
4. Point A (201 Brinell, 16720 PSI).
5. Point B (341 Brinell, 29040 PSI).
6. This curve only applies to teeth of pinions and gear rims machined from carbon and alloy steel forgings.

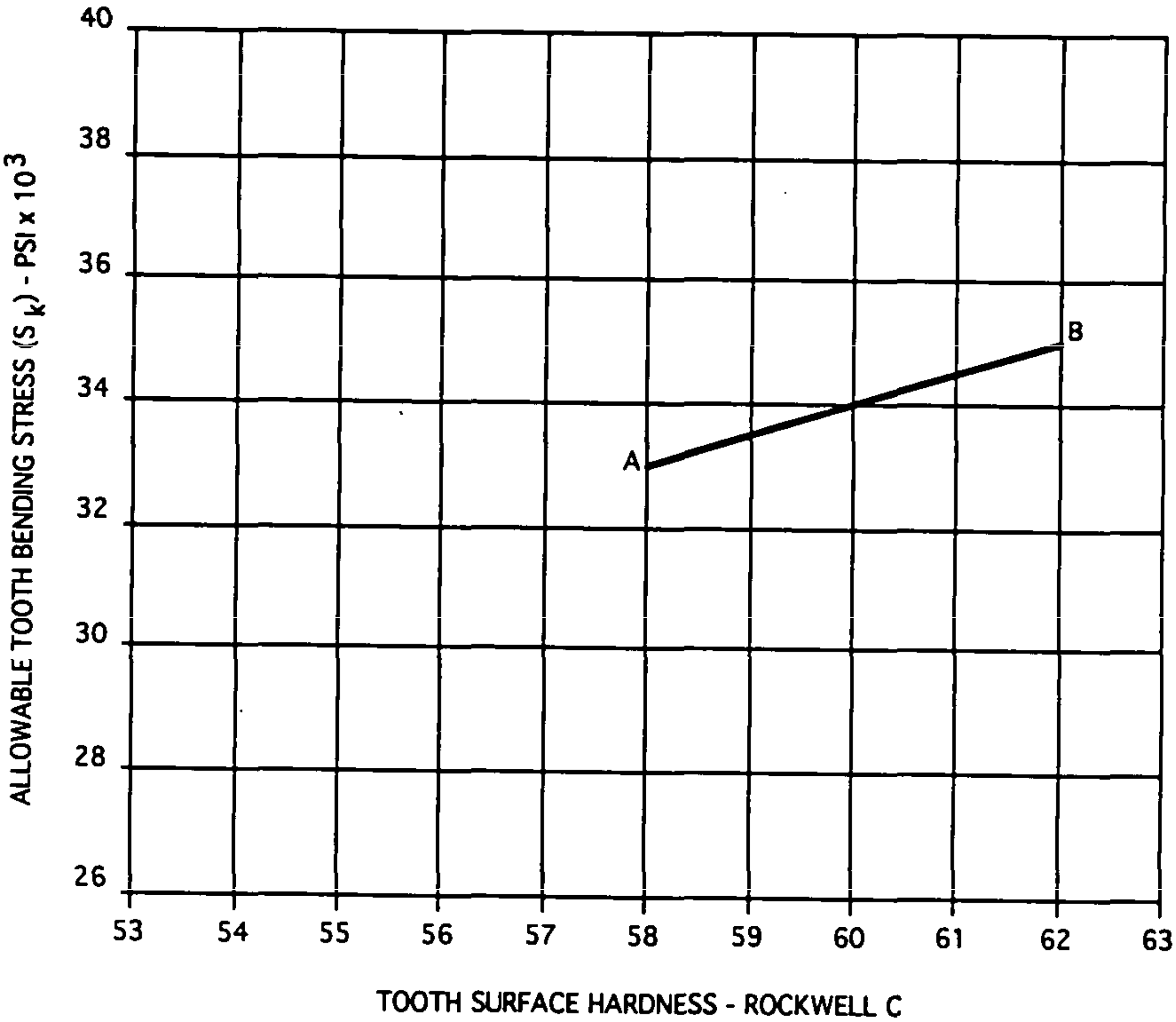
FIGURE 5. Allowable tooth bending stress, through-hardened teeth.



NOTES:

1. This curve applies where 100 percent of effective tooth width is used.
2. Allowable tooth bending for Diesel engine gears shall be limited to 75 percent of the curve value.
3. Curve applies to main propulsion reduction gears, conventional design, helical tooth, when calculated as specified on figure 4.
4. Point A (302 Brinell, 27000 PSI).
5. Point B (341 Brinell, 30500 PSI).
6. This curve only applies to teeth of pinions and gear rims machined from nitriding steels.
7. Minimum core hardness for nitrided teeth is 302 Brinell.

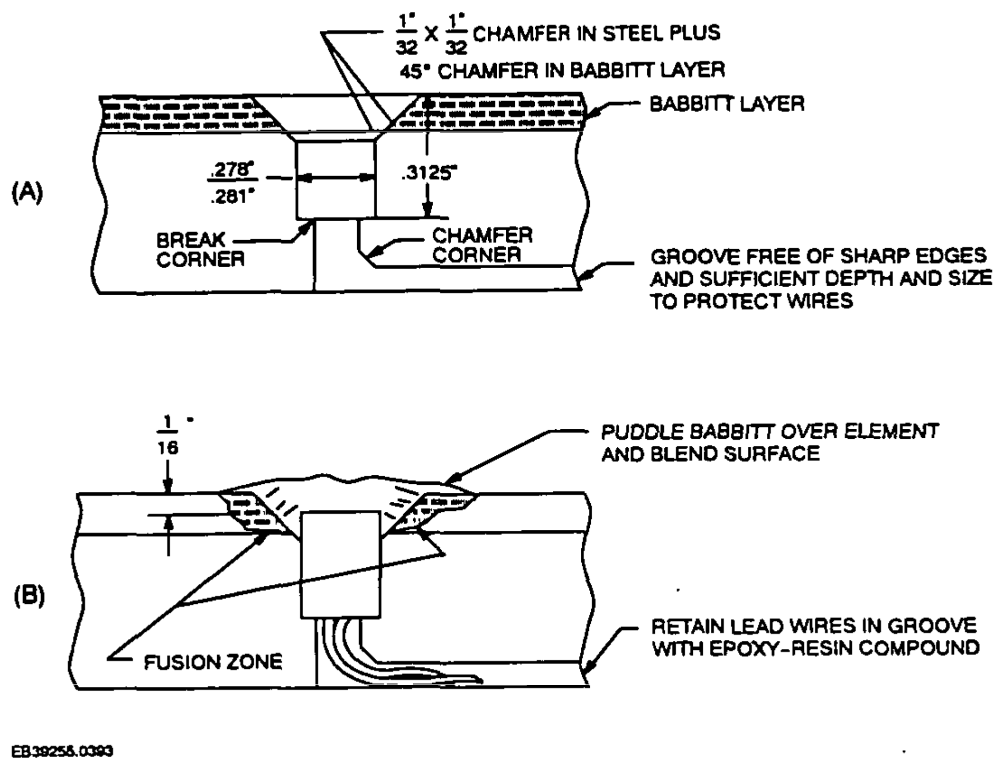
FIGURE 6. Allowable tooth bending stress, nitrided teeth.



NOTES:

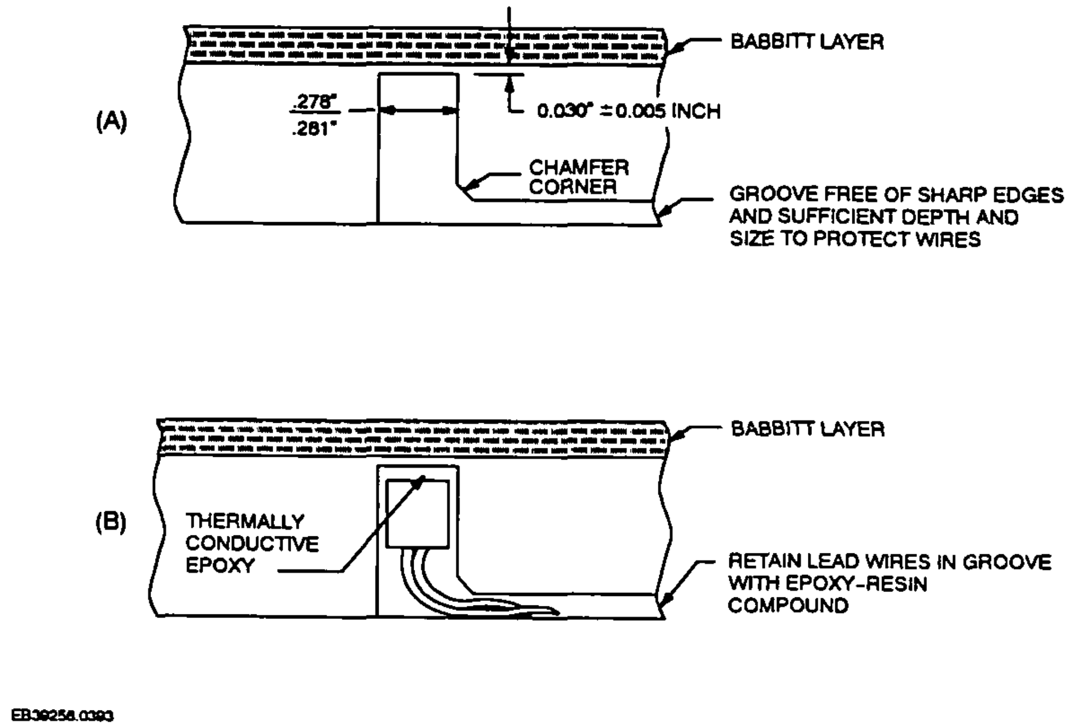
1. This curve applies where 100 percent of effective tooth width is used and where root fillets are shot peened.
2. Allowable tooth bending for Diesel engine gears shall be limited to 75 percent of the curve value.
3. Curve applies to main propulsion reduction gears, conventional design, helical tooth, when calculated as specified on figure 4.
4. Point A (58 Rockwell C, 33000 PSI).
5. Point B (62 Rockwell C, 35000 PSI).
6. This curve only applies to teeth of pinions and gear rims machined from carburizing steels.
7. Minimum core hardness for carburized teeth is 280 Brinell.

FIGURE 7. Allowable tooth bending stress, carburized teeth.



NOTE: Ensure RTE is fully seated in hole during puddling of babbitt.

FIGURE 8. RTE fusion bonded to surrounding bearing babbitt.



NOTE: Ensure RTE is fully seated in hole during installation.

FIGURE 9. RTE below babbitt to shoe/shell interface.

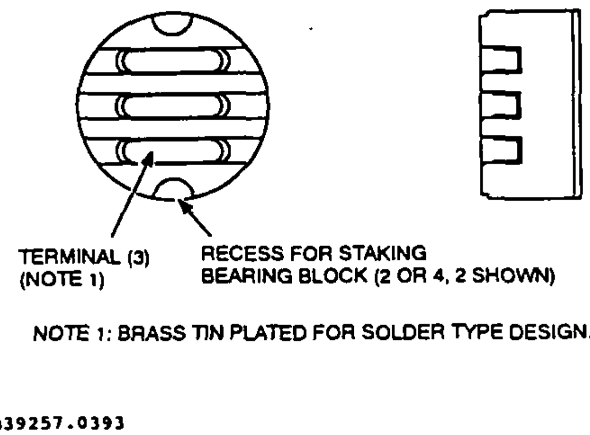


FIGURE 10. RTE connection blocks.

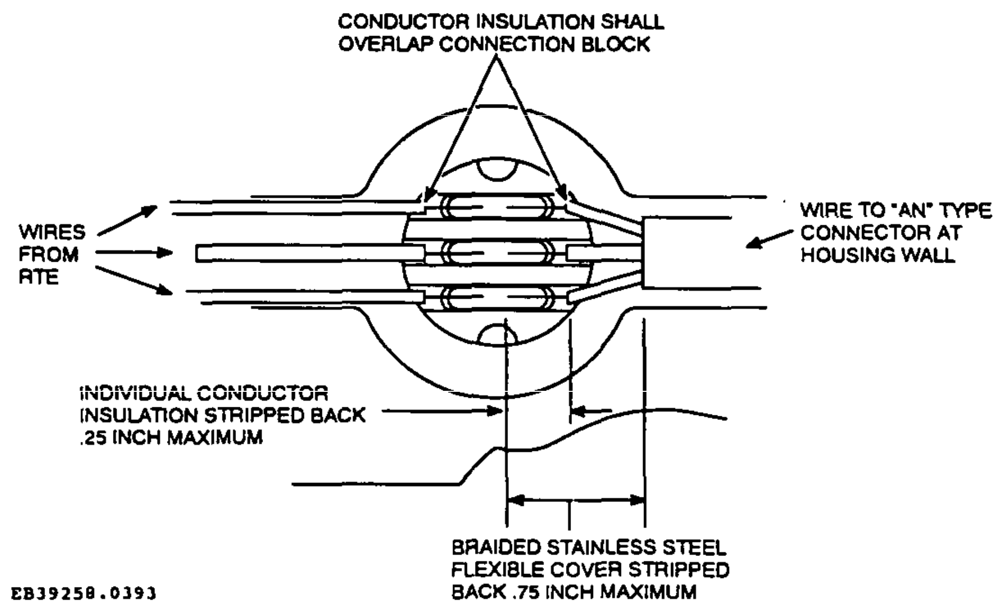
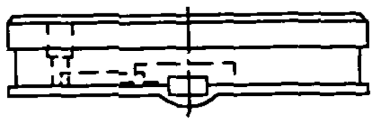
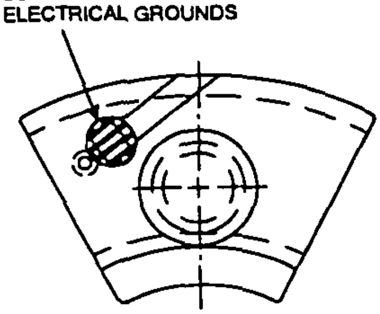


FIGURE 11. Attachment of wires to connection block.

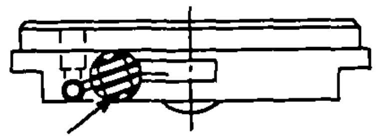
ARRANGEMENT "A"



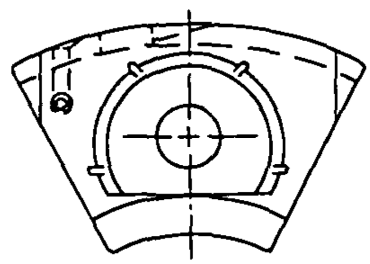
COUNTERBORE TO ENSURE CONNECTION BLOCK IS RECESSED TO PREVENT ELECTRICAL GROUNDS



ARRANGEMENT "B"



COUNTERBORE TO ENSURE CONNECTION BLOCK IS RECESSED TO PREVENT ELECTRICAL GROUNDS



ARRANGEMENT "A"

1. CONNECTION BLOCK INSERTED FROM BACK OF SHOE WITH CIRCUMFERENCE TANGENT TO OR CLOSE TO RTE LEAD WIRE HOLE.
2. BACK OF SHOE GROOVED BETWEEN CONNECTION BLOCK AND EDGE OF SHOE AT OR CLOSE TO PIVOT LINE.
3. WIRE FROM CONNECTION BLOCK TO PIVOT POINT SHALL BE HEADED IN DIRECTION OF HORIZONTAL JOINT.

ARRANGEMENT "B"

1. CONNECTION BLOCK INSERTED RADIALLY INTO EDGE OF SHOE.
2. RTE LEAD WIRES SHALL BE RUN TO CONNECTION BLOCK THROUGH A DRILLED PASSAGEWAY OR GROOVES ON BACK OR EDGE (OR COMBINATION OF SAME).
3. RADIAL EDGE OF SHOE GROOVED BETWEEN CONNECTION BLOCK AND EDGE OF SHOE AT OR CLOSE TO PIVOT LINE.
4. WIRE FROM CONNECTION BLOCK TO PIVOT POINT SHALL BE HEADED IN DIRECTION OF HORIZONTAL JOINT.

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FIGURE 12. RTE installations in thrust bearing.

