

NAVAL SHIPS' TECHNICAL MANUAL
CHAPTER 241

**PROPULSION REDUCTION GEARS,
COUPLINGS, CLUTCHES, AND ASSOCIATED
COMPONENTS**



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TABLE OF CONTENTS

Chapter/Paragraph	Page
241 PROPULSION REDUCTION GEARS, COUPLINGS, CLUTCHES, AND ASSOCIATED COMPONENTS	1-1
SECTION 1 INTRODUCTION AND SAFETY PRECAUTIONS	1-1
241-1.1 INTRODUCTION.	1-1
241-1.1.1 APPLICABLE EQUIPMENT.	1-1
241-1.1.2 MANUALS AND DRAWINGS.	1-1
241-1.2 SAFETY PRECAUTIONS.	1-1
SECTION 2 GENERAL INFORMATION	2-1
241-2.1 TYPICAL ARRANGEMENT OF PROPULSION MRG's.	2-1
241-2.1.1 PARALLEL AXIS GEARS.	2-1
241-2.1.2 DUAL TANDEM ARTICULATED ARRANGEMENT.	2-1
241-2.1.3 TANDEM ARTICULATED ARRANGEMENT.	2-1
241-2.1.4 SINGLE REDUCTION ARRANGEMENT.	2-1
241-2.2 GENERAL GEAR INFORMATION.	2-2
241-2.2.1 INTRODUCTION.	2-2
241-2.2.2 GEAR TOOTH NOMENCLATURE.	2-4
241-2.2.3 TYPES OF GEAR ELEMENTS.	2-7
241-2.2.4 GEAR ELEMENT HARDENING PROCESSES.	2-7
241-2.3 THROUGH HARDENED, HOBBED AND SHAVED GEAR TEETH.	2-7
241-2.3.1 GENERAL.	2-7
241-2.3.2 SURFACE HARDENED AND FINISH GROUND GEAR TEETH.	2-8
241-2.3.2.1 Carburizing.	2-8
241-2.3.2.2 Nitriding.	2-8
241-2.3.3 PINIONS.	2-8
241-2.3.4 GEAR WHEELS.	2-8
241-2.3.5 MRG Casings.	2-9
241-2.3.6 SOUND ISOLATION MOUNTING SYSTEM.	2-10
241-2.3.7 BEARING TYPES.	2-10
241-2.3.8 SIGHT FLOW INDICATOR AND THERMOMETER FITTINGS.	2-11
241-2.3.9 TURNING GEAR AND SHAFT LOCKING DEVICES.	2-11
241-2.3.10 SHAFT REVOLUTION COUNTER OR TACHOMETER DRIVE.	2-11
241-2.3.11 FLEXIBLE COUPLINGS.	2-11
241-2.3.12 THRUST BEARINGS.	2-15
241-2.3.13 DEHUMIDIFIER.	2-15
241-2.3.14 ELECTROSTATIC PRECIPITATOR AND MIST ELIMINATOR.	2-15
241-2.3.15 CLUTCHES AND BRAKES.	2-15
241-2.3.16 SYNCHRO-SELF-SHIFTING (SSS) CLUTCHES.	2-16
241-2.3.17 HYDRAULIC COUPLINGS.	2-19
241-2.3.18 GAS TURBINE BRAKE.	2-19

TABLE OF CONTENTS - Continued

Chapter/Paragraph	Page
SECTION 3 OPERATION	3-1
241-3.1 GENERAL INFORMATION.	3-1
241-3.1.1 OVERVIEW.	3-1
241-3.1.2 TURNING GEAR OPERATING GUIDELINES.	3-1
241-3.2 LUBRICATION.	3-1
241-3.2.1 LUBRICATING OIL.	3-1
241-3.2.2 CARE OF LUBRICATION SYSTEM.	3-1
241-3.2.3 EFFECTS OF FOREIGN MATERIAL IN OIL.	3-2
241-3.2.4 LEVEL OF OIL IN MRG SUMP.	3-3
241-3.2.5 GEAR MESH OIL SPRAYS.	3-3
241-3.2.6 MRG CASE VENTS.	3-3
241-3.2.7 MRG CASE OVERHEATING.	3-3
241-3.3 PLANT OPERATING CONFIGURATIONS.	3-3
241-3.4 UNDERWAY OPERATION.	3-4
241-3.4.1 PREPARATION FOR GETTING UNDERWAY.	3-4
241-3.4.2 NORMAL ROUTINE WHEN OPERATING MRG.	3-5
241-3.4.3 INITIAL MRG OPERATION.	3-5
241-3.4.4 UNUSUAL NOISE OR VIBRATION.	3-5
241-3.4.4.1 Distinctive Noise.	3-5
241-3.4.4.2 Rumbling on Steam Turbine Powered Ships.	3-6
241-3.4.4.3 Rumbling on Gas Turbine Powered Ships.	3-6
241-3.4.4.4 Unusual Noise at Low Speeds.	3-6
241-3.4.4.5 Bearing Stick Slip.	3-6
241-3.4.4.6 Noise Caused by Unstable Bearing Loads.	3-6
241-3.4.4.7 Noise Caused by the Torsional Critical Speed.	3-6
241-3.4.4.8 Checking the Source of Vibration.	3-7
241-3.4.4.9 Imbalance.	3-7
241-3.4.4.10 Rumbling During Abnormal Operating Conditions.	3-7
241-3.4.4.11 Rumbling Caused by Propeller Blade Damage.	3-7
241-3.4.5 BEARING TEMPERATURE (MONITOR AND CONTROL).	3-7
241-3.4.5.1 Remote Alarms.	3-7
241-3.4.5.2 Sight Flow Indicators.	3-8
241-3.4.6 REQUIREMENTS FOR LOCKING A PROPULSION LINESHAFT.	3-8
241-3.4.7 LOCKED SHAFT PRECAUTIONS.	3-9
241-3.4.8 CASUALTY CONTROL PROCEDURE FOR STOPPING, LOCKING, AND UNLOCKING SHAFT WHEN UNDERWAY (GAS TURBINE AND DIESEL PRIME MOVERS).	3-9
241-3.4.9 CASUALTY CONTROL PROCEDURE FOR STOPPING, LOCKING, AND UNLOCKING SHAFT WHEN UNDERWAY (STEAM TURBINE PRIME MOVERS).	3-9
241-3.4.10 TRAIL SHAFT(S).	3-10
241-3.4.11 PREVENTION OF OVERTORQUING.	3-10

TABLE OF CONTENTS - Continued

Chapter/Paragraph	Page
241-3.5 LAY-UP.	3-10
241-3.5.1 SECURING.	3-10
241-3.5.2 EXTENDED LAY-UP.	3-10
SECTION 4 MAINTENANCE	4-1
241-4.1 MACHINERY HISTORY.	4-1
241-4.1.1 MACHINERY RECORDS.	4-1
241-4.1.2 CONTINUOUS MONITORING.	4-1
241-4.2 ACCESS TO GEARS.	4-1
241-4.2.1 ACCESS TO MRG INTERNALS.	4-1
241-4.2.2 PERMISSION TO OPEN.	4-1
241-4.2.3 MINIMUM PHYSICAL SECURITY.	4-1
241-4.2.4 METHODS OF SECURING SITES PROVIDING ACCESS TO MRG INTERNALS.	4-2
241-4.2.5 ADDITIONAL SECURITY METHODS.	4-15
241-4.2.6 WELDING.	4-15
241-4.3 BEARING MAINTENANCE.	4-15
241-4.3.1 BEARING FAILURES.	4-15
241-4.3.1.1 Fatigue.	4-15
241-4.3.1.2 Poor Bonding.	4-16
241-4.3.1.3 Wiping, Scoring, and Seizure.	4-17
241-4.3.1.4 Wear.	4-17
241-4.3.1.5 Electric Currents.	4-17
241-4.3.1.6 Abrasion.	4-18
241-4.3.1.7 Corrosion.	4-18
241-4.3.1.8 Water Contamination.	4-18
241-4.3.1.9 Tin Oxide Formation.	4-18
241-4.3.1.10 Troubleshooting Bearing Failures.	4-18
241-4.3.2 INSPECTION OF JOURNAL BEARINGS.	4-18
241-4.3.2.1 Wear Pattern and Wear Limits.	4-18
241-4.3.2.2 Babbitt Discoloration.	4-19
241-4.3.2.3 Bonding.	4-20
241-4.3.3 BEARING ALLOWABLE WEAR.	4-20
241-4.3.4 RENEWAL OF BEARINGS.	4-20
241-4.3.5 FITTING BEARINGS.	4-20
241-4.3.6 BEARING SCRAPING.	4-21
241-4.3.7 REBABBITTING JOURNAL BEARINGS.	4-23
241-4.3.8 REBUSHING MRG CASING BORES.	4-25
241-4.3.9 ROLLING CONTACT.	4-25
241-4.3.10 RTE AND THERMOCOUPLE INSTALLATIONS.	4-25
241-4.3.11 JOURNAL REPAIR.	4-25
241-4.3.12 CHECKING END PLAY (AXIAL CLEARANCE) OF PIVOTED SHOE TYPE INTEGRAL THRUST BEARINGS.	4-25
241-4.3.12.1 Checking End Play While Running.	4-25

TABLE OF CONTENTS - Continued

Chapter/Paragraph	Page
241-4.3.12.2	Barring on Shaft Flange. 4-26
241-4.3.12.3	Barring by Means of Thrust End Plate. 4-26
241-4.3.12.4	Measuring Inside a Two-Shoe Thrust Bearing. 4-26
241-4.3.12.5	General Notes. 4-27
241-4.3.12.6	Precautions. 4-27
241-4.4	GEAR MAINTENANCE. 4-28
241-4.4.1	BACKLASH. 4-28
241-4.4.2	DAMAGE TO GEAR ELEMENTS IN HANDLING. 4-28
241-4.4.3	DAMAGE TO GEAR ELEMENTS BY FOREIGN PARTICLES. 4-28
241-4.4.4	DETECTING DAMAGED TEETH. 4-28
241-4.4.5	REPAIRING DAMAGED TEETH. 4-29
241-4.4.5.1	Bearing Failure. 4-29
241-4.4.5.2	Damage in Handling. 4-29
241-4.4.5.3	Tooth Crushing. 4-29
241-4.4.5.4	Tracking. 4-30
241-4.4.5.5	Severe Tracking. 4-30
241-4.4.5.6	Rusting. 4-30
241-4.4.5.7	Worn Gear. 4-30
241-4.4.5.8	Heavy Loading. 4-31
241-4.4.5.9	Pitting. 4-31
241-4.4.6	TOOTH CONTACT. 4-31
241-4.4.7	TOOTH CONTACT DETERMINED BY STATIC CHECK. 4-31
241-4.4.7.1	Static Checking Method. 4-31
241-4.4.7.2	Marking Compound Transfer Method. 4-31
241-4.4.7.3	Static Check Precautions. 4-32
241-4.4.8	TOOTH CONTACT DETERMINED BY OPERATION. 4-32
241-4.4.8.1	DYKEM Material List. 4-32
241-4.4.8.2	Recommendations. 4-33
241-4.4.8.3	DYKEM Application Procedure. 4-33
241-4.4.8.4	Operation for Determining Dynamic Tooth Contact. 4-34
241-4.4.9	TOOTH MARKING. 4-35
241-4.4.10	CORRECTIVE ACTION. 4-37
241-4.4.11	RECORDING GEAR TOOTH DAMAGE. 4-38
241-4.4.11.1	Casting Dental Stone Impressions from Silicone Rubber Molds. 4-38
241-4.4.12	TIMING OF LOCKED TRAIN GEARS. 4-40
241-4.4.13	TOOTH WEAR. 4-42
241-4.4.14	TOOTH WEAR AND FAILURE. 4-42
241-4.4.15	ALIGNMENT. 4-49
241-4.4.16	ALIGNMENT CHECK. 4-49
241-4.4.16.1	Crown Thickness and Pin Check Methods. 4-49
241-4.4.16.2	Alignment Check for Older Ships. 4-50
241-4.4.16.3	Check of Alignment of MRG and Lineshaft. 4-50
241-4.4.17	ALIGNMENT CHECK AFTER GROUNDING OF PROPELLERS. 4-51
241-4.4.18	ALIGNMENT CHECK OF PRIME MOVER AND MRG. 4-51
241-4.4.19	ALIGNMENT BETWEEN PRIME MOVER AND MRG PINION. 4-51

TABLE OF CONTENTS - Continued

Chapter/Paragraph		Page
241-4.4.20	FLEXIBLE COUPLINGS.	4-55
241-4.4.21	INSTALLING FLEXIBLE COUPLINGS.	4-55
241-4.4.22	LUBRICATED COUPLING TOOTH WEAR.	4-56
241-4.4.23	NONLUBRICATED COUPLING DISTRESS.	4-57
241-4.4.24	LUBRICATED COUPLING BACKLASH MEASUREMENT.	4-57
241-4.4.25	LUBRICATED COUPLING TOOTH WEAR LIMIT.	4-60
241-4.4.26	COUPLING INSTALLATION PRECAUTIONS.	4-62
241-4.4.27	COUPLING WITH SELF-CONTAINED LUBRICANT.	4-63
241-4.4.28	TURNING GEARS.	4-64
241-4.4.29	DISMANTLING MRG ASSEMBLIES.	4-64
241-4.4.30	REASSEMBLING MRG's.	4-66
 SECTION 5 TESTS AND INSPECTIONS		 5-1
241-5.1	GENERAL TEST AND INSPECTION INFORMATION.	5-1
241-5.1.1	OVERVIEW.	5-1
241-5.1.2	ASSEMBLY AND DISASSEMBLY.	5-1
241-5.1.3	ALIGNMENT.	5-1
241-5.1.4	SCHEDULING WORK.	5-1
241-5.1.5	CLEANING MRG SUMPS.	5-1
241-5.1.6	LUBRICATING OIL.	5-1
241-5.2	INSPECT FOR FOREIGN MATTER IN MRG CASING OR OIL LINES.	5-2
241-5.2.1	INSPECTION REQUIREMENTS.	5-2
241-5.2.2	CARE OF LUBRICATION SYSTEM.	5-2
241-5.3	INSPECTING MRG'S.	5-2
241-5.3.1	GENERAL.	5-2
241-5.3.2	WEEKLY.	5-2
241-5.3.3	BI-WEEKLY.	5-2
241-5.3.4	QUARTERLY	5-3
241-5.3.5	SEMIANNUALLY	5-3
241-5.3.6	ANNUALLY.	5-3
241-5.3.7	SHIPYARD OVERHAUL.	5-4
241-5.3.8	UNSCHEDULED INSPECTIONS.	5-4
241-5.3.9	TRIALS.	5-5
 SECTION 6 PRECAUTIONS, REPORTING PROCEDURES, AND MRG CASUALTY		
GUIDANCE		6-1
241-6.1	SPECIAL PRECAUTIONS.	6-1
241-6.2	REPORTS.	6-2
241-6.3	MRG CASUALTY GUIDANCE.	6-2
241-6.4	MRG SALT WATER CONTAMINATION GUIDANCE	6-2

TABLE OF CONTENTS - Continued

Chapter/Paragraph	Page
241-6.4.1 Extent Of Contamination	6-3
241-6.4.1.1 MINIMAL CONTAMINATION	6-3
241-6.4.1.2 SEVERE CONTAMINATION	6-3
A Technical Manual Deficiency/Evaluation Report (TMDER)	A-1

LIST OF TABLES

Table	Title	Page
241-4-1	JOURNAL BEARING TROUBLESHOOTING CHART	4-19

LIST OF ILLUSTRATIONS

Figure	Title	Page
241-2-1	Dual Tandem Articulated, Double-Reduction Gear	2-2
241-2-2	Tandem Articulated, Double Reduction Gear	2-3
241-2-3	Twin Pinion, Single Reduction Gear	2-3
241-2-4	Single Pinion, Single Reduction Gear	2-4
241-2-5	Gear Tooth Nomenclature I	2-6
241-2-6	Gear Tooth Nomenclature II	2-7
241-2-7	Typical Forged Steel Pinion	2-9
241-2-8	LS (Bull) Gear with Thrust Collar and Shaft Flange	2-10
241-2-9	Cutaway View of an Articulated Intermediate Speed Rotating Assembly	2-10
241-2-10	Main Reduction Gear Unit with Top Covers Removed	2-12
241-2-11	Main Reduction Gear Unit Assembled	2-13
241-2-12	RTE and Bearing Shell of Sleeve-Type Bearing	2-14
241-2-13	Electric Motor Driven Turning Gear with Positive Locking Device	2-14
241-2-14	Gear Coupling	2-15
241-2-15	Single Diaphragm Coupling	2-16
241-2-16	Multiple Diaphragm Coupling	2-17
241-2-17	Dehumidifier Airflow Diagram	2-18
241-2-18	Vent Fog Precipitator	2-20
241-2-19	Gas Turbine Clutch	2-21
241-2-20	Reversible Converter Coupling	2-22
241-2-21	Gas Turbine Brake	2-23
241-3-1	Dehumidifier/Vent System Diagram	3-11
241-3-2	MRG Lay-Up Rust-Protection Procedure	3-12
241-3-3	Electrostatic Precipitator Closure Assembly	3-13
241-4-1	MRG Case Inspection Cover, Strongback Type	4-4
241-4-2	MRG Case Inspection Cover, Center Bolt Locking Device	4-5

LIST OF ILLUSTRATIONS - Continued

Figure	Title	Page
241-4-3	MRG Case Inspection Cover, Bayonet Type Locking Device Modification	4-6
241-4-4	Cover Plate Security Device (Padlocked)	4-7
241-4-5	Cover Plate Security Device Details	4-8
241-4-6	Epoxy Filled Cup for Bolt and Nut Security	4-9
241-4-7	Spray Nozzle Installation Security Device	4-10
241-4-8	Oil Sight Flow Indicator Locking Plate and Pin Arrangement	4-11
241-4-9	Oil Sight Flow Fitting	4-12
241-4-10	Conical Strainer for Sight Flow Fitting	4-13
241-4-11	Flange Shroud	4-14
241-4-12	Sight Flow Indicator	4-16
241-4-13	Lens Retaining Ring	4-16
241-4-14	Bearing Wall Thickness and Contact Chart	4-24
241-4-15	Locations of Tooth Markings by Contact Inspection	4-36
241-4-16	Misalignment in the Plane of the Centers (Parallel Misalignment)	4-37
241-4-17	Misalignment Normal to the Plane of the Centers (Crossed Axes Misalignment)	4-37
241-4-18	Typical Rotor Diagram	4-41
241-4-19	Intermediate Flexible Coupling Matchmarks	4-42
241-4-20	First Reduction Pinion Rolled Out for Adjusting Timing	4-43
241-4-21	Progressive, Destructive Pitting	4-44
241-4-22	Scoring	4-45
241-4-23	Dirt Tracking	4-46
241-4-24	Scoring, Heavy Pitting, and Extreme Tooth Wear	4-47
241-4-25	Cracked Teeth	4-48
241-4-26	Broken Tooth	4-49
241-4-27	Alignment Reference Measurements (Erection Data)	4-52
241-4-28	Misalignment Types	4-53

LIST OF ILLUSTRATIONS - Continued

Figure	Title	Page
241-4-29	Alignment Measurements	4-54
241-4-30	Severe Galling or Worm Tracking	4-57
241-4-31	Indenting (Sheet 1 of 2)	4-59
241-4-31	Indenting (Sheet 2 of 2)	4-61
241-4-32	Knife Edged Teeth	4-62
241-4-33	Shouldering	4-63
241-4-34	Moderate Axial Scoring	4-64
241-4-35	Severe Axial Scoring	4-65

CHAPTER 241

PROPULSION REDUCTION GEARS, COUPLINGS, CLUTCHES, AND ASSOCIATED COMPONENTS

SECTION 1

INTRODUCTION AND SAFETY PRECAUTIONS

241-1.1 INTRODUCTION.

241-1.1.1 APPLICABLE EQUIPMENT. Information in this chapter applies to propulsion main reduction gear (MRG) units and their associated components. Propulsion MRG's use gear elements that have a wide face width and are usually supported on their shafts by sleeve or tilting pad type babbitted journal bearings. Most non-propulsion reduction gear units use gear elements that have a narrow face width and are usually supported on their shafts by anti-friction (e.g., roller) bearings. This chapter may apply only in part to non-propulsion reduction gear units and their components.

241-1.1.2 MANUALS AND DRAWINGS. The Engineering Officer should refer to the ship's MRG technical manual and engineering drawings for specific information(e.g. safety precautions, equipment and functional descriptions, operation, maintenance, troubleshooting, inspections, repair procedures, parts lists, etc.) on the design of the propulsion MRG unit and its associated components. The Steam and Electric Plant Manual (SEPM), the Engineering Operational Sequencing System (EOSS) and the Engineering Operational Casualty Control (EOCC) procedures contain specific operational instructions for each ship class. The information contained in these documents take precedence over the guidance provided herein.

241-1.2 SAFETY PRECAUTIONS.

241-1.2.1 Safety can be defined as freedom from those conditions that can cause an accident resulting in injury or death to personnel or damage to or loss of equipment or property. The paragraphs in this chapter that identify potential hazards and methods of controlling or eliminating them are [241-3.1.1](#), [241-3.2.2](#), [241-3.2.4](#), [241-3.2.7](#), [241-3.4.7](#), [241-3.4.10](#), [241-3.4.11](#), [241-4.2](#), [241-4.4.30](#), [241-5.2](#), and [241-6.1](#).

SECTION 2

GENERAL INFORMATION

241-2.1 TYPICAL ARRANGEMENT OF PROPULSION MRG's.

241-2.1.1 PARALLEL AXIS GEARS. Most propulsion MRG's use a parallel axis gear element arrangement to transfer power and rotation from the prime movers (e.g., turbines, engines, and motors) to the propeller at a reduced speed. These reduction gear arrangements contain either single or double helical gear elements. The following paragraphs identify the most common naval ship parallel axis reduction gear arrangements.

241-2.1.2 DUAL TANDEM ARTICULATED ARRANGEMENT. The dual tandem articulated double reduction gear arrangement (Figure 241-2-1) is very common in naval combatant ships. This arrangement is more commonly referred to as a locked train double reduction gear set. It incorporates two first reduction high speed (HS) pinions, four first reduction HS gears, four second reduction low speed (LS) pinions, and one LS (bull) gear. It is dual tandem (locked train) because the two adjacent HS gear/LS pinion intermediate speed assemblies are locked in mesh together between their respective HS pinion and the LS gear. It is articulated because each HS gear is connected to its respective LS pinion through a flexible quill shaft and coupling. Double reduction gear arrangements are used principally on ships with high speed prime movers (up to 4,000 rpm).

241-2.1.2.1 Each prime mover is connected to a HS pinion through a HS coupling or HS coupling and clutch arrangement. In the first reduction, each HS pinion meshes with two of the four HS gears (one upper and one lower) to split the input power in half and provide the first stage speed reduction. The HS pinions and gears can be located either forward or aft of the LS pinions and gear depending on arrangement constraints, alignment influences, and input/output interface requirements. For the second reduction, each of the four LS pinions mesh with the LS gear to recombine the split input power. The two reductions reduce the prime mover speed to the propeller speed.

241-2.1.2.2 In a double reduction gear, each HS gear coupled to its LS pinion through the flexible quill shaft and coupling is called an intermediate speed (IS) assembly. The power carried by the upper and lower IS assemblies must be equal to ensure that stresses are minimized. To achieve the equal load split, the gear elements are timed by a process of selected tooth engagements. Following timing, each gear mesh and coupling joint is matchmarked at the manufacturing facility. If disassembly of this arrangement is required, consult the applicable MRG technical manual to ensure the timing is properly restored.

241-2.1.3 TANDEM ARTICULATED ARRANGEMENT. The tandem articulated double reduction gear arrangement (Figure 241-2-2) can have one or more power inputs that are connected to each prime mover through a HS coupling or HS coupling and clutch. This arrangement is used primarily on naval auxiliary ships. Because the tandem articulated arrangement has half as many power paths as the dual tandem articulated arrangement, it is generally used on lower powered ships. It has the same articulated flexible quill shaft and coupling between the first and second reductions as the locked train arrangement but without the need for timing.

241-2.1.4 SINGLE REDUCTION ARRANGEMENT. The single reduction gear arrangement has one or more power inputs (Figure 241-2-3 and Figure 241-2-4) connected to each prime mover through a HS coupling or HS coupling and clutch. This arrangement is used principally for ships using low speed prime movers (1,000 rpm and less).

241-2.2 GENERAL GEAR INFORMATION.

241-2.2.1 INTRODUCTION. Propulsion MRG's reduce the rotating speed of the prime mover to a speed suitable for turning the ship's propeller. Propulsion MRG's are also torque multipliers. Helical gear elements with external teeth are typically used in MRG's.

241-2.2.1.1 The involute is the tooth form most commonly used for helical gear elements. By using the involute tooth form, tooth mesh action is unaffected by small variations in center distance (provided that backlash and root clearance are present).