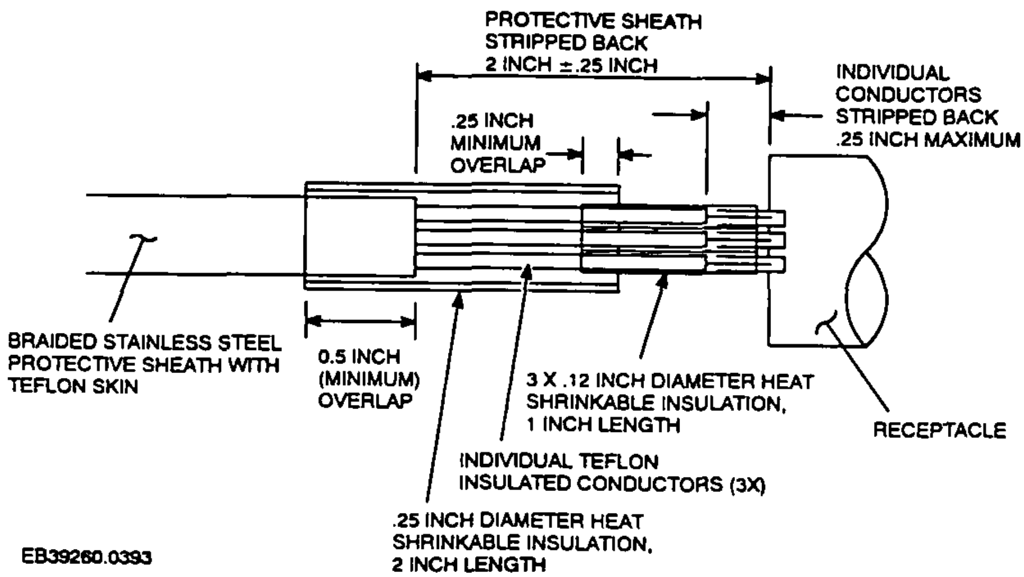


FIGURE 13. Connection to internal side of "AN" type connectors.

NONPREFERRED PART DATA SHEET

NPP Identification No. ____________________

1. Part is used in: (Identification of equipment and assembly) ____
2. Part reference designation(s): (List all applications) ____
3. Prime contractor: ____________________
4. Contract No.: ____________________
5. Description of part: (Complete detailed technical description) ____

   ____

   ____
6. Prime contractor's specification control document (drawing) No. and part No.: ____

   ____
7. Actual manufacturer(s): ____________________
8. Actual manufacturer's drawing No. and part No.: ____________________
9. Previously approved by: (Give the Government procurement agency approval letter)

   ____________________ for use in ____________________

   ________ on contract ____________________
10. Reason for not using specified material: (Give reason and include the following:
    - (a) If electrical characteristics, reliability, quality or application are the reason for not using the specified material, give detailed circuit analysis and quantitative data showing the degree of superiority of performance of the nonpreferred part compared with the specified material. This performance shall be measured in terms of overall equipment performance as well as the performance of the particular part.
    - (b) If undue delay in production of equipment is threatened by not being able to procure specified material, give delivery dates and sources of both specified material and nonpreferred parts.)
11. Reason for not using a nonpreferred part previously approved: ____________________

    ____
12. Reliability assurance: (Test data (life test, etc.) performance limits, failure rate/10^6 hours, and design details such as construction, dimensions, performance, characteristics, ratings and drawings.) ____

    ____
13. Quality assurance: (Inspection procedures, applicable specification, including qualification report numbers covering NPP transformers and semiconductors, etc.)
14. Application data: (detail any special mounting or connection adapter required).

    ____
15. If 10b above applies, give full identification of the specified material to be substituted and instructions for making the change. ____________________

    ____

    ____

As the designated representative of the contractor I certify that to the best of my knowledge the above information and data are correct and the nonpreferred part for which approval is requested is suitable for its intended prolonged use.

Engineer's signature ____________________ Date __________

FIGURE 14. Sample nonpreferred part data sheet.

APPENDIX A

ENGINEERING DRAWINGS TECHNICAL CONTENT REQUIREMENTS

1. SCOPE

10.1 Scope. This appendix covers information that shall be included on drawings when specified in the contract or order. This appendix is mandatory only when data item description DI-DRPR-81000, DI-DRPR-81001 or DI-DRPR-81002 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-M-9868	- Microfilming of Engineering Documents, 35 mm Requirements for.
MIL-T-31000	- Technical Data Packages, General Specification for.
MIL-M-38761	- Microfilming and Photographing of Engineering/ Technical Data and Related Documents: PCAM Card Preparation, Engineering Data Micro-Reproduction System, General Requirements for, Preparation of.
MIL-M-38761/2	- Microfilm Aperture, Tabulating Cards and Ships Drawing Indexes for Naval Sea Systems Command Ships, Systems, and Equipment, Preparation of.

STANDARDS

MILITARY

DOD-STD-100	- Engineering Drawing Practices.
MIL-STD-278	- Welding and Casting Standard.

(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 REQUIREMENTS

30.1 General drawing requirements. The requirements in this section apply to all drawings, as applicable, unless otherwise specified in this specification.

30.1.1 Conceptual and developmental design drawings and associated lists. Conceptual and developmental design drawings and associated lists shall be in accordance with MIL-T-31000, DID DI-DRPR-81001 and DID DI-DRPR-81002. These drawings shall be presented throughout the design process to demonstrate that the design is technically acceptable, to demonstrate that the design meets specification requirements, to provide the shipbuilder with information to design support systems and to install the equipment aboard ship, and to support development of prototype hardware. As a minimum, preliminary version(s) of the drawings discussed in 30.2 shall be provided for this purpose.

30.1.2 Product drawings and associated lists. Product drawings and associated lists shall be in accordance with MIL-T-31000 and DID DI-DRPR-81000. These drawings shall contain information necessary to permit manufacture, maintenance and installation of all gear unit and associated equipment parts. The drawings discussed in 30.2 shall be provided for this purpose.

30.1.3 Drawing numbers and code identification.

30.1.3.1 Contractor drawing numbers and code identification. Contractor drawing numbers and code identification shall be used for all contractor drawings.

30.1.3.2 Subcontractor drawing numbers and code identification. Subcontractor's drawing numbers and code identification shall be used for all subcontractor drawings. Prime machinery contractor shall not add his drawing number or code identification to the drawing, except as an unofficial reference outside the drawing border or margin.

30.1.3.3 Identification by Government or industry specification. Preparation of engineering drawings to cover items which could be described by reference to Government or industry specifications is acceptable when identification of the item is thereby improved.

30.1.4 Information to be included on drawings.

30.1.4.1 Title block. Title block shall be in accordance with DOD-STD-100 except that the revision symbol shall be shown in the title block following the drawing number. Also, the title block shall reference the next assembly drawing. Contractor drawings shall contain a notation citing acceptance by the contractor's designated specialist(s) (qualified in engineering and drafting) who has design responsibility.

30.1.4.2 Revision block. Revision block shall be in accordance with DOD-STD-100. Revision block shall include columns showing revision symbol, description of change, zone, date of revision and NAVSEA or the supervisor of shipbuilding acceptance letter where applicable. Each change shall be separately described (i.e., "numerous changes", "revised extensively" or similar shall not be used).

30.1.4.3 Parts list. Each assembly and subassembly drawing shall have a parts list (either on the drawing or on a separate drawing properly referenced) which shall include the following:

(a) Find number.
(b) Quantity required.
(c) CAGE code (i.e., FSCM). CAGE code is only required to be listed for subcontractor parts.
(d) Part identification (e.g., drawing and part number).
(e) Nomenclature or description.
(f) Item weight (where over 10 pounds).
(g) Material identification.

30.1.4.4 Zoning. Vertical and horizontal zoning shall be used for C size drawings and larger (see DOD-STD-100).

30.1.4.5 "Manufacturer's use only" notes. Information intended for manufacturer's use only shall be so designated.

30.1.4.6 Fastener installation requirements. Drawings shall specify installation procedure requirements for all fasteners. Specified information shall include torque limits, torque check and inspection requirements, thread lubricant requirements and, as necessary, requirements for treatment with a retaining anaerobic compound.

30.1.4.7 Marking. Drawings shall specify marking details (where, how, and what to be marked).

30.1.4.8 Welding and nondestructive testing information. Drawings shall show all essential welding fabrication details and areas requiring nondestructive testing (NDT). Welding and NDT symbols shall be in accordance with MIL-STD-278.

30.1.4.9 Balance. Drawings of rotating parts shall state permissible amount of residual unbalance in inch-ounces.

30.2 Specific drawing requirements. This section provides technical content requirements for specific gear unit drawing related deliverables. Other drawings may be required for a specific application or to meet the requirements of associated equipment applicable documents. When other drawings are required, the technical content requirements for these additional drawings shall be in accordance with the contract or order.

30.2.1 Outline and arrangement. The outline and arrangement drawing shall include sufficient information to permit the contracting activity to verify compatibility with ship systems, compatibility with ship arrangement, and aid the shipbuilder and NAVSEA in assembly. The outline and arrangement drawing shall include or reference all requirements for interface with ship systems. This drawing will also be used to verify that specification requirements are met. This drawing shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing separate drawings. The outline and arrangement drawing shall consist of the following:

(a) Part list of all materials and parts at contractor to shipbuilder interface locations (e.g., gear unit to prime mover, propulsion shaft, lubrication system, mounting, electrical power supplies, bearing RTE and electrical instrumentation system, alignment and erection, etc.). Part name, identifying number (e.g., drawing number), materials, quantities, and responsible supply organization (e.g., shipbuilder) shall be listed.
(b) Depiction of the location (with tolerance) and details of all interface locations.
(c) Drawing notes or separate procedures properly referenced which detail installation requirements.
(d) Interface requirements shall be either included on or referenced on the subject drawing. The current revision of referenced drawings or procedures shall be available to the contracting activity.
(e) Overall and principal dimensions of major gear unit and associated equipment components.
(f) Lifting heights of major gear unit and associated equipment components.
(g) A table of all connections to ship systems (mechanical and electrical) with location, size, and rating listed or referenced.
(h) Center of gravity in two planes of entire assembled gear unit with associated equipment installed.
(i) Arrow at output shaft depicting rotation when operating in the ahead direction.
(j) Seating arrangement with foundation fasteners indicated (quantity, fastener specifications, size, location, type of fit).
(k) Openings for examination or clearance measurement.
(l) Attached instrumentation and fittings such as bearing sight-flow fittings, thermometers, RTE system external components, gauges, and connections for same. Orientation of thermometer gauges shall be depicted.
(m) List of reference drawings, including reference to drawing list and sectional assembly. All drawings which include requirements for interface with the ship (e.g., alignment and erection, bearing RTE and electrical instrumentation system, lubrication system, foundation loading plan) shall be listed.
(n) Table of power and speeds (r/min). (Confidential data shall not be included.)
(o) Table of applicable ships and contracts.
(p) A chart or graph of attached oil pump design flows versus propulsion shaft speeds r/min.
(q) Gear unit to prime mover(s) and gear unit to propulsion shaft interface requirements.
(r) All gear unit and associated equipment external parts shall be depicted. As a minimum, the following drawing views shall be included:

    (1) Aft looking forward.
    (2) Forward looking aft.
    (3) Side elevation - looking port.

(4) Side elevation - looking starboard.
(5) Plan view.
(6) Bottom view.

30.2.2 Sectional assembly. The sectional assembly drawing shall include sufficient information to aid the shipbuilder and NAVSEA in assembly and verification that specification requirements are met. This drawing shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing separate drawings. The sectional assembly drawing shall consist of the following:

(a) Part list which includes part name, identifying number (e.g., drawing number) and quantities.
(b) Drawing sectional views which include side elevations sectioned longitudinally and end elevations of transverse sections. These sectional views shall depict the following (NOTE: External views shall be sufficient to accurately locate and depict sectional views. If all external gear unit and associated equipment are not shown, reference to the outline and arrangement drawing shall be included):

(1) All rotating parts of the gear unit and associated gear drives.
(2) All bearings, bearing caps and covers with sight-flow fittings and sight-flow fitting supply and drain.
(3) All bearing seals.
(4) All shaft seals and oil deflectors.
(5) All removable internal piping.
(6) All boots.
(7) Appropriate portions of gear housing and access openings.
(8) All mesh spray nozzles and piping.

(c) The current revision of referenced drawings shall be available to the contracting activity.

30.2.3 Marking identification. The marking identification drawing shall depict marking on all gear unit and associated equipment to aid in assembly, disassembly, timing, balance repeatability, and inspection. This drawing shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing a separate drawing. The marking identification drawing shall consist of the following (see 3.1.7.1):

(a) Sufficient detail to allow the contracting activity to verify that all related requirements of this specification are met.
(b) Sufficient detail to allow the contracting activity to locate and use each marking to aid in disassembly, assembly, timing, balance repeatability, and inspection.
(c) Marking on all stationary and rotating parts which can be disassembled and which ensure parts are installed in proper locations and orientations after disassembly.

(d) Type(s), sizes, locations, orientations, and other details of markings.
(e) Related marking process specification(s).
(f) All required marking shall be either included on the marking identification drawing or referenced on the subject drawing. The current revision of referenced drawings shall be available to the contracting activity.

30.2.4 Lifting arrangement. The lifting arrangement drawing shall depict lifting information for all components and parts of components in the gear unit and associated equipment which weigh more than 35 pounds and may be lifted separately. This drawing shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing a separate drawing. The lifting arrangement drawing shall consist of the following (see 3.1.10):

(a) Part list including components to be lifted, lifting and handling equipment (standard and special), tools (standard and special), and quantities. Part name and identifying number (e.g., drawing number) shall be listed.
(b) Depiction of all components and parts of components greater than 35 pounds which may be lifted separately.
(c) Depiction of hoisting equipment and lifting configurations.
(d) Requirements for maximum angular pulls at each lift point.
(e) Weights and center of gravities (in at least two planes for each item). Lift points shall be located relative to the center of gravity.
(f) Depiction of use of tools, and lifting and handling equipment.
(g) Notes which address applicable precautions (e.g., protect journal surfaces, gear teeth, diaphragm couplings, etc.).
(h) Identification of tools and lifting and handling equipment to be provided by the contractor.
(i) Sufficient detail to allow the contracting activity to verify that all related requirements of this specification are met.
(j) All lifting arrangement information shall be either included on the lifting arrangement drawing or referenced on the subject drawing. The current revision of referenced drawings shall be available to the contracting activity.

30.2.5 Main pinion and gear details. The main pinion and gear detail drawings shall include a complete set of manufacturing drawings for each pinion and gear. These drawings shall permit the contracting activity to verify that design objectives and specification requirements are met with the contractor proposed design. These drawings shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing separate drawings. The main pinion and gear detail drawings shall consist of the following (see 3.2.1.1, 4.10.1.2.1, 4.10.1.3.1, 4.13.1, and 4.13.2):

(a) Detailed manufacturing drawings with part lists. Part lists shall include part name, identifying number (e.g., drawing number), material, and quantities.

(b) Tooth data (see 30.2.6 (a) of this appendix) except data related to "minimum strength section" is not required.
(c) Complete dimensional details of pinions and gears (including journals, flanges, and collars), welding requirements, nondestructive testing, heat treatment, shot peening, machining, and all other fabrication requirements.
(d) Details of all test coupons prepared to meet the requirements of this specification including, dimensions, heat treatment, testing, and acceptance criteria.
(e) Details of tooth chamfers, radii, and shoulder.
(f) Limits on gear and pinion accuracies (see 3.2.1.1.6 and 3.2.1.2.5).
(g) Details of balancing requirements (e.g., permissible amount of residual unbalance in ounce-inches, balance correction locations, size and location of drilled holes, etc.).
(h) Tooth hardness (on surface and core for surface hardened pinions and gears) and related requirements (e.g., measurement locations and material condition).
(i) Case depth for surface hardened pinions and gears and related requirements (e.g., measurement locations and material condition).
(j) Weight of part.
(k) Dimensioned views of each loaded tooth flank showing location and size of minimum acceptable contact band. Dimensions from base-end along the lead to contact band, from apex-end along the lead to contact band, from tooth top land along the profile to top of contact band, and from tooth top land along the profile to bottom of contact band. Dimensioned views shall be provided for the following conditions:

    (1) Static tooth contact inspection torque condition.
    (2) Spin test - no load condition.
    (3) 25, 50, 75, 100 percent maximum steady state torque conditions.
    (4) Ahead maneuvering torque condition.
    (5) Emergency maneuvering torque condition.

(l) The current revision of referenced drawings shall be available to the contracting activity.

30.2.6 Main pinion and gear tooth data and stresses. The main pinion and gear tooth data and stresses shall be summarized to permit the contracting activity to verify that design objectives and specification requirements are met with the contractor proposed design. This document shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing a separate document. The main pinion and gear tooth data and stresses document shall consist of the following (see 3.2.1.1.2.6):

(a) Tooth data including number of teeth, diametral pitch (transverse and normal), pitch diameter, addendum, dedendum, whole depth, outside diameter, chordal or arc tooth thickness (maximum and minimum), helix angle, pressure angle (transverse and normal), reduction ratio, face width (total and effective), L/d ratio, minimum transverse backlash, minimum root fillet radius, tooth thickness thru minimum strength section, height of load above minimum strength section, angle between "LA" and the normal to tooth centerline (see figure 4).
(b) Tooth hardness (on surface and core for surface hardened pinions and gears).
(c) Case depth in final condition for surface hardened pinions and gears.
(d) Load and stress data at maximum steady state power and maximum maneuvering power for ahead conditions. Data for one prime mover operation is required when this is a normal non-emergency operating mode; otherwise data for two prime mover operation shall be listed. Load and stress data shall include tangential tooth load, K factor, compressive stress, bending stress, depth of maximum shear and shear stress, and applicable design operating condition. (Confidential data shall not be included.)
(e) Scoring resistance calculations, results, acceptance criteria, and justification for acceptability (see 3.2.1.1.2.6).

30.2.7 Mesh inspection opening covers. The mesh inspection opening cover drawing(s) shall permit the contracting activity to verify compatibility with ship arrangement and to verify specification requirements are met with the contractor proposed design. These drawing(s) shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing a separate drawing(s). The mesh inspection opening cover drawing(s) shall consist of the following (see 3.2.2.2.1):

(a) Detailed manufacturing drawing(s) with part list(s). Part list(s) shall include part name, identifying number (e.g., drawing number), material, and quantities.
(b) Methods of securing all cover parts.
(c) Mechanical provisions to restrain cover in open position.
(d) Mesh inspection cover orientations or housing covers.
(e) Height of coaming at edge of each opening.
(f) Mesh inspection opening sizes and locations on housing covers relative to the rotating pinions and gears to verify accessibility of teeth and ability to view oil mesh spray patterns.
(g) The current revision of referenced drawings shall be available to the contracting activity.

30.2.8 Security provisions. The security provision drawing shall depict security features on all gear unit and associated equipment to aid the shipbuilder and NAVSEA in final assembly, in reassembly after disassembly, and in assuring design objectives and specification requirements are met with the contractor proposed design. This drawing shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing a separate drawing. The security provision drawing shall consist of the following (see 3.2.2.3):

(a) Part list of all materials and parts of security features. Part name, identifying number (e.g., drawing number), materials, and quantities shall be listed.
(b) Depiction of the location and details of security features. Dimensions are required only where this information is considered necessary to properly install a particular feature.
(c) Drawing notes or separate procedures properly referenced which detail installation requirements (e.g., fastener torque, epoxy application).
(d) All security provisions shall be either included on the security provision drawing or referenced on the subject drawing. The current revision of referenced drawings shall be available to the contracting activity.

30.2.9 Bearing reaction. The bearing reaction drawing shall include sufficient information to aid the shipbuilder and NAVSEA in verification that specification requirements are met. This drawing shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing a separate drawing. The bearing reaction drawing shall consist of the following (see 3.2.3.8):

(a) A vector representation (i.e., magnitude and direction) of bearing reactions for each design operating condition as specified (see 6.2). The total reaction load of each bearing shall be located from the housing joint or bearing part line. The bearing part line shall be located relative to the housing joint. Vector representations of bearing reactions shall be part of a schematic or, as an alternative, may be included in a table.
(b) A tabulation of the following:

    (1) Bearing type(s).
    (2) Bearing sizes including diameter, overall length, pad length (when applicable), angular extent of each pad (when applicable), and number of pads (when applicable).
    (3) Design diametral clearance (machined and assembled; maximum and minimum).
    (4) Preload.
    (5) Maximum clearance (i.e., maximum permissible clearance before replacement is required).
    (6) Shaft r/min, journal velocity (feet per second), total pressure and unit pressure on projected area for maximum steady state operating conditions (see 3.1.4). Confidential data shall not be included.
    (7) Rotating part static load (i.e., load caused by weight) at each bearing.

(c) Reference to bearing drawings. The current revision of referenced drawings shall be available to the contracting activity.
(d) When single turbine vector representation of bearing reactions is required, data for both prime movers, each operating one at a time, shall be included.

30.2.10 Thrust meter. The thrust meter drawing(s) shall include details of the entire thrust meter system from strain gage type load cells on thrust pads or leveling links to terminal box terminal board shipbuilder interface locations. These drawing(s) shall also include details of all parts which will replace the thrust meter system upon removal. These drawing(s) shall aid the shipbuilder and NAVSEA in assembly and removal of the thrust meter system and assembly of non-instrumented thrust bearing parts. These drawing(s) shall also be used to verify specification requirements are met, compatibility with ship systems, and compatibility with the ship arrangement. These drawings shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing separate drawing(s). The thrust meter drawing(s) shall consist of the following (see 3.2.4.12):

(a) Detailed manufacturing drawing(s) with part list(s). Part list(s) shall include part name, identifying number (e.g., drawing number), material, and quantities. All components and compounds shall be included.
(b) Electrical schematic from each load cell to shipbuilder connection points.
(c) Instructions for installation and removal.
(d) The current revision of referenced drawings shall be available to the contracting activity.

30.2.11 Bearing RTE and electrical instrumentation system. The bearing RTE and electrical instrumentation system drawing(s) shall include details of the entire metal temperature indication system from RTE locations in gear bearings to terminal box terminal board shipbuilder interface locations. This drawing shall also include all gear unit and associated equipment instrumentation and control wiring and connection requirements. The RTE system drawing(s) shall aid the shipbuilder and NAVSEA in final assembly and reassembly after disassembly, shall be used to verify specification requirements are met, shall be used to verify compatibility with ship systems, and shall be used to verify compatibility with the ship arrangement. These drawings shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing separate drawing(s). The bearing RTE system drawing(s) shall consist of the following (see 3.2.5, 3.2.5.2, 4.12):

(a) Detailed manufacturing drawing(s) with part list(s). Part list(s) shall include part name, identifying number (e.g., drawing number), material, and quantities. All RTE system components and compounds shall be included.
(b) Electrical schematic from each RTE to shipbuilder connection points.

(c) Sufficient information to ensure the shipbuilder can perform RTE system maintenance, material ordering of RTE system components and compounds, and connection to terminal boards. Compatibility with the ship and ship systems, and suitability of the design for its intended end use will be verified.
(d) Special instructions for installation or removal.
(e) RTE, RTE location in bearing, RTE installation procedure, RTE lead wire routing, connection block, connection block location and protection, wiring between connection block and housing wall "AN" type connector, "AN" connector type and location, external RTE wiring, terminal boxes, terminal boards, steel conduit, wire markers, and any other RTE feature provided.
(f) All RTE wire holes, slots, grooves, and conduit in bearing, housing, and housing covers.
(g) Solder type and soldering procedure.
(h) Epoxy resin and non-oil soluble silicon rubber types and installation instructions.
(i) Wire insulation stripping at connection block and "AN" type connector, overlap of individual conductor insulations with connection block, and heat shrink insulation at "AN" type connector.
(j) Provisions for storage of excess wire.
(k) Heat shrink insulation type, size, and locations.
(l) Warning plate.
(m) Instructions for wiring checks.
(n) In addition to the RTE system, this drawing shall depict all electrical instrumentation and control wiring requirements for gear unit and associated equipment.
(o) All RTE system and electrical instrumentation and control wiring shall be either included on or referenced on the subject drawing. The current revision of referenced drawings shall be available to the contracting activity.

30.2.12 Lubrication system. The lubrication drawings shall include an oil flow diagram and manufacturing drawings of contractor supplied lubrication provisions. The lubrication drawing shall permit the contracting activity to verify compatibility with ship systems, compatibility with ship arrangement, and aid the shipbuilder and NAVSEA in final assembly. These drawings will also be used to verify that specification requirements are met. These drawings shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing separate drawings. The lubrication system drawings shall consist of the following (see 3.2.6):

(a) Lube oil flow diagram shall indicate schematically gear unit and associated equipment oil supply lines, drain lines, instrumentation connections, and control connections. Orifices, bearings, mesh spray nozzles, clutches (when provided), couplings (which require lube oil), interconnecting piping, shipbuilder connections, and pressure gauge connections (when provided) shall be indicated schematically. A list of symbols shall be provided and direction of flow indicated by an arrow. Oil flow rate (gal/min), heat rejection rate, pipe diameter, and pipe schedule at each pipe and at each component shall be included (as part of schematic or if so desired in a table). Type of oil, inlet oil pressure, inlet oil temperature, and assumed pressure drop at each orifice shall be identified. All data on this drawing shall be based on maximum ahead steady state design operating conditions. Equipment and piping shown, but not furnished by the contractor, shall be dotted or phantomed, while solid lines shall represent items and connections furnished with the gear unit.

(b) Manufacturing drawings of contractor supplied lubrication provisions shall include part list(s) which identify part name, identifying number (e.g., drawing number), material, and quantities. Notes shall be provided which detail special assembly or test requirements. Details of contractor to shipbuilder interface connections which include location with tolerance, fastener requirements, gasket requirements, security provisions (may be referenced to a separate drawing; see 30.2.8), flange sizes, etc. shall be depicted. All removable lubrication related components and parts (see 3.2.6) shall be separately identified. Parts to be provided by the shipbuilder shall be clearly identified. The current revision of referenced drawings shall be available to the contracting activity.

30.2.13 Alignment and erection. The alignment and erection drawing shall include methods and criteria for alignment of the gear unit to prime mover(s) and gear unit to propulsion shaft; erection methods and criteria for establishing internal gear unit alignment; and, when specified in the contract or order, methods and criteria for alignment of gear unit to other components (e.g., auxiliary gear drives). The alignment and erection drawing shall permit the contracting activity to verify compatibility with ship systems, compatibility with ship arrangement, and aid the shipbuilder and NAVSEA in final assembly and reassembly after disassembly. These drawings will also be used to verify that specification requirements are met. These drawings shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing separate drawings. The alignment and erection drawing shall consist of the following (see 3.2.15.1, 3.2.15.2, 3.2.15.3):

(a) Sketches, illustrations, procedures, and special instructions for establishing gear unit to prime mover and gear unit to propulsion shaft alignment. Criteria including field tolerances for vertical, horizontal, and axial alignment shall be identified.

(b) Sketches, illustrations, procedures, and special instructions for establishing class B gear unit low speed gear bearing load differential (horizontal and vertical). Criteria including field tolerances shall be identified.

(c) Sketches, illustrations, procedures, and special instructions for establishing internal gear alignment during erection including housing flatness check methods, bearing thickness measurements, etc. Criteria including field tolerances shall also be identified. Data recording and hardware stamping requirements shall be identified.

30.2.14 Machinery variation summation. The machinery variation summation drawing shall apply to all units of a specific design. Separate drawings for port and starboard units (if provided) are not required if these units are similar in arrangement. The machinery variation summation drawing shall consist of the following (see 3.3 and 3.3.2):

(a) Post production summation of all major variations.
(b) A brief description of each deviation from the basic drawing(s).
(c) The serial number of the unit affected for each variation.
(d) The hull number of the ship to which the affected unit is assigned for each variation.
(e) The necessary correlation with special parts and repair parts which result from the variation.

30.2.15 Foundation loading plan. The foundation loading plan shall show static load values, reaction torque loads, and overturning moments due to worst case design operating conditions (see 3.1.4) at each foundation mounting location. Loads and moments at each mounting location caused by ship attitudes (see 3.1.14) and maximum misalignments shall also be included. The proposed gear unit seating arrangement shall be identified (fully dimensioned). This drawing shall include sufficient data and drawing views to enable the shipbuilder to design the gear unit foundation. The foundation loading plan shall permit the contracting activity to verify compatibility with ship arrangement. These drawings shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing separate drawings.

30.2.16 Drawing list. The drawing list shall apply to all units of a specific design. Separate drawing lists for port and starboard units are not required if these units are similar in arrangement. Drawings which apply to port only or starboard only gear units (if provided) shall be identified by drawing note. The drawing list shall consist of the following:

(a) A list of all drawing numbers (contractor and sub-contractor) for the main reduction gear and associated equipment.
(b) Drawing title for each drawing number listed.
(c) Manufacturer code (e.g., FSCM) for each drawing number listed.

30.2.17 Microfilm. One set of microfilm drawings shall consist of all drawings used to manufacture, assemble, install and maintain the gear unit and associated equipment. All drawings required by this specification shall also be included. The microfilm drawings shall be consistent with those listed on the drawing list discussed in 30.2.16. Microfilm in aperture cards shall be in accordance with MIL-M-38761 and MIL-M-38761/2, 35 mm microfilm in accordance with MIL-M-9868 (type I, class 1).

30.2.18 Packaging. The packaging drawing(s) shall include all packaging details for each gear unit and associated equipment part. The packaging drawing(s) shall include sufficient information to aid the shipbuilder in reassembly and to aid the shipbuilder and NAVSEA in verification that specification requirements are met. The packaging drawing(s) shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing a separate drawing. The packaging drawing(s) shall consist of the following (see 5.1):

(a) Method of preservation and applicable specification.
(b) Level of preservation and packing.
(c) Weight and center of gravity.
(d) Dimensions; interior and overall exterior of the container.
(e) Dimensional location of shock mounts, anchoring, blocking, bracing, etc.
(f) Bill of material listing specifications, material, type, class, grade, or other information necessary for identification.
(g) Unpacking, depreservation, and reassembly instructions including special tools if required.
(h) Marking, including handling, structural markings, such as "Use no hooks," "Center of Gravity," and so forth.

APPENDIX B

TECHNICAL INFORMATION REPORT TECHNICAL CONTENT REQUIREMENTS

10. SCOPE

10.1 Scope. This appendix covers information that shall be included in technical information reports when specified in the contract or order. This appendix is mandatory only when data item description DI-MISC-80652 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-Q-9858 - Quality Program Requirements.

(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 (see 6.2), the issues are those cited in the solicitation.

PUBLICATIONS

NAVAL SEA SYSTEMS COMMAND (NAVSEA)

NDMS 920239-000 - Generic Technical Manual Contract Requirement (TMCR) for Hull, Mechanical and Electrical (HM&E) Equipment Technical Manuals for Ship's Main Propulsion Reduction Gear Assembly.

(Application for copies should be addressed to: Commander, Naval Surface Warfare Center Division Naval Sea Data Support Activity, 4363 Missile Way, Port Hueneme, CA 93043-4307.)

30. TECHNICAL INFORMATION REPORTS

30.1 List of preferred materials. The contractor list of preferred materials shall consist of the information depicted in table V. All materials proposed for principal parts per table I and as specified in the associated equipment specifications in table II shall be included on this list. The information discussed in paragraphs 30.1.1 through 30.1.4 of this appendix shall be included (see 3.1.11 and 3.1.11.8). This list shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing a separate list.

TABLE V. List of preferred materials - information required.

ITEM NO.	PRINCIPAL PART	PREFERRED MATERIAL SPEC NO./REV (WITH AMENDMENTS ETC. IF APPLICABLE)	ORDERING DATA (RAW MATERIAL)	FINISHED PRODUCT REQUIREMENTS	JUSTIFICATION IF UNSPECIFIED OR SPECIAL MATERIAL	PRIOR USE

30.1.1 Material technical information. Material technical information report requirements are divided into four general categories as follows (see 6.5.10):

(a) Principal part specified material.
(b) Principal part unspecified standard material.
(c) Principal part special material.
(d) Not a principal part.

Each acquisition requirement for specified, unspecified, and special material specifications shall be listed for all principal parts. Additionally, the contractor shall address differences between the raw material and finished product where additional processing (e.g., heat treatment) has been performed or quality assurance provisions are required in the final condition (e.g., fastener in final heat treated and machined condition may require a final magnetic particle or material property test). All inspections, tests, heat treatments (temperature and time at temperature), and differences in material properties shall be clearly specified. The revision level of each material specification proposed (including amendments etc.) shall be specified. Quality control and impact requirements (as required) shall be clearly stated.

30.1.2 Technical information for principal part specified materials. Technical information requirements are as specified in 30.1 and 30.1.1.

30.1.3 Technical information for principal part unspecified standard materials. Technical information requirements are as specified in 30.1 and 30.1.1. Additionally, unspecified standard materials can be used only when adequately justified taking into account both the technical and economical aspects and considering maintenance and support requirements as well as initial supply.

30.1.4 Technical information for principal part special materials. Technical information requirements are as specified in 30.1 and 30.1.1. Additionally special materials can be used only when adequately justified taking into account both the technical and economical aspects and considering maintenance and support requirements as well as initial supply. Technical justification for the selection and use of special materials shall be supported by an explanation of why the conditions under which it must perform are such that a special material is required. A copy of the complete specification shall be provided to the contracting activity. If a material is not ordered in strict accordance with a standard material specification (e.g., differing material properties or closer tolerances than required) this material is considered a special material.

30.1.5 Not a principal part. Materials for parts and components other than those listed in tables I and II shall be selected by the contractor. They shall be suitable for the intended service, have adequate quality control provisions specified and not conflict with any other requirements specified herein. These materials are not required to be included on the contractor list of preferred materials.

30.2 Special material requirements for electronic/electrical equipment. In addition to the requirements of 30.1, electronic/electrical equipment which may require spare or repair parts for maintainability or repair over the life of the ship shall meet the requirements of 30.2.1 and 30.2.2 (see 3.1.11 and 3.1.11.8).