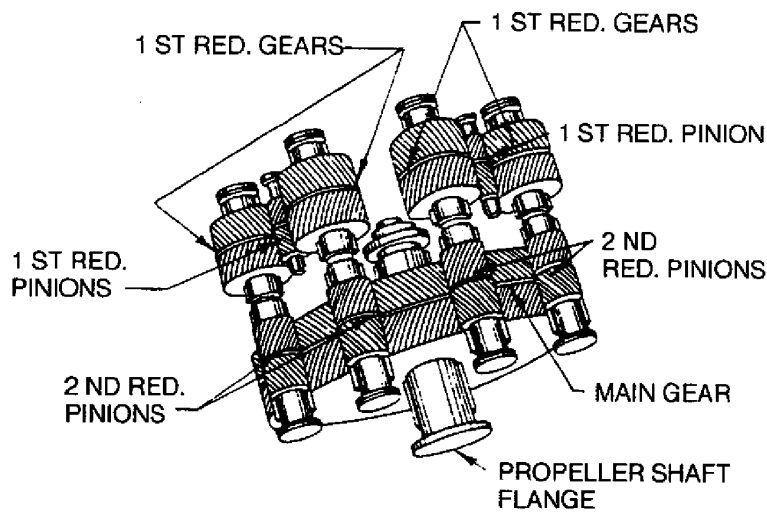


Figure 241-2-1 Dual Tandem Articulated, Double-Reduction Gear

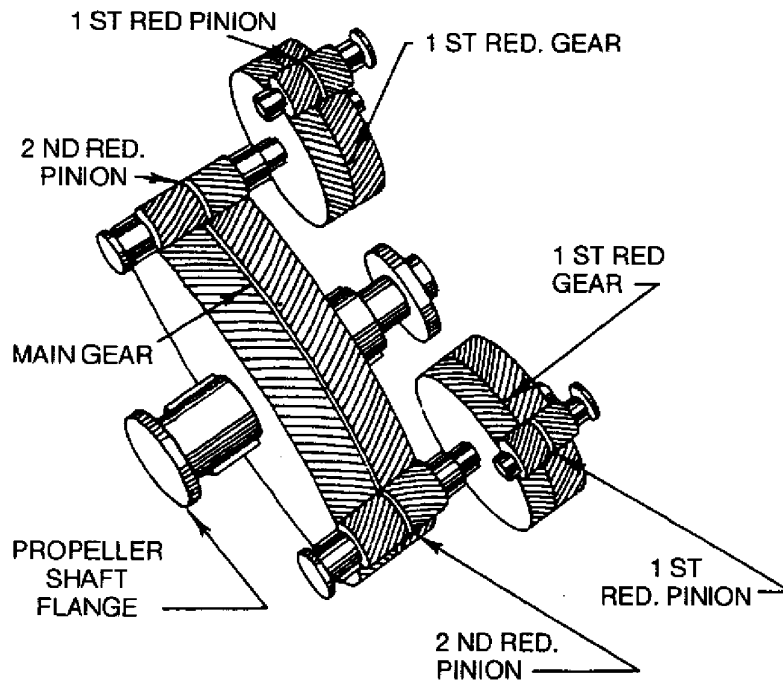


Figure 241-2-2 Tandem Articulated, Double Reduction Gear

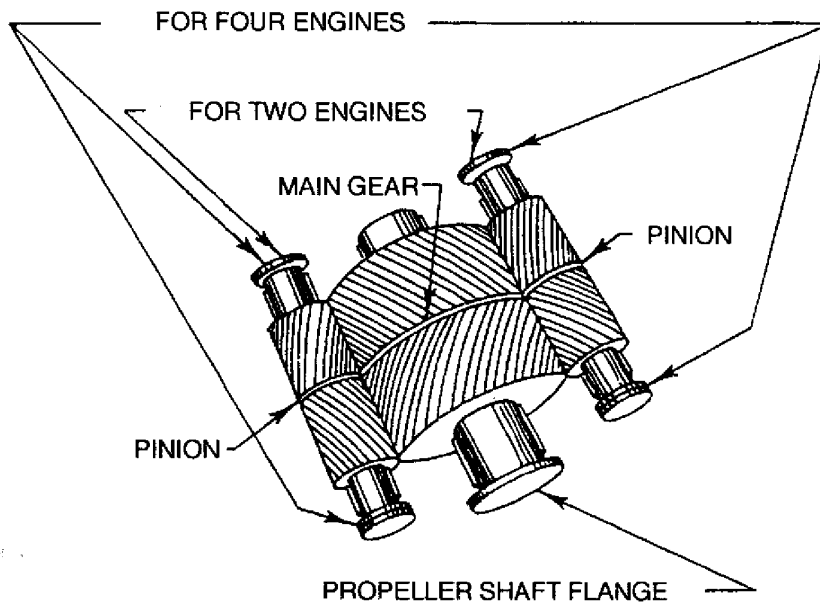


Figure 241-2-3 Twin Pinion, Single Reduction Gear

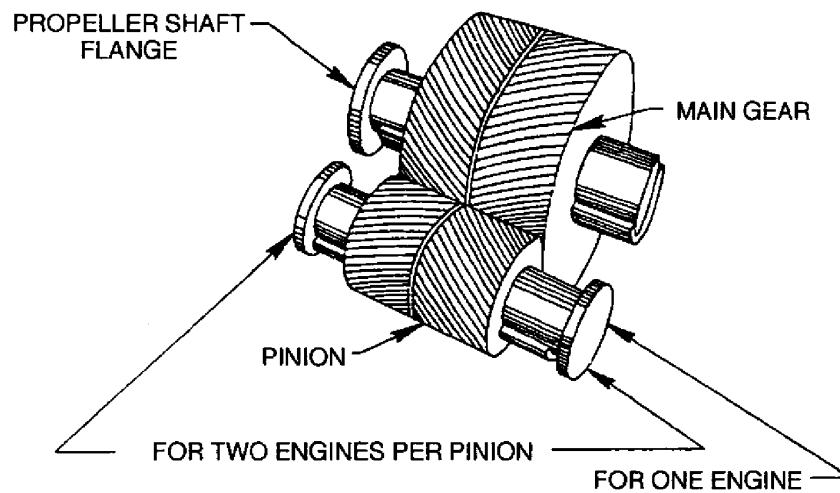


Figure 241-2-4 Single Pinion, Single Reduction Gear

241-2.2.1.2 Mating helical gear elements of parallel axis gear sets must have the same helix angle but of opposite hand helices for proper meshing of the teeth. For example, a right hand helix angle pinion meshes with a left hand helix angle gear. Conversely, a left hand helix angle pinion meshes with a right hand helix angle gear. A simple method for determining the hand of the helix is to stand on the side of the gear element, and while looking directly at its full length, salute it with both hands. Whichever hand lines up with the angle of the teeth is the hand of the helix.

241-2.2.1.3 Common helix angles range from approximately 10 to 45 degrees. Single helical gears have helix angles in the lower portion of this range while double helical gears have helix angles in the higher portion.

241-2.2.1.4 As helical gear teeth mesh, the contact between two gears begins at one end of a tooth and sweeps along the tooth to the other end as the gears rotate. If the face width is long enough, two or more adjacent teeth on each gear will be engaged at all times. This overlapping enables the helical gears to carry a higher load than spur gears, and operate more quietly and smoothly.

241-2.2.1.5 Single helical gears generate an axial (thrust) load that must be absorbed by a thrust bearing on each helical gear shaft. Double helical gears, on the other hand, are a combination of both left and right hand helices which generate opposite axial loads that cancel.

241-2.2.2 GEAR TOOTH NOMENCLATURE. The following nomenclature applies only to helical gears. Some of the definitions are shown in [Figure 241-2-5](#) and [Figure 241-2-6](#).

- a. **Reduction Ratio (RR).** Mesh RR is the number of teeth of the gear divided by the number of teeth of the pinion it is meshed with, or the rpm of the gear divided by the rpm of the pinion. Gearbox RR is the HS mesh RR multiplied by the LS RR.
- b. **Line of Action.** The line of action is the locus of the points of contact as the profiles rotate through mesh. This line passes through the pitch point and is tangent to the base circle.
- c. **Helix Angle.** The angle formed by a tooth and a plane passing through the axis of the gear.
- d. **Pressure Angle.** The angle between the line of action and the line tangent to the pitch circles (pitch line).
- e. **Transverse Diametral Pitch.** The ratio of the number of teeth to the number of inches of the pitch diameter.

- f. **Line of Centers.**The line connecting two meshed element centers in a plane of rotation. The length of this line is called the Center Distance.
- g. **Pitch Point.**The point on the line of centers that divides the center distance in the same proportion as the gear reduction ratio.
- h. **Pitch line.**The line tangent to the pitch circles of two meshing gears.
- i. **Normal Diametral Pitch.**The transverse diametral pitch divided by the cosine of the helix angle.
- j. **Chordal Tooth Thickness (Normal).**The thickness of the tooth measured on the chord of the pitch diameter in the normal plane.
- k. **Circular Pitch (Transverse).**The length of the arc on the pitch circle between similar points of adjacent teeth in the plane of rotation.
- l. **Circular Pitch (Normal).**The length of the arc on the pitch circle between similar points of adjacent teeth in the normal plane.
- m. **Outside Diameter.**The diameter measured over the tops of the teeth.
- n. **Pitch Diameter.**The diameter of the pitch circle.
- o. **Base Diameter.**The circle from which a line is unwound to generate the involute curve.
- p. **Root Diameter.**The diameter of the root circle.
- q. **Addendum.**The distance from the pitch circle to the top of the tooth.
- r. **Dedendum.**The distance from the pitch circle to the bottom of the tooth space.
- s. **Working Depth.**The depth to which the teeth of a gear enter into their mating element space.
- t. **Clearance (Root).**The distance between the top of a tooth and the bottom of its mating element space.
- u. **Whole Depth.**The total depth of the tooth space; also the sum of addendum and dedendum.
- v. **Fillet.**The concave radius that joins the tooth profile and the bottom of the tooth space.
- w. **Undercut.**The portion of the tooth profile in the tooth root removed by the action of the mating element teeth in failure. The driver will remove material from the flanks of the driven teeth which are then undercut.
- x. **Backlash.**The amount by which the width of a tooth space exceeds the tooth thickness of the engaging tooth at the operating pitch circle.
- y. **Transverse Contact Ratio.**A numerical index that indicates the average number of teeth in contact in the transverse direction.
- z. **Axial Contact Ratio.**Exists only in helical gears and is a numerical index that indicates the average number of teeth in contact in the axial direction.
- aa. **K Factor.**An index that indicates the intensity of tooth load from the standpoint of tooth surface durability.

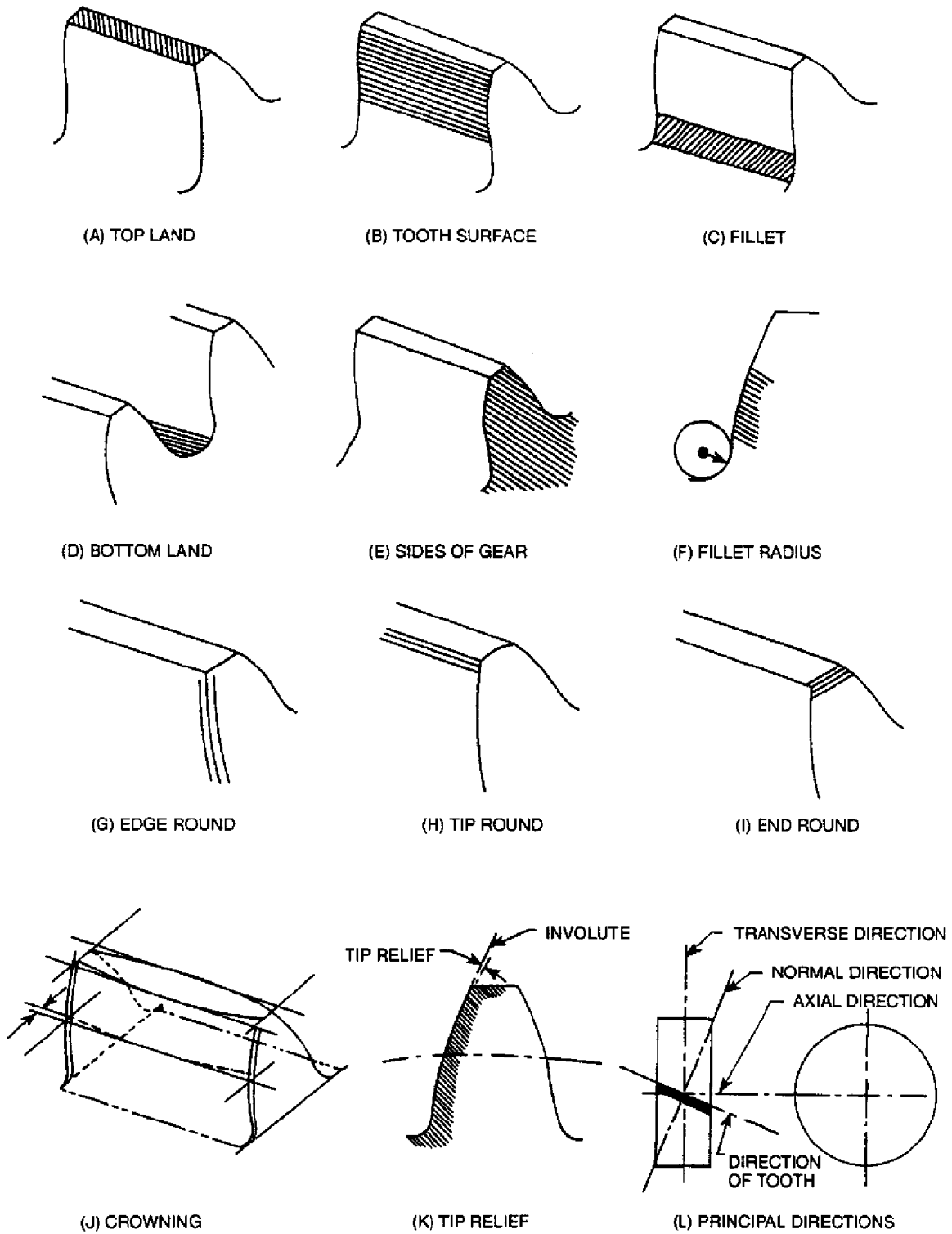


Figure 241-2-5 Gear Tooth Nomenclature I

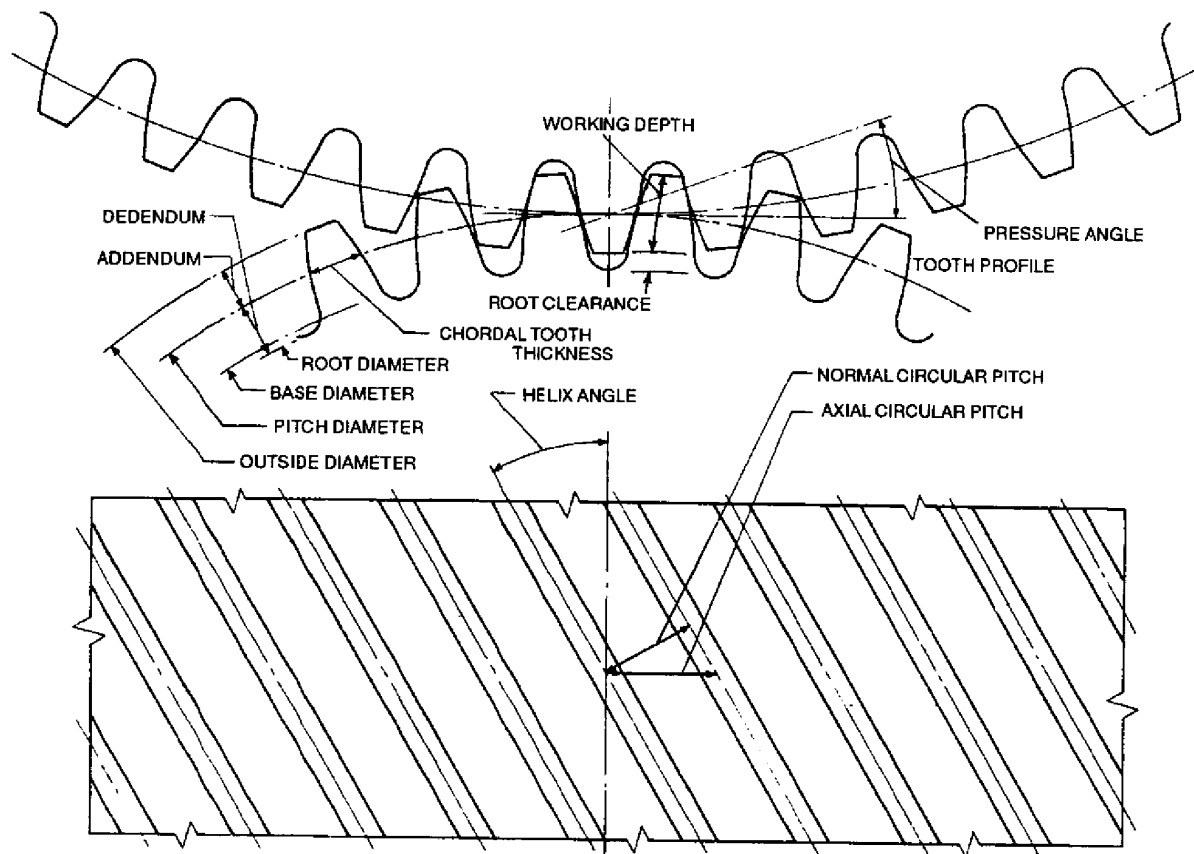


Figure 241-2-6 Gear Tooth Nomenclature II

241-2.2.3 TYPES OF GEAR ELEMENTS. Most MRG's use double helical gear elements although single helical gear elements are used in some diesel propulsion applications, reversing gears, and turbine generator sets. Bevel gear elements, which meet at right angles, are occasionally used in reversing gears, hydrofoil propulsion gears, and attached lube oil and controllable pitch propeller pump drives.

241-2.2.4 GEAR ELEMENT HARDENING PROCESSES. Gear element teeth are either through hardened or surface hardened. Through hardened gear elements are uniformly hardened throughout. Surface hardened gear elements are hardened by either carburizing or nitriding the teeth locally. Carburizing produces the strongest gear teeth, followed by nitriding, and then through hardening. Usually, the pinion teeth are selected to be harder than the gear teeth (for example, a nitrided pinion meshes with a through hardened gear). Whether a gear element is through hardened or surface hardened, the teeth are surface finished. Surface finishing may be accomplished by one or more of the following finishing processes: finish hobbing, lapping, shaving, grinding, and honing. Surface finishing the teeth improves load distribution and minimizes noise by improving contact between meshing gear elements.

241-2.3 THROUGH HARDENED, HOBBED AND SHAVED GEAR TEETH.

241-2.3.1 GENERAL. Through hardened gear elements are used when high load carrying capacity is not required. This typically happens when the gear element sizes are dictated by engine spacing requirements or other MRG interface constraints. Through hardened gear materials are typically alloy steels. Through hardened gears are heat treated uniformly such that the entire part develops a uniform hardness profile throughout.

241-2.3.2 SURFACE HARDENED AND FINISH GROUND GEAR TEETH. Gear elements with surface hardened and finish ground teeth can carry significantly higher loads than through hardened teeth and result in reduced size and weight of a gear set. The two processes currently used for surface hardening the teeth are carburizing and nitriding.

241-2.3.2.1 Carburizing. Carburizing is one of the most widely used methods for hardening gear teeth. The teeth are cut and all major machining is accomplished while the gear blank is soft. Rim areas, web areas, and hub areas that are not to be carburized are masked off. Then, the cut gear is placed in a carburizing medium and heated above its critical range. Carbon is absorbed into the surface layer of the gear teeth, and after one or more hours at temperature, the carbon has penetrated to give the required case depth. The carburized gear is then cooled by one of several methods depending on desired results to achieve the specified hardness in the carburized case. The carburizing process results in very strong and durable teeth, but if not done properly, it can cause undesirable residual stress levels, distortion, cracking, and ultimately lead to premature failure of a gear element.

241-2.3.2.2 Nitriding. Nitriding is a process for case hardening alloy steel gear teeth that results in little distortion of the finished gear element. The gear blank is finish machined to size and the teeth are cut and finished. The parts of the gear that are not to be nitrided are masked off with a suitable medium. The gear is put in a nitriding furnace and heated. Various techniques for nitriding exist, but the most popular used for gear elements is gas nitriding. The useful case on the teeth is formed by the nitrogen and the alloying elements present in the gear blank material. Nitrided gear teeth do not have as much case depth as carburized gear teeth. A gear properly nitrided will exhibit little or no distortion which makes it possible to finish grind nitrided gears prior to nitriding. Generally the only work done after nitriding is to strip the masking and polish the journals or bores to exact size. However, high precision gear teeth can be finish ground after nitriding.

241-2.3.3 PINIONS. Pinions are generally cut from a one piece solid steel forging ([Figure 241-2-7](#)). Where pinions are very large, they may be a weldment similar to gear wheels. For minesweeper applications, pinions are made of aluminum bronze, nonmagnetic steel, or steel that has been depermed (degaussed) to reduce its magnetic signature.

241-2.3.4 GEAR WHEELS. The construction techniques and materials used in the manufacture of gear wheels depend on the application. The entire gear wheel may be made from a solid steel forging or a casting, but in most cases it is a steel fabrication.

241-2.3.4.1 Steel fabricated gear wheels consist of a rim, web (sideplate), possibly a hub (center), and the gear shaft. Usually, the web is welded to the shaft. In some configurations, the web is either welded to a hub that is shrunk and keyed to the shaft, or it is bolted to the shaft.

241-2.3.4.2 Minesweeper MRG's require special construction and materials. Gear wheels are usually aluminum bronze forgings but may be depermed steel or a combination of an aluminum bronze rim mounted on an aluminum body.

241-2.3.4.3 For most low powered ships, the forward end of the LS gear shaft has a removable thrust collar. In most high powered ship designs, the aft end of the LS gear shaft, forward of the lineshaft connecting flange, has an integral flange for attaching the thrust bearing facing collars as shown in [Figure 241-2-8](#). For surface ships, these collars act on the propeller thrust bearing located within, attached to, or separate from the propulsion gear casing for both low and high powered ships. On submarines, these collars act on the gear locating thrust bearing to absorb the thrust due to ship trim and to axial force transmitted by the sound isolation (SI) coupling.

241-2.3.4.4 A typical intermediate speed (IS) rotor assembly shown in [Figure 241-2-9](#) is comprised of a fabricated first reduction HS gear wheel, a forged second reduction LS pinion, a quill shaft, and a flexible coupling on one end.

241-2.3.5 MRG Casings. MRG casings (housing), except for some small MRG's, are fabricated weldments. Most MRG's have an upper and a lower casing, and casing covers. These casings are of box girder construction with integral bearing blocks. The LS gear bearing housing is typically an integral part of the lower casing. Casing covers are bolted to the upper casing and removing them provides access to the gearing and the bearing caps. Cases and covers have inspection plates or hinged covers so that rotating parts can be visually inspected. Inspection plates are either hinged and locked or bolted to the cases. Casings are arranged for access to gear mesh spray fittings so that nozzles can be removed and cleaned.

241-2.3.5.1 Equipment such as turning gears, shaft locks, brakes, clutches, lube and Controllable Pitch Propeller (CPP) pump drives, tachometer drives, sight flow indicators, electro-static vent fog precipitator fittings, dehumidifier fittings, thermometer fittings, and thermocouples or resistance temperature element (RTE) junction boxes are attached to the MRG casing. [Figure 241-2-10](#) shows the gears in the upper casing of a locked train, double reduction gear with the covers removed. A fully assembled MRG unit is shown in [Figure 241-2-11](#).

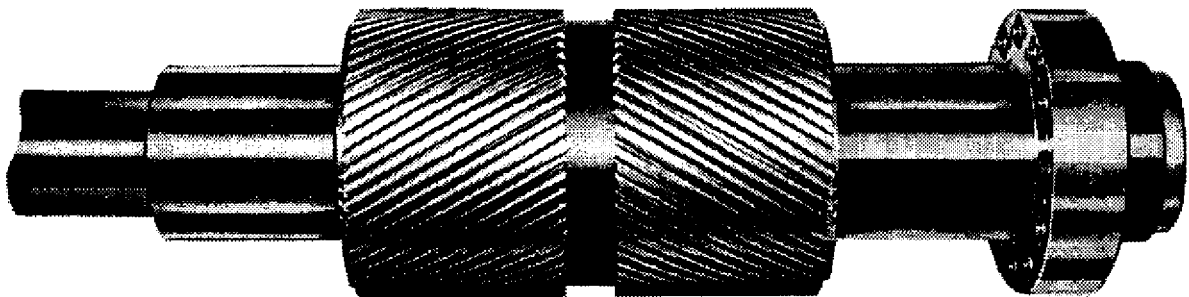


Figure 241-2-7 Typical Forged Steel Pinion

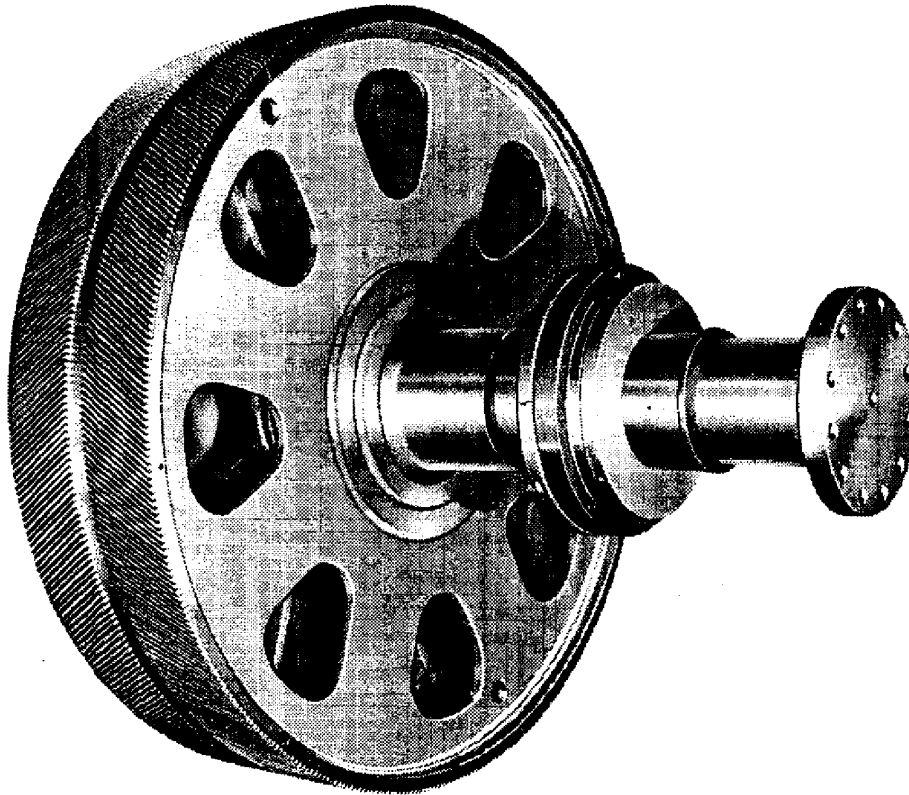


Figure 241-2-8 LS (Bull) Gear with Thrust Collar and Shaft Flange

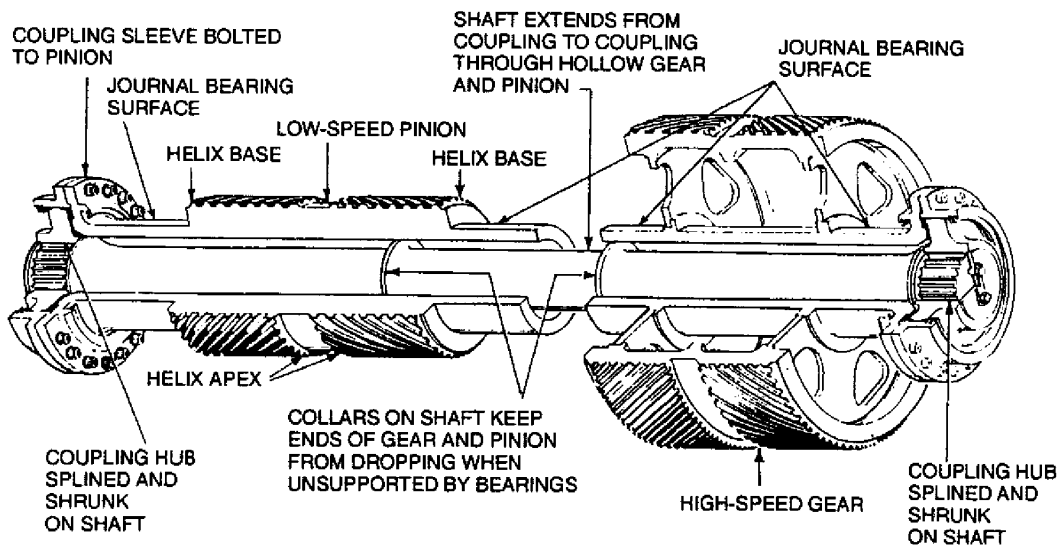


Figure 241-2-9 Cutaway View of an Articulated Intermediate Speed Rotating Assembly

241-2.3.6 SOUND ISOLATION MOUNTING SYSTEM. Some ships use a sound isolation mounting system to prevent structureborne noise transmission from the MRG to the ship's foundation. These systems may employ rubber or low deflection metallic isolators. See applicable technical manuals for details.

241-2.3.7 BEARING TYPES. Propulsion MRG's are usually designed with the following types of bearings:

- a. Sleeve (Sliding Surface) Type. The sleeve type bearing design is most commonly found in MRG's. Both cylindrical and multiple lobe bearings are used. These bearings have steel shells lined with babbitt. The elliptical (two lobe) bearing (Figure 241-2-12) is found frequently in MRG's because it is made in halves for removal. Multiple lobe bearings provide better resistance to rotor whirl in high speed low load applications than cylindrical type bearings but are more clearance sensitive. Sleeve type bearings are marked for crown thickness measurements (paragraph 241-4.4.16.1). Directions for reboring bearings designed for rebabbiting are usually marked on the bearing. Each bearing is in halves or sections that are aligned with each other by dowels. Bearings are positioned in casing bores and prevented from rotating by a dowel or locking screw and washer. In some MRG designs RTE's (or thermocouples) are installed in the bearings to measure babbitt temperature. Figure 241-2-12 shows a typical RTE installation in the bearing.
- b. Tilting Pad. Tilting pad journal bearings consist of multiple self-tilting pads. This bearing configuration is the most resistant to rotor whirl and is used primarily in high speed applications.
- c. Roller Bearings. Roller bearings generally used in small MRG's are rigid, and capable of supporting radial and axial loads. Roller bearings may be used in some turning gears and accessory pump drives.

241-2.3.8 SIGHT FLOW INDICATOR AND THERMOMETER FITTINGS. Oil sight flow indicator and thermometer fittings are installed on the MRG case. In some MRG designs, RTE's or thermocouples are installed in the sight flow fitting to monitor oil temperature remotely, locally or both.

241-2.3.9 TURNING GEAR AND SHAFT LOCKING DEVICES. Most diesel and turbine driven ships have electric motor driven turning gears. Most turning gear designs incorporate a positive propulsion shaft locking device that engages both internal and external gear teeth to prevent propulsion shaft rotation (Figure 241-2-13). Some turning gears lock the propulsion shaft by using a clamp type brake to prevent propulsion shaft rotation. Turning gears that are operated by air motors or by hand are primarily used where continuous turning is not required. Many turning gears employ worm gear drives which are highly loaded and require constant lubrication to prevent rapid wear of the elements. Some turning gears have their own self-contained oil supply employing a higher viscosity lubricant selected for the load on the worm gears.

241-2.3.10 SHAFT REVOLUTION COUNTER OR TACHOMETER DRIVE. On most ships, a propulsion shaft tachometer or shaft revolution counter is driven off the MRG at an exact multiple of propulsion shaft speed. On gas turbine powered ships, an electronic rpm sensor may also be installed on the MRG to provide a rotational speed signal to the machinery control system.

241-2.3.11 FLEXIBLE COUPLINGS. Flexible couplings transfer power between two components and are designed to accommodate a certain degree of misalignment and axial motion.

241-2.3.11.1 Dental, gear, or fine tooth type couplings (Figure 241-2-14) require lubrication. These couplings are usually lubricated by a continuous flow of oil to the coupling teeth through the adjacent bearing feedline or spray nozzles. Occasionally, a gear coupling is used that requires a self-contained grease lubricant. These couplings accommodate axial and angular misalignment by the relative sliding and rocking action of the crowned coupling teeth within the mating hub.

241-2.3.11.2 Single diaphragm (Figure 241-2-15), multiple diaphragm (Figure 241-2-16), and elastomer couplings do not require lubrication. These couplings accommodate misalignment by deflection of the metallic or elastomer member(s).

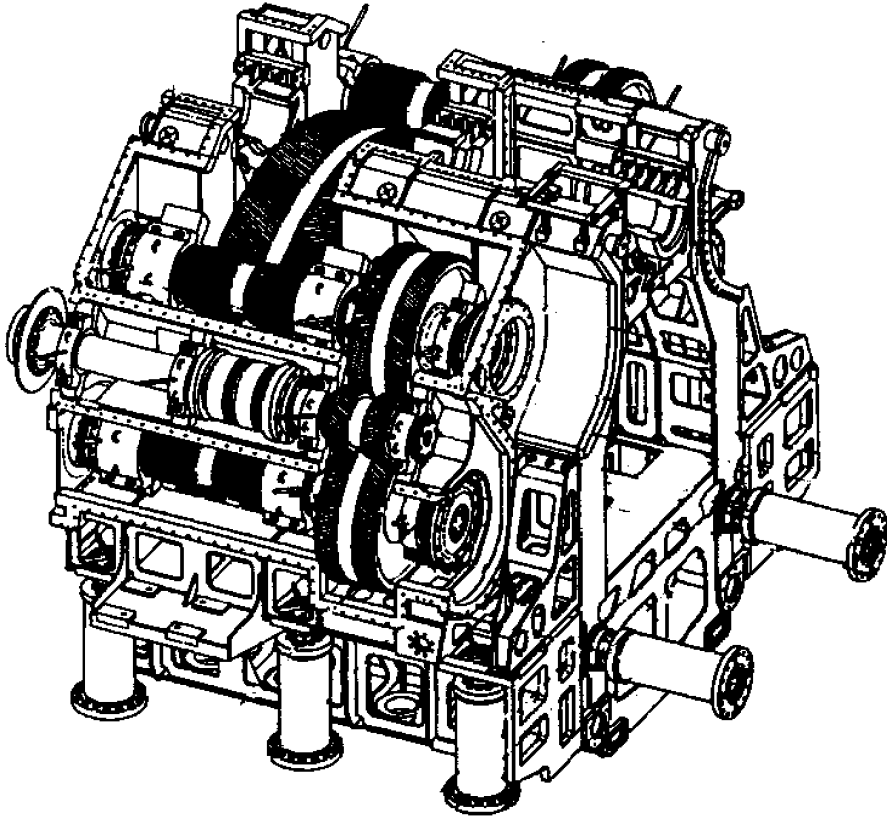


Figure 241-2-10 Main Reduction Gear Unit with Top Covers Removed

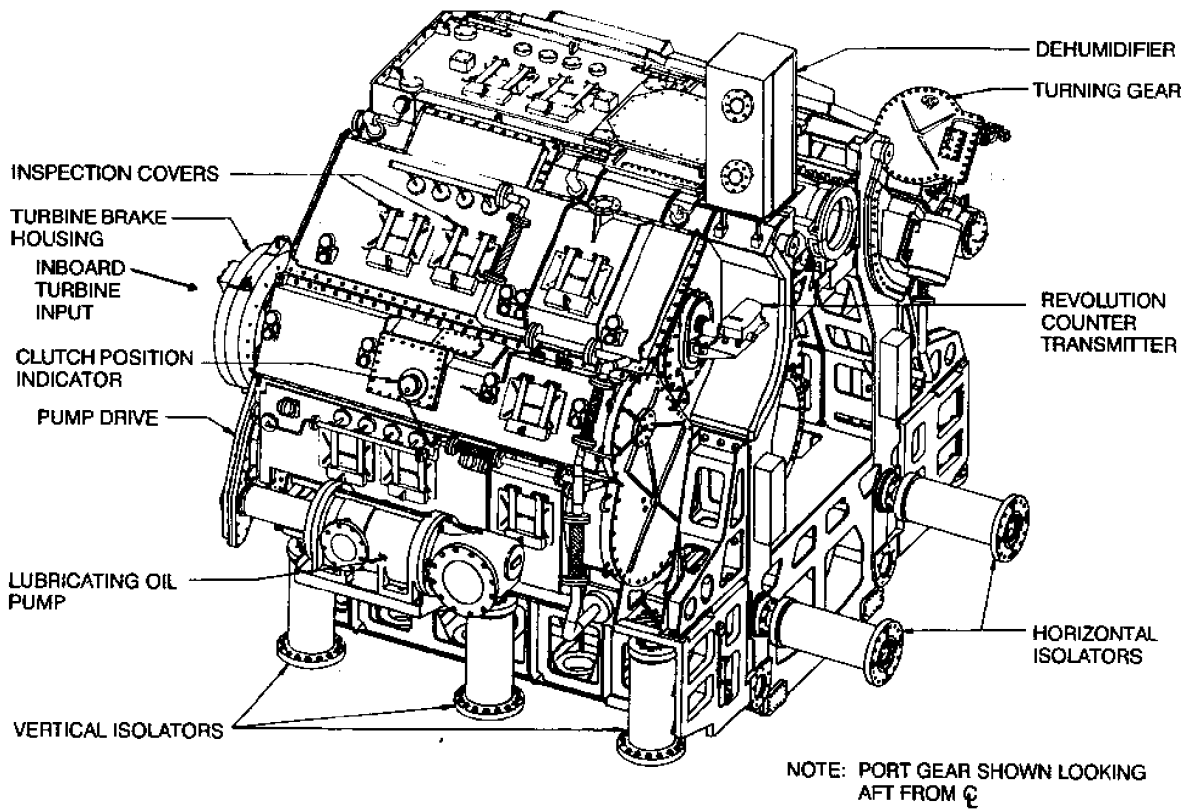


Figure 241-2-11 Main Reduction Gear Unit Assembled

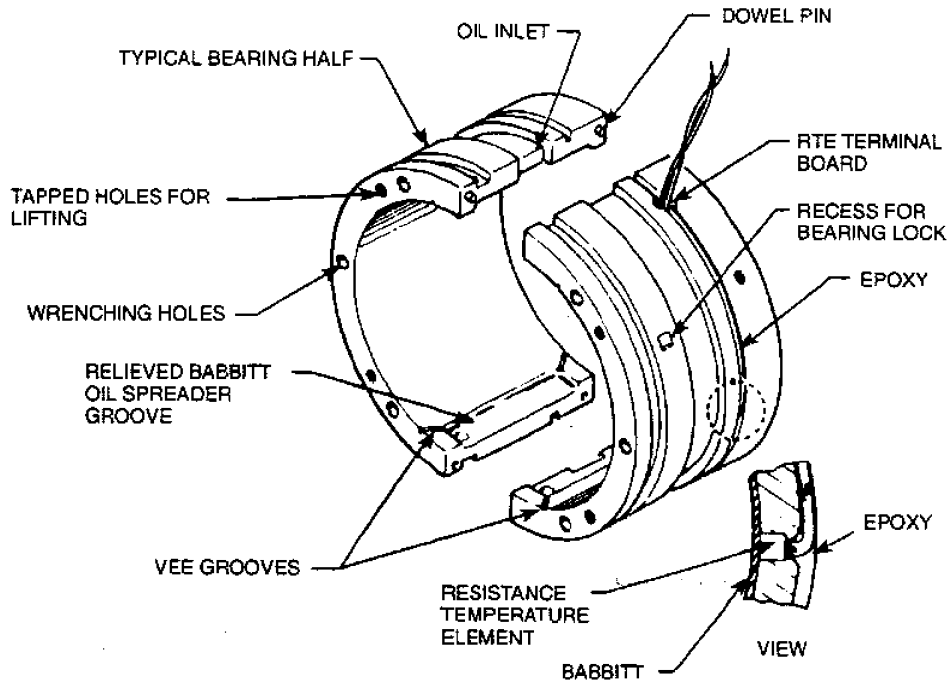


Figure 241-2-12 RTE and Bearing Shell of Sleeve-Type Bearing

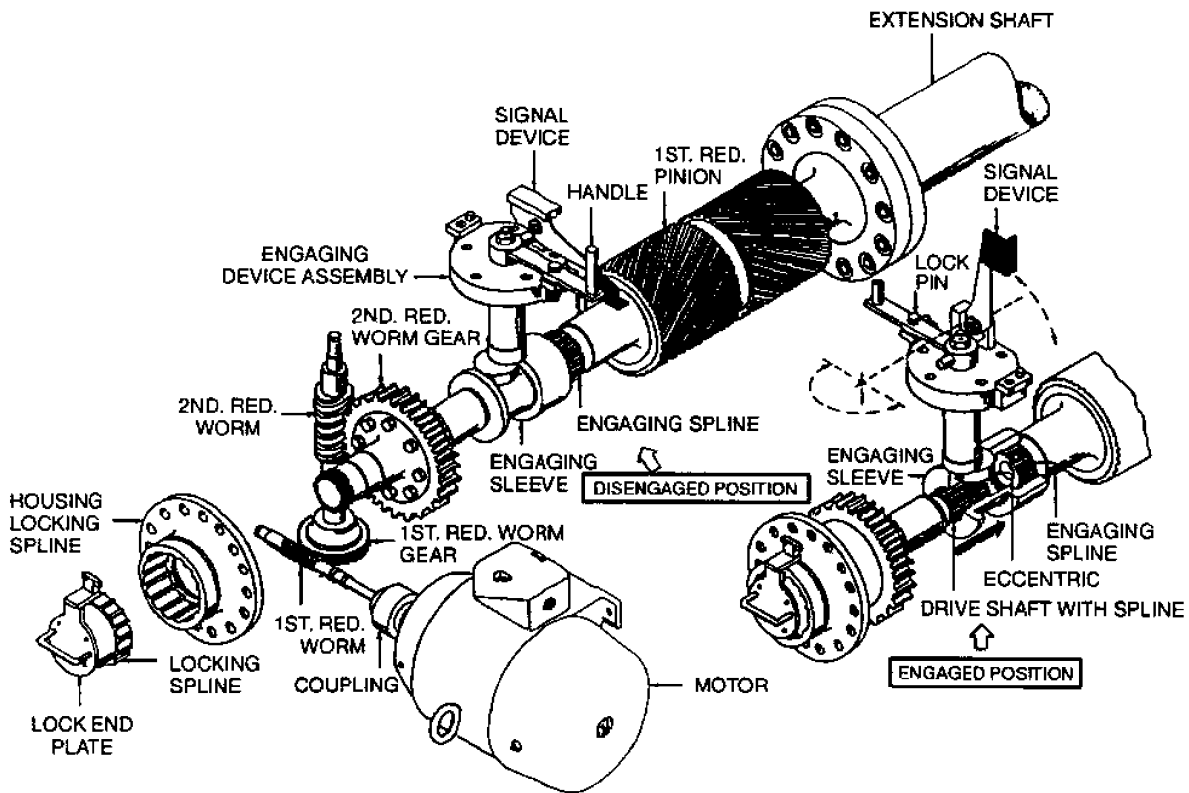


Figure 241-2-13 Electric Motor Driven Turning Gear with Positive Locking Device

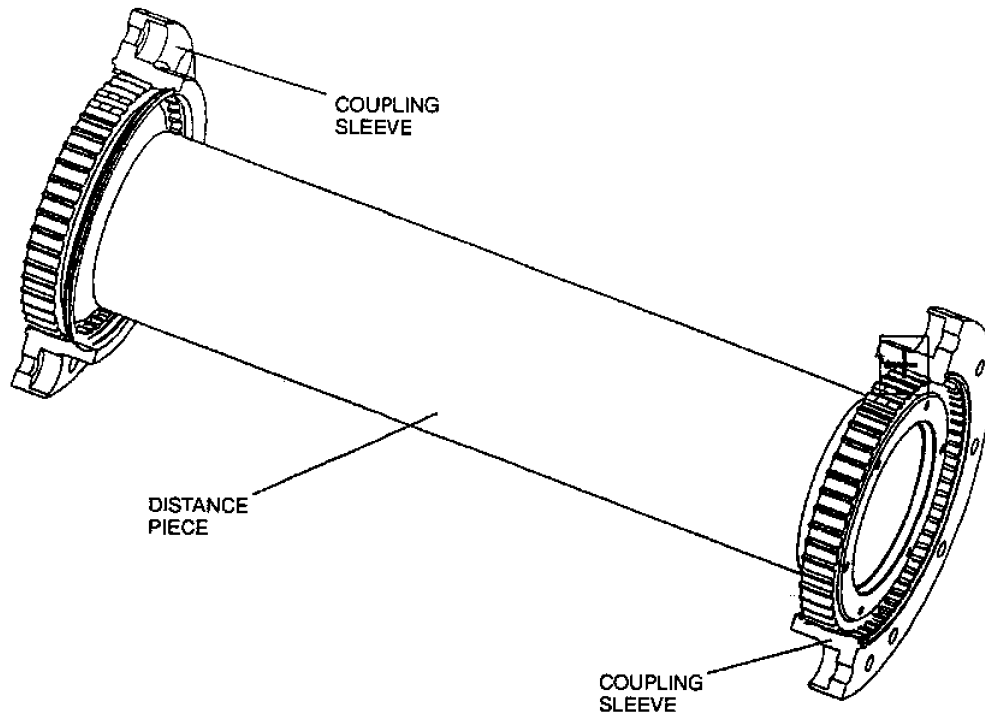


Figure 241-2-14 Gear Coupling

241-2.3.11.3 SI couplings are used where noise transmitted through the lineshaft must be held to a minimum. The SI coupling has elastomer elements that prevent any metal-to-metal noise paths from the MRG to the propulsion shaft.

241-2.3.12 THRUST BEARINGS. Propeller thrust bearings are usually of the pivoted shoe, self-equalizing type. Smaller units frequently use spherical or tapered roller anti-friction bearings. Thrust bearings for gear element locating purposes are usually flat-face or tapered-land type. Additional detailed information on propeller thrust bearings can be found in NSTM Chapter 244, Propulsion Bearings and Seals.

241-2.3.13 DEHUMIDIFIER. Dehumidifiers remove moisture from the air inside the MRG to prevent internal rusting. Dehumidifiers may or may not be permanently installed aboard ship. Most new ships have permanently installed desiccant wheel type dehumidifiers. Permanently installed dehumidifiers shall incorporate flame arrestors in their inlet and outlet piping as shown in [Figure 241-3-1](#). Dehumidifier operating requirements can be found in paragraph [241-3.5.2](#), with sub-assembly components and air flows as shown in [Figure 241-2-17](#).

241-2.3.14 ELECTROSTATIC PRECIPITATOR AND MIST ELIMINATOR. The electrostatic (vent fog) precipitator (ESP) removes airborne oil fog emanating from the MRG vent airstream before it can be discharged into the machinery space. Currently, there are two standard sizes of ESP's; 10 scfm and 50 scfm. The 10 scfm unit is shown in [Figure 241-2-18](#). It can be installed with and without a surge blow-off relief valve which is for protection against a sudden increase in internal gear case pressure. The 50 scfm unit is considerably different in shape, and comes with a built-in surge blow-off valve, closure device, and flame arrestor. Mist eliminators are installed on vents to remove oil from the air to prevent coating surfaces. The mist eliminator is a filter which removes oil mist and returns that oil to the sump tank.

241-2.3.15 CLUTCHES AND BRAKES. MRG's on gas turbine and diesel powered ships may have both clutches and brakes. The clutches couple and uncouple the prime mover to the first reduction HS pinions. The brakes slow, stop, and hold the prime mover and in a few cases, the propeller shaft. By controlling the clutches and brakes, different plant configurations can be selected ([paragraph 241-3.3](#)).

241-2.3.16 SYNCHRO-SELF-SHIFTING (SSS) CLUTCHES. The SSS clutch is primarily used on gas turbine powered ships to automatically engage and disengage the engine to the MRG (See [Figure 241-2-19](#)). They are also used to engage emergency propulsion motors in a few specialized applications. The basic operating principle of the SSS clutch can be compared to the action of a nut screwed on to a bolt. If the bolt rotates with the nut not held, the nut will rotate with the bolt. If the nut is held while the bolt is rotated, the nut will move in a straight line along the bolt. In an SSS clutch, the input shaft has helical splines which correspond to the thread of a bolt. Mounted on the helical splines is a sliding component which simulates the nut. The sliding component has external clutch teeth at one end, and a set of pawls at the other. When the input shaft rotates, the sliding component rotates with it until the tip of a pawl contacts a ratchet tooth on the output clutch ring to prevent rotation of the sliding component relative to the output clutch ring. As the input shaft continues to rotate, the sliding component will move axially along the helical splines of the input shaft. When a ratchet tooth is in contact with a pawl tip, the clutch engaging teeth are perfectly aligned for engagement and will thus pass smoothly into mesh in a straight line path. As the sliding component moves along the input shaft, the pawl passes out of contact within the ratchet tooth, allowing the clutch teeth to come into flank contact and continue the engaging travel. "Synchro-Self-Shifting" Note that the only load on the pawl is that required to shift the sliding component along the helical splines. Driving torque from the input shaft will only be transmitted when the sliding component completes its travel by contacting an end stop on the input shaft with the clutch teeth fully engaged and the pawls unloaded. If the speed of the input shaft is reduced relative to the output shaft, the torque on the helical splines will reverse. This causes the sliding component to return to the disengaged position and the clutch will overrun. Additional features, such as an oil dashpot and automatic and manual lock-in and lock-out controls, are provided in most SSS clutch installations.

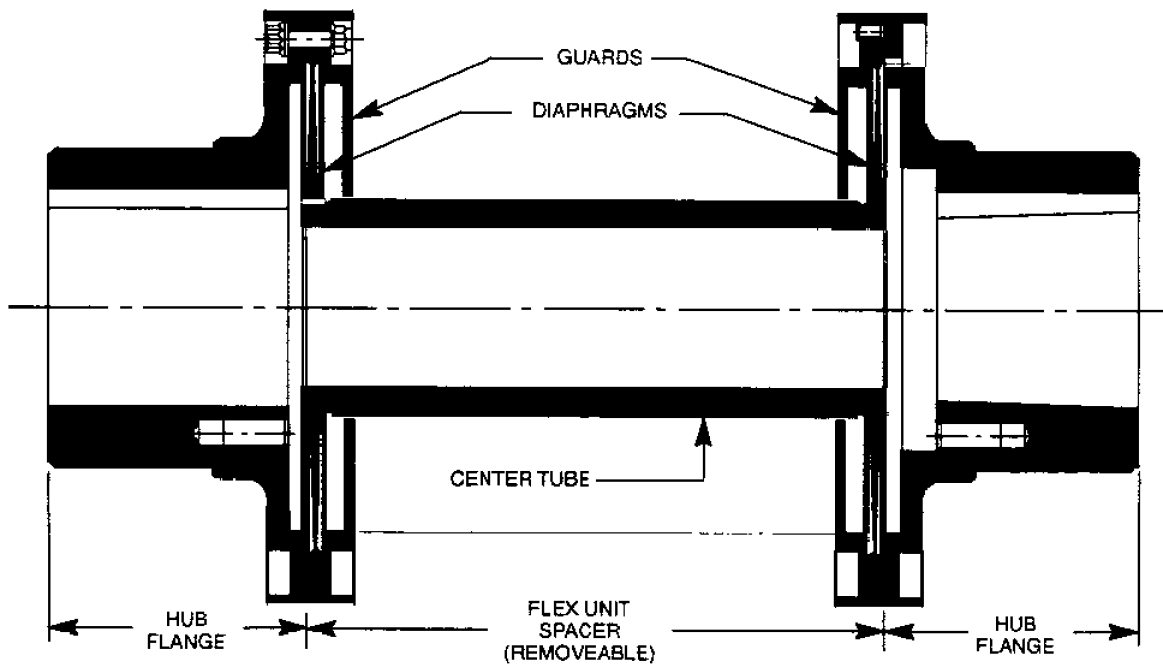


Figure 241-2-15 Single Diaphragm Coupling

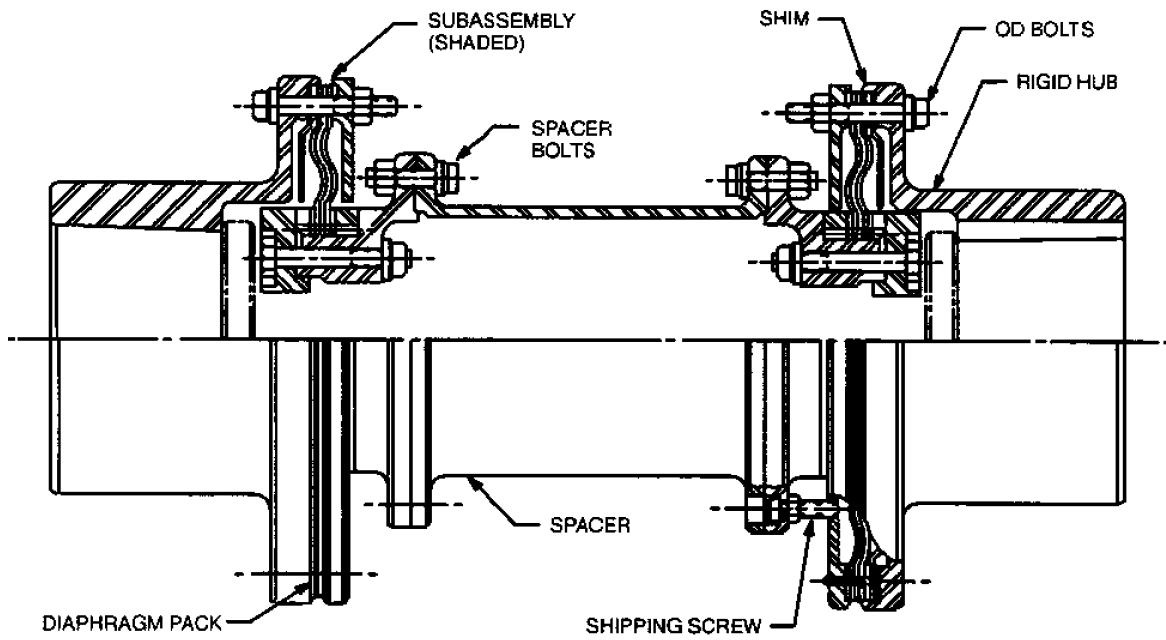


Figure 241-2-16 Multiple Diaphragm Coupling

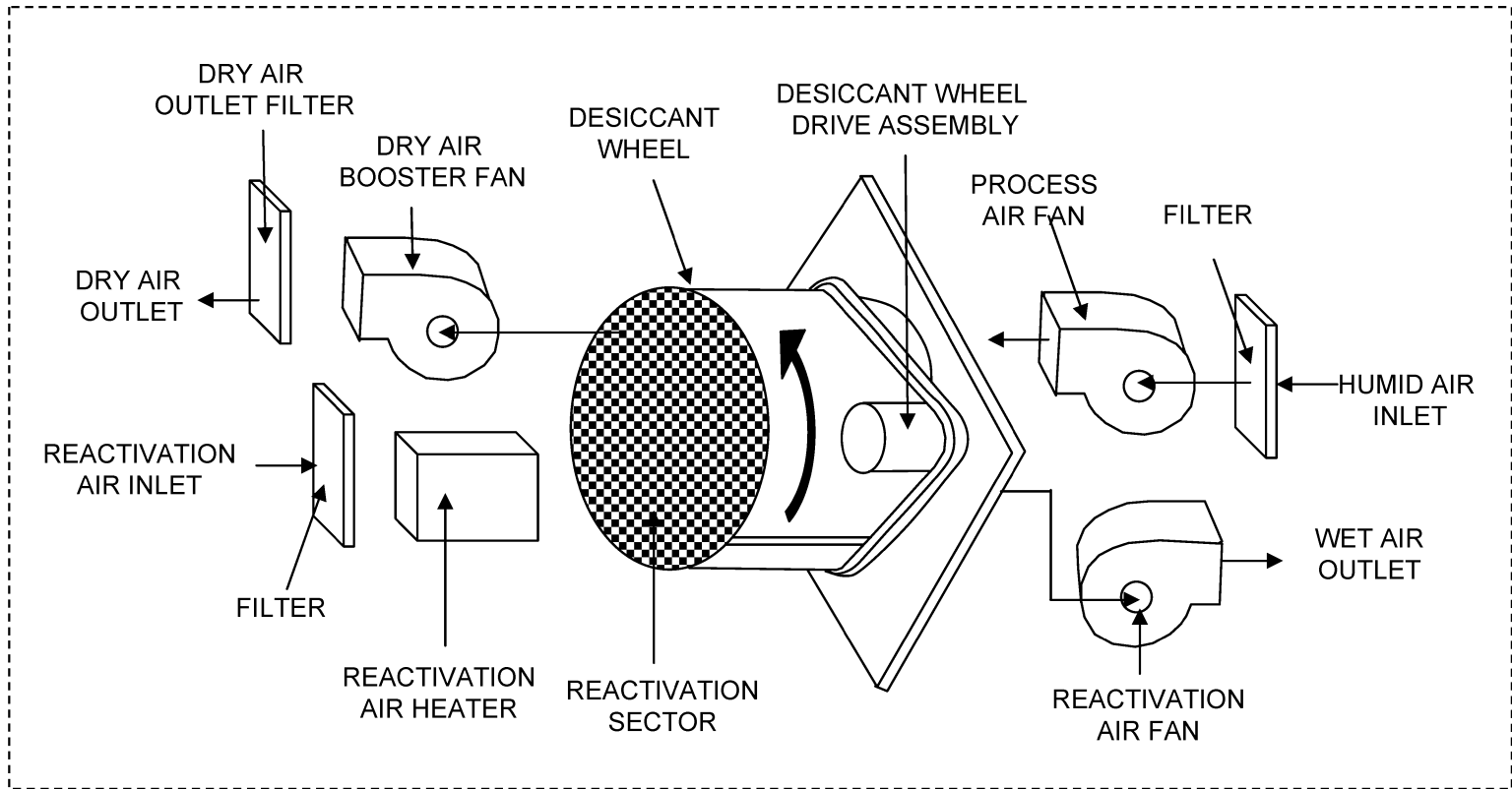
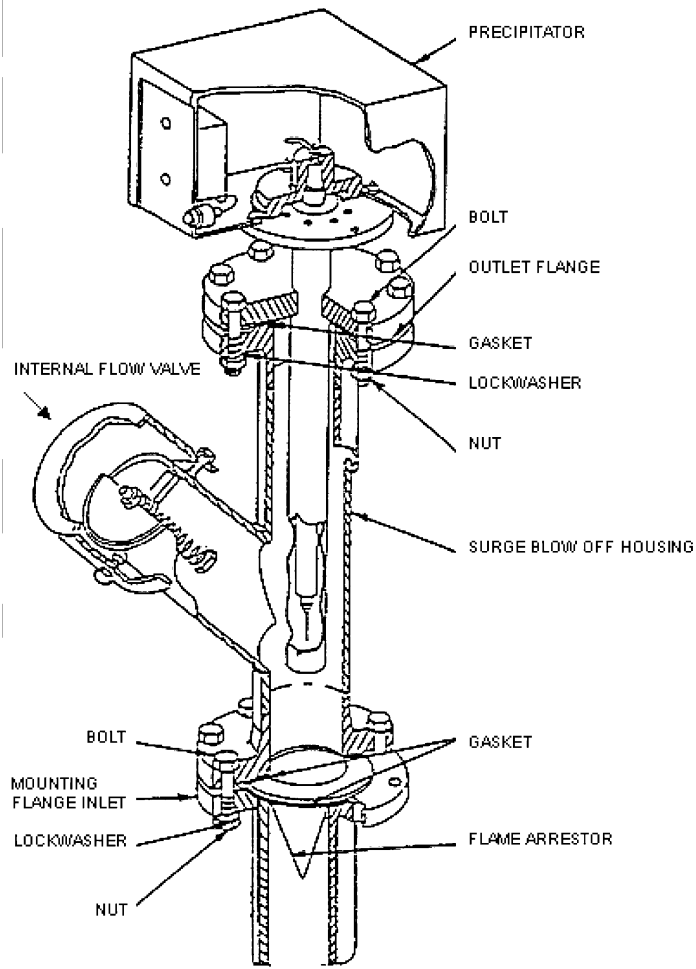