30.2.1 Nonpreferred parts. Only specified materials shall be incorporated into the design of the equipment. The use of specified materials does not relieve the contractor of the responsibility for conforming to all performance requirements. When a contractor has determined that the performance requirements cannot be met by using a specified material, he shall immediately determine the "nonpreferred part" which will be suitable and obtain approval from the contracting activity prior to incorporation into the design. The contractor shall use previously approved nonpreferred parts prior to requesting approval to use a nonpreferred part not previously approved. The request shall be accompanied by accurate identifying information on the nonpreferred part in accordance with figure 14. Each nonpreferred part data sheet shall be given a number by the contractor which shall not be repeated for any other sheet prepared under the same order. This information shall be submitted and shall be accompanied by all necessary drawings (such as drawings indicating size, shape, material and method of assembly). Approval will not be granted for the use of parts of special or novel design where specified materials are suitable or available, except in cases where a new or improved part may be substituted which will significantly enhance the overall equipment performance and dependability. All nonpreferred part data sheets and/or the associated specification or source control drawing shall identify at least two manufacturers for each nonpreferred part. If only one source exists for the part at the time of delivery of the first unit, the contractor shall prepare, for approval by the contracting activity, a plan to ensure lifetime support for the single source part. In those cases where the use of a nonpreferred part has been authorized because of delivery schedules, the contractor shall take appropriate action so that a specified material may be easily and quickly installed by semi-skilled Naval field technicians. Mechanical replacement shall be provided for by allowing mounting space and holes for the specified material. Where matched parts (i.e., part with special characteristics beyond that required by equipment specification) are required for proper operation of the equipment, the matched parts shall be treated as nonpreferred parts.

30.2.2 Qualified products. When any electronic/electrical equipment specification requires that the product be subjected to and pass qualification tests, only products which are listed on the applicable Qualified Products List on the date of invitation for bids or which may be added to the Qualified Products List subsequent to that date shall be utilized in the construction of equipment. In the event no Qualified Products List has been issued, the contractor shall request instructions as to what testing will be required to determine whether the product meets the requirements of the specification.

30.3 Torsional and longitudinal vibration report. This report shall consist of data for all rotating parts, sufficient for the shipbuilder to perform calculations of torsional and longitudinal vibration in accordance with MIL-STD-167-2. This data shall apply to all units of a specific design. If similar in arrangement, differences in data for port and starboard units (if provided) may be shown by note(s) in lieu of furnishing a separate report. Torsional and longitudinal vibration report shall include the following data (see 3.1.12.2):

(a) Mass moment of inertia about rotational axis.
(b) Torsional stiffness.
(c) Maximum stress per radian of deflection.
(d) Maximum allowable torsional vibratory stress.
(e) Weight.
(f) Axial stiffness (Note: In addition to data for all rotating parts, data shall be provided for the thrust bearing(s)).
(g) Maximum allowable longitudinal vibration amplitude.

30.4 Dynamic analysis mathematical model report and detailed report. These reports shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note(s) in lieu of furnishing separate reports (see 3.1.15.2).

30.4.1 Dynamic analysis mathematical model report. Mathematical models which the contractor proposes to use shall be summarized in a report prior to performing a detailed analysis to permit the contracting activity to verify that acceptable methods are proposed which meet specification requirements. This report shall identify all critical areas to be analyzed and provide a mathematical outline and description of the analysis method.

30.4.2 Dynamic analysis detailed report. The detailed dynamic analysis report shall cover all critical areas for which shock stresses were calculated and shall indicate the applicable yield strength for each stress reported. (Refer to NAVSEA 0908-LP-000-3010 and SUPSHIP 280-3 for dynamic design and analysis method.) The analysis shall identify discrepancies between shock factors (see 3.1.15.1) and the dynamic analysis. Where calculated stresses exceed design allowables or where other unsatisfactory conditions are predicted as a result of the dynamic analysis, the contractor shall provide a proposal including cost and time estimates for correction of indicated discrepancies.

30.5 Weight management. The weight management plan shall include requirements to be followed by the contractor to ensure that the specified weight limit is not exceeded. As part of the weight management plan, weight reports shall be prepared for the first unit of each new design as specified in 30.5.1. This plan shall be followed for all units of a specific design. If similar in arrangement, differences in plan requirements for port and starboard units (if provided) may be shown by note(s) in lieu of furnishing a separate plan (see 3.1.16). The weight management plan shall also address, as a minimum, the following:

(a) Methods used for estimating and calculating weights and centers of gravity.
(b) Methods used to identify and eliminate hidden margins.
(c) Cognizant personnel and position in organization.
(d) Means to identify variances - alarm points.
(e) Program to correct variances in an expeditious manner.
(f) Methods of identifying and correcting overages in plates, castings, and forgings.
(g) Methods for contractor and subcontractor weight control.
(h) Brief description of equipment and setups to be used to weigh parts and assemblies.
(i) Evidence of management's commitment to a rigorous and effective program to minimize and control weight.

30.5.1 Weight reports. (See 3.1.16.)

30.5.1.1 Interim weight reports. The contractor shall prepare interim weight reports monthly, starting one month after award of contract. The weight reports shall identify individual weights as estimated, calculated or weighed. Each interim weight report, except the first submittal, shall identify and explain the reason for change from the previous interim weight report. Centers of gravity shall also be reported, referenced to a set of clearly defined reference planes perpendicular to each other. The weight reports shall list separately the dry, fluid and wet weights.

30.5.1.2 Final weight report. The contractor shall prepare a final weight report in the final stage of manufacture and prior to crating of the unit for shipment. The unit shall be weighed by the contractor using a certified weighing device. The scale weight shall be recorded by the contractor along with the following data:

(a) Type and make of weighing device.
(b) Accuracy of weighing device.
(c) Sensitivity of weighing device.
(d) Date weighing device was last calibrated.
(e) Weight of all rigging and handling gear, packing, and chafing gear included in the reported scale weight.
(f) List, with calculated or estimated weights and centers of gravity, accessories and other parts of the unit which have not been weighed.

30.6 Alignment and erection. The alignment and erection report shall include specific information for each gear unit and provide documentation of the results of contractor alignment and erection efforts. This data shall be consistent with the alignment and erection drawing discussed in 30.2.13 of appendix A and provide the shipbuilder and NAVSEA with sufficient information to aid in final assembly and reassembly after disassembly. This report will also be used to verify that specification requirements are met. The alignment and erection report shall consist of the following (see 3.2.3.12.1, 3.2.3.12.2, 3.2.3.12.3 and 3.2.15.1):

(a) Record of serial numbers of rotating parts.
(b) Rotor assembly chart showing location of rotating parts in gear housing by serial number.
(c) Results of measurements which establish internal gear alignment including housing flatness check, bearing crown thickness measurements, etc.
(d) Axial backlash and rotor clearances.
(e) Ship name and unit serial number.
(f) All measurements required to position rotating parts with respect to each other and with respect to the gear housing.

30.7 Bearing thickness measurement method for pivoted-shoe type bearing. A report describing the bearing thickness measurement method for pivoted-shoe type bearings shall include sufficient information to aid the shipbuilder and NAVSEA in re-establishing bearing dimensions if bearing repair or replacement is required and to ensure bearing adjustments can be made to obtain acceptable gear tooth contacts. This method shall consider the "stack-up" of bearing components which establishes the journal location and will be reviewed by the contracting activity for technical acceptability and to ensure specification requirements are met. This method shall apply to all units of a specific design (see 3.2.3.12.3).

30.8 Lubrication systems. A report of contractor lubrication requirements shall be prepared to aid the shipbuilder in design of the lubrication system, to verify compatibility with ship systems and to verify that specification requirements are met. This report shall consist of oil flow rate, pressures, and heat rejection rate at 60, 90, 120, and 130°F oil inlet temperatures for all design operating conditions (see 3.1.4) and all components including bearings, mesh oil nozzles, couplings, clutches, attached oil pump, and components requiring control oil. These lubrication requirements shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing a separate report (see 3.2.6).

30.9 Securing of threaded fasteners on rotating parts and parts internal to the gear housing. The report which discusses securing of threaded fasteners on rotating parts and on parts internal to the gear housing shall include a brief description and pictorial representation of each proposed locking method. Applicable specifications, drawings, and procedures shall be identified and be available to the contracting activity. The location of all the subject fasteners shall be identified by component, part number and drawing number. This report shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing a separate report (see 3.2.14.1.6 and 3.1.12.1.1).

30.10 Threaded fastener locking compound. The threaded fastener locking compound report shall demonstrate the acceptability of the contractor's "Process Specifications" covering application of threaded fastener locking compounds. This report shall apply to all units of a specific design (see 3.2.14.1.7.1 and 3.2.14.1.7.2).

30.11 Quality program. The quality program manual shall be in accordance with MIL-Q-9858 and be of sufficient depth to ensure that the technical and quality requirements of this specification are met. This manual shall apply to all units of a specific design (see 4.2).

30.12 Fabricated gear qualification test assembly. The plan for a final qualification of the composite assembly weld for fabricated gear assemblies shall identify all materials, full heat treatment details, stress reliefs and nitriding, carburizing or through-hardening cycles; and tests and inspections to be utilized. The plan for and results of this qualification assembly shall show conformance to acceptance criteria for mechanical properties after all heat treatments (including nitriding, carburizing or through-hardening) are complete (see 4.9.1).

30.13 Hardness inspection on surface hardened pinions and gears. The hardness inspection results of surface hardened pinions and gears shall be summarized in a report. This report will be used to verify technical acceptability and verify that specification requirements are met. This report shall consist of the following (see 4.10.1.2 and 4.10.1.3):

(a) For nitrided and carburized pinions and gears:

(1) Test coupon surface hardnesses, core hardnesses and full profile microhardness surveys to the core.
(2) Test coupon compensation for maximum grinding stock removal and corresponding case depths.
(3) Pinion and gear as ground surface hardnesses.
(4) The applicable unit and gear or pinion serial numbers.

(b) For carburized pinions and gears:

(1) Test coupon retained austenite.
(2) Test coupon results of metallographic examination.
(3) Pinion or gear results of grind burn inspection.
(4) Pinion or gear amount of material removed by grinding. The amount of material removed from tooth flanks shall be compared with the amount of material removed from tooth top lands if surface hardness measurements are taken on tooth top lands.

(c) For nitrided pinions and gears:

(1) Test coupon white layer thickness.
(2) Test coupon hardness level for case depth measurements (i.e., 40 Rockwell C or 110 percent of core hardness).
(3) Test coupon minimum acceptable surface hardness and minimum acceptable case depth after compensation for maximum grinding stock removal.

(4) Pinion or gear minimum acceptable surface hardness.
(5) Pinion or gear amount of material removed by grinding. The amount of material removed from tooth flanks shall be compared with the amount of material removed from the tooth top lands and end face of rim, as applicable.

30.14 Static tooth contact inspection results. The static tooth contact inspection results shall consist of good quality color photographs of the contact tapes. The applicable unit and gear or pinion serial numbers shall also be identified. Booklet cover shall be plasticized for protection of the contents (see 4.13.1).

30.15 Technical manuals. Technical manuals and technical manual procedure validation shall be in accordance with TMCR NDMS-920239-000 and as specified in the contract or order.

APPENDIX C

TEST REPORT TECHNICAL CONTENT REQUIREMENTS

10. SCOPE

10.1 Scope. This appendix covers information that shall be included in test reports when specified in the contract or order. This appendix is mandatory only when data item description DI-MISC-80653 is cited on the DD Form 1423.

20. APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

30. TEST REPORTS

30.1 Test reports. The test reports shall include the results of the spin tests and load tests performed by the contractor. The following information shall be recorded during the tests and included in the reports:

(a) Inlet oil temperature and oil pressure to the gear unit and associated equipment.
(b) Temperature of each journal and thrust bearing: babbitt temperature and drain temperature.
(c) Oil flow to gear unit and associated equipment.
(d) Vibration amplitudes.
(e) Mesh spray patterns prior to spin test.
(f) Any oil leaks, improper functioning sight-flow indicators, unusual bearing conditions, or any other abnormal conditions.
(g) Turning gear motor current and voltage. Document results of functional tests.
(h) Times, torques and speeds at low speed shaft.
(i) Results of visual inspections of gear internals including 360 degree of all rotating gears and pinions.
(j) Gear tooth contact patterns.
(k) Attached oil pump capacity and speed at which pump is self sufficient (when pump is provided).
(l) Results of functional tests of all gear unit and associated equipment.
(m) Oil pressure at most remote bearing (when pressure measurement provisions are provided).

APPENDIX D

MAIN REDUCTION GEAR SHAFTING

10. SCOPE

10.1 Scope. This document applies to the main reduction gear shafting design of all naval ships, surface and submarine, single- or multiple-shaft. 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).

MIL-S-24093 - Steel Forgings, Carbon and Alloy Heat Treated.

(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.

DRAWINGS

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.)

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

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

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. NOMENCLATURE

30.1 Nomenclature. Abbreviations and symbols used in this appendix are listed here for convenient reference. 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.

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
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
FL	Fatigue limit	lb/in^2
FS	Factor of safety	---
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	---

Symbol	Meaning	Units
M_T	Total bending moment	in-lb
N_1	Number of keys	---
OD	Outside diameter of shaft	inch
Q_T	Total torque (adjusted for gear ratio)	in-lb
RPM	Shaft rotational speed	r/min
r_f	Radius of flange fillet	inch
r_k	Radius of keyway fillet	inch
S_{ar}	Resultant alternating stress	lb/in^2
S_{as}	Alternating torsional shear stress	lb/in^2
S_b	Alternating bending stress	lb/in^2
S_{bt}	Shear stress of shaft coupling bolts	lb/in^2
S_c	Steady compressive stress	lb/in^2
S_{ck}	Allowable compressive stress of key	lb/in^2
S_s	Steady shear stress	lb/in^2
S_{sk}	Allowable shearing stress of key	lb/in^2
S_{sr}	Resultant steady stress	lb/in^2
T_T	Total thrust	pound
W	Width of key	inch
YP	Yield point of material	lb/in^2

40. GENERAL REQUIREMENTS

40.1 Design requirements. The design of the main reduction gear shafting shall be in accordance with the methods and criteria described herein. Material selection shall be in accordance with 3.1.11 and tables I, VII, and VIII.

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

40.3 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. In as much 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.

40.4 Factors of safety. Main reduction gear shafting designs shall meet the factors of safety tabulated in table VI.

TABLE VI. Factors of safety for main reduction gear shafting.

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

40.5 Clad weld inlays. Clad weld inlays shall not be used on main reduction gear shafts.

40.6 Shaft inside diameter. For controllable pitch propulsion systems, the inside diameter of the low speed gear shaft shall not be decreased from forward to aft.

50. DETAILED REQUIREMENTS

50.1 Design loads. Main reduction gear 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 and moment peaks. Steady and alternating stresses shall be analyzed separately, then combined using equations based on the Soderberg diagram to determine factors of safety.

50.1.1 Design torque. The ahead maneuvering torque (Q_T, see 3.1.4) shall be used for calculation of stresses and safety factors.

50.1.2 Total thrust load. The total thrust load (T_T) shall be as specified in 3.2.4.8.1.

50.2 Shafting design equations.

50.2.1 Steady stresses.

50.2.1.1 Steady shear stress. (Eq-1a) through (Eq-1c) apply for the calculation of steady shear stress (S_s).

$$S_s = \frac{Q_T \times OD}{2 \times J} \qquad \text{(In general)} \qquad \text{(Eq-1a)}$$

$$= \frac{5.1 \times Q_T \times OD}{OD^4 - ID^4} \qquad \text{(Hollow shaft)} \qquad \text{(Eq-1b)}$$

$$= \frac{5.1 \times Q_T}{OD^3} \qquad \text{(Solid shaft)} \qquad \text{(Eq-1c)}$$

Where:

Q_T is the design torque (see 50.1.1).

50.2.1.2 Steady compressive stress. (Eq-2) applies for calculation of the steady compressive stress (S_c) due to thrust.

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

Where:

T_T is the total thrust load (see 50.1.2).

50.2.1.3 Resultant steady stress. (Eq-3) applies for calculation of the resultant steady stress (S_{sr}).

$$S_{sr} = \left[S_c^2 + (2 \times S_s)^2\right]^{1/2} \qquad \text{(Eq-3)}$$

Where:

S_S is the steady shear stress (see 50.2.1.1).
S_C is the steady compressive stress.
(see 50.2.1.2).

50.2.2 Alternating stresses.

50.2.2.1 Total bending moment. The total bending moment, M_T, shall be calculated in accordance with 50.2.2.1.1 or 50.2.2.1.2, as applicable.

50.2.2.1.1 Bending moments for low speed gear shafts with rigid couplings. For main reduction gear units which are rigidly coupled to the line shaft, the following loads shall be included in total bending moment calculations for low speed gear shafts:

(a) The weight of propulsion shafting. Bending moments due to propulsion shafting weight will consider the following conditions (see 3.2.15.2):

(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.