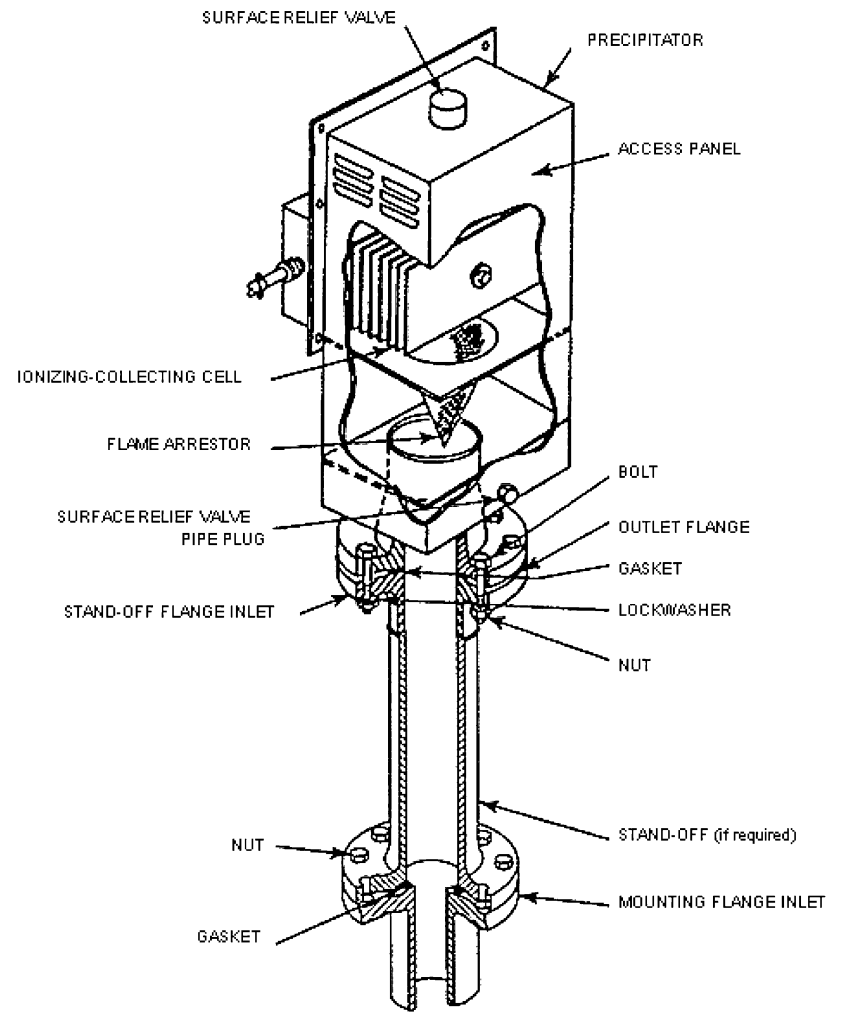
Figure 241-2-17 Dehumidifier Airflow Diagram

241-2.3.17 HYDRAULIC COUPLINGS. Hydraulic couplings use fluid, such as oil to "couple" the input and output rotors and transmit torque. These are often used in diesel applications to prevent harmful torsional vibrations from reaching the reduction gear. Reversible converter couplings (RCC's) (See [Figure 241-2-20](#)) are a special type of hydraulic coupling that have been used for low speed maneuvering and reversing in ships which have gas turbine prime movers and fixed pitch propellers. The RCC has a primary impeller (input rotor) and a secondary runner (output rotor) characteristic of normal hydraulic couplings, but it also incorporates retractable stator vanes for controlling the direction of the oil flow in the hydraulic loop between the two rotors. When the stator vanes are withdrawn, the RCC acts like a conventional hydraulic coupling and provides low speed ahead maneuvering. When the stator vanes are inserted between the impeller and runner they divert the oil flow causing the runner (output) to rotate in the opposite direction. RCC's are built into the MRG drive train as they operate most efficiently at intermediate speeds.

241-2.3.18 GAS TURBINE BRAKE. Generally, gas turbines use hydraulically actuated, air-cooled, caliper type disc brakes to stop the power turbine. They are attached to the turbine end of each gear input shaft. Turbine brakes should only be operated while the turbine throttle is at idle. Typically, turbine brakes are capable of bringing the power turbine to a stop from idle within 25 seconds. See [Figure 241-2-21](#).



10 CFM VENT FOG PRECIPITATOR



50 CFM VENT FOG PRECIPITATOR

Figure 241-2-18 Vent Fog Precipitator

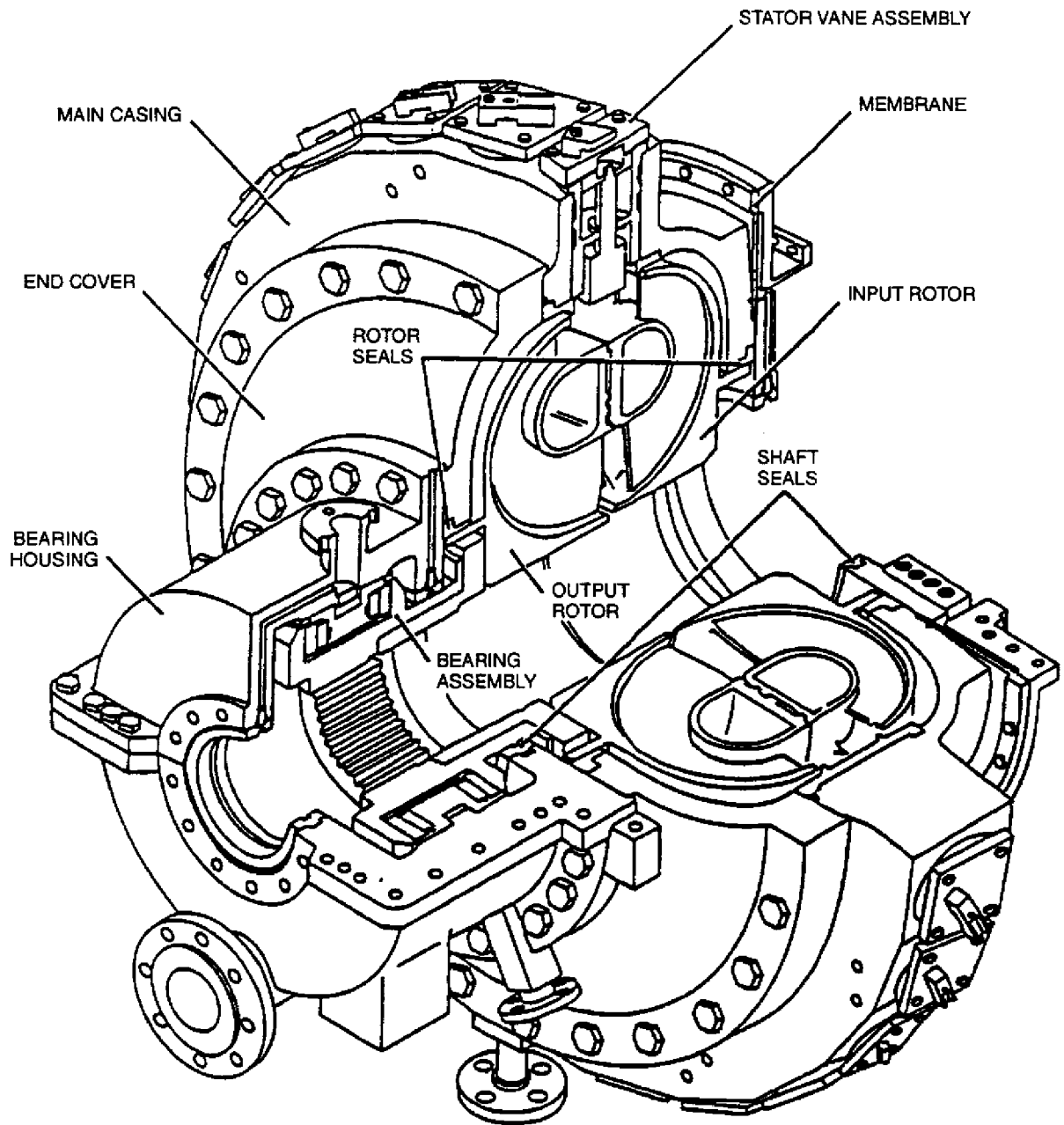


Figure 241-2-19 Gas Turbine Clutch

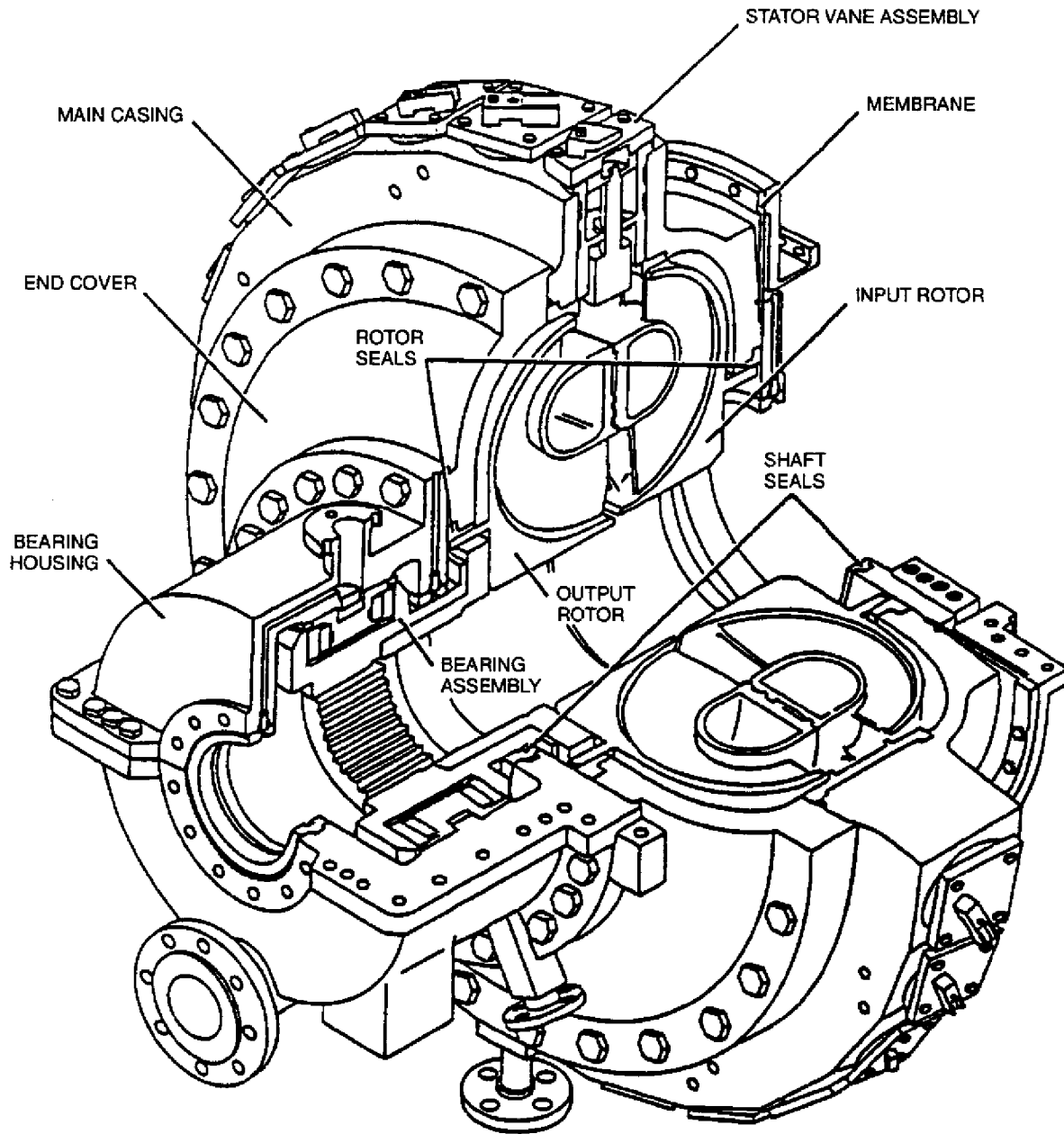


Figure 241-2-20 Reversible Converter Coupling

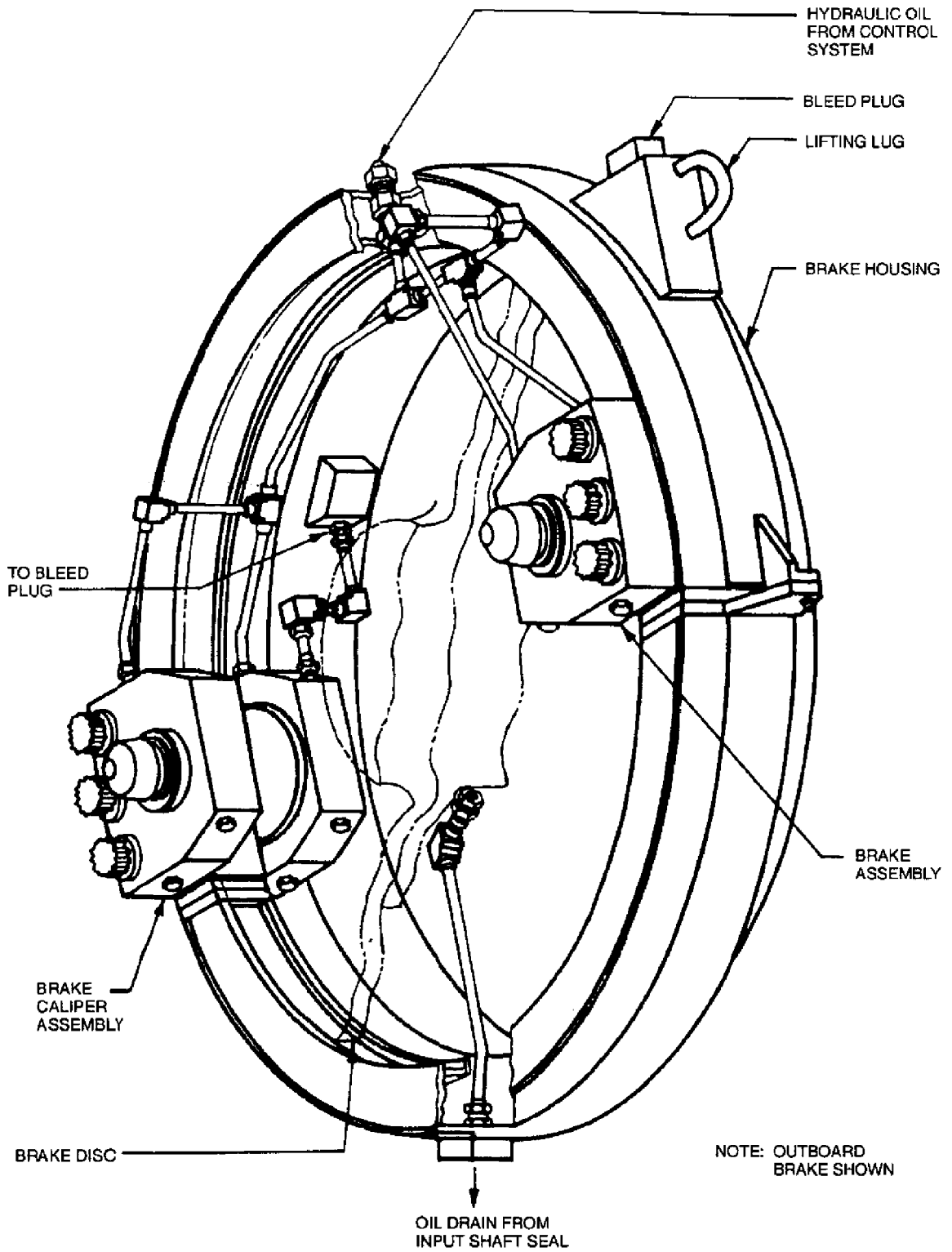


Figure 241-2-21 Gas Turbine Brake

SECTION 3 OPERATION

241-3.1 GENERAL INFORMATION.

241-3.1.1 OVERVIEW. This section is concerned with operation of the MRG and its associated components, including starting, maneuvering, underway operation, and securing. In many respects the operating instructions for propulsion machinery are based on the requirements for operating the prime movers. See the following NSTM chapters for operating instructions for the prime mover:

- **NSTM Chapter 231, Propulsion and SSTG Steam Turbines**
- **NSTM Chapter 233, Diesel Engines**
- **NSTM Chapter 234, Marine Gas Turbines**
- **NSTM Chapter 235, Electric Propulsion Installations.**

241-3.1.2 TURNING GEAR OPERATING GUIDELINES. Turning gears shall be operated in accordance with approved on-board procedures. However, the following are some general guidelines to observe when operating the turning gear:

- a. All MRG bearings and turning gear elements should be supplied with lube oil prior to rotation. If these components are not supplied with an adequate supply of lube oil, damage caused by overheating could occur.
- b. When MRG rotation without the lube oil system operating is required, rotation should be limited to one and one quarter revolutions of the LS gear. An additional one and one quarter revolution of the LS gear is allowable following a one hour cool down period between cycles if the turning gear elements are not experiencing excessive wear.
- c. Prior to rotating without lube oil, all MRG bearings and turning gear elements should be lubricated. MRG bearings can be lubricated through the sight flow indicators and turning gear elements, requiring forced lubrication, can be lubricated through inspection covers.
- d. The MRG dehumidifier shall not be operating when the lube oil system is operating.

241-3.2 LUBRICATION.

241-3.2.1 LUBRICATING OIL. The lubricant used is specified in the MRG technical manual. Instructions on lubrication and lubrication systems can be found in **NSTM Chapter 262, Lubricating Oils, Greases, Specialty Lubricants, and Lubricating Systems**. The propulsion lube oil (PLO) system is designed to supply the proper quantity of oil at the required pressure and temperature.

241-3.2.2 CARE OF LUBRICATION SYSTEM. To ensure satisfactory MRG operation and assure full service life of the MRG, keep the lube oil clean at all times. Lube oil can be contaminated by freshwater, seawater, and foreign particles such as dirt, sediment, and metal debris.

241-3.2.2.1 The most common contaminants are water and foreign particles. These contaminants can be detected in 2190 TEP lube oil using the clear and bright visual method and should be removed using a purifier. Purifiers

and filter separators can operate continuously or on a batch cycle to remove water and foreign particles from the lube oil. Lube oil inspection, cleaning procedures, and purifier operation for 2190 TEP and 9250 lube oil can be found in **NSTM Chapter 262**.

241-3.2.2.2 For installations where the oil cannot be purified or settled out, replace the oil. Refer to the MRG technical manual and **NSTM Chapter 262** for the lube oil change out requirements.

241-3.2.2.3 Large amounts of foreign particles may enter into and contaminate the lube oil whenever MRG casing covers or bearing caps are lifted for maintenance, inspection, or repair; and during extended system shut-downs. If contamination is present, install temporary muslin or nylon filter bags (**NSTM Chapter 262**) in the strainer baskets until those particles that would normally pass through the strainer are removed from the system and the bags are free from debris. Ships using filters may be able to replace the filters with temporary strainer baskets and muslin or nylon bags. When the bags are clean, remove the strainer and muslin bag assembly and reinstall the filters. Even though filters may provide a higher level of filtration, strainer bags are preferred for inspection for foreign material.

241-3.2.2.4 Unless otherwise directed by an approved on-board procedure, after shutting down propulsion engines, continue lube oil circulation and rotate the MRG on turning gear while circulating cooling water and operating the purifier or filter separators. After two hours, shut down the cooling water and purifier but continue circulating lube oil until the temperature of the lube oil is stable within 10_ F of engine room ambient temperature. The turning gear can be secured any time after the initial two hours and when the lube oil pump is secured. Once lube oil temperature is within 10_ F of engine room ambient temperature, the lube oil pumps can be secured. This will minimize the amount of condensation which causes rusting.

241-3.2.2.5 The MRG lube oil condition should be monitored on a regular basis to detect the condition of used lube oil, detect unusual wear, and to predict impending equipment failures. The lube oil should be monitored in accordance with NSTM Chapter 262 and as directed by applicable PMS requirements.

241-3.2.3 EFFECTS OF FOREIGN MATERIAL IN OIL. Freshwater can enter the propulsion lube oil (PLO) system through leaky steam turbine glands and from condensation inside the MRG casings. Water in the oil increases frictional resistance, breaks down the oil film prematurely, and causes corrosion. Rusting usually begins inside the upper parts of the casing and when present on machined surfaces such as gear teeth, could initiate a failure.

241-3.2.3.1 Depending on the oil used, water can be present in a free or emulsified state and is corrosive in either form. In 2190 TEP steam turbine oil, water exists in a free state and, therefore, can be centrifuged out of the oil using the purifier. In 9250 diesel oil, however, the water is suspended in the oil, forming an emulsion, thus making purification difficult. Evaporation will remove some, but not all of the emulsified water. Maintain and monitor the PLO system in accordance with **NSTM Chapter 262** to prevent water contamination and remove any water when detected.

241-3.2.3.2 Salt water in the PLO system is extremely dangerous because even small amounts can severely corrode and pit MRG elements. Past experiences indicate salt water can enter PLO from leaking lube oil coolers, and due to space flooding. For MRG's with the oil sump at the skin of the ship, test oil salinity numbers frequently and inspect the gear teeth for corrosion more thoroughly during scheduled gear teeth inspections. When salt water is found in the PLO system, take immediate corrective action to locate and seal off the source of the contamination, remove the contaminated oil, follow the casualty control procedures provided in paragraph

241-6.4 for MRG salt water contamination and refill with clean oil. Technical assistance from FTSCCLANT, FTSCPAC, NSWCCD, or NAVSEA should be initiated immediately to ensure complete corrective action is followed and witnessed. Delay in responding to salt water contamination can damage and reduce the service life of the MRG.

241-3.2.3.3 Acids are formed when oil oxidizes in the presence of air and heat. These acids break down the load carrying capacity of the oil, and this rapidly deteriorates the gear teeth. For 2190 TEP oil, monitor the acid content or neutralization number of the oil. Similarly, monitor the base number or quantity of base material in 9250 oil. Monitor both oils in accordance with **NSTM Chapter 262**.

241-3.2.3.4 Foreign materials such as dirt, sludge, rust, gasket sealers (e.g. Permatex), and metal debris may scratch and deteriorate gear teeth, wipe bearings, and score bearing journals. Foreign material can restrict or block the supply of oil to the oil spray nozzles and bearings.

241-3.2.4 **LEVEL OF OIL IN MRG SUMP.** The oil level in the bottom of the MRG case must not rise above the lower level of the teeth of the LS gear unless an oil shield is fitted around the LS gear for the purpose of carrying a higher oil level. If this precaution is not observed, the gear will churn and aerate the oil, causing foaming and a sudden increase in its temperature. Oil churning can also prevent full speed operation of the shaft. This condition may be detected by observation in sight flow fittings, by an overflow of foaming oil through the vent or electrostatic precipitator (if one is fitted) at the top of the case, and by oil leakage at the casing joints and shaft seals. If this occurs, slow or stop the engines, and drain excessive oil from the case. If oil buildup is caused by a blockage in the drain, examine the lines to the sump tank to determine and correct the cause of the blockage. Each Engineering Officer should determine and make a matter of record the proper oil level for the ship.

241-3.2.5 **GEAR MESH OIL SPRAYS.** Keep oil spray nozzles open at all times. Where feasible, visually inspect nozzles (and spray strainers, where fitted) quarterly to determine if they are operating properly. The spray pattern from properly operating nozzles will completely and evenly cover a gear mesh with some overlap from adjacent sprays. If foreign material is found in the PLO strainer or filter, inspect the sprays. Inspect spray patterns when the MRG is not rotating through an inspection port. If done with cold oil, recognize that the patterns may indicate less coverage than when the oil is at operating temperature.

241-3.2.6 **MRG CASE VENTS.** Pressure can buildup in MRG cases because of windage and air expansion due to change in temperature, if not vented. Pressure buildup can prevent proper oil drainage and cause leakage of oil through the bearing seals and casing joints. To prevent pressure buildup, vents are usually provided on casings. On most MRG's, electrostatic precipitators are fitted to the vent; others may extend to a point above the waterline and end as a gooseneck. Because the vapor may be explosive, keep exposed lights away from vents. Where dehumidifiers have been installed and operating, after they are secured, make certain that the electrostatic precipitator vent opening closure device is removed or opened.

241-3.2.7 **MRG CASE OVERHEATING.** Excessive MRG case surface temperature indicates inadequate drainage or venting. The casings of turning gears with self contained lube oil supplies should also be monitored for excessive heat generation.

241-3.3 PLANT OPERATING CONFIGURATIONS.

241-3.3.1 Steam turbines and propulsion electric motors are usually connected to the MRG input shaft by a flexible coupling. They are only disconnected for emergency operation. For diesel and gas turbine powered ships, a

clutch usually couples an input shaft to a first reduction pinion. The clutch can engage or disengage the prime mover to the first reduction pinion. For dual input MRG's, the following plant configurations can be selected for each propulsion shaft:

- a. **Secure.**Both engines secured or disengaged on each shaft
- b. **Split Plant.**One engine engaged and driving the MRG on each shaft (Diesel and gas turbine only).
- c. **Full Power.**All engines engaged and driving each MRG on all shafts.
- d. **Trail Shaft.**(Applies to multiple shaft ships only) Unpowered shaft(s) windmilling with propeller(s) set at 100 percent ahead pitch and clutches disengaged. Propulsive power supplied by engines driving the other shaft(s). Primarily used for fuel economy with diesel and gas turbine prime movers. Not used with steam turbines or electric motors except as a casualty mode.
- e. **Locked Shaft.**Used primarily when a casualty has occurred to the propulsion train. This is not a normal operating mode. The locked shaft mode is similar to the trail shaft mode, except the unpowered shaft(s) is locked in place using the shaft locking device. The propeller is set at maximum ahead pitch (if adjustable) to reduce drag.

241-3.4 UNDERWAY OPERATION.

NOTE

The following are general guidelines that should be considered when developing specific operating procedures.

241-3.4.1 PREPARATION FOR GETTING UNDERWAY.

1. Inspect the lube oil sump or supply for sufficient oil for the system.
2. Inspect for water in the lube oil in accordance with **NSTM Chapter 262**. If the lube oil does not meet **NSTM Chapter 262** clean and bright criteria, remove water in accordance with guidance provided in **NSTM Chapter 262** or the Ship Information Book (SIB).
3. Ensure that the PLO system operates satisfactorily and is lined up properly before operating propulsion machinery.
4. The lube oil cooler outlet temperature should be above 90° F before starting propulsion machinery. It may be necessary to heat the oil before starting the propulsion machinery. Most MRG's are designed to operate at a minimum lube oil temperature of 90° F.
5. Ensure that oil is free flowing at the correct temperature to all bearings and spray nozzles, and lineshaft components. Most MRG's are operated with the lube oil cooler outlet temperature at 120° F to 130° F. With the oil circulating at operating temperatures to all bearings and spray nozzles, check the oil level in the sump or supply tank.
6. When applicable, check that oil pressure at the most remote bearing is within the allowable operating range.
7. When applicable, check that control air pressure is available to gas turbine brake air regulating valve and that outlet pressure is set to the correct value.

8. When applicable, check the turbine brake air or oil boosters oil reservoir level and replenish if necessary.
9. When applicable, check that the attached CPP hydraulic and lube oil pump drives are engaged and properly lined up unless tagged out for repair.
10. Check that the turning gear is disengaged.
11. Check that shaft lock is disengaged.
12. When applicable, check that the gas turbine clutches are not locked out.
13. Ensure that lockout tools are removed from the clutches and properly stowed.
14. Check that all inspection and access covers are closed and locked.

241-3.4.2 **NORMAL ROUTINE WHEN OPERATING MRG.** When the ship is underway, observe all oil pressures and temperatures and sight flow indicators to ensure satisfactory operation. Enter pressure and temperature (RTE or bubbler) readings hourly in the appropriate log. Check the oil level in the sump frequently; if changes occur, investigate for leaks. Although a properly sealed MRG case will not leak oil, deteriorating seals, packing, and sealing compounds may allow some oil leakage. Minor oil leakage (i.e. one drop per minute) is not a hazard to equipment and, if not a fire hazard, should not restrict MRG operation.

241-3.4.2.1 If the ship is getting underway after an extended time in port or following an MRG repair or when lube oil contamination is suspected, muslin or nylon bags should be used in PLO system strainers. Operate with the bags until accumulation of foreign particles in a 4-hour period meets acceptable limits specified in **NSTM Chapter 262**. Ships with installed filter systems should closely monitor the differential pressure across the filter(s).

241-3.4.2.2 Continuous operation of the purifier will aid in removing fine foreign particles and water from the oil. The more the purifier is operated, the cleaner the oil will be. Continuous purifier operation will also remove any contamination in the MRG case. Refer to **NSTM Chapter 262**.

241-3.4.2.3 Refer to **NSTM Chapter 262** for oil sampling, purifying, and cleaning procedures. Oil samples should be taken and checked weekly (paragraph [241-5.2.2](#)).

241-3.4.2.4 If the lineshaft is stopped while underway, no damage will occur to the MRG, but instructions for handling other propulsion components should be considered (**NSTM Chapters 231 and 234**).

241-3.4.3 **INITIAL MRG OPERATION.** New MRG's, MRG's with new elements or bearings, or MRG's that have been realigned, should be run at lower power for several hours and inspected for proper tooth contact before being subjected to the maximum tooth load of full power.

241-3.4.4 **UNUSUAL NOISE OR VIBRATION.**

241-3.4.4.1 **Distinctive Noise.** A properly operating MRG has its own distinctive noise or sound that the operator should learn to recognize. This noise is from numerous causes: cyclic tooth errors in action (meshing errors), misalignment between prime mover and MRG, resonant panels, roughness of tooth surfaces, etc. The noise is not an indication of a problem, but it is unique to each MRG. MRG's of the same type operating in different engine spaces may emit different operating noises. Any change in the characteristic noises could be cause for concern

and should be investigated. It may be necessary to stop and lock the shaft until the ship is dead in the water. Rotating the MRG with the turning gear may help isolate the source of the noise. Operating an MRG with an unusual noise could cause a gear tooth failure.

241-3.4.4.2 Rumbling on Steam Turbine Powered Ships. A rumbling sound usually occurs on multishaft ships while the ship maneuvers. On steam turbine powered ships at slow lineshaft speeds, rumbling occurs due to the low pressure steam turbine gearing floating through its backlash. During very low power ahead operation, the low pressure turbine develops very little power. The power developed by the high pressure turbine rotates the lineshaft and windmills the low pressure turbine rotor. In this condition, the astern tooth faces of the low pressure gear train are in contact. As the low pressure turbine develops more power, there is a speed where the low pressure gear train floats through backlash. As the gear floats, the ahead and astern faces of the teeth are alternately in contact causing the rumbling sound. This rumbling is common in steam turbine gearing. Operate the MRG above or below this speed to stop this rumbling.

241-3.4.4.3 Rumbling on Gas Turbine Powered Ships. A rumbling sound may occur on gas turbine powered ships during split plant operation. In this operating condition the non-powered branch gearing will be back driven by the lineshaft allowing the unloaded gears to float through their backlash and cause the rumbling sound. This condition can exist at varying speeds and depends on the dynamic characteristics of the gearing and sea state. There may be a speed or speed range where the noise is more pronounced. Avoid this condition by operating above or below the shaft speeds where it is most pronounced.

241-3.4.4.4 Unusual Noise at Low Speeds. On multishaft turbine geared ships, an unusual noise may occur at low shaft revolutions when maneuvering or when operating over very shallow water. The rumbling and thumping noise is caused by a torsional vibration initiated by the propeller. The noises are not due to any defect in the MRG and will not occur during normal operation in deeper water.

241-3.4.4.5 Bearing Stick Slip. At slow lineshaft speeds stick slip can occur; however, the noise in the gear train seems louder for the longer lineshafts. The stick slip slows down the aft end of the lineshaft; however, the second reduction gear wheel on the forward end of the lineshaft continues to rotate and twists the lineshaft until it slips in the stern tube and strut bearing. The slipping lineshaft allows the propeller to rotate through a large arc (like a flywheel) and forces the aft end of the lineshaft to rotate ahead of the forward end. This forces the LS gear wheel to float through the backlash, causing a rumbling sound similar to that described in paragraph [241-3.4.4.2](#).

241-3.4.4.6 Noise Caused by Unstable Bearing Loads. If the lineshaft bearing reactions are incorrect, the first lineshaft bearing (aft of the gear) could lift the LS gear shaft clear of its aft bearing. At light loads the aft LS gear bearing journal may ride in the top half of the bearing. As the load increases the tooth load tends to move the journal downward. At a certain speed the spring force of the shaft will equal the pinion tooth reaction. This will cause an unstable condition and change the gear operating noise. Similarly, if the first lineshaft bearing is too low, it will unload the bottom half of the forward LS gear bearing.

241-3.4.4.7 Noise Caused by the Torsional Critical Speed. Propulsion systems frequently have a torsional critical speed that occurs at a low speed. This speed is a design determination and can be located in the manufacturer's technical manual. At low speeds, torsional criticals are not destructive, but can cause backlash rumbling noise.

241-3.4.4.7.1 The torsional vibration may cause the gear mesh to separate under load. It is best to avoid this critical speed when operating the ship. Operate the MRG a few turns above or below this speed to avoid the torsional vibration. The most likely causes for an unusual torsional vibration would be hard rudder turns or a fouled propeller.

241-3.4.4.8 Checking the Source of Vibration. Vibration is usually caused by misalignment, bent shafts, damaged propellers, improper balance, or problems with the prime mover before the gears. Therefore before instrumenting the MRG, measure vibration from the prime mover, shafting system, and propeller before inspecting the MRG as the source of the vibration.

241-3.4.4.9 Imbalance. Gear wheels and pinions are balanced during manufacture and will remain in balance unless improperly assembled or damaged in service. Indications of imbalance are unusual vibration, noise, and unusual bearing wear. Refer to paragraph 241-3.4.4.8 regarding sources of vibration before disassembling an MRG. To determine if an imbalance exists, use vibration measuring equipment to determine if a once per revolution amplitude exists.

241-3.4.4.10 Rumbling During Abnormal Operating Conditions. Rumbling of the MRG is common during abnormal operating conditions such as crash back tests, shallow water, or whenever the propeller is driving the MRG, such as during trail shaft operation.

241-3.4.4.11 Rumbling Caused by Propeller Blade Damage. The irregular rotation of a damaged propeller blade could cause high lineshaft vibration and rumbling of the MRG, especially during trail shaft operation or during split plant operation. This may damage the main reduction gear.

241-3.4.5 BEARING TEMPERATURE (MONITOR AND CONTROL). The temperature of the oil supplied to the bearings from the lube oil cooler should be maintained at a temperature recommended by the applicable MRG technical manual. The temperature of the oil from the lube oil cooler usually ranges from 120 to 130° F. The temperature of oil discharged from a bearing should not exceed 180° F or a 50° F rise above the cooler outlet temperature, whichever is less (unless otherwise stated in the applicable technical manual or waived by the Naval Sea Systems Command (NAVSEA) on a case-by-case basis).

241-3.4.5.1 Remote Alarms. In addition to local reading thermometers, some MRG's have thermocouples or resistance temperature elements (RTE) installed for remote temperature indication. Thermocouples or RTE's are installed in either the sight flow fitting or are mounted directly in the load section of the bearing babbitt. For surface ships, an RTE for journal bearing babbitt is normally set to alarm 20° F above the maximum steady state temperature measured on trials or 250° F whichever temperature is lower. For submarines, an RTE for journal bearing babbitt is normally set to alarm 30° F above the maximum steady state temperature measured during sea trials or 250° F, whichever comes first. Periodically, PMS will require confirming that the alarm set point is correct. This will be accomplished by measuring bearing temperatures during a new controlled steady state evolution. For each bearing, 30° F is added to the maximum steady state temperature measured during the new controlled steady state evolution. If the resulting temperature differs by more than 10° F from the old alarm set point, then the alarm set point may be reset to 30° above the maximum steady state temperature measured during the new controlled steady state evolution, or 250° F, whichever is less. Otherwise, the alarm set point shall remain unchanged. When setting journal bearing RTEs, lube oil cooler outlet temperature shall be maintained between 126° F and 130° F with temperature as close as possible to 130° F. Thrust bearing babbitt RTE's should be set in accordance with **NSTM Chapter 244, Propulsion Bearings and Seals**.

241-3.4.5.1.1 Casualty Control Procedure for Hot Bearings. The conditions that result in hot bearings and the casualty control procedures to be followed can be found in **NSTM Chapter 079, Volume 3**.

241-3.4.5.2 Sight Flow Indicators. A sight flow indicator (SFI) is used in journal and thrust bearings to provide visual indication of oil flow. Most have provision for installing a thermometer for local temperature reading and in some designs provision for installing RTD's for remote temperature monitoring. In cylindrical and multiple lobe bearings, the oil that circulates through an SFI is a small sample of the oil that has already passed through the bearing. In tilting pad bearings, the oil in the SFI is only a sample of the oil flooding the bearing cavity.

241-3.4.5.2.1 Because bearing designs and operating conditions vary widely, it is not possible to achieve a consistent oil supply to the SFI at all operating conditions. Some variables that affect flow are; bearing geometry, journal speed, journal position resulting from load reaction, direction of rotation, oil pressure, and bearing unit loading. Because of these variables, flow may vary from minimum to fully flooded and still be considered satisfactory. It is more difficult to detect flow through a flooded sight flow indicator, and it is preferable that SFI's do not run flooded.

241-3.4.5.2.2 If operating experience shows that a bearing SFI normally runs partially full or flooded, but there is evidence of flow as indicated by oil turbulence in the SFI, then this condition is considered satisfactory and no corrective action is required.

241-3.4.5.2.3 Removal or replacement of bearings for the sole purpose of investigating and correcting flooded sight flow indicators where flow is evident is not justified. Do not operate the MRG when any sight flow indicators show complete loss of flow, except on turning gear during emergency cooldown to prevent bowing of the turbine rotors. Bearing SFI's that normally run empty and become suddenly flooded should be investigated to determine if the SFI drain has become plugged. Complete loss of flow may indicate bearing damage, incorrect bearing installation, misalignment of the supply pipe, deterioration of the rubber grommet between the pipe and the indicator, or reduced oil pressure. Investigate cause for loss of sight flow indication prior to resuming operation.

241-3.4.5.2.4 Erratic oil flow and a complete loss of oil flow to a single sight flow indicator at partial or full load conditions can occur following reinstallation of a bearing that had been removed. This is generally caused by a restriction in the oil line from the bearing to the sight flow fitting. The restriction normally results from improper assembly of the bearing cap on the shell such that the oil passages are not directly in line or improper handling has resulted in a nick or a burr appearing at the edge of the passage. Check for any restrictions and remove them at the earliest opportunity.

241-3.4.6 REQUIREMENTS FOR LOCKING A PROPULSION LINESHAFT.



Do not attempt to lock the propulsion lineshaft until it comes to a complete stop.

- a. Locking the propulsion lineshaft may be required to prevent fouling of diving lines and hoses due to inadvertent rotation of machinery or rotation of propellers due to tide or current.
- b. Stopping and locking a lineshaft with way on the ship may be necessary to prevent serious equipment damage from occurring due to the loss of PLO or component failure.
- c. Under normal conditions the propeller shaft should not be locked until the ship has come to a complete stop. For periodic training or in the event of an emergency (such as a casualty to the main propulsion machinery), the propeller shaft may be stopped and then locked when the ship is underway and the shaft is stopped in accordance with the ships emergency stop and lock procedures.
- d. Engage the propulsion shaft locks when it is necessary to prevent rotation of the propulsion machinery when the ship has suffered a casualty, is under tow, is anchored with divers in the water, or is anchored or birthed in an area that has strong tides or currents that could cause rotation of the propeller (windmilling).

241-3.4.7 LOCKED SHAFT PRECAUTIONS.

- a. When the turning gear is engaged, the propeller shaft must not rotate and under no circumstances should the throttles be opened. With the high gear ratio in the turning gear, even one rpm on the propeller shaft, will overspeed the turning gear and possibly destroy the device.
- b. When the turning gear or shaft lock is engaged, the throttles should be secured with a chain and lock. A sign indicating that the turning gear or shaft lock is engaged should be attached to the chain.
- c. Machinery operators shall be thoroughly familiar with the exact procedure for engaging, locking, unlocking, and disengaging the shaft lock while underway. Engaging and locking must be performed quickly with the affected shaft stationary.
- d. A team, consisting of a throttle man and a lock man, engages the shaft lock and observes the propulsion shafting. If required by machinery design or arrangement, a third man may be necessary to observe propulsion shaft rotation or to rotate the turning gear drive by hand to align the lock for engagement.
- e. On single shaft ships, when the engine is applied to stop and hold the shaft prior to engaging the shaft lock, the throttleman must be aware that the amount of power required to hold the shaft stationary will decrease as the ship speed decreases.
- f. On multiple shaft ships, when the ship has been driven after a shaft is locked, additional twist (residual torque) can be experienced in the locked shaft, which may be greater than the initial torque. When unlocking, it may be necessary to apply reverse torque greater than the initial torque. Great care must be exercised to prevent overtorquing locked components when applying reverse torque to release the shaft lock.

241-3.4.8 CASUALTY CONTROL PROCEDURE FOR STOPPING, LOCKING, AND UNLOCKING SHAFT WHEN UNDERWAY (GAS TURBINE AND DIESEL PRIME MOVERS). The conditions that require underway engagement or disengagement of the turning gear lock on gas turbine ships can be found in **NSTM Chapter 079, Volume 3**. Gas turbine powered ships use their controllable pitch propeller or their reversible converter coupling systems to stop shaft rotation while underway before locking. Diesel engine powered ships use controllable pitch or a combination of controllable pitch and shaft brakes depending on the propulsion plant configuration to stop the shaft underway before locking. Because the detailed procedures and sequencing for underway turning gear lock engagement vary for different gas turbine and diesel powered classes, refer to particular class EOCC for the specific procedures.

241-3.4.9 CASUALTY CONTROL PROCEDURE FOR STOPPING, LOCKING, AND UNLOCKING SHAFT WHEN UNDERWAY (STEAM TURBINE PRIME MOVERS). The conditions that require underway engage-

ment or disengagement of the turning gear or shaft lock on steam turbine powered ships can be found in **NSTM Chapter 079, Volume 3**. Because the equipment design and operational sequencing may vary for different classes, refer to applicable SEPM or EOCC for the specific procedures.

241-3.4.10 TRAIL SHAFT(S). When a shaft is trailed, lubricating oil must be furnished to the propulsion machinery unless a drop-out section of shafting is removed. See **NSTM Chapter 231 or 234** for limiting turbine conditions.

241-3.4.11 PREVENTION OF OVERTORQUING. A ship hull is designed to ride at a predetermined depth in the water with designed size propellers and a clean hull. Under these design conditions the torque developed by the prime movers will allow flank speed without overload. If the ship is overloaded and sits lower in the water, it will require more torque to attain rated propeller speed. If the underwater hull is fouled, the power to attain full speed may overtorque the system. Even the trim of the ship may cause overtorquing. Overtorquing can also occur during split plant operations in the MRG driving power path. MRG technical manuals should specify power torque and rpm limits for both full power and split plant operating modes. Avoid overtorquing the MRG's. See **NSTM Chapters 231, 233, 234, and 235** for further information on overtorquing.

241-3.5 LAY-UP.

241-3.5.1 SECURING. The following is general guidance to consider when developing shut down procedures:

241-3.5.1.1 When an MRG is to be secured, consideration of the oil temperature will aid in reducing MRG case rusting. One hour before reaching port (or anchorage), reduce the PLO cooler outlet temperature 10° to 15° F while maintaining at least 100° F. At standard speed this relatively cold oil thrown on the case by the spinning gears will put a heavy film of oil on the inside of the case that will not easily run off. (Placing a heavy film of oil on the inside of the case cannot be achieved during turning gear operation.) This heavy oil film helps prevent case rusting.

241-3.5.1.2 Once propulsion engines have been secured, continue circulating lube oil and rotate the MRG on turning gear while circulating cooling water and operating the purifier (**NSTM Chapter 262**). After two hours, shut down the cooler and purifier and continue circulating until the temperature of the lube oil is stable within 105°F of engine room ambient temperature. The turning gear can be secured any time after the initial two hours but not before the lube oil pump is secured. Once lube oil temperature is within 10° F of engine room ambient temperature, secure the lube oil pumps. For turbine requirements under this condition see **NSTM Chapter 231 or 234**.

241-3.5.1.3 When the ship is docked and the gears are rotated by the turning gear, throttles should be closed and secured with a chain and lock. A sign should be posted indicating that the turning gear is engaged. This sign should be attached to the chain. The key to the lock shall be the responsibility of the Engineering Officer.

241-3.5.2 EXTENDED LAY-UP. During extended ship lay-up, rotating elements and MRG casing internal areas have to be protected against rust. This requires the use of a dehumidifier, circulation of lubricating oil, rotation of pinion and gear elements, and periodic inspections of the MRG. Dehumidifiers are required and shall be installed and operational for extended lay-up. [Figure 241-3-1](#) shows a typical dehumidifier and vent system diagram. The MRG lay-up procedure for protecting against rust is outlined in [Figure 241-3-2](#). Operate dehumidifiers according to applicable Maintenance Requirement Card (MRC) or shipyard procedures.

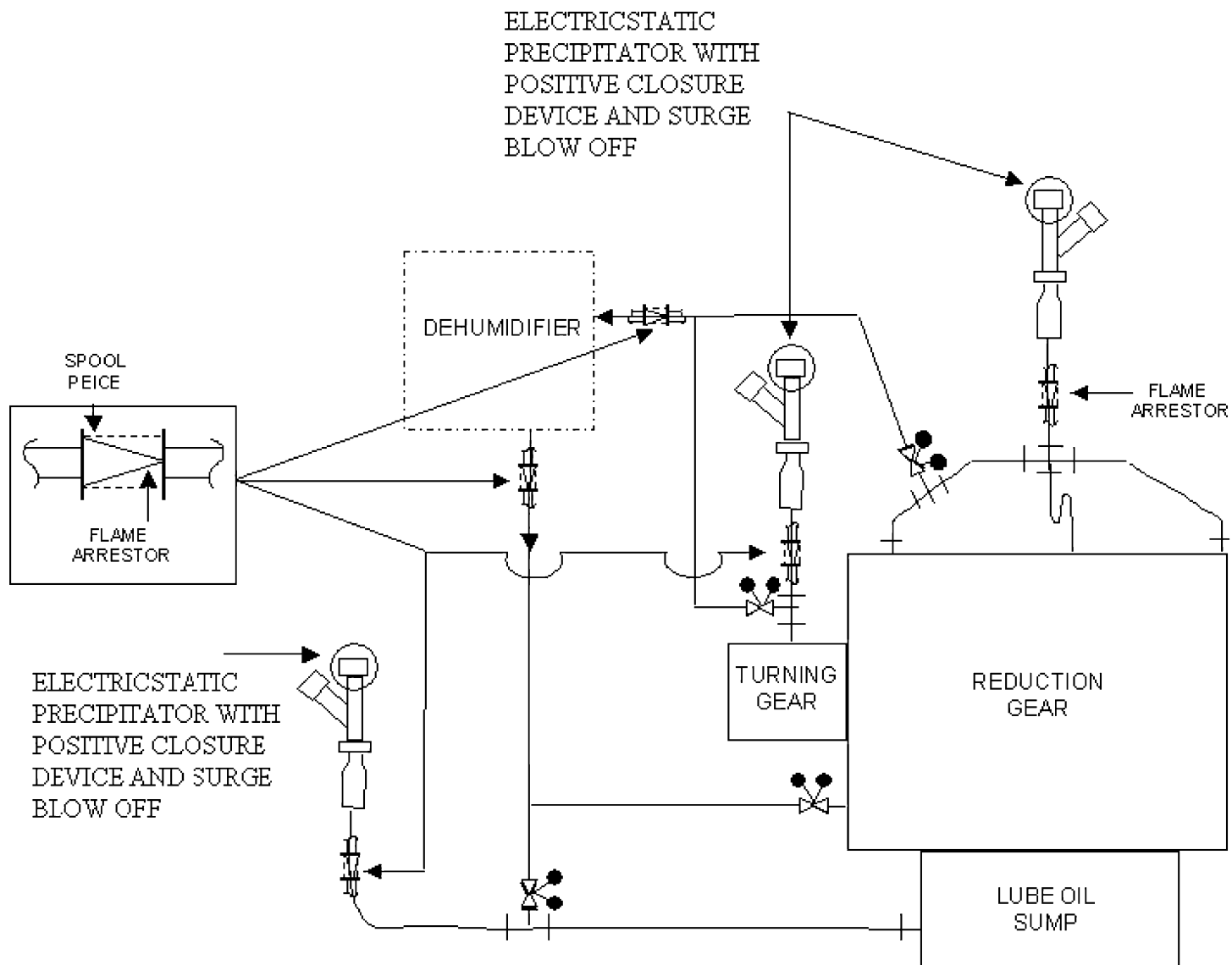


Figure 241-3-1 Dehumidifier/Vent System Diagram

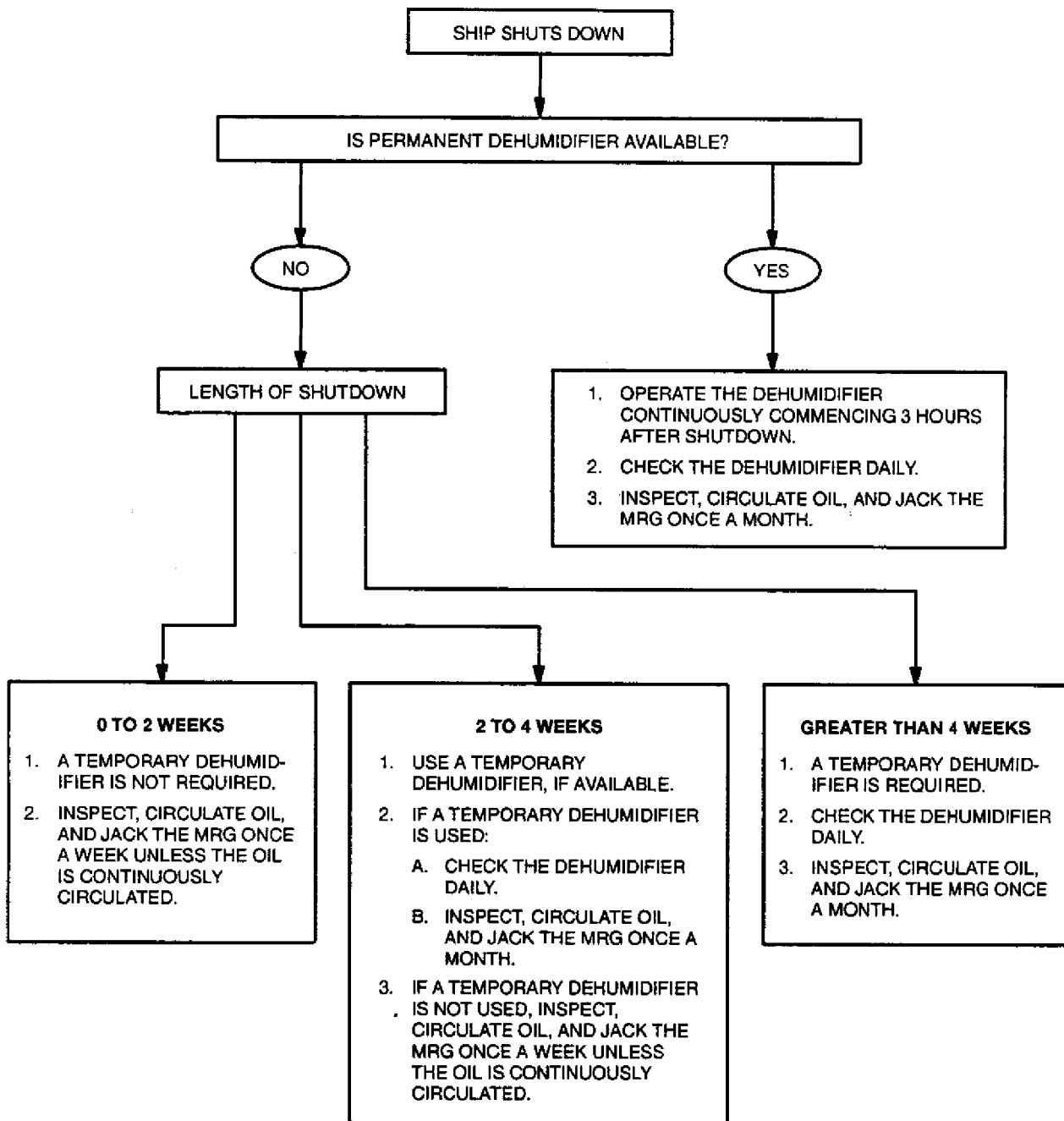
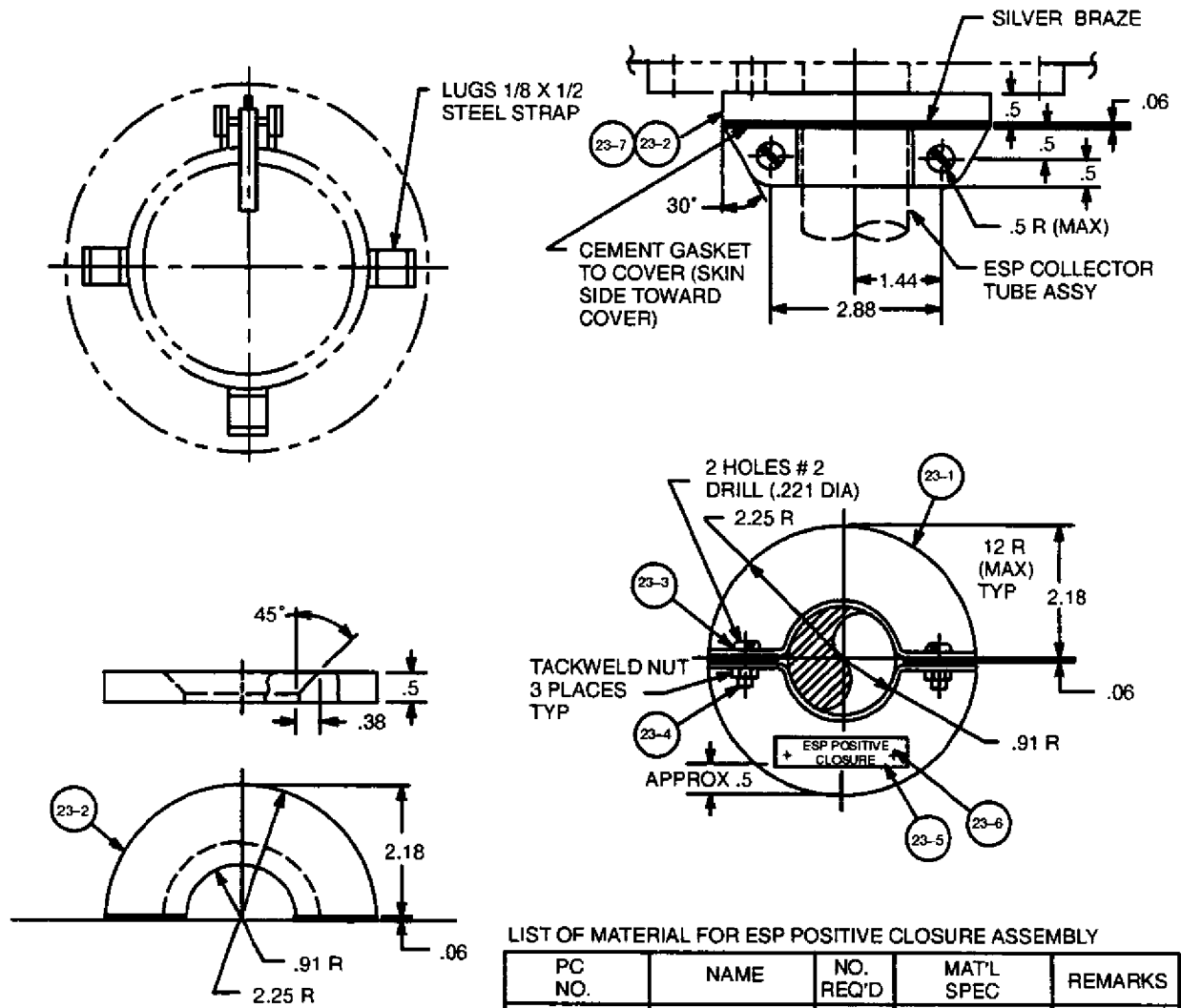