(b) Gear tooth loads.

50.2.2.1.2 Bending moments for low speed gear shafts with flexible couplings and all other shafts. The following loads shall be included in total bending moment calculations for low speed gear shafts which are flexibly coupled to the line shaft and all other shafting in the gear unit:

(a) The weight of the gear (including internal components such as piping) and gear shaft.
(b) Gear tooth loads.
(c) Coupling reaction loads.

50.2.2.2 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 50.2.2.2.1 and 50.2.2.2.2.

50.2.2.2.1 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 15 of this appendix. 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.

50.2.2.2.2 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 16 and 17 of this appendix respectively.

50.2.2.2.3 Holes in shafting. Unless otherwise specified (see 6.2), drilling of holes in gear unit shafts is prohibited. When holes are drilled in shafts, a stress concentration factor of three for the bending stress shall be applied. The stress concentration factor to be applied for the torsional stress shall be in accordance with R.E. Peterson's Stress Concentration Factors.

50.2.2.3 Alternating bending stress. (Eq-4a) through (Eq-4c) apply for the calculation of alternating bending stress (S_b) due to bending moment (M_T, see 50.2.2.1).

$$S_b = \frac{M_T \times OD}{2 \times I} \qquad \text{(In general)} \qquad \text{(Eq-4a)}$$

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

$$S_b = \frac{10.2 \times M_T}{OD^3} \qquad \text{(Solid shaft)} \qquad \text{(Eq-4c)}$$

50.2.2.4 Alternating (vibratory) torsional shear stress. Alternating torsional shear stresses in the shaft are generated by the propulsor and occur predominantly at blade frequency, except for diesel propulsion plants, where the cyclic engine torque is significant also.

Unless otherwise specified (see 6.2), (Eq-5) shall be used to approximate the alternating torsional shear stress (S_{as}) as a function of the steady shear stress (S_s, see 50.2.1.1).

$$S_{as} = 0.05 \times S_s \qquad \text{(Eq-5)}$$

If the alternating torsional shear stresses, as determined by the torsional vibration analysis (see 3.1.12.2), are found to be larger at the corresponding shaft RPM than the approximation given by (Eq-5), the alternating torsional shear stresses determined by the vibration analysis shall be used for design calculations.

50.2.2.5 Resultant alternating stress. (Eq-6) applies to the calculation of the resultant alternating stress which shall be found by multiplying the alternating bending stress (S_b, see 50.2.2.3) and torsional stress (S_{as}, see 50.2.2.4) by the appropriate stress concentration factor (K_b or K_t, see 50.2.2.2.1 through 50.2.2.2.3, as applicable), and then combining the results as prescribed in the maximum shear theory:

$$S_{ar} = [(K_b \times S_b)^2 + (2 \times K_t \times S_{as})^2]^{1/2} \qquad \text{(Eq-6)}$$

50.2.3 Factor of safety. (Eq-7a) and (Eq-7b) apply to the calculation of the factor of safety (FS), based on the resultant steady stress (S_{sr}, see 50.2.1.3), the resultant alternating stress (S_{ar}, see 50.2.2.5), and the minimum allowable material yield point (YP) and fatigue limit (FL) defined by the appropriate material specification.

$$\frac{1}{FS} = \frac{S_{sr}}{YP} + \frac{S_{ar}}{FL} \qquad \text{(Eq-7a)}$$

$$FS = \frac{1}{\frac{S_{sr}}{YP} + \frac{S_{ar}}{FL}} \qquad \text{(Eq-7b)}$$

50.3 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.

50.3.1 Design formulas. (Eq-8) and (Eq-9) apply to the calculation of the minimum key width (W) and contact depth of the keyway (b_1), respectively, based on the design torque (Q_T, see 50.1.1), number of keys (N_1), effective length of the key (B_e), the diameter of the shaft taper at the midlength of B_e (D_m), the allowable shearing stress of the key (S_{sk}, see table VII), the allowable compressive stress of the key (S_{ck}, see table VIII), and the diameter at the midpoint of contact depth b_1, at midlength B_e (D_k), as applicable.

$$W = \frac{2 \times Q_T}{N_1 \times B_e \times D_m \times S_{sk}} \qquad \text{(Eq-8)}$$

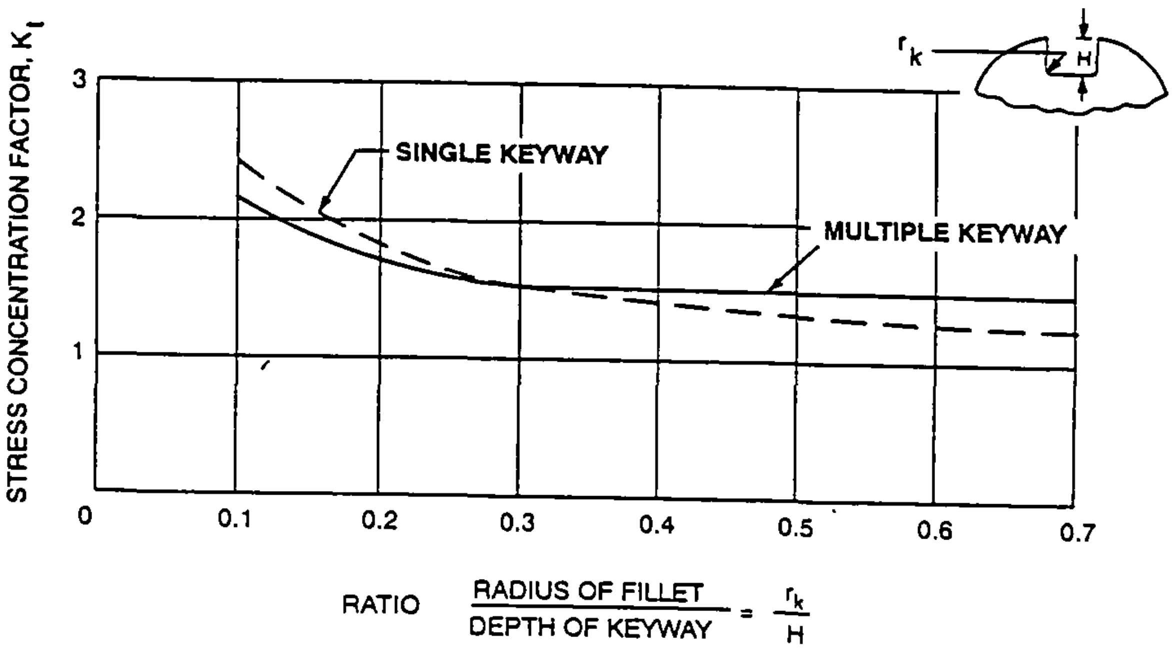
$$b_1 = \frac{2 \times Q_T}{N_1 \times B_e \times D_k \times S_{ck}} \qquad \text{(Eq-9)}$$

TABLE VII. Allowable shearing stress for key materials.

Material	Specification	S_{sk} Allowable shearing stress, (lb/in^2)	
		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 B 150, 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	Specification	S_{ck} Allowable compressive stress, (lb/in^2)	
		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 B 150, 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



EB38281.0193

FIGURE 15. Stress concentration factors at keyway fillets in torsion.

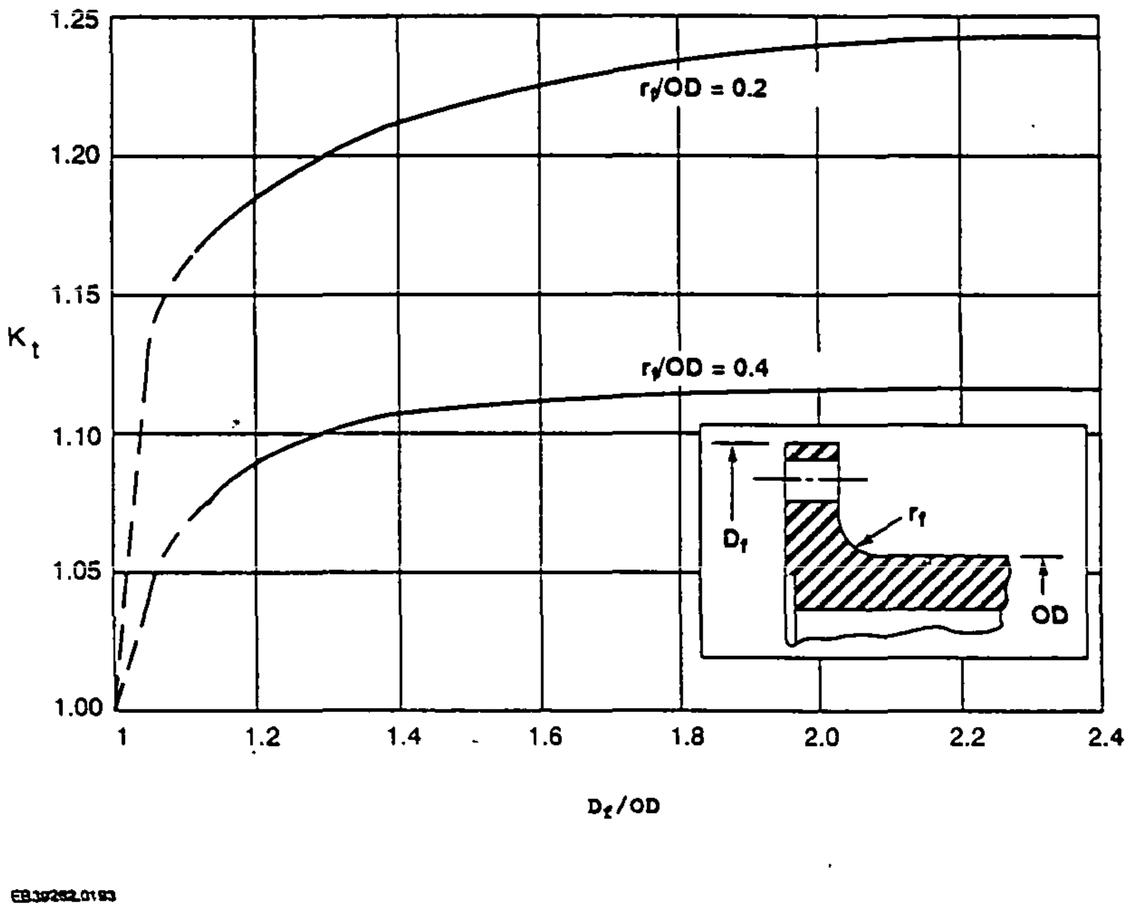
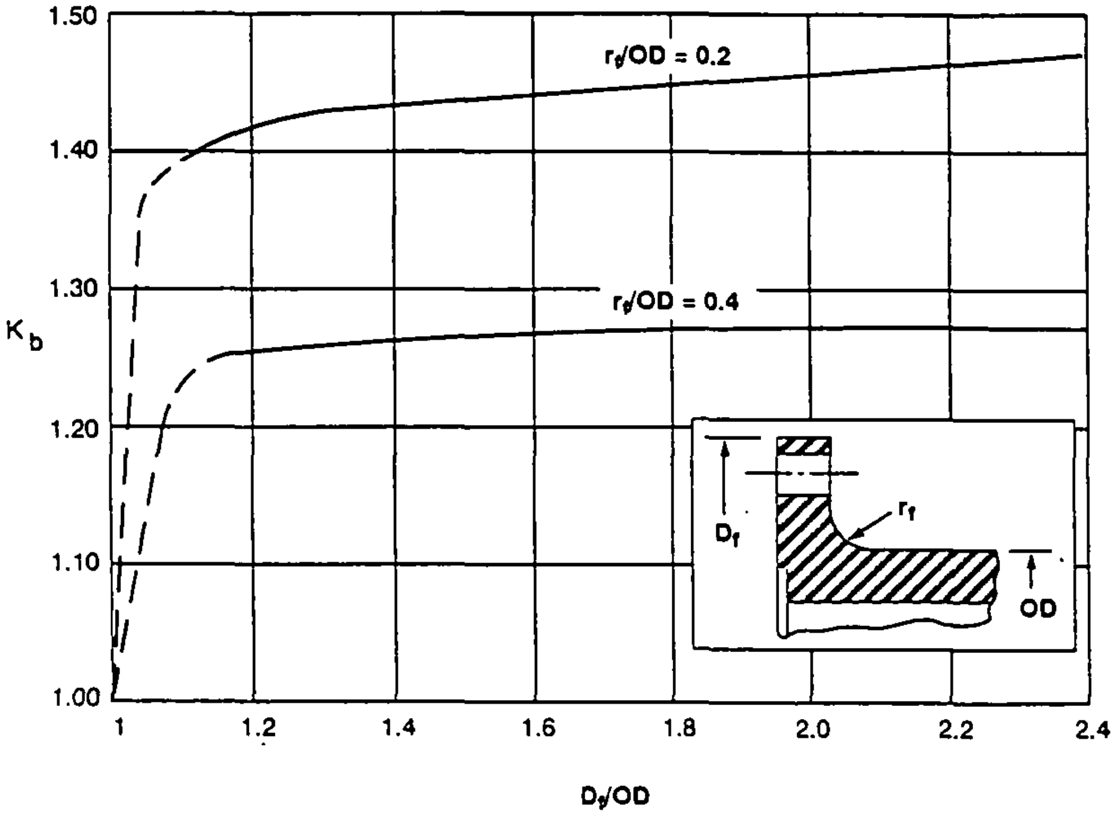


FIGURE 16. Stress concentration factor, K_t, for torsion at flange fillet.

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



EB39263.0193

FIGURE 17. Stress concentration factor, Kb, for bending at flange fillet.

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

APPENDIX E

GEAR ACCURACY MEASUREMENTS

10. SCOPE/CLASSIFICATION

10.1 Scope. This appendix provides the accuracy requirements for measurement systems (i.e., measurement system calibration and certification requirements) used to determine the accuracy of main propulsion reduction gears. This appendix also provides gear error limits and requirements for measurement of main propulsion reduction gears. This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

10.2 Classification. Main propulsion reduction gears shall conform to grade 1 or 2 accuracy as specified (see 6.2).

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).

STANDARDS

MILITARY
MIL-STD-45662 - Calibration Systems Requirements.

(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. REQUIREMENTS

30.1 Nomenclature. Nomenclature for gear accuracy shall be as specified in 30.1.1 below.

30.1.1 Gear accuracy definitions.

Ahead flank is defined as the working, or contacting, side of the gear tooth when the main propulsion reduction gear is propelling the ship in the ahead direction.

Flange end journal is the journal closest to the flange located on the driven end of the pinion or driving end of gear.

Opposite end journal is the journal farthest from the flange end.

Journal roundness error is defined as the difference in radii of two concentric coplaner circles which just contain the measured profile of the journal surface.

Runout is a composite tolerance used to control the functional relationship of one or more features of a part to a datum axis.

Journal runout is defined as the total radial variation in a direction perpendicular to the axis of rotation of the journal surface from a surface of revolution when the journal is rotated through 360 degrees.

Perpendicularity is the condition of a surface, median plane, or axis at a right angle to a datum plane or axis.

Perpendicularity tolerance specifies the tolerance zone defined by two parallel planes perpendicular to a datum plane, or axis, within which the surface or median plane of the considered feature must lie.

Concentricity is the condition where the axes of all cross-sectional elements of a surface of revolution are common to the axis of a datum feature.

Concentricity tolerance specifies a cylindrical tolerance zone whose axis coincides with a datum axis and within which all cross-sectional axes of the feature being controlled must lie.

Pitch is defined as the distance in the transverse plane from a point on a given flank of one tooth to a corresponding point on the flank of an adjacent tooth as measured on a circle concentric with the center of rotation.

Average pitch is defined as the average of all actual pitch measurements taken for one revolution of the gear being measured.

Pitch variation (ISO fpt; AGMA V_P) is defined as the difference, plus or minus, between the average of all pitch measurements for one revolution and the measured distance between corresponding points on any two adjacent teeth. This error is equal to the algebraic difference between average and actual pitch measurements.

Index variation (ISO Fpk; AGMA V_{apk}) (formerly accumulated tooth spacing error) is defined as the deviation plus to minus of any two pitch measurements from the average of all pitch measurements taken during one revolution. The largest such deviation is the maximum index variation (ISO Fp; AGMA V_{ap}).

Undulation error is defined as the peak to peak amplitude of a periodic sinusoidal surface wave along the helicoidal surface of the tooth.

Lead mismatch is defined as the algebraic deviation in slope between the helicoidal surfaces of a mating gear and pinion over the full face width of the helix, less end reliefs, measured at the pitch diameter normal to the tooth surfaces when meshed together with axes parallel.

Design lead mismatch is defined as the intentional lead mismatch provided to compensate for tooth distortions and temperature differentials which result from load.

Lead mismatch error is defined as the algebraic deviation between the actual lead mismatch and the design lead mismatch.