Figure 241-3-2 MRG Lay-Up Rust-Protection Procedure



LIST OF MATERIAL FOR ESP POSITIVE CLOSURE ASSEMBLY

PC NO.	NAME	NO. REQ'D	MAT'L SPEC	REMARKS
23-1	COVER, .062" THK	2	MIL-C-15726	CU-NI
23-2	GASKET, .5" THK	1	MIL-P-15280	PLASTIC FOAM
23-3	SCREW, MACH 10-24UNC-2A	2	FF-S-92	CRES
23-4	NUT, HEX 10-24UNC-2B	2	FF-N-836	CRES
23-5	NAMEPLATE, .032" THK	1	MIL-P-15024	PHOTO-SENSITIVE
23-6	RIVET, BLIND .125" DIA	2		
23-7	CEMENT	AS REQD	MIL-A-24179	

Figure 241-3-3 Electrostatic Precipitator Closure Assembly

241-3.5.2.1 An approved silica gel desiccant type dehumidifier with approximately 150-ft³ /min flow capacity shall be used. It shall be piped to draw moist air from the uppermost regions of the casing and to circulate dry air to the lowest part of the casing. Dehumidifiers should not be operated while lube oil is being circulated. Once the lube oil system has been secured, allow three hours for the oil mist to settle before operating the dehumidifier.

241-3.5.2.2 Some MRG designs incorporate attachments such as an emergency propulsion drive, a turning gear drive, a maneuvering drive, and pump drives. Additional dehumidifier suction piping shall be connected to these attachment vents or upper inspection openings with suitable adapters.

241-3.5.2.3 Open the valves in the piping that connects the case to any permanent dehumidifier and install or close the electrostatic precipitator closure device (See [Figure 241-3-3](#)). If a temporary dehumidifier is used, its piping may be connected to independent dehumidifier flanges that are provided on the case. If the case vent and sump vent connections are used, temporarily remove the electrostatic precipitators, where installed, to facilitate the connection of the dehumidifier piping. (The completed installation shall retain a one-vent electrostatic precipitator with a safety blowoff valve assembly for combined sump tank (case) venting and pressure relief.)

241-3.5.2.4 The dehumidifier shall maintain air in the MRG casing at less than 35 percent relative humidity. Heating or cooling of the dehumidified air is not required.

241-3.5.2.5 A humidistat that senses the humidity in the MRG casing shall be used to electrically control the operating cycle of the dehumidifier. A humidity indicator indicates the relative humidity in the casing.

241-3.5.2.6 Consider the following when removing the dehumidifier after lay-up:

- a. Before MRG lube oil warm-up, shut down the dehumidifier. Close the valves in the piping that connects the MRG case to the permanent dehumidifier and remove or open the electrostatic precipitator closure device. If a temporary dehumidifier was used, disconnect it and secure the flanges with their covers to isolate the dehumidifier from the case. If the MRG and sump vent connections were used, reinstall the temporarily removed electrostatic precipitators and their pipe connections.
- b. Do not operate dehumidifiers while the ship is underway.

241-3.5.2.7 Perform the following periodic dehumidification actions during MRG extended lay-up:

a. **Daily:**

1. Inspect dehumidifying equipment to ensure that it is operating properly and that all connections are in place.
2. Check the humidity indicator to ensure that the relative humidity in the MRG casing is less than 35 percent.
3. For temporary installation, ensure that there are no low spots in the air suction and return piping and all connections are properly made up. Also, ensure that the reactivation air discharge does not blow on the gear case.

b. **Monthly.** Shut down the dehumidifier while performing the following:

1. Open the uppermost MRG casing inspection ports and inspect the inside upper surfaces of the casing and the rotating elements for rust. Remove the uppermost bolted inspection covers on all attachments to ease inspection of each attachment's interior and the rotating elements. Soft (wet) rust that can be reached through inspection ports shall be removed by rubbing with lint-free rags. Dry rust scale that can be reached through inspection ports shall be removed with a crocus cloth. (Do not attempt to remove rust pits below the working surface.) Suspend a blanket secured with lanyards inside the case, below the work area, to catch the debris. Hand coat rusted areas with oil before closing inspection ports. If heavy rusting is observed in inaccessible areas, which subsequent inspections indicate has not abated, lift the casing covers to clean the affected areas. With proper dehumidification rust should not occur. If rust is found, check the

dehumidifier for proper operation and installation. Inspect and circulate oil at least twice a week, if necessary. Notify FTSCCLANT, FTSCPAC, NSWCCD or NAVSEA of rust problems and proposed corrective actions.

2. Circulate lube oil for 1 hour using a lube oil service pump. Do not operate the purifiers. Maintain circulating lube oil at approximately the MRG and clutch casing metal temperature to prevent moisture in the air or oil from condensing on the colder casing. Rotate the pinion and gear elements approximately 1-1/4 turns of the bull gear during oil circulation to ensure repositioning of the gear meshes. When the emergency propulsion drive is an attached case appendage, declutch the drive from the MRG and rotate slowly for 10 minutes on the motor after securing the turning gear.

CAUTION

If the following method of oil supply is used, ensure that the hose is completely free of contamination both inside and out or damage to the MRG may occur.

3. If oil cannot be circulated with the lube oil service pump, then apply oil at approximately the MRG casing temperature to the inside surfaces of the casing and to the rotating elements. This may be done by operating the lube oil purifier and pump with bowl and heater bypassed, attaching a hose to the purifier oil discharge piping, and hosing through open casing inspection ports and unbolted appendage inspection covers, if applicable. When applying oil in this manner, do not rotate the pinion and gear elements. It may be necessary to install temporary fittings in the purifier discharge piping for attachment of the hose. The hose assembly shall consist of a 1-inch oil resistant hose, cutout valve, and nozzle.
4. Paragraphs in this chapter that direct attention to the rusting of MRG casings and rotating elements are paragraphs [241-3.2](#), [241-4.4.5.6](#), and [241-5.1](#).
5. When inspection ports are open, exercise extreme caution to prevent tooth damage or loose objects from falling into the MRG. Shirt pockets of all personnel associated with the opened MRG shall be empty. Install dehumidification equipment in a manner that does not compromise MRG security required by paragraph [241-4.2](#). Paragraphs in this chapter that highlight this danger are paragraphs [241-4.2](#) and [241-5.2](#).
6. Ships that have been deactivated in accordance with **NSTM Chapter 050, Readiness and Care of Inactive Ships**, do not require preservation protection because the machinery compartment is dehumidified at all times and the interior surfaces are preserved in accordance with MIL-C-161713D.

SECTION 4 MAINTENANCE

241-4.1 MACHINERY HISTORY.

241-4.1.1 MACHINERY RECORDS. Although maintenance and retention of machinery history records is not required, an accurate record of all repairs, adjustments, readings, and casualties should be kept by the Engineering Officer.

241-4.1.2 CONTINUOUS MONITORING. The MRG shall be continually monitored when operating for indications of potential problems. Record and examine any abnormal or unusual conditions such as unusual gear train noise or vibration, high bearing temperatures, low lube oil flow at the sight flow indicators, or babbitt particles in the lube oil system and strainer. A large, rapid increase in bearing temperature may indicate that a casualty is about to or has already occurred. Gradual increases in bearing temperature may indicate a casualty will eventually occur. Babbitt particles in lube oil strainers are an indication that damage has occurred.

241-4.2 ACCESS TO GEARS.

241-4.2.1 ACCESS TO MRG INTERNALS. Access to MRG internals can be obtained through hinged inspection covers or external items removable or movable by removing threaded fasteners. These items include, but are not limited to, cover plates, lube oil lines, mesh spray nozzles, vent and dehumidifier piping, sight flow fittings, fixtures and plugs.

241-4.2.2 PERMISSION TO OPEN. Do not dismantle or remove any portion of the MRG casing or its access openings, plugs, piping, attached fixtures, or fittings without the specific authorization of the Engineering Officer.

241-4.2.3 MINIMUM PHYSICAL SECURITY. Using the methods of paragraph [241-4.2.4](#), to prevent, deter, and detect unauthorized access to the MRG internals, establish the following minimum security conditions and procedures:

- a. Secure all inspection covers, whether hinged, pinned, or bolted. Unsecured inspection covers can provide the quickest access, with no ability to detect intrusion to the most critical areas in the MRG. Secure access covers or panels normally removed for major repair or overhaul. (This does not apply to casing joints.)
- b. Secure sites where access to gear internals may be had by removal or movement of external items by removing threaded fasteners. This includes, but is not limited to cover plates, sight flow indicators, thermometer and resistance temperature element (RTE) wells, flanges in piping and components permitting entry into the gear case, including, but not limited to, precipitator piping, breather piping, and any piping which would likely lead foreign material introduced into the pipe through an unsecured flange to come into the gear case under the effects of oil flow, gravity or vibration.
- c. Custody of keys for all security locks shall be the responsibility of the Engineering Officer.
- d. Whenever the MRG case is opened for maintenance, inspection, or repair, follow the special precautions listed in paragraph [241-6.1.1.m](#).
- e. Forces afloat shall initiate and maintain an ongoing program of security training for engineering personnel to make them aware of the importance of MRG security and the consequences of unauthorized entry. This pro-

gram shall be designed to ensure that engineering personnel are trained in the methods and devices being used to provide this security. Engineering personnel shall be instructed to report any tampering with these devices.

- f. When it is determined that a ship does not meet the minimum requirements for MRG case physical security, initiate the efforts needed to meet these requirements. Suggested methods and general guidelines, are provided in paragraph 241-4.2.4. Because of the large number of different designs and configurations, however, modifying these methods may be necessary. Any method other than those listed here that will prevent, deter, and detect unauthorized access may be used provided it is approved by the Type Commander (TYCOM). Lock-wire and lead seals, however, are unacceptable. When stringent access controls are maintained and watch standing requirements ensure a constant watch in the area, only the minimum requirements should be necessary. Additional methods are also provided that allow each TYCOM to increase the security of MRG's above the minimum standards when an increase is considered appropriate. Security measures implemented in response to previous directives may continue to be used if they meet present security objectives.

NOTE

All hardware added to minesweepers MRG shall be nonmagnetic to be compatible with MRG material requirements.

241-4.2.4 METHODS OF SECURING SITES PROVIDING ACCESS TO MRG INTERNALS. In order to achieve the minimum security requirements defined in paragraph 241-4.2.3, the following methods may be used, as appropriate to the configuration of the site providing access to the mrg. All security hardware shall, to the maximum extent practical, be captive to prevent accidental entry into the MRG case.

- a. Install locks that meet or exceed Federal Specification FF-P-2827A, Padlock, Key Operated. When a damaged lock is to be replaced, replace it with the same type and style if possible. Where the above is inappropriate and modification is required, recommend an alternative method to the TYCOM for review and approval.

NOTE

The General Field Service Padlock, Model 655 (3/8-inch shackle diameter) or Model 656 (1/2-inch shackle diameter) are acceptable for MRG applications and meet the requirements of Federal Specification FF-P-2827. Abloy padlocks may be purchased directly from code 4044 via funding document by contacting Defense Locking Systems, code 4044, Naval Surface Warfare Center, 300 Highway 361, Crane, IN 47522-5001 at (812) 854-1354 or by contacting Abloy Security, Inc., phone number (800) 367-4598. (When calling, specify padlocks are for MRG application).

S & G Model 826 Series Padlocks, Model 826A (3/8-inch shackle diameter), Model 826C/D (1/2-inch shackle diameter) are still acceptable for use in MRG applications. Model 826 Series padlocks are no longer purchased by Defense Supply Center Philadelphia (DSCP, Philadelphia, PA) but refurbished Model 826 Series Padlocks may be purchased directly from Code 4044 via funding docu-

ment by contacting Defense Locking Systems, code 4044, Naval Surface Warfare Center, 300 Highway 361, Crane, IN 47522-5001 at (812) 854-1354 or DSN 482-1354.

- b. Inspection covers can be secured by the methods depicted in Figures 241-4-1, 241-4-2, and 241-4-3 or equivalent. Where more than one strongback is installed on one inspection cover, lock each strongback. On covers using center bolt construction, secure the center bolt to prevent it from backing off.
- c. Sites where access to gear internals may be had by removal or movement of external items by removing threaded fasteners, other than oil sight flow indicators (SFI), must have a minimum of 25 percent of the threaded fasteners (but not less than two fasteners) secured. This may be achieved with a lockable cover, counter drilled bar, locking pin (Figure 241-4-4, Figure 241-4-5, Figure 241-4-7, Figure 241-4-8, Figure 241-4-9 and Figure 241-4-11) or use of locknuts (MIL-N-25027) and epoxy filled caps (Figure 241-4-6). Items installed on the MRG case attached with more than twelve threaded fasteners meet the minimum security requirements. Likewise, pipe sections with two or more flanges meet the minimum security requirements if the total number of fasteners, counting all flanges on the pipe section, is greater than twelve, since the stiffness of the pipe prevents significant movement of any flange until all fasteners but one have been removed.
- d. Each sight flow indicator (SFI) shall be secured by installing an epoxy filled cap around at least one of the stud nuts or bolt heads. Where through bolts are used to secure SFI flanges, and epoxy filled caps restrict wrench access, equivalent socket head capscrews may be substituted to allow tool access. An alternate method for securing SFI housings is a locking plate and pin arrangement similar to that shown in Figure 241-4-8, Figure 241-4-9, and Figure 241-4-10. Although tack welding is discouraged, if the above methods are impractical, tack welding the nut or bolt head to the SFI flange is acceptable.
- e. Thermometer and resistance temperature element (RTE) wells must be secured by brazing. Sight flow indicators that do not have thermometer and RTE wells brazed shall be removed from the MRG casings and seal brazed.

NOTES:

- (1) GENERAL - This sketch depicts an approach to improve security for gear case inspection covers. It depicts one typical situation and has not been fitted to or devised for any particular gear case. This sketch is to be used for guidance only in developing the final security device for each gear case to be so fitted.
- (2) SPECIFIC -
 - (a) Pc 1 - Surface-harden steel toggle to 45 Rc.
 - (b) Pc 2 - Surface-harden steel collar bolt to 45 Rc.
 - (c) Pc 3 - Surface-harden steel security plate to 45 Rc.

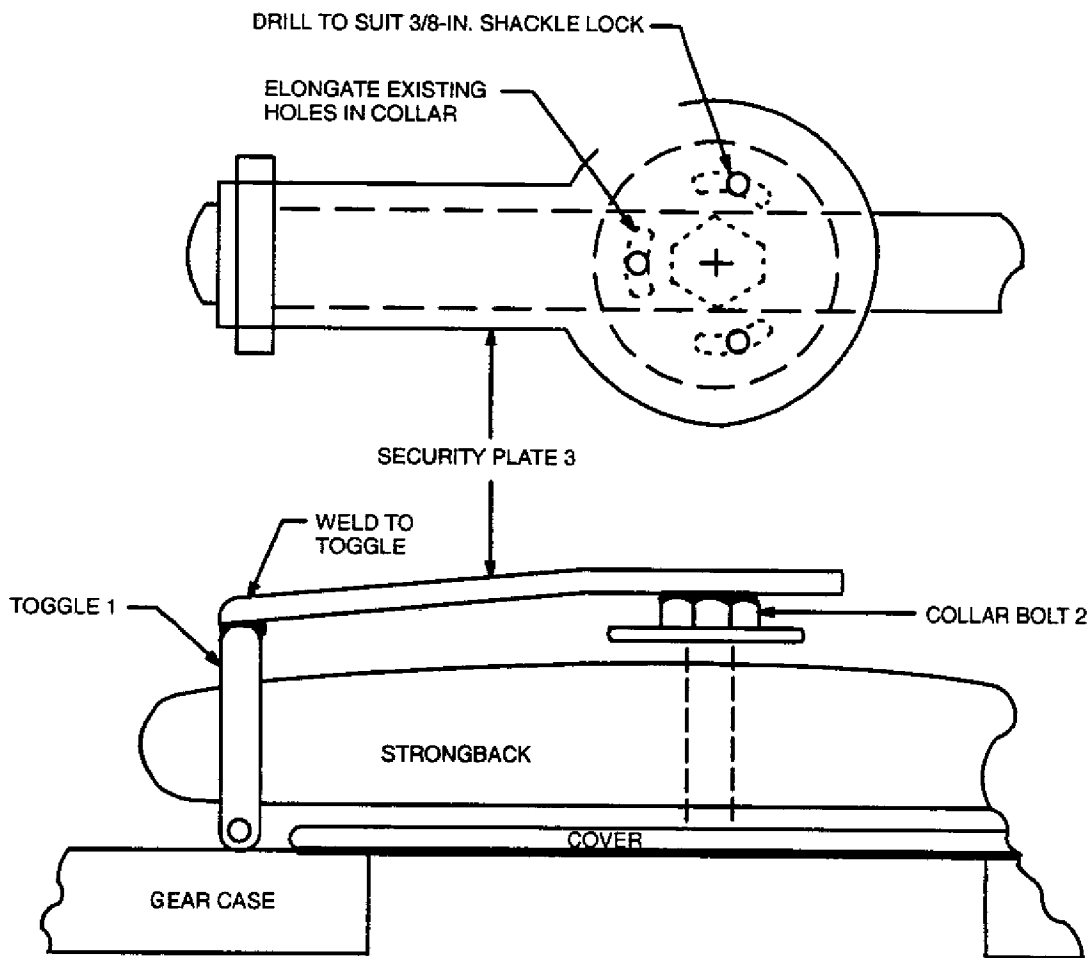


Figure 241-4-1 MRG Case Inspection Cover, Strongback Type

NOTES:

- (1) GENERAL - This sketch depicts an approach to improve security for gear case inspection covers. It depicts one typical situation and has not been fitted to or devised for any particular gear case. This sketch is to be used for guidance only in developing the final security device for each gear case to be so fitted.
- (2) SPECIFIC -
- (a) Pc 1 - Center-bolt locking device shall be hardened to 45 Rc, and dimensions L, M & N determined at installation.

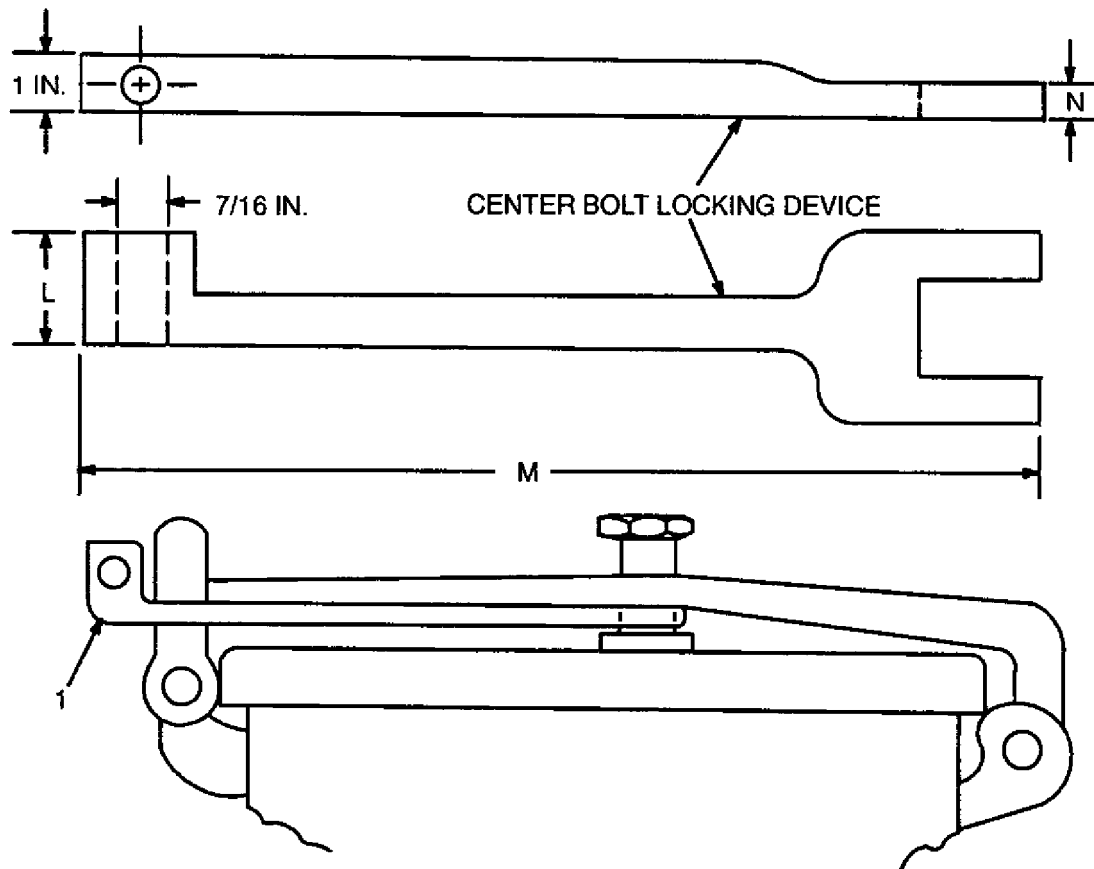


Figure 241-4-2 MRG Case Inspection Cover, Center Bolt Locking Device

NOTES:

(1) GENERAL - This sketch depicts an approach to improve security for the Bayonet-Type Locking Device employed on some Falk gears. It depicts a typical situation and has not been fitted or devised for any particular gear case. This sketch is to be used for guidance only in developing the final security device for each gear case to be so fitted.

(2) SPECIFIC -

- (a) Pc 1 - Stud to be Grade 5. MIL-B-857. Size to suit installation.
- (b) Pc 2 - Nut to be Grade 5. MIL-B-857 (surface harden to 45 Rc). Size to suit pc. 1.
- (c) Pc 3 - Security Nut in accordance with Sketch No. Figure 241-4-9.
- (d) Pc 4 - Security rod in accordance with Sketch No. Figure 241-4-9.
- (e) Pc 5 - Block Matl AISI 4140, 4310, 4337, 4340, 4615, 5147, 6120, 6150, 8620, 8645, 8740, or 9310 alloy steel (surface harden to 45 Rc).

(3) Dimensions in inches

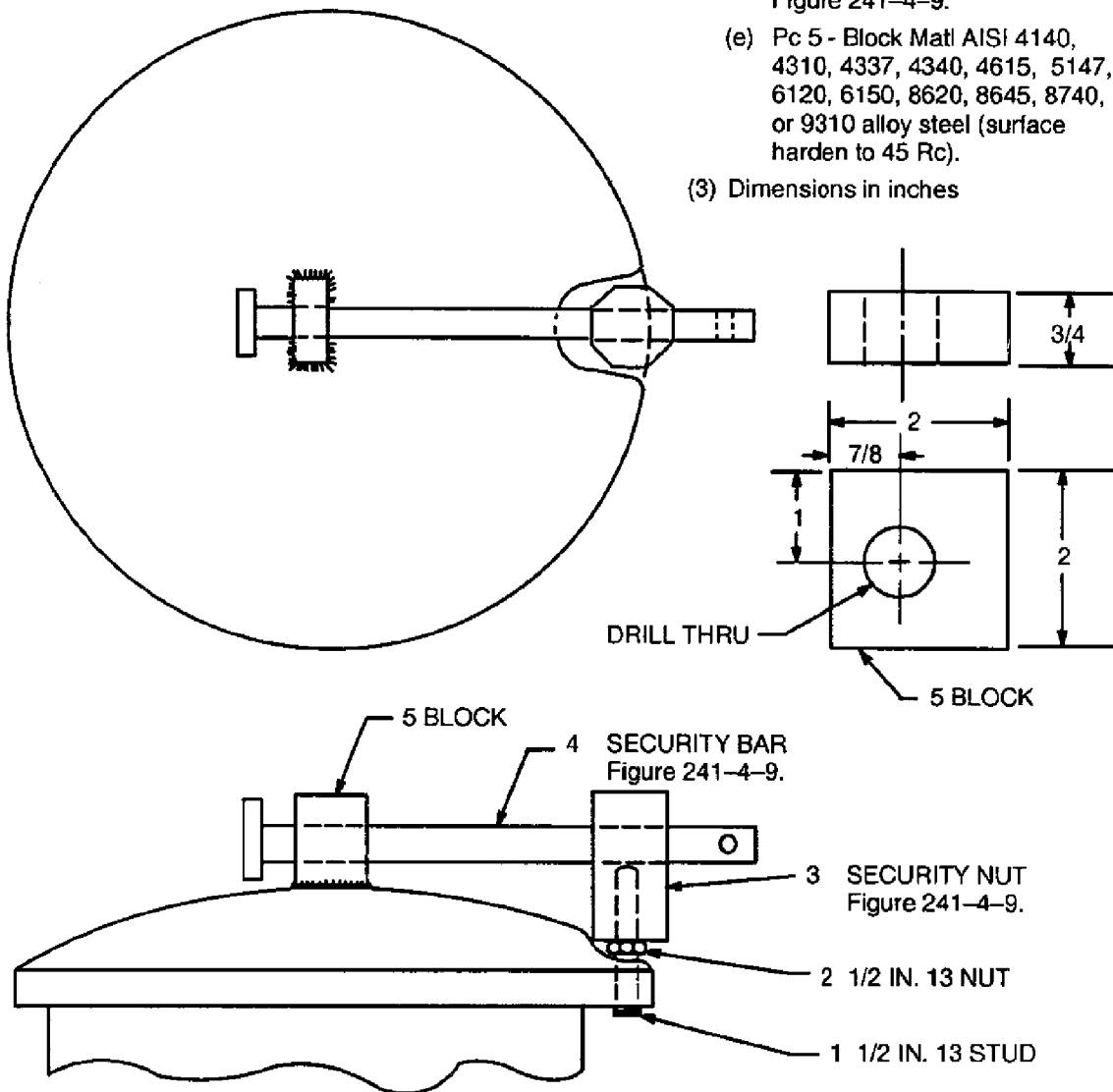


Figure 241-4-3 MRG Case Inspection Cover, Bayonet Type Locking Device Modification

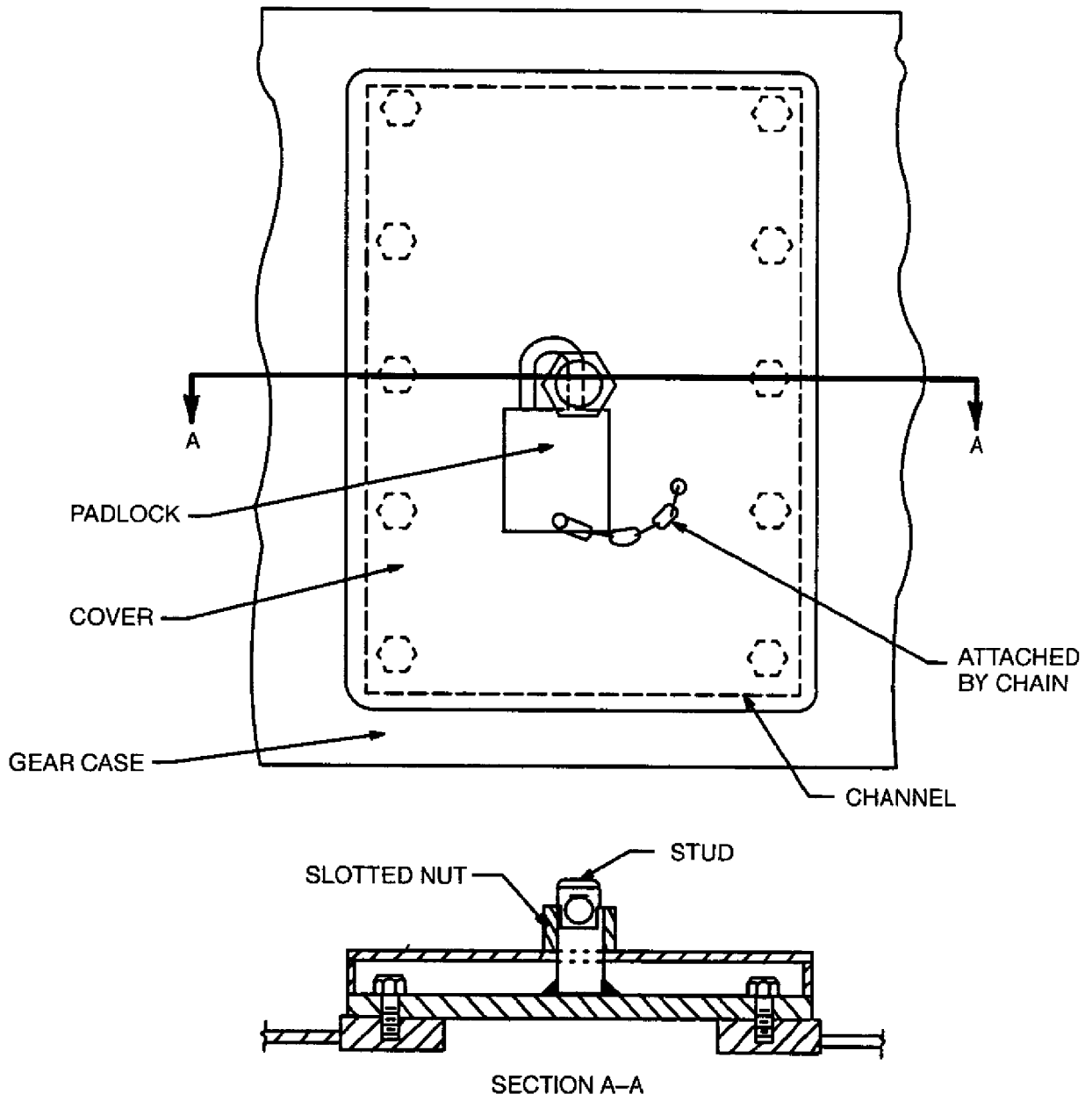


Figure 241-4-4 Cover Plate Security Device (Padlocked)

NOTES:

(1) GENERAL - This sketch depicts an approach to improve security for cover plate security device. It depicts (dimensions in inches) a typical situation and has not been fitted to or devised for any particular gear case. This sketch is to be used for guidance only in developing the final security device for each gear case to be so fitted.

(2) SPECIFIC -

- (a) Pc 1 - 2 IN. steel channel with ends enclosed & length to suit installation; harden to 45 Rc.
- (b) Pc 2 - security Nut Matl AISI 4140, 4310, 4337, 4340, 4615, 5147, 6120 6150, 8620, 8645, 8740, or 9310 alloy steel (surface harden to 45 Rc).
- (c) Pc 3 - Stud (or bolt) Matl AISI 4140, 4310, 4337, 4340, 4615, 5147, 6120, 6150, 8620, 8645, 8740, or 9310 alloy steel (surface harden to 45 Rc).

(3) Dimensions in inches.

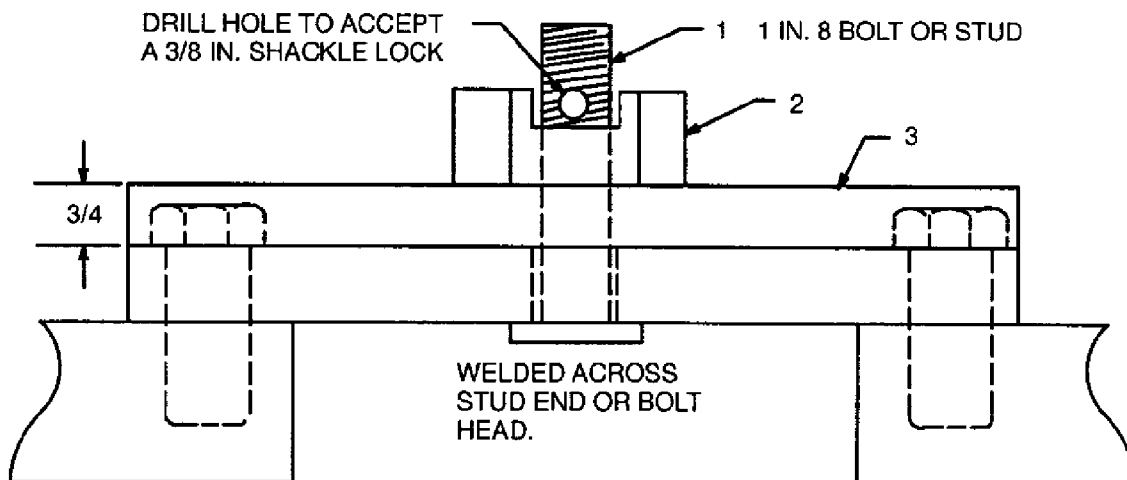
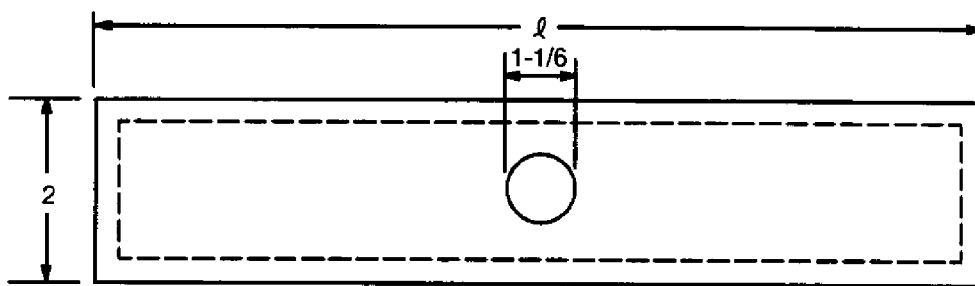
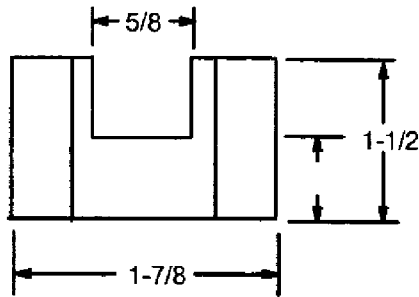
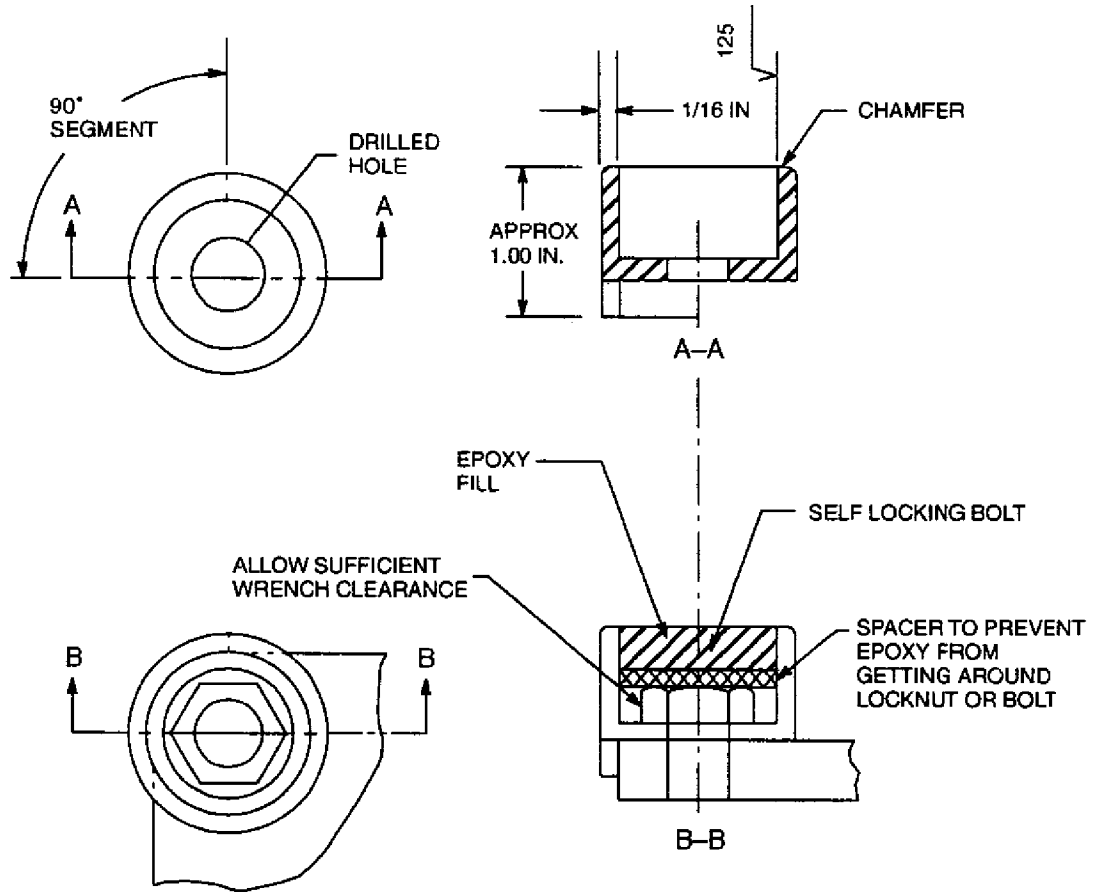


Figure 241-4-5 Cover Plate Security Device Details



WHEN USED WITH A STUD AND NUT ARRANGEMENT THE EXPOSED STUD THREADS MUST BE PROTECTED OR COATED WITH A RELEASE AGENT PRIOR TO EPOXYING. MAY BE USED AROUND ONE OR MORE OF THE LOCK NUTS THAT ATTACH THE BUBBIER TO THE GEAR HOUSING. MAY ALSO BE MODIFIED FOR USE AS OTHER ACCESS POINTS.

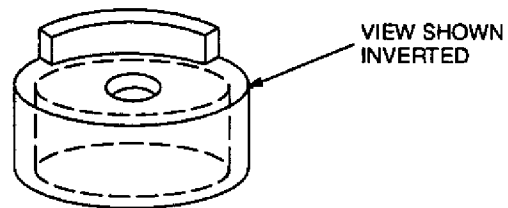


Figure 241-4-6 Epoxy Filled Cup for Bolt and Nut Security

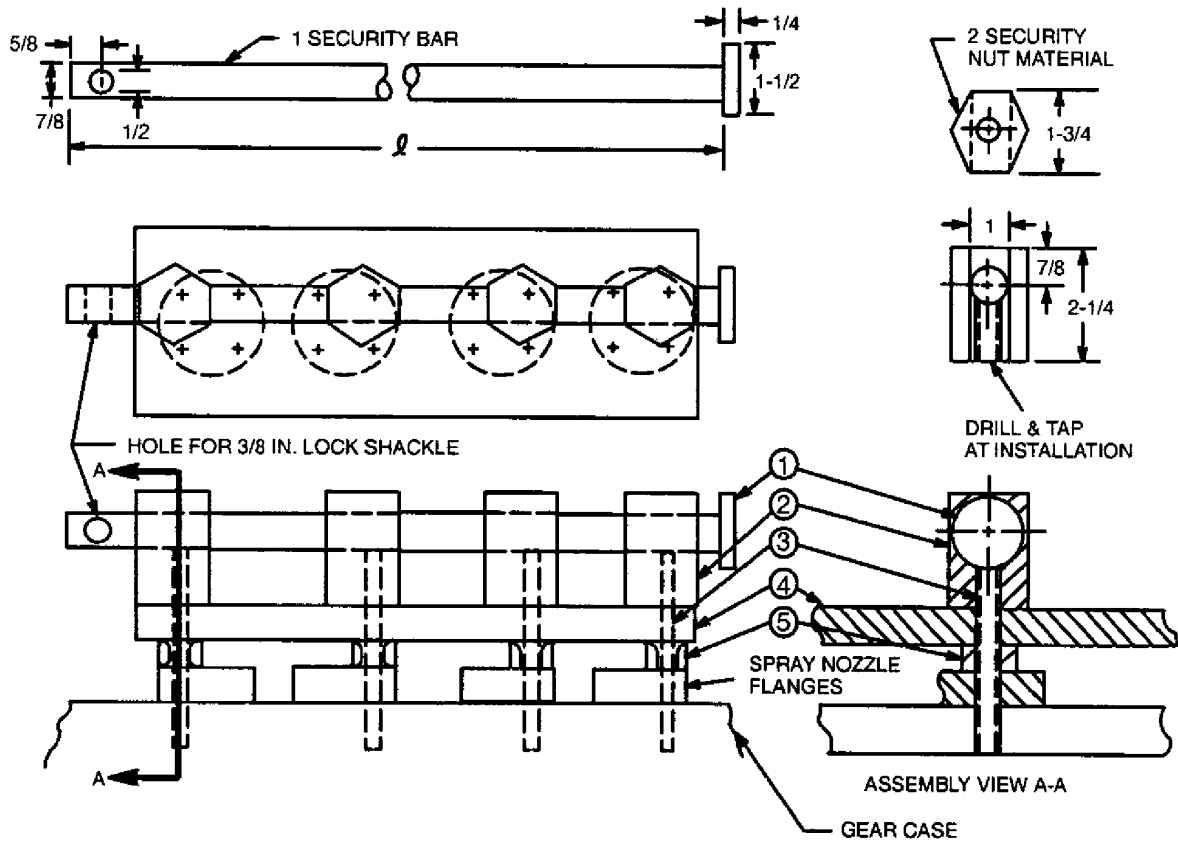


Figure 241-4-7 Spray Nozzle Installation Security Device

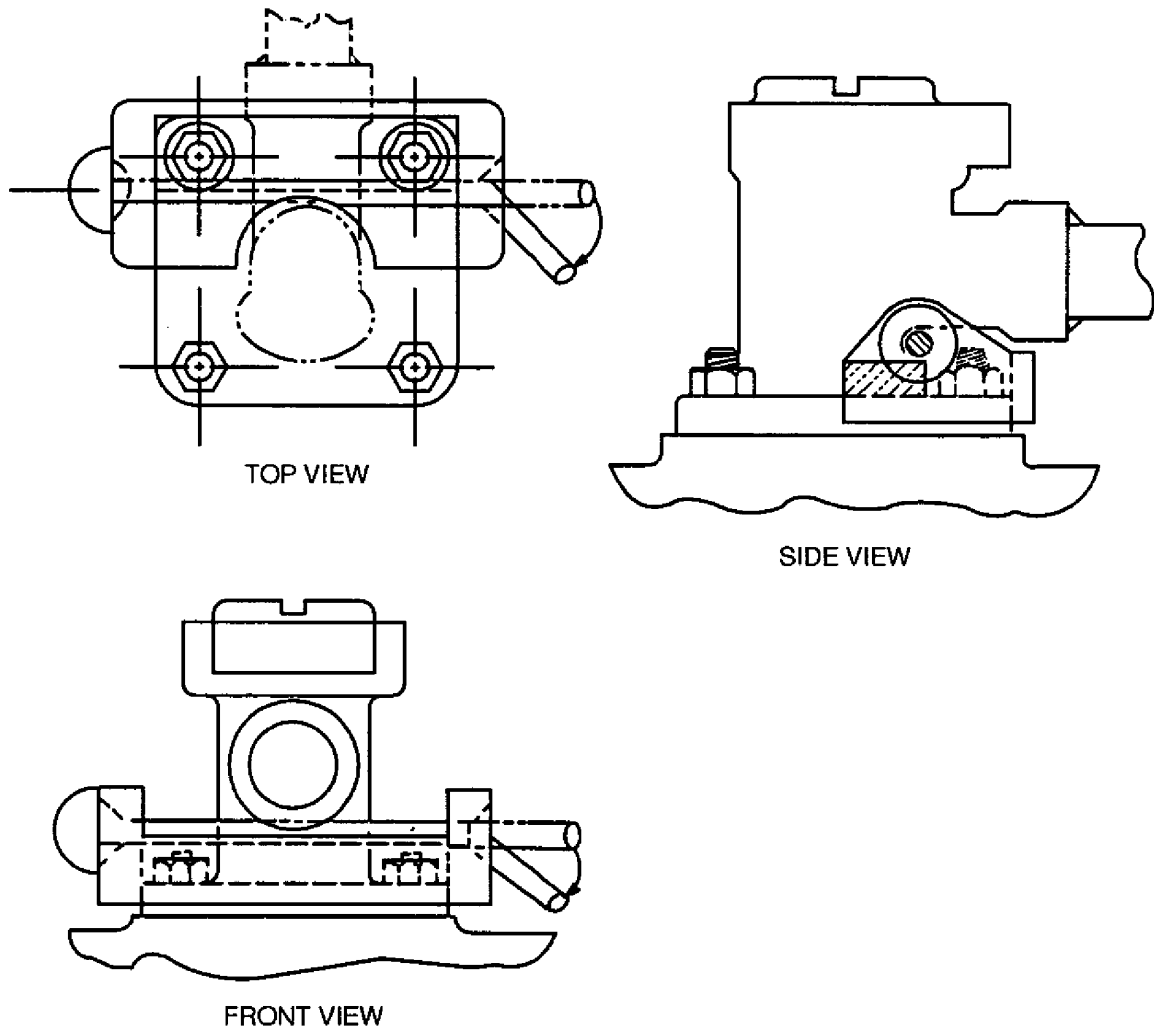


Figure 241-4-8 Oil Sight Flow Indicator Locking Plate and Pin Arrangement

NOTES:

(1) GENERAL - This sketch depicts an approach to improve security for sight-flow fitting body. It depicts (dimensions in inches) a typical situation and has not been fitted to or devised for any particular gear case. This sketch is to be used for guidance only in developing the final security device for each gear case to be so fitted.

(2) SPECIFIC -

- (a) Replace existing glass or plastic top lens with steel disc (pc. 1) of same geometry as lens and braze lens keeper to body.
- (b) Where possible, utilize scheme 4 for securing sight-flow body to gear case; this involves introducing a conical strainer (see sketch SEC-6145-6) between S.F. body and gear case, and using a nut-lock (pc. 2) under two existing nuts (pc. 3) and spot welded thereto.
- (c) Where thermometer fitting (not shown in sketch) is installed in S.F. body or in a separate fitting, braze thermometer well to fitting.

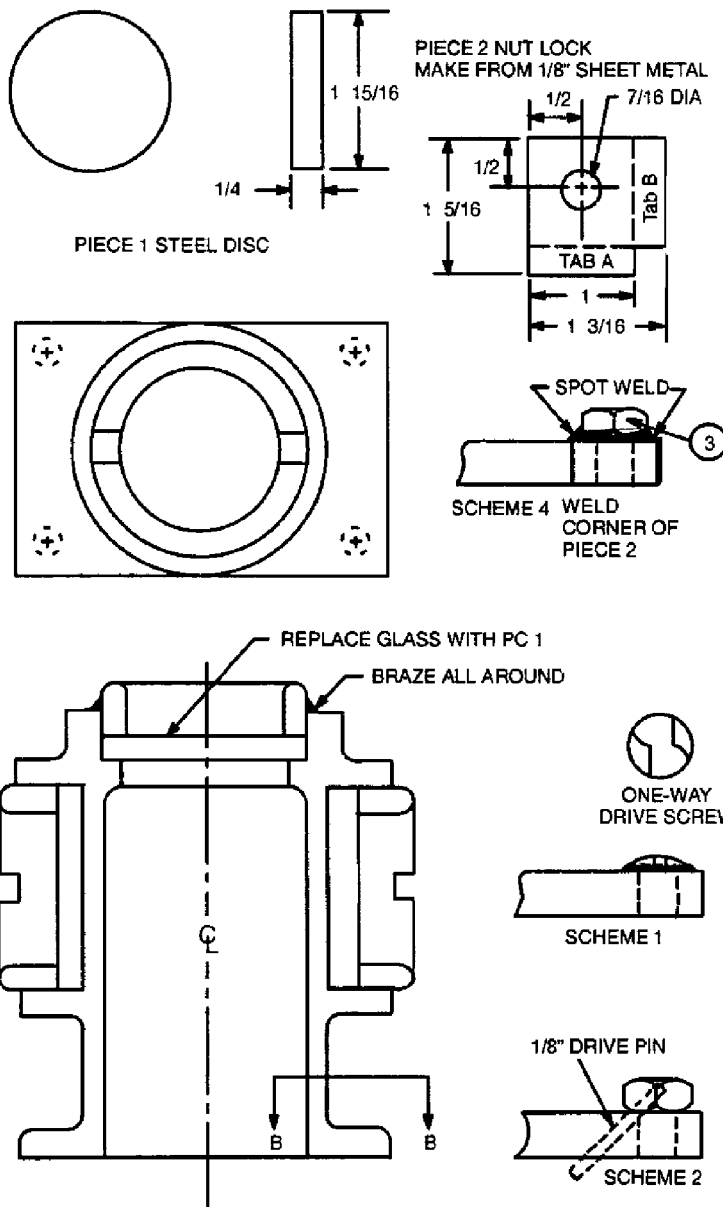


Figure 241-4-9 Oil Sight Flow Fitting

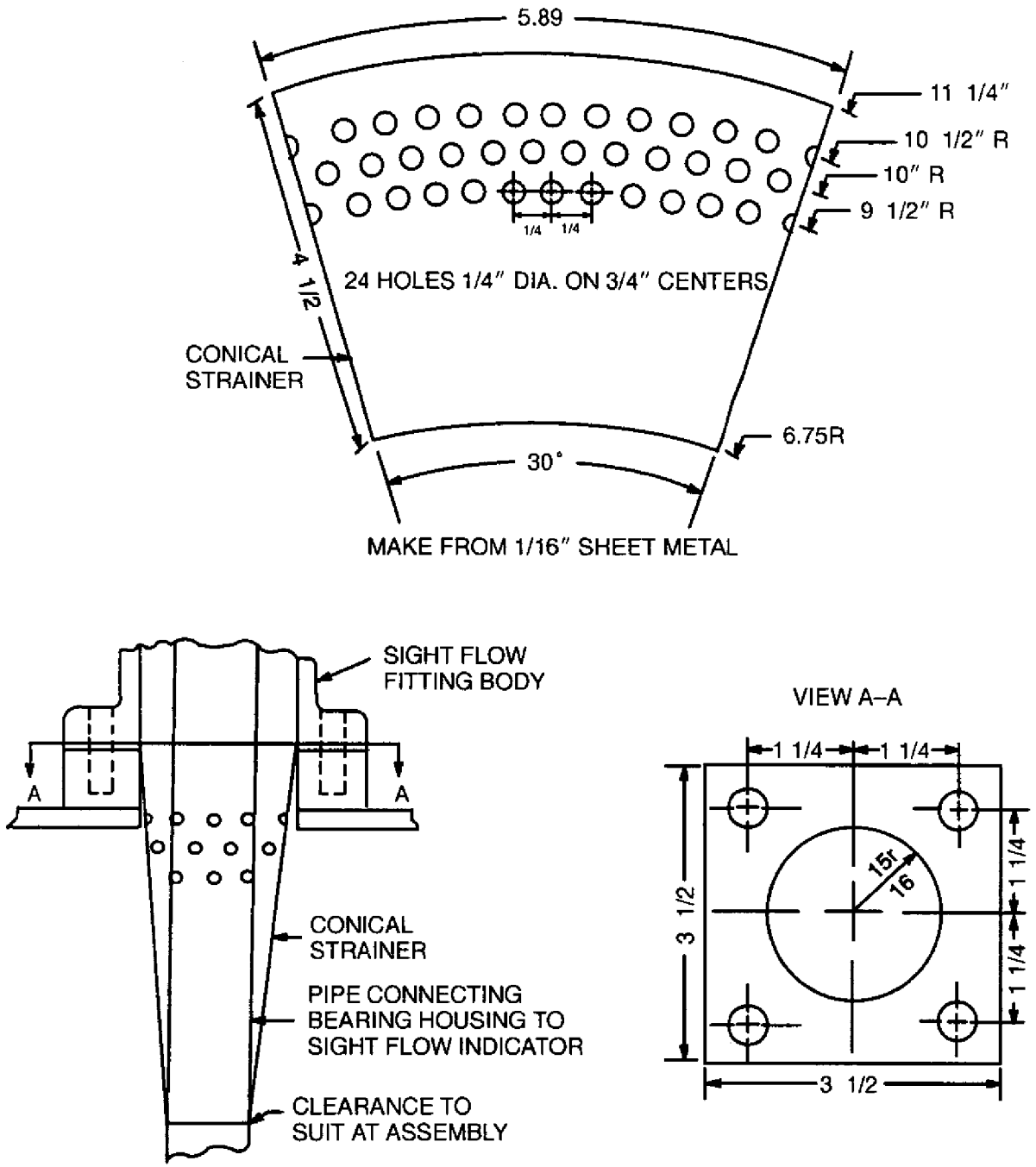


Figure 241-4-10 Conical Strainer for Sight Flow Fitting

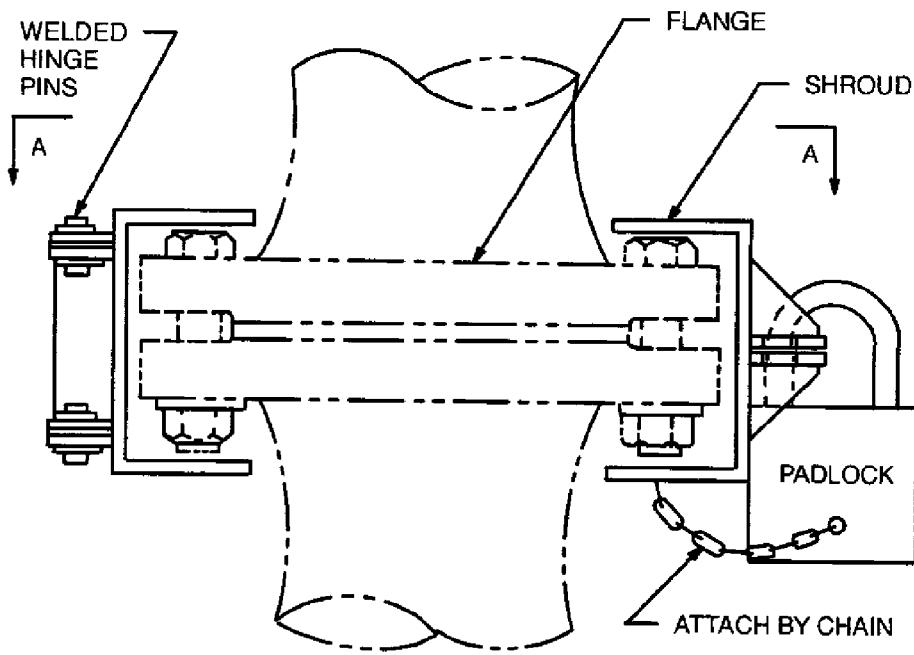
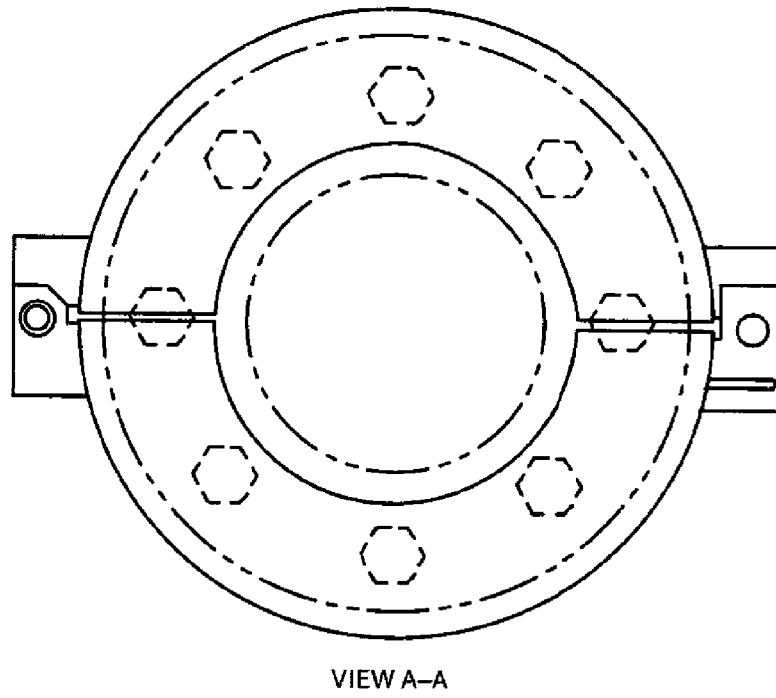


Figure 241-4-11 Flange Shroud

241-4.2.5 **ADDITIONAL SECURITY METHODS.** The following additional methods may be used to increase security when directed by the TYCOM:

- a. Replace glass sight lenses with shock resistant material according to MIL-G-2860, Glasses, Sight Flat, Clear, Borosilicate, (Figure 241-4-12), if not known to meet that specification.
- b. Install modified lens retaining rings (Figure 241-4-13).
- c. Secure precipitator and dehumidifier piping with a lockable shroud (Figure 241-4-7). Where combination nut and bolt fasteners are used, place epoxy caps around the nut and corresponding bolt head.
- d. Where inspection covers have a hinge pin design that could easily be removed, consider tack welding washers on the ends of the pins to prevent pin removal. See welding precautions in paragraph 241-4.2.6.