Lead form error is defined as the distance between two parallel lead lines which just contain the gear tooth lead measurement as measured at the pitch diameter over the full face width of the teeth of each helix, less end reliefs.

Profile error is defined as the deviation from a theoretical gear tooth profile or from the design-modified profile as measured in the transverse plane.

Individual profile slope error is defined as the distance perpendicular to the theoretical involute slope and measured from the theoretical (or design-modified) slope, to the actual slope line at the location shown on figure 18 of this appendix.

Total profile slope error is defined as the algebraic difference between the individual profile slope errors of mating elements as shown on figure 18 of this appendix.

Profile form error is defined as the deviation of the actual profile from the actual slope line as shown on figure 18 of this appendix.

Surface finish is defined as the surface-texture irregularities resulting from the manufacturing process or the cutting action of tools or abrasive grains.

30.2 General requirements. During measurement system certification and measurement of main propulsion reduction gears, the general requirements specified in 30.2.1 through 30.2.5 shall apply.

30.2.1 Environment. The measurement system and gear element being measured shall be at a temperature of 66 to 70°F. The maximum temperature change of the measurement system and gear shall not exceed 2 degrees during each of the measurement periods described in 30.3, 30.4.4, 30.4.6, and 30.4.7 below. A measurement period begins with the initial runout measurement and ends with the final runout measurement on the precision sphere or on the reference surfaces.

30.2.2 Reference axis. The reference axis will be the axis of the journal.

30.2.3 Reference surfaces. The journal surface will be the reference surface. If one journal will be inaccessible during "set-up" for machining or measurement of gear teeth, an axial reference surface (i.e., plane perpendicular to axis of gear) and a radial reference surface, machined at appropriate locations, shall be provided and used in conjunction with the accessible journal for ensuring the gear is properly positioned relative to the axis of the work table.

The accuracy of the radial reference surface shall be verified by concentricity measurements taken while supported by V-blocks at each journal or taken while on a rotary table. If the accuracy of the radial reference surface is taken while on a rotary table, a reference standard for roundness that is round within 0.000010 inch (0.00025 millimeter) shall be used in conjunction with the measurements on the radial reference surface. An electronic indicator with matched-impedance recorder shall be used. The radial reference surface shall have a maximum error as specified by the contractor to ensure this surface is sufficiently accurate to be used for the runout measurements specified in 30.4.3.

The accuracy of the axial reference surface shall be verified by perpendicularity measurements taken while supported by V-blocks at each journal. An electronic indicator with matched-impedance recorder shall be used. The axial reference surface shall have a maximum error as specified by the contractor to ensure this surface is sufficiently accurate to be used for the runout measurements specified in 30.4.3.

30.2.4 Tooth-related diagrams. The following identification shall be used:

(a) The helices shall be identified "RH" or "LH" (for right or left hand helix).
(b) The tooth flank shall be identified as "IV" or "OV" (inside or outside the "V").

30.2.5 Journal-related diagrams. The journal shall be identified as "FE" or "OE" (flange end or opposite end).

30.3 Certification. When specified (see 6.2), the requirements in this section shall be met to verify the accuracy of measurement systems used to determine the accuracy of main propulsion reduction gears. The measurements taken to certify the gear accuracy equipment shall be as specified in 30.4 as modified by this section. The contractor is responsible for obtaining certification. The certification facility shall be as specified (see 6.2).

30.3.1 General requirements. The contractor shall arrange to have gear measurement devices and work support tables used for pitch, profile, and lead gear accuracy measurements certified by the certification facility. If the certification facility cannot or does not certify the equipment being used, the contractor shall demonstrate conclusively to the contracting activity and certification facility representatives that the equipment necessary to produce the type and quality of measurements described in this appendix are present in the contractor's facility. Certification of each measurement device and work table used to measure main propulsion reduction gear elements covered by this specification for pitch, profile, and lead measurements shall occur on a yearly basis (minimum). It is required that a representative of the contracting activity and certification facility be present during certification. The certification facility requires an IBM PC compatible computer system to be available. If this system is not available, then the contractor shall inform the certification facility prior to certification.

30.3.1.1 Certification facility reference standard. In order to establish the accuracy of a measurement system, the contractor shall arrange to have the certification facility reference gear brought to the contractor's place of measurement and a series of measurements taken (on each measurement system) as discussed in 30.3.3 and 30.3.4 below. These measurements will be analyzed to determine the measurement system capability. The certification facility reference standard is available on a first come, first serve basis. Any disputes arising out of the measurement of the certification facility reference standard shall be resolved by a mutually acceptable procedure between the contracting activity, certification facility, and the contractor.

30.3.1.2 Requirements for measurement charts and numerical printouts. For the measurements discussed in 30.3.2, 30.3.3, and 30.3.4 below, measurement charts and numerical printouts shall be developed. These charts and printouts shall be annotated with date, time, error measurement, machine/device (make, model, and serial number), probe radius of curvature, probe type (i.e., ball or standard knife edge), gear element identification, journal or tooth identification, and other specific measurement machine settings required to describe charts and numerical printouts (e.g., pause time at each measurement point and points per millimeter of travel for three axis coordinate gear profile/lead inspection systems).

30.3.1.3 Tooth locations and special instructions. For the verification measurements, tooth locations and special instructions will be supplied by the certification facility representatives. The certification facility reference gear has teeth which have been numbered by the certification facility. These tooth numbers are to be used for the measurements.

30.3.1.4 Contractor reference standards. The contractor may also have its own references measured and certified by the certification facility. Thereafter, the measurement system accuracy may be reverified either by measurement of the certification facility reference standard or the contractor's own certified references. If the contractor has its own references certified, the term "certification facility reference" (i.e., gear, standard) may be replaced with "certified contractor reference" throughout this specification.

30.3.1.5 Measurement device calibration requirements. All measurement equipment used in establishing the accuracies which are required as listed in 30.4 for main propulsion reduction gears shall be calibrated and meet the requirements of MIL-STD-45662. At the time of measurement, the contractor shall be able to demonstrate that a system for calibration of all measuring and test equipment has been established to assure accuracy of all devices used during measurement. The contractor shall allow the contracting activity and certification facility to review calibration results upon request to verify conformance with contractual requirements. The description of the calibration system and applicable procedures and reports of calibration shall be made available to contracting activity and certification facility representatives upon request.

30.3.2 Measurement machine work table certification. If the reference gear is not successfully measured on a work table which may be used to support main propulsion reduction gear elements during the gear accuracy measurements discussed in 30.4.4, 30.4.6, and 30.4.7 below that table shall be certified by the certification facility. The certification requirements for measurement machine work tables are defined in 30.3.2.1 and 30.3.2.2 below.

30.3.2.1 Measurement requirements. The stability of the work table axis of rotation shall be determined using the certification facility or contractor precision sphere.

30.3.2.1.1 Work table radial runout. With an electronic indicator, record the radial runout of the precision sphere, which is round within 0.000010 inch (0.00025 millimeter), mounted on the work table (as concentric as possible to the axis of rotation) for three work table revolutions (minimum). The precision sphere shall be located at approximately the height of the grinding wheel or probe (e.g., 42 ± 6 inches above work table for Hofler grinding machines). Strip chart recordings are to be taken at 5,000 magnifications. These measurements shall be taken on the side of the sphere at the three or nine o'clock position, assuming that the grinding wheel is at the twelve o'clock position when viewed from above.

30.3.2.1.2 Work table axial runout. With an electronic indicator, record the axial runout of the precision sphere, which is round within 0.000010 inch (0.00025 millimeter), mounted on the work table (as concentric as possible with the axis of rotation) for three work table revolutions (minimum). Strip chart recordings are to be taken at 5,000 magnifications.

30.3.2.2 Accuracy limits. The rotary table radial and axial runout shall each be less then 0.000080 inch (0.0020 millimeter).

30.3.3 Pitch measurement machine certification. Pitch measurements shall be taken on the certification facility reference gear (if available and usable) for verification of a contractor's measurement equipment accuracy and repeatability. Verification measurements on the reference gear are to be taken as outlined in 30.3.3.1 and 30.3.3.2 below.

30.3.3.1 Measurement requirements.

30.3.3.1.1 Pitch measurement machine certification with reference gear.

30.3.3.1.1.1 Locate reference gear on work table. Set-up the certification facility reference gear with the flange end resting on the measurement machine work table with each journal running out less than 0.000150 inch (0.00381 millimeter). This runout shall be measured as described in 30.4.3 below. Runout charts shall be prepared as described in 30.3.1.2.

30.3.3.1.1.2 Parallel planing of probes for pitch measurements. An imaginary line connecting the centers of the two ball probes of the circular pitch measurement machine shall lie in a plane that is parallel with the end faces of the gear being measured within 0.002 inch (0.05 millimeter).

30.3.3.1.1.3 Pitch variation measurement. Measurements are to be taken on each tooth at the middle of the lower helix (i.e., flange end) set to record pitch outside the "V". The work table shall be rotated with the gage head cycling for a sufficient length of time to ensure stability of the measurement system. Pitch variation (fpt) shall then be recorded for at least three revolutions of the reference gear. The operator shall then stop the gage head from cycling, break the measuring cycle and repeat measurements for at least three revolutions of the reference gear. Pitch variation measurements shall be taken and recorded as described in 30.4.4 below, except as modified by this paragraph. Numerical printout accuracy and resolution shall be 0.000004 inch (0.0001 millimeter).

30.3.3.1.1.4 Uncertified contractor reference gear. If the certification facility reference gear is unavailable or unusable and if the contractor does not have certified references as specified in 30.3.1.4, measurements are to be taken on a contractor supplied gear (uncertified reference gear) on which the above measurement capabilities are to be demonstrated. The uncertified contractor reference gear, if possible, is to be of a size similar to the certification facility reference gear (approximately 34 inches in diameter). The uncertified contractor reference gear shall be recognized by the certification facility representatives as an acceptable substitute for the certification facility reference gear. During the measurement of the contractor's uncertified reference gear, all instructions contained in 30.3 shall be adhered to as if the uncertified contractor reference gear was the certification facility reference gear.

30.3.3.1.1.5 Final runout measurement. A final runout measurement on the journal surfaces shall be taken as specified in 30.3.3.1.1.1 above.

30.3.3.2 Accuracy limits. Six revolutions of pitch variation measurements (total of 1,596 measurements for the certification facility reference gear) shall be taken on the reference gear or an acceptable substitute. Corresponding tooth measurements from the six revolutions of data shall agree within 0.000016 inch (0.0004 millimeter) with the following exceptions:

(a) For the certification facility reference gear, no more than 27 of the 1,596 measurements may disagree by more than 0.000016 inch (0.0004 millimeter).
(b) For the certification facility reference gear, no more than one measurement may disagree by more than 0.000024 inch (0.0006 millimeter).
(c) The accuracy limits for certified or uncertified contractor references shall be established by the certification facility for that particular reference gear.

30.3.4 Involute profile and lead measuring machine certification. Profile and lead measurements shall be taken on the certification facility reference gear for certification facility verification of a contractor's measurement equipment accuracy. Verification measurements on the reference gear are to be taken as outlined in 30.3.4.1 and 30.3.4.2 below.

30.3.4.1 Measurement requirements.

30.3.4.1.1 Profile and lead measurement machine certification with reference gear.

30.3.4.1.1.1 Locate reference gear on work table. Locate reference gear on work table as specified in 30.3.3.1.1.1 above.

30.3.4.1.1.2 Probe zeroing for profile measurements. The probe shall have a zero location in the axial direction to properly locate it for the required profile measurements which is established as follows:

(a) With gear properly set up on the work table, rotate the holder of the pickup probe so that it is set to read displacement in the axial direction.
(b) Bring the probe into contact with the lowermost end of "number one" gear tooth until the probe displacement indicator reads zero.
(c) Compensate for the probe radius and zero the face width indicator. This is the axial (face width) zero for the profile measurements. Face width distances for profile measurement locations shall be measured from this starting position.

30.3.4.1.1.3 Profile and lead measurement. The certification facility representatives will choose 15 teeth to be measured. The tooth numbers will be supplied and will apply to the teeth chosen on the lower helix (i.e., flange end) of the certification facility reference gear. On each of the 15 teeth, 3 profiles and 3 lead measurements shall be taken at the axial and radial coordinates supplied by the certification facility. In addition, a repeat set of profile and lead measurements shall be taken on the above measured teeth. All measurements taken on the reference gear shall be outside the "V" (OV). Lead and profile measurements shall be taken and recorded as described in 30.4.6 and 30.4.7 below, except as modified by this paragraph. Specific measurement machine settings required to obtain the required level of accuracy for profile and lead measurements shall be determined during certification. For example, for the Hofler TPF-40 three axis coordinate gear inspection system, the pause time at each measurement point and points per millimeter of travel (e.g., 3 points/mm for profile and 1 point/mm for lead measurements) shall be determined. Magnification of the generating path length shall be 8 to 1 for profile measurements and 1 to 1 for lead measurements.

30.3.4.1.1.4 Runout measurement. In addition to the requirements of 30.3.4.1.1.1 above, runout measurements shall be taken on the journal surfaces after the first set of data; and before and after the repeat set of data. Runout measurements shall be taken as specified in 30.3.3.1.1.1 above.

30.3.4.2 Accuracy limits. The first and repeat set of profile and lead measurements shall agree with those taken by the certification facility within the required (guaranteed) accuracy as specified below:

(a) Lead

Required Acc. = $\pm(20+20\sqrt{F}/\cos\psi)(\mu\ in.)$
Where: F = Face Width (in.).
ψ = Helix Angle (deg.).

(b) Profile

Required Acc. = $\pm(20+2B+D/2)\ (\mu\ in.)$
Where: B = Roll Angle (deg.).
D = Pitch Diam. (in.).

30.4 Main propulsion reduction gear accuracy measurement. The error measurements for the main propulsion reduction gears which are to be documented on chart recordings are as follows:

(a) Journal roundness (or equivalent for axial and radial reference surfaces).
(b) Runout.
(c) Pitch variation and index variation.
(d) Undulation.
(e) Lead mismatch and lead form measurements.

(f) Profile measurements.
(g) Gear tooth surface finish.
(h) Journal surface finish

30.4.1 General requirements.

30.4.1.1 Requirements for measurement charts and numerical printouts. Unless otherwise specified (see 6.2), a legible chart shall be recorded for every set of measurements listed in 30.4 above. Charts shall be annotated with the data listed in 30.3.1.2 along with the date of last certification (measurement device and work table). For pitch measurements, the numerical printouts shall also be recorded. Additionally, the results of the analyses required by 30.4.4.2 (difference in index variation values and 1 through 20 cycle tooth errors) and 30.4.5.1(a) (magnitude of undulation levels) shall be documented.

30.4.2 Journal roundness error. For grades 1 and 2 main propulsion reduction pinions and gears, journal roundness error measurements shall be performed on every pinion and gear produced.

30.4.2.1 Measurement requirement. Measurement shall be accomplished with center plugs, if any, removed. If a rotary table is used, it shall be certified as specified in 30.3.2 unless the contracting activity reference gear was successfully measured on the subject work table. An electronic indicator with matched impedance recorder shall be used. Roundness shall be measured on each journal surface at the bearing axial centerline. Measurements shall be taken for at least two uninterrupted revolutions of each journal. Measurements are to begin at the position of "number one" tooth and proceed through increasing tooth numbers. Requirements to stamp-etch tooth numbers are specified in 30.6(a) below. Chart recordings are to be taken at a minimum of 5,000 magnifications or the maximum magnification feasible to ensure that the chart recording will fit on the largest recording paper available. Chart recording magnification shall be in no case less than 1,000 magnifications. For roundness measurements taken on a rotary table, a reference standard for roundness that is round within 0.000010 inch (0.00025 millimeter) shall be used in conjunction with the measurements on the journal surfaces to verify journal roundness. As an alternative to measurement on a rotary table journal roundness may be measured using another measuring device (e.g., bridge gauge).

30.4.2.2 Accuracy limit. The error shall not exceed the following:

Pinion or gear	Grade 1 Maximum error allowed	Grade 2 Maximum error allowed
3,000 r/min and above	0.000050 inch (0.00127 millimeter)	0.000100 inch (0.00254 millimeter)
200 r/min and below	0.000250 inch (0.00635 millimeter)	0.000300 inch (0.00762 millimeter)
All others	0.000100 inch (0.00254 millimeter)	0.000200 inch (0.00508 millimeter)

30.4.3 Runout. For grades 1 and 2 main propulsion reduction pinions and gears, runout error measurements shall be performed on every pinion and gear produced.

30.4.3.1 Measurement requirement. Runout of the work piece axial centerline relative to the work table axial centerline shall be measured on the work table of the gear measurement machine or on a gear finishing machine. If both journals are accessible, the measurement is to be taken using two electronic indicators, one on each journal at the bearing axial centerline. The indicator on a given journal is to be in line with (directly over or under) the indicator on the other journal. If one journal is inaccessible, measurements shall be taken on an axial and radial reference surface as discussed in 30.2.3 above in addition to the required runout measurement on the accessible journal. Runout is to be taken before and after the measurements described in 30.4.4, 30.4.6, and 30.4.7. The measurement is to be recorded on strip or polar charts and is to consist of three successive revolutions of runout measurements. Runout measurements are to begin at the "number one" tooth and proceed through increasing tooth numbers. The direction of positive movement is radially outward for journal runout measurements. Strip chart recordings are to be taken at a minimum of 5,000 magnifications or the maximum magnification feasible to ensure that the chart recording will fit on the largest recording paper available. Strip chart recording magnification shall be in no case less than 1,000 magnifications. If the element is moved or bumped, all gear tooth measurement data recorded after the last acceptable runout reading shall be rejected. New gear tooth measurement data shall then be recorded after any re-adjustment and after a new set of runout data is taken. Tooth measurements are rendered void if runout variation exceeds requirements specified in 30.4.3.2 below prior to or after a given gear tooth measurement.

30.4.3.2 Accuracy limit. A pinion or gear shall be positioned on the work table to meet the following requirements:

Pinion or gear	Grade 1 Maximum journal runout error allowed	Grade 2 Maximum journal runout error allowed
3,000 r/min and above	0.000150 inch (0.00381 millimeter)	0.000300 inch (0.00762 millimeter)
200 r/min and below	0.000500 inch (0.0127 millimeter)	0.000700 inch (0.0178 millimeter)
All others	0.000300 inch (0.00762 millimeter)	0.000500 inch (0.0127 millimeter)

The runout as measured on the axial and radial reference surfaces, if used, shall be as specified by the contractor to ensure the pinion or gear is properly located within the above requirements.

30.4.4 Pitch variation and index variation. For grades 1 and 2 main propulsion reduction pinions and gears, pitch and index variation error measurements shall be performed on every pinion or gear produced.

30.4.4.1 Measurement requirement. Pitch variation and index variation shall be measured using an automatic single flank tooth comparator device as follows:

(a) The pinion or gear shall be positioned and runout measured as described in 30.4.3 above.
(b) The probe shall have the form of a sphere or slice of a sphere which is mounted symmetrically about an axis perpendicular to the axis of the pinion or gear being measured and which has a local radius of curvature at the contact point which is as large as practically possible. The radius of curvature of the probes at the contact point shall be sized as closely as practical to that used in measuring profile and lead.
(c) The probes shall be positioned as specified in 30.3.3.1.1.2. For measurement devices which do not have electronic diagnostic checks and where comparator calibration procedures are required, compensation for cosine of the helix angle and cosine of the pressure angle shall be verified during probe positioning by placing feeler stock against the tooth surface.
(d) Pitch variation and index variation measurements are to be taken on the ahead flanks, near the pitch diameter at mid-face width, one location for each tooth and each helix. Three revolutions of data shall be taken. Chart recordings are to be taken at a minimum of 5,000 magnifications or the maximum magnification feasible to ensure that the chart recording will fit on the largest recording paper available. Chart recording magnification shall be in no case less than 1,000 magnifications. Numerical printout accuracy and resolution shall be 0.000004 inch (0.0001 millimeter).

30.4.4.2 Accuracy limit. For grades 1 and 2, the error shall not exceed those specified on figures 19 and 20 of this appendix. For grade 1 only, the maximum difference in index variation values between RH and LH helices of each pinion and gear at any circumferential tooth location shall not exceed (0.001 TAN ψ) inch, where ψ is the helix angle in degrees. Also, for grade 1 only, the maximum peak-to-peak amplitude of the 1 through 20 cycle tooth errors of index variation of each pinion and gear shall not exceed 1/N times the allowable value on figure 20 of this appendix, where N is the cyclic error harmonic number.

30.4.5 Undulation error.

30.4.5.1 Measurement requirement. For grade 1 main propulsion reduction pinions and gears, undulation error measurements shall be performed on every pinion or gear produced. For grade 2 main propulsion reduction pinions and gears, undulation error measurements shall be accomplished on the first pinion or gear of each design; and from each succeeding lot of 5 pinions or gears of each design, one pinion or gear randomly selected.

(a) Undulation error measurements shall be made on the ahead flank of four teeth spaced approximately 90 degrees apart on each helix at the pitch diameter. The device employed shall be either the Tomlinson 3-ball principle or 10,000:1 magnified lead check or equivalent. The Tomlinson 3-ball machine shall be set to 4,000:1 magnification after correction for the action of the Tomlinson undulation head since the recorded measurement will be twice the actual peak-to-peak undulation error when set at the proper wavelength. The contractor shall perform the necessary analysis on the measurement machine output data to ensure the magnitude of required undulation limits are not exceeded. An electronic indicator with a matched-impedance electronic recorder shall be used for the Tomlinson 3-ball inspection. The movement of the chart shall be directly proportional to movement of the measurement device along the helix.

(b) For gear teeth finish machined on work tables which utilize a worm drive to index the blank, the span of the undulation measurement device shall be set to an odd multiple of the wavelength resulting from cyclic error of the worm. Wavelength (λ) resulting from the cyclic error of the worm or other process that created the undulation is equal to:

$$\lambda = \frac{\pi D}{\frac{n_w}{n} \text{ SIN } \psi}$$

Where: D = Pitch diameter of gear or pinion (i.e., work piece).
n_w = Number of teeth on worm wheel of round work table.
ψ = Helix angle of work piece at pitch diameter.
n = Number of worm threads.

(c) For gear teeth finish machined on work tables which do not utilize worm gears, the undulation measurements shall be made as described in 30.4.5.1(a) above, with the span of the device initially set at 25 percent of the face width. The record thus produced shall be analyzed to determine the wavelength of any undulation present. The measurement shall then be repeated with the span of the device set at an odd multiple of the wavelength detected by the first measurement.

30.4.5.2 Accuracy limit. For the ahead flanks of both helices; the undulation level for grades 1 and 2 shall be 0.000060 inch (0.0015 millimeter) or below and as required to meet noise performance requirements.

30.4.6 Lead mismatch and lead form. For grades 1 and 2 main propulsion reduction pinions and gears, lead error measurements shall be performed on every pinion or gear produced.

30.4.6.1 Measurement requirement. The lead errors shall be established from lead measurements taken on the pinions and gears as follows:

(a) The pinion or gear shall be positioned and runout measured as described in 30.4.3 above.
(b) The probe shall be as described in 30.4.4.1(b) above.

(c) Lead measurements shall be taken at the pitch diameter on four teeth per helix, on the ahead flanks, at 90 degree intervals. Chart recordings are to be taken at a minimum of 5,000 magnifications or the maximum magnification feasible to ensure that the chart recording will fit on the largest recording paper available. Chart recording magnification shall be in no case less than 1,000 magnifications.

(d) For measurements taken using a three axis coordinate gear inspection system, the pause time at each measurement point and points per millimeter of travel shall be identical or as close as practical to that used during certification.

30.4.6.2 Accuracy limit. The lead mismatch and lead form error shall not exceed the following:

(a) For the lead measurements described above, taken at the pitch diameter, the worst mating pair of teeth shall be combined to establish the lead mismatch. The lead mismatch error shall not exceed the following:

Face width each helix	Grade 1 Maximum lead mismatch error allowed	Grade 2 Maximum lead mismatch error allowed
up to 8 inches	± 0.0002 inch (0.005 millimeter)	± 0.0004 inch (0.010 millimeter)
8 to 16 inches	± 0.0003 inch (0.008 millimeter)	± 0.0005 inch (0.013 millimeter)
above 16 inches	± 0.0004 inch (0.010 millimeter)	± 0.0006 inch (0.015 millimeter)

(b) Lead form error for each lead measurement described above shall not exceed the following:

Face width each helix	Grade 1 Maximum lead form error allowed	Grade 2 Maximum lead form error allowed
up to 8 inches	0.00025 inch (0.0064 millimeter)	0.00040 inch (0.0102 millimeter)
8 to 16 inches	0.00030 inch (0.0076 millimeter)	0.00050 inch (0.0127 millimeter)
above 16 inches	0.00040 inch (0.0102 millimeter)	0.00060 inch (0.0152 millimeter)

30.4.7 Profile error. For grades 1 and 2 main propulsion reduction pinions and gears, profile error measurements shall be performed on every pinion or gear produced.

30.4.7.1 Measurement requirement. The error shall be established from profile measurements taken on the pinions and gears as follows:

(a) The pinion or gear shall be positioned and runout measured as described in 30.4.3 above.
(b) The probe shall be as described in 30.4.4.1(b) above and shall be zeroed as described in 30.3.4.1.1.2 above.
(c) Profile measurements on stationary measurement machines are to be taken with probe deflection normal to the tooth flank. For portable measuring equipment, probe deflection may be in the transverse plane but shall be recalculated and recorded as if measured with deflection normal to the tooth surface. The probe's measuring head shall move in the transverse plane.
(d) Measurements are to be taken at one location, mid helix on four teeth each helix, 90 degrees apart on the ahead flanks. Chart recordings are to be taken at a minimum of 5,000 magnifications or the maximum magnification feasible to ensure that the chart recording will fit on the largest recording paper available. Chart recording magnification shall be in no case less than 1,000 magnifications.
(e) For measurements taken using a three axis coordinate gear inspection system, the pause time at each measurement point and points per millimeter of travel shall be identical or as close as practical to that used during certification.

30.4.7.2 Accuracy limit. The worst profile trace at the mid helix measurement location of the tooth shall be used to evaluate conformance to the limits provided below:

(a) For grades 1 and 2, the profile shall not deviate from a reasonably smooth line from the form diameter to the chamfer diameter. The trace shall not change by more than 0.00005 inch (0.0013 millimeter) for every 10 percent change in total roll angle from the lowest point of active tooth profile or from the end of root relief, if present, to the highest point of active tooth profile or to the beginning of tip relief, if present.
(b) The total profile slope error shall be determined for each pair of mating pinions and gears and shall not exceed the following:

	Grade 1	Grade 2
First reduction	0.00020 inch (0.0051 millimeter)	0.00030 inch (0.0076 millimeter)
Second reduction	0.00025 inch (0.0064 millimeter)	0.00040 inch (0.0102 millimeter)

(c) The profile form error shall be determined for each pinion and gear, and have the following limits:

	Grade 1	Grade 2
First reduction	0.00015 inch (0.0038 millimeter)	0.00030 inch (0.0076 millimeter)
Second reduction	0.00020 inch (0.0051 millimeter)	0.00040 inch (0.0102 millimeter)

Negative form error relative to the actual profile slope line is not allowed. A straight line shall be drawn from the lowest point of single tooth contact to the highest point of single tooth contact and no point of the profile may go below (i.e., negative direction) this line.

30.4.8 Tooth and journal surface finish. For grades 1 and 2 main propulsion reduction pinions and gears, surface finish measurements shall be performed on every pinion or gear produced.

30.4.8.1 Measurement requirement. Journal surface roughness shall be measured on each journal in the axial direction. Tooth surface roughness shall be measured along the helicoidal surface and along the profile in the transverse plane. Measurements are to be taken on four teeth, 90 degrees apart, on the ahead flanks of each helix at approximately the pitch diameter for roughness measured along the helicoidal surface and mid-face width for roughness measured along the profile. The device employed shall be a profilometer, brush surface analyzer, or equivalent. This device shall be used to measure surface roughness with results given in terms of the arithmetic average R_a (previously RHR) from the mean surface.

30.4.8.2 Accuracy limit. For Grades 1 and 2, journal and tooth maximum surface roughness shall be specified by the contractor to prevent scoring or any other surface failure. Tooth surface finish shall in no instance be greater than 32 microinches R_a and journal surface finish shall in no instance be greater than 16 microinches R_a.

30.5 Proposal requirements. In the proposal, the contractor shall identify:

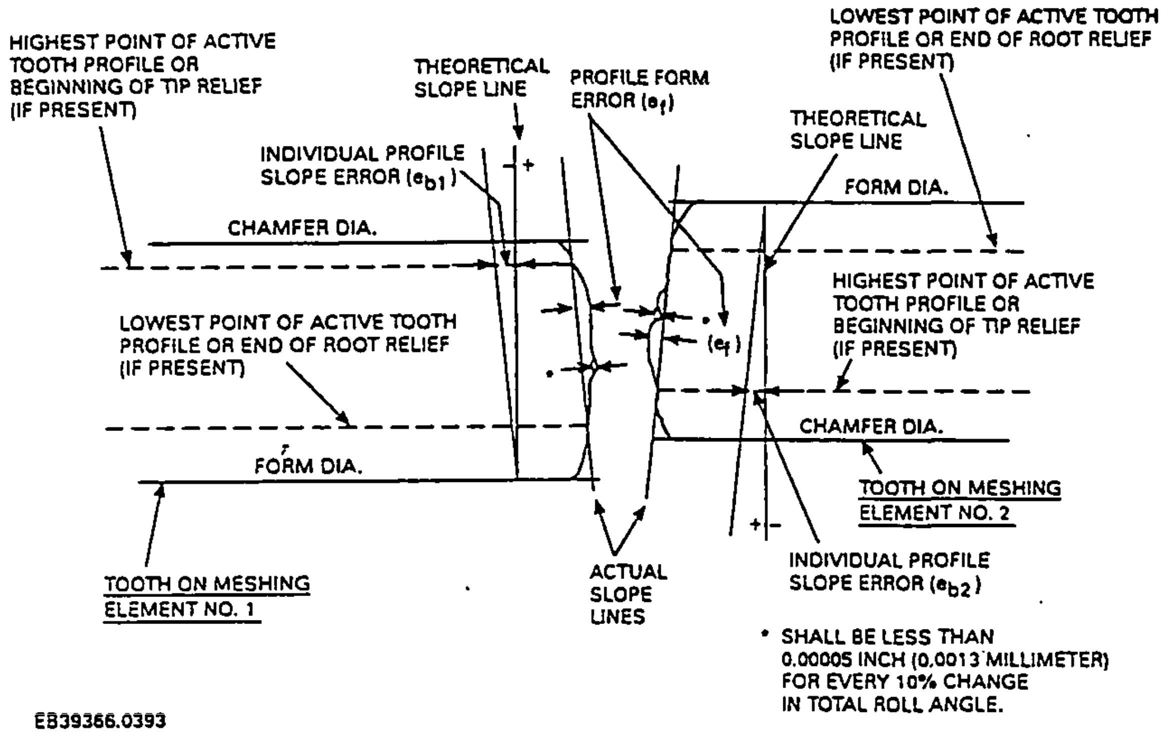
(a) The specific machine/device, including recording/processing units to be used for determination of the errors on the main pinions and gears: make, model, serial number, magnification scales available, description of probe designs available and approximate age of manufacture.
(b) The name(s) and telephone number(s) of cognizant company representatives.

30.6 Drawing requirements. The following requirements shall be included on the appropriate drawing(s):

(a) Identify by stamp-etch in a non-critical area adjacent to the teeth:

  (1) Tooth No. 1 and the tooth number of at least three other teeth at approximately 90, 180 and 270 degree positions. For double-helical gears, the same tooth numbers shall apply to the teeth of both helices.
  (2) The ahead flank on tooth No. 1.

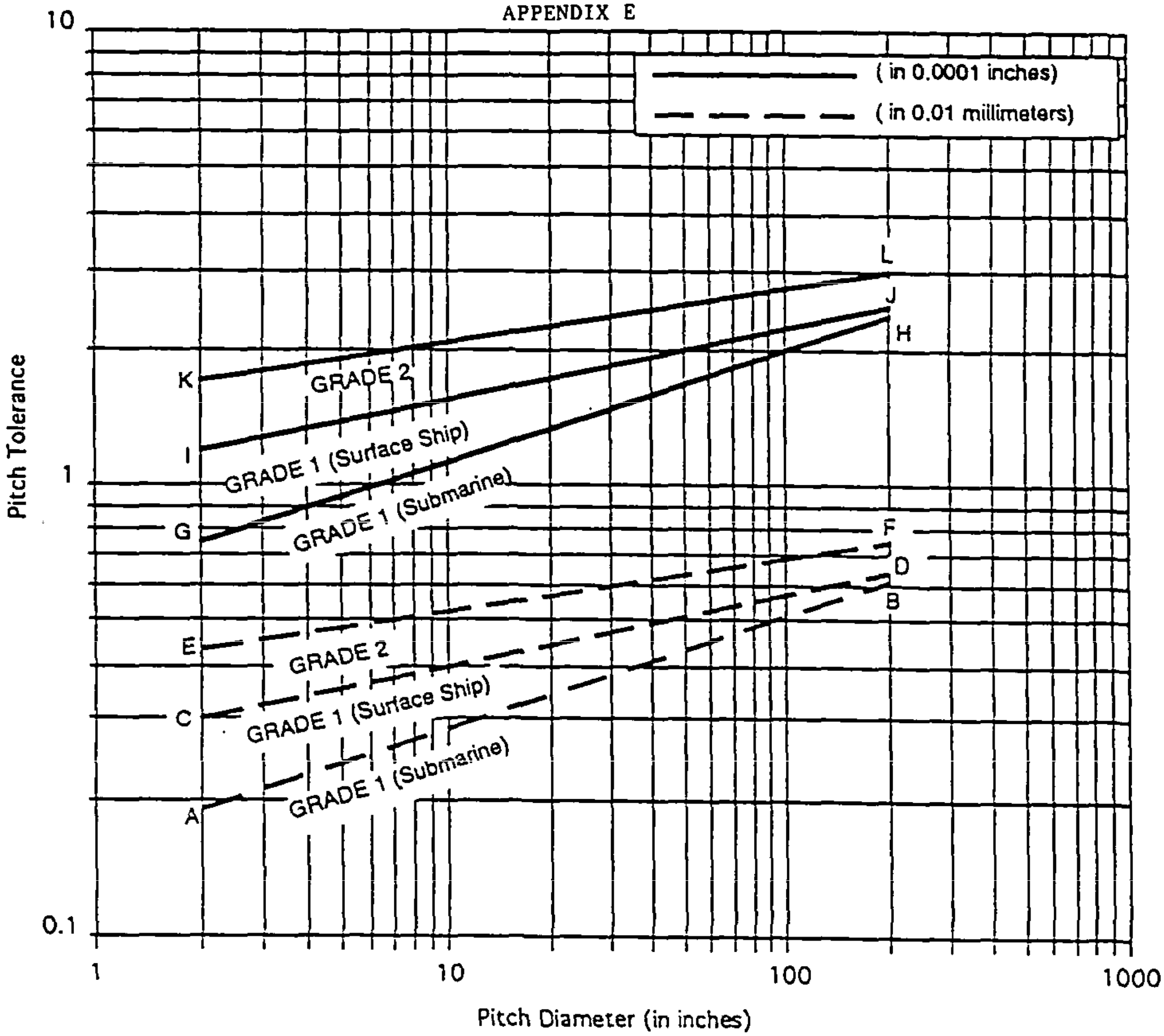
(b) The value at the point of maximum plus error shall be stamp-etched in a non-critical area adjacent to the reference surfaces discussed in 30.2.3, (e.g., +0.00055 inch).



NOTES:

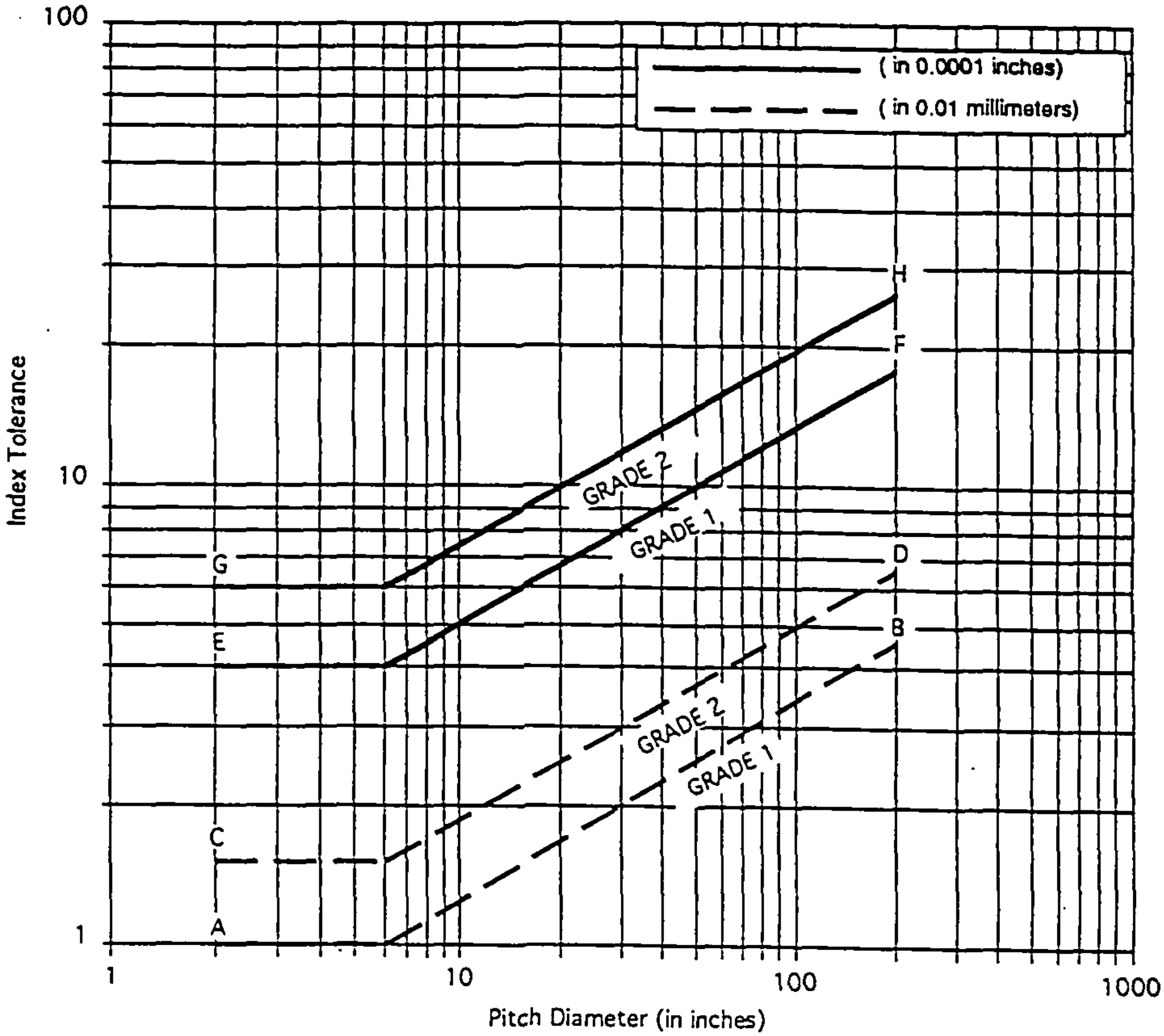
1. The following sign convention shall be used for both pinions and gears: Positive slope indicates more metal at tip relative to perfect involute with zero slope (e.g., in the example depicted above, Tooth No. 1 has negative slope while Tooth No. 2 has positive slope).
2. The actual slope lines shall be drawn using the actual in lieu of theoretical start of tip relief (if present) and the actual in lieu of theoretical end of root relief (if present). The individual profile slope error shall be evaluated at the theoretical beginning of tip relief (if present) or highest point of active tooth profile. In the example above, the actual and theoretical start of tip relief and end of root relief are identical.
3. Profile form errors and profile irregularity shall be measured perpendicular to the actual, in lieu of theoretical, slope line.

FIGURE 18. Profile errors.



NOTES:
1. Pitch tolerance is the allowable amount of pitch variation.
2. Includes permissible journal runout at time of measurement.
3. Point A (2 inches, .0019 mm)
   Point B (200 inches, .0061 mm)
   Point C (2 inches, .0030 mm)
   Point D (200 inches, .0064 mm)
   Point E (2 inches, .0043 mm)
   Point F (200 inches, .0076 mm)
   Point G (2 inches, .000075 inches)
   Point H (200 inches, .00024 inches)
   Point I (2 inches, .00012 inches)
   Point J (200 inches, .00025 inches)
   Point K (2 inches, .00017 inches)
   Point L (200 inches, .00030 inches)

FIGURE 19. Pitch tolerance.



NOTES:
1. Index tolerance is the allowable amount of index variation.
2. Includes permissible journal runout at time of measurement.
3. Point A (2 inches, .010 mm)
   Point B (200 inches, .046 mm)
   Point C (2 inches, .015 mm)
   Point D (200 inches, .066 mm)
   Point E (2 inches, .00040 inches)
   Point F (200 inches, .0018 inches)
   Point G (2 inches, .00060 inches)
   Point H (200 inches, .0026 inches)

FIGURE 20. Index tolerance.

APPENDIX F

PROCEDURE FOR APPLYING DYKEM TO GEAR TEETH FOR INSPECTION OF RUNNING TOOTH CONTACTS

10. SCOPE

10.1 This procedure covers the application of red Dykem layout lacquer to gear teeth to produce a coating suitable for checking gear tooth contact. This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

20. APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

30. NOTES

30.1 Every gear mesh (both helices) requires verification of running tooth contact. Dykem shall not be applied to a pinion or gear which meshes with multiple pinions or gears to ensure acceptable contact is separately verified (e.g., for arrangement 1, Dykem shall be applied to high speed gears but not high speed pinion). Test procedures shall state which pinions or gears require application of Dykem.

30.2 The running time for a particular running tooth contact test shall be as specified in the applicable test procedure.

30.3 If turning gear operation is required after Dykem application but prior to testing or evaluation of running tooth contacts, the direction of rotation shall, if possible, be opposite to that which is being evaluated. When operating to check ahead and astern contacts, run the turning gear in the direction of lower horsepower during the marking run.

30.4 Dykem shall be applied immediately prior to gear operation for each running tooth contact test, if possible, to minimize the time and torque of gear operation at power levels other than that being evaluated.

30.5 The gear running tooth contact shall be inspected and recorded immediately following a particular running tooth contact test, if possible, to minimize time and torque of gear operation at power levels other than that being evaluated.

40. PREREQUISITES

40.1 The items on the paragraph 50 material list should be obtained prior to the start of this procedure.

40.2 Fresh Dykem DX-296 red layout lacquer (within 1 year of date of manufacture) shall be used, from a bottle that has not been previously opened.

Dykem Company will provide DX-296 Dykem red layout lacquer with the date of manufacture on the bottle if it is requested when ordered.

Dykem Company
8501 Delport Drive
St. Louis, MO 63114
(314) 423-0100

50. STEPS

50.1 Wait a minimum of 2 hours from the time the lubricating oil system is shut down and the covers are opened before starting to clean the gear teeth.

50.2 Inspect and rotate the gearing as required to ascertain that the teeth to be cleaned and dykemed are free of old Dykem and any signs of rust.

50.3 Clean a sufficient number of teeth on each pinion or gear to allow Dykem application without residual oil from adjacent teeth contaminating the area to be dykemed. Use denatured alcohol, a bucket, and a paint brush or lint free or low lint cloths. Use Scotchbrite to remove any minor rust or stubborn preservative.

50.4 In the gap between the helices for each pinion or gear to be marked, mark the area (teeth) to be finish cleaned to differentiate from other Dykem applications on the particular pinion or gear to which Dykem will be applied. This marking shall be done using a Dykem DX-296 felt tip applicator (1/2 oz. size) and Dykem DX-296.

50.5 Finish clean the defined teeth using lint free or low lint cloths and "Dykem Remover and Thinner #138." Re-mark as in 50.4 above if required.

50.6 Check the cleanliness of the gear teeth using a clean white lint free or low lint cloth. If the cloth does not become discolored when rubbed vigorously on the face of the gear teeth, the teeth can be considered to be clean enough for the application of Dykem.

50.7 Dykem a minimum of six consecutive teeth as specified in 30.1. Apply a light, thin, uniform coat of Dykem to the entire tooth (face, root, and tip) using clean felt pads, lint free cloths, or low lint cloths. The Dykem shall be poured into a shallow wide mouth plastic container for easy access. Replace the pad or cloth as necessary. The Dykem shall not be diluted either by adding thinner to the Dykem or by applying thinner to the felt pad or cloth.

50.8 Inspect the dykemed teeth to assure complete uniform coverage.

50.9 Allow the Dykem to dry a minimum of 30 minutes after completion of application. Before closing the inspection covers, coat selected teeth with lubricating oil to prevent corrosion if start-up of the oil system will not immediately occur.

60. MATERIAL LIST

(a) DX-296 DYKEM LAYOUT RED
(b) DYKEM REMOVER & THINNER 138
(c) DX-296 DYKEM LAYOUT RED MARKER
(d) LINT FREE OR LOW LINT CLOTH
(e) PLASTIC CONTAINER W/LIDS
(f) 1/8" INDUSTRIAL FELT
(g) 4" PAINT BRUSHES
(h) SCOTCHBRITE PADS
(i) LANYARD MATERIAL
(j) DENATURED ALCOHOL
(k) BUCKET
(l) LUBRICATING OIL (SEE 3.1.11.4)

APPENDIX G

TURNING GEAR ASSEMBLY REQUIREMENTS

10. SCOPE

10.1 Scope. This appendix includes requirements for the turning (jacking) gear assembly. This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

20. APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

30. REQUIREMENTS

30.1 Turning (jacking) gear assembly. A turning gear assembly shall be provided by the contractor. The turning gear assembly shall consist of an auxiliary gear drive, locking mechanism for propulsion shaft, electric motor and electric motor controller. The turning gear assembly shall be designed to permit manual rotation of the auxiliary gear drive and electric motor shaft. The turning gear assembly shall contain interlocks when and as specified (see 6.2). The turning gear assembly shall be rated to drive the prime mover(s), the gear unit, and the propulsion shaft continuously at a propulsion shaft speed of approximately one revolution every 10 minutes in the ahead or astern direction. Breakaway and running torque for line shaft components shall be as specified (see 6.2). The turning gear assembly shall be designed for 100,000 hours of operation.

30.2 Auxiliary gear drive. The contractor shall provide an auxiliary gear drive as specified in 3.2.7. Engagement and disengagement of the turning gear drive shall be accomplished by one individual by the movement of a hand lever or crank. The lever or crank shall lock in the fully disengaged and engaged positions. Identification plates shall indicate the "engaged" and "disengaged" positions. A turning gear drive switch which energizes a "turning gear engaged" warning light on a shipbuilder supplied control panel shall be provided. The warning light shall energize whenever the hand lever or crank is not in its fully "disengaged" position. The switch shall be rated 115 volts, 5 amperes, 60 hertz (Hz), alternating current (ac). Engagement and disengagement of the turning gear drive shall be accomplished with minimal or no rotation of the turning gear drive output shaft.

30.3 Locking mechanism for propulsion shaft. The turning gear assembly shall lock the propulsion shaft by engaging the turning gear drive and actuating a locking mechanism. The turning gear assembly shall be designed to permit immediate actuation of the locking mechanism before or after engagement of the turning gear drive. For multiple screw ships, the turning gear locking mechanism shall resist the maneuvering torque (at the propulsor). Unless otherwise specified (see 6.2), for single screw ships, the turning gear locking mechanism shall resist 60 percent of the maneuvering torque (at the propulsor).

30.3.1 Locking mechanism drawing. The contractor shall provide a locking mechanism drawing. The locking mechanism drawing shall include sufficient information to permit the contracting activity to verify compatibility with ship systems, compatibility with ship arrangement and aid the shipbuilder and NAVSEA in assembly. The drawing will be used to verify that specification requirements are met. The drawing shall apply to all units of a specific design. If similar in arrangement, differences in port and starboard units (if provided) may be shown by note in lieu of furnishing separate drawings.

30.4 Electric motor. An electric motor shall be provided in accordance with MIL-M-17060. The electric motor shall be provided with sealed insulation system and shall have the following characteristics:

(a) Service - A
(b) Ambient temperature - 122°F (50°C)
(c) Rating - 440-volt, 3-phase, 60-Hz
(d) Duty - Continuous
(e) Enclosure - Dripproof protected
(f) Horsepower - As required
(g) R/min - As required
(h) Speed - Constant
(i) Type - Squirrel-cage induction
(j) Design - C or D
(k) Bearings - Ball
(l) Insulation - Class B or F (class B temperature limits)
(m) Cooling - Self-ventilated

30.5 Electric motor controller. When and as specified (see 6.2), the contractor shall provide a motor controller in accordance with MIL-C-2212. The motor controller shall be designed for low voltage protection.

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INSTRUCTIONS

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

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

I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER MIL-G-17859D(SH)	2. DOCUMENT DATE (YYMMDD) 930930

3. DOCUMENT TITLE
GEAR ASSEMBLY, PROPULSION (NAVAL SHIPBOARD USE)

4. NATURE OF CHANGE (identity 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) DSN (If applicable)	7. DATE SUBMITTED (YYMMDD)

8. PREPARING ACTIVITY

a. NAME Technical Point of Contact (TPOC) MR. ROBERT COBLENZ 03X44 ADDRESS ALL CORRESPONDENCE AS FOLLOWS:	b. TELEPHONE (Include Area Code) (1) Commercial: TPOC: 703-602-6757 DSN: 8-332-6757
c. ADDRESS (Include Zip Code) COMMANDER, NAVAL SEA SYSTEMS COMMAND ATTN: SEA 03R42 2531 JEFFERSON DAVIS HIGHWAY ARLINGTON, VA 22242-5160	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 DSN 289-2340