241-4.2.6 **WELDING.** Tack welding or brazing of nuts to flanges, sight flow indicators, and other attachments on the MRG casing is an effective method that may be used to make the reduction gear more secure. This approach is discouraged, however, and should be used only when other methods cannot be accomplished or an increased level of security is required. Where fasteners have already been tack welded in response to previous directives and the weld provides an adequate level of security, it may remain until it is necessary to remove the weld for maintenance. A method that does not require welding on the case or attachments should then be used to provide necessary security. If welding or brazing is used, consider the following:

- a. Welding any fixture to the MRG case cover requires authorization by NAVSEA and compliance with existing safety regulations.
- b. A potential explosion and fire hazard exists with the oil film and vapors inside the MRG casing.
- c. Arc welding could create stray currents through the gears or bearings that may damage those components. When arc welding is performed, a good ground connection shall be established with a separate lead attached as close to the work site as possible.
- d. Oil sight flow indicators, inspection and access covers, and other attachments could be damaged by warpage or distortion from excess heat.
- e. Routine maintenance is more complicated and requires the services of a qualified welder to re-establish security maintenance. Additionally, maintenance time is lengthened, the fasteners are usually destroyed, and the potential for grinding dust and small pieces of metal to enter the MRG case exists.

241-4.3 BEARING MAINTENANCE.

241-4.3.1 **BEARING FAILURES.** While not totally inclusive, the following paragraphs discuss various failures that occur in MRG bearings.

241-4.3.1.1 **Fatigue.** Fatigue is caused by alternating stresses that eventually cause fatigue cracks, usually starting at the point of maximum stress just below the surface of the bearing metal. With babbitted bearings, these fatigue cracks first progress through the babbitt lining to the bond and then extend around the bond until they meet with other radial cracks. The loose pieces of lining material that result break loose from the bearing surface. With bronzes and other solid bearings, the fatigue usually progresses as a more local pitting of the bearing surface. These pits are generally much smaller than the sections removed by fatigue from a babbitt lined bearing.

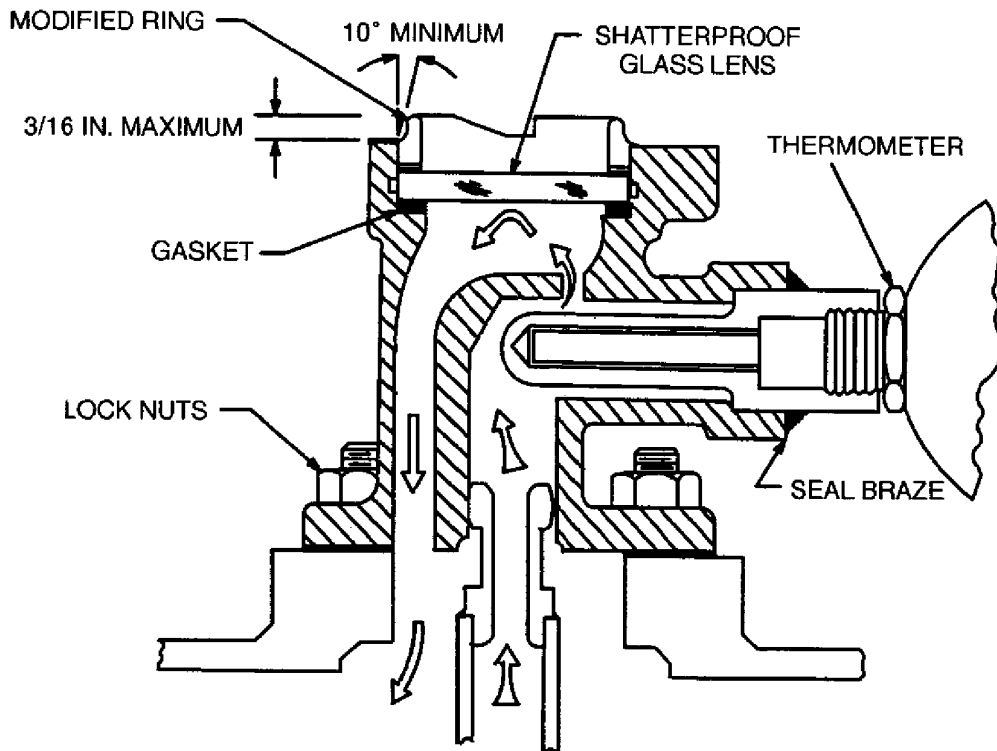


Figure 241-4-12 Sight Flow Indicator



Figure 241-4-13 Lens Retaining Ring

241-4.3.1.1.1 Once started, fatigue is self-accelerating. Loose material produced during the initial fatigue breakdown moves to other parts of the same bearing or to other bearings. These loose particles generate local stress concentrations and hot spots, leading to further material breakdown. In this way, bearing clearances are also reduced, unit bearing load and temperature are increased, and a complete bearing failure ensues.

241-4.3.1.1.2 Misalignment, edge loading of the bearing, a tapered or bent shaft, improper assembly, dirt or chips in the oil stream, improper lubrication, or use of improper lubricants can highly stress and fatigue a bearing or raise the bearing material temperature and reduce its fatigue life.

241-4.3.1.2 Poor Bonding. Poor bonding of the bearing surface layer to the bearing shell may also cause premature fatigue failure. In such cases any fatigue cracks spread rapidly along the juncture between the bearing material and its backing, with the resultant spalling out of large pieces of the bearing metal. If the bearing material has been well bonded to the bearing shell, a thin surface layer of the bearing material will remain on the

shell under the fatigue cracks. This factor may be used to determine whether or not poor bonding contributed to the fatigue failure. The bonding of babbitt on steel bearings may be checked by soaking them in oil at 3005 F. Any imperfections in the bonding will show up as blisters in the babbitt surface after such treatment.

241-4.3.1.2.1 Corrosion will also contribute to weakening and fatigue of some types, such as copper lead bearings, by selective removal of one of the alloy elements. Attack by corrosive contaminants in an oil or by a corrosive oil itself may make the bearing material brittle. Corrosive action is characterized by some change in the material chemical composition, which would not be present in simple fatigue failure.

241-4.3.1.3 Wiping, Scoring, and Seizure. Where alternating stresses are not present to cause fatigue failures, the most frequent causes of failure are foreign particles in the lube oil system, loss of lube oil, and inadequate pressure. After a bearing wipes, bubbler temperature will drop and there may be babbitt in the strainers.

241-4.3.1.3.1 Wiping usually results from rubbing a shaft on a soft bearing material such as babbitt when there is a temporary break in the oil film. Such a condition may be encountered during initial start-up of a machine in which there is some misalignment, bearing pinching, insufficient clearance, oil pump stoppage, plugged oil lines, or some other defect in the bearing or journal. Wiping of bearing material, particularly babbitt, generally provides sufficient clearance or conformity so that further satisfactory operation will be possible. Slow run in periods are generally desirable so that wiping may take place without generating extremely high temperatures, which would destroy the bearing.

241-4.3.1.3.2 With harder bearing materials such as the bronzes, failure of the oil film generally results in scoring of both the bearing surface and the journal. Relatively hard particles torn from the bearing surface by initial contact promote scoring and scratching of surfaces, rather than the simple wiping encountered with babbitt.

241-4.3.1.4 Wear. Wiping and scoring can rapidly wear away bearing surface metal. Other factors, however, can contribute to much slower bearing wear. Gradual mechanical wear occurs in any bearing in which the journal and bearing surfaces are not separated by a lubricant film, but in which the design, lubricant, and materials are selected so that there is no extensive or sudden destruction of the bearing surface. Starting and stopping, high loads, low viscosity oils, high operating temperatures, and vibration may contribute to mechanical wear.

241-4.3.1.4.1 Wear may also be caused abrasively by dirt particles that pass through the bearing and slowly remove material from the bearing surface. Similarly, corrosion by contaminants in the oil or by oxidized oil itself may cause wear.

241-4.3.1.5 Electric Currents. Destructive electric current can flow through most journal bearings if the voltage potential difference between the journal and bearing is high enough. The sparks that pass through the oil film can gradually or rapidly deteriorate the journal and bearing surfaces depending on the magnitude of the current.

241-4.3.1.5.1 Electrical wear shows up as a frosted surface in the loaded zone of the bearing where the oil film is thinnest. Under a microscope the frosted area will appear as a multitude of small craters. These craters each result from the fusing temperature generated by the passage of an electrical spark.

241-4.3.1.5.2 Changes in bearing design, bearing materials, or lubricants are ineffective in preventing electrical wear. There are, however, several methods of preventing current from flowing through the oil film:

- a. Insulate the bearing from its housing by an insulated lining such as phenolic plastic.
- b. Apply a grounding brush to the shaft to provide a lower resistance path for the current to pass around the bearing.
- c. The most effective although most difficult approach to solving the problem is to analyze the electrical system of the unit to identify and then eliminate the cause of the electrical potential drop across the bearing.

241-4.3.1.6 Abrasion. Circumferential scratches on bearing surfaces and embedded hard particles are typical of abrasion. The nature of this scratching may vary from an almost microscopic effect with very fine particles that result in slow wear to the other extreme of severe scoring caused by large abrasive dirt particles.

241-4.3.1.6.1 Abrasion may be distinguished from scoring or simple wear by foreign particles in the surface of bearing materials. Careful probing with pick, microscopic examination, and chemical spot testing are all valuable tools in identifying the abrasive material. If the source of the problem cannot be eliminated, the dirt should be removed as completely as possible by carefully filtering the oil entering the bearing and by using positive sealing of the bearing housing to prevent the entry of airborne matter.

241-4.3.1.7 Corrosion. Bearing corrosion results from attack by reactive chemical materials in the lubricating oil. Probably the most widespread source of corrosive attack is the oxidation products formed in the oil itself. By reacting with the oxygen in the air, oil is gradually transformed to various organic acids and peroxides that corrode a number of the more common bearing materials such as those containing lead, copper, cadmium, and zinc. Tin babbitt, aluminum, and silver are not normally affected by these oxidation products.

241-4.3.1.8 Water Contamination. Under light loads a mixture of oil with less than one percent water will carry load. As load increases, the water in the oil film will vaporize and degrade the load carrying capacity of the oil allowing the journal to make contact with the bearing and wipe it.

241-4.3.1.9 Tin Oxide Formation. Babbitt bearings operating in oil with greater than 500 ppm of water are prone to electrolytic corrosion. This produces a progressive darkening and buildup of hard brittle layers of tin oxide that can cause bearing failure. Salt water contamination and increased temperatures accelerate this rate. This corrosion generally starts in the loaded region of the bearing where temperatures are highest. For further details and information on renewing affected bearings, see **NSTM Chapter 244, Propulsion Bearings and Seals**.

241-4.3.1.10 Troubleshooting Bearing Failures. Symptoms, causes, and remedies of bearing failures are listed in [Table 241-4-1](#).

241-4.3.2 INSPECTION OF JOURNAL BEARINGS. Journal bearings need not be disassembled periodically for inspection. If a Maintenance Requirement Card (MRC) action discloses an out-of-tolerance measurement, however, or if an operational difficulty develops, disassembly and inspection may be necessary. At such times the various bearing surfaces should be visually examined and measured for wear, babbitt discoloration, and bonding.

241-4.3.2.1 Wear Pattern and Wear Limits. A properly installed bearing that has been in service for some time will usually display a worn or polished area centered in the lower half of the bearing. The width of the worn area will vary, depending on the degree of hand fitting, if any, previously performed, and on the amount of wear that has occurred. Variations in pattern width in the fore-and-aft direction are a measure of angular alignment between the bearing and journal when stopped or operating at very low speed. The contact pattern does not normally represent the running position of the journal since the hydrodynamic film should completely eliminate contact and the minimum film location will be displaced angularly from the bottom of the bearing by an amount set by the particular speed and load conditions.

241-4.3.2.1.1 Bearing wear would be almost completely eliminated under ideal conditions. Some journal to bearing rubbing occurs on each start, however, and oil contaminants accelerate wear. Most propulsion turbine technical manuals specify the wear limit at which the bearing shall be rebabbitted or replaced.

Table 241-4-1 JOURNAL BEARING TROUBLESHOOTING CHART

Symptom	Cause	Remedy
Wiping	Lack of Oil	Depending on extent of wipe, replace bearing or clean by scraping. Restore oil supply.
	Poor bearing contact	Poor bearing contact usually results in localized wipes..
		Scraping to a mandrel to obtain contact across the entire length of the bearing is normally required
		Severe overheating may damage a bearing sufficiently to require replacement.
	Pinched bearing	Pinched bearings require correct installation or, in the case of warped bearings, replacement
	Misalignment of gearing	The wipe is due to the fact that the journal is not on the entire bearing length. Realignment of gearing will rectify.
Insufficient clearance	Bore or scrape to correct clearance, or replace with bearing having correct clearance.	
Wear	Normal	A small amount of wear is normal.
	Low oil viscosity	For high-wear rates, use of cooler oil or use of oil of higher viscosity is required.
	Starts and stops	This wear is normal since the oil film is not present when the unit is at rest. Always supply oil to bearings when jacking to reduce such wear.
	High operating temperature	See low oil viscosity.
Abrasion (circumferential scratches and embedded particles)	Vibration	Locate source and correct.
	Dirt and grit in oil	Clean lube oil system.
Corrosion	Acid, salt water, wrong type extreme-pressure lubricant	Replace oil.
Cracking	Fatigue	Very rare in gear bearings. May be due to severe misalignment or heavy vibration.
		Locate source and correct.
	Poor bonding	Separation of babbitt from back due to poor bonding. Bond failure can be detected by squeezing babbitt to see if oil squeezes out between babbitt and back, by dye penetrant method, or by ringing with a hammer. Cracks may be apparent on surface of the babbitt.
		Replace bearing.

241-4.3.2.2 Babbitt Discoloration. Discolored bearing babbitt surfaces almost always indicate lubrication problems. Moisture and iron oxide in the oil and operation under relatively high temperatures can produce a tin oxide coating on the bearing that may vary from a mottled dark gray to a highly polished black. The coating is very hard and builds up, reducing bearing clearance. The babbitt then no longer has the desirable properties of the original babbitt. If coating particles break off or the oil system is contaminated, the journals will probably score. Thin coatings can normally be satisfactorily scraped without exceeding clearance limits, but thick coatings usually require bearing replacement or rebabbiting. Eliminating water leaks, following proper oil cooldown procedures, and using oil purifiers to the greatest extent possible will minimize difficulties.

241-4.3.2.2.1 High temperatures can create decomposition products (hydrocarbons), which deposit on bearing surfaces, journals, or drain passages. The color can vary from tan to dark brown to black, depending on the degree of overheating and oil decomposition.

241-4.3.2.2.2 If discoloration cannot be traced to overheating, investigate the possibility that oil additives are plating out. A chemical laboratory qualified to analyze lubricating oils should check the oil.

241-4.3.2.3 Bonding. Faulty bonding usually results from deviating from proper babbitting procedures and inadequate quality assurance inspections. If a bond is faulty at an outside juncture of babbitt to shell, the improper bond can be detected visually or by squeezing oil from the interface, using thumb pressure applied to the babbitt adjacent to the area to be checked. One hundred percent bonding is not required for satisfactory operation, and minor bonding flaws that meet the acceptance standard should not be cause for replacing the babbitt. See paragraph [241-4.3.7](#) for guidance on rebabbitting bearings and bond testing.

241-4.3.3 BEARING ALLOWABLE WEAR. Excessive wear of bearings can cause incorrect tooth contact. The designed and maximum clearances are shown on drawings or in technical manuals. Where these are unavailable, the crown thickness measurement stamped on the end faces of each journal bearing may be used as a guide for establishing wear. These limits are merely a guide. Repairs shall be made if a smaller amount of wear causes undue vibration or other abnormal operating conditions. The minimum clearance in the main thrust bearing is also shown on the drawings and is usually about (0.0005 to 0.001 inch) D, where D is the outside diameter of the thrust collar. The maximum allowed clearance is about twice the minimum.

241-4.3.4 RENEWAL OF BEARINGS.

- a. If a bearing is performing satisfactorily, leave it alone.
- b. If a pinion or gear bearing is wiped, has excessive clearance, or is heavily scored, examine other bearings to determine the extent of damage.
- c. When bearings are replaced, always check for proper tooth contact.
- d. When bearings are removed, always support journals.
- e. Refer to paragraph [241-4.4.16.1](#) for bearing wear measurements.

241-4.3.5 FITTING BEARINGS.

- a. Review machinery history and manufacturer's technical manuals to determine whether special bearings are required or journal diameter is less than design.
- b. If one bearing on a gear element is wiped, always check the remaining bearing(s) and replace one or all bearings so that correct gear alignment is maintained.
- c. Check crown thickness measurements of installed and replacement bearings. Compare readings. Refer to manufacturer's technical manual and paragraph [241-4.4.16.1](#) relating to crown thickness measurements and bearing reaction points. Scrape replacement bearing to size if difference exceeds 0.001 inch. If scraping is required, refer to paragraph [241-4.3.6](#).
- d. Crown thickness measurements of bearings on both ends of a gear or pinion shall not differ by more than 0.0005 inch.
- e. Roll the journal in the bearing to check bearing contact.
- f. If one bearing wipes and a spare is unavailable, bore or scrape the bearing on the opposite end of the shaft to the same approximate crown thickness so as to operate with the shafts parallel until such time as the bearings may be replaced.

- g. When a spare bearing is installed or if a bearing is scraped to obtain correct tooth contact, stamp the crown thickness measurements on the bearing. Remove old markings.
- h. One or more bearings may have to be eccentric to avoid rechocking a gear to correct existing tooth contact. When such eccentric bearings are required, make a detailed record in the machinery history.
- i. Always check the drawings or technical manual to ensure that bearings are installed correctly.
- j. Take care to fit dowels between the bearing halves and fit the keys or dowels used for locating bearings in the casing. Always mate upper and lower bearing halves. Interchanging of upper and lower halves between bearings is prohibited.
- k. Flat face or tapered land thrust bearings must be fitted to be parallel with the runner. Where such bearings are in halves, they must be installed so that the faces of the halves are in exactly the same plane.

241-4.3.6 BEARING SCRAPING. Manufacturing variables may require that a bearing be scraped to obtain acceptable tooth contact when installing new bearings. If scraping is required, it should be done by a qualified Original Equipment Manufacturer (OEM), NSWCCD, FTSCPAC, FTSLANT or NAVSEA technical representative. The following guidance is provided:

- a. Measure the bearing crown thickness before scraping. The pipe micrometer is the recommended tool for measuring bearings. Ball type attachments are not recommended because of the brinelling to babbitted surfaces, hence false wall thickness or crown readings. The use of a standard piece of 0.250-inch drill rod and a standard caliper micrometer is acceptable. When using this method be sure to deduct the 0.250-inch diameter from the reading. A form for a typical bearing that has been marked with a crayon at ten different points for measuring purposes is shown in [Figure 241-4-10](#). Use this type of form when scraping bearings. When checking wall thickness, be sure to consult the specific bearing reaction diagram pertaining to the gear unit in question. This will permit the operator to scrape in the proper half of the bearing.
- b. Before scraping a bearing, determine the actual contact marking of the bearing by contacting the bearing to a mandrel that has been coated with Prussian blue. The mandrel diameter is the journal diameter plus the oil clearance or bearing bore diameter and is slightly longer than the bearing. Apply the blue to the arbor, spread it evenly over the entire arbor, and wipe the bearing off and examine the contact.
- c. Scrapers:
 - 1 Bearing scrapers are probably made in a larger variety of styles and materials than any other tool. Each variation has its own advantages and drawbacks, and each requires more or less skill to use.
 - 2 Considerable success in scraping bearings of a 5-inch (or larger) bore diameter has been achieved using scrapers fashioned from through hardened power hacksaw blades. With the saw teeth ground off, the blade is finished in a surface grinder by grinding each face to cleanup, then grinding each edge straight and at right angles to the faces. The result is a piece of tool steel about 12 to 15 inches long, 1 inch wide, and 0.050 inch thick, with four 90 degree cutting edges.
 - 3 To use, hold the scraper in both hands, flexed down in the center with the thumbs. Pull circumferentially around the bore of the babbitt in a fast, firm stroking motion. Good control of the cutting action is achieved in varying the curvature of the edge by flexing a greater or lesser amount. In addition, all the cutting force is between the two hands, permitting the most efficient use of the effort required as opposed to the cutting edge being supported from one end only.
- d. Scraping bearings:
 - 1 Bearings are scraped for the following reasons:
 - (a) To dress off rough edges left by machining and to blend oil distribution pockets into the bearing bore.
 - (b) To reduce operating temperature by increasing oil clearance and improving contact pattern.

- (c) To remove high spots.
 - (d) To clean up a slight wipe or remove embedded foreign particles.
 - (e) To improve gear alignment.
- 2 Reasons (1), (3), and (4), require only local scraping, which is easily monitored.
 - 3 When it is necessary to reduce crown thickness or otherwise scrape a large area, use a mandrel of a diameter equal to the journal diameter plus bearing clearance or bearing bore diameter as an aid in obtaining a good scraping job. Unfortunately, this is not always obtainable.
 - 4 Reasons (2) and (5) can require an extensive amount of scraping, which is difficult to control and can lead to bearing bores that are tapered, hourglass shaped, etc. When it is determined that a bearing bore must be scraped for reason (2) or (5), control of the amount of babbitt removed can be greatly improved by first coating the areas to be scraped with red or blue lay-out dye. After scraping has removed all the dye, in addition to a layer of babbitt, recoat with dye before scraping again. After two or three scrapings, use the scraper as a straight edge to locate and remove any high spots. Use a mandrel to control the amount of babbitt to be removed.
 - 5 The decision to scrape a bearing to improve gear alignment shall be made after performing a dynamic tooth contact check in accordance with paragraph 241-4.4.8 and reviewing the marking contact pattern at full power and speed. At full power each mating element is positioned in the proper reaction point in its bearings, centered in the helix angle, and properly torqued to make a proper evaluation. Making bearing corrections on the basis of static marking information is unacceptable. A qualified OEM, NSWCCD, FTSC-PAC, FTSC/LANT, or NAVSEA representative should evaluate the dynamic tooth contact patterns and determine how much to scrape a bearing to correct unacceptable alignment. To determine the amount to scrape, insert shims in the other end bearing between the journal and the bearing reaction point until alignment is achieved. Measure the thickness of shims required and reduce the crown thickness of the other end bearing reaction point by the measured amount.
 - 6 Maximum amount to scrape:
 - (a) When a bearing is being scraped to provide necessary clearance or increase contact area, the bearing should be scraped as required to produce the desired results, using all the precautions described in paragraph 241-4.3.6. It is well to reduce the wall thickness uniformly so the resultant ten readings (Figure 241-4-14) are within 0.0005 inch of each other. Sketch the final contact pattern on the chart and record the final wall thickness readings. The final fit of both pinion and gear bearings must maintain proper gear alignment.
 - (b) When it is necessary to increase the oil clearance by enlarging the bore diameter or to reduce crown thickness of the half to obtain gear alignment, the decision must be made to either scrape or machine out the excess babbitt. As a general guide removing more than 0.005 inch from the crown thickness should be accomplished by machining, if possible.
- e. Scraping a bearing in the field requires special attention to the blending of the oil spreader grooves. These should be blended in tangent to the bore of the bearing. On a bearing whose spreader groove is well blended, no hump should be felt when passing the finger circumferentially past the spreader groove into the bearing bore.
 - f. Bearing wear is significant mainly because of its relation to the proper contact of the mating pinion and gear teeth.
 - g. The important thing to remember when considering changing a bearing is the effect this change will have on tooth contact distribution between the pinion and gear involved. Bearings should never be changed because of some slight wall thickness variations between the measured values and the values scribed on the end of the bearing shell.
 - h. A slightly scored journal bearing does not need to be replaced. Removing high spots or embedded particles by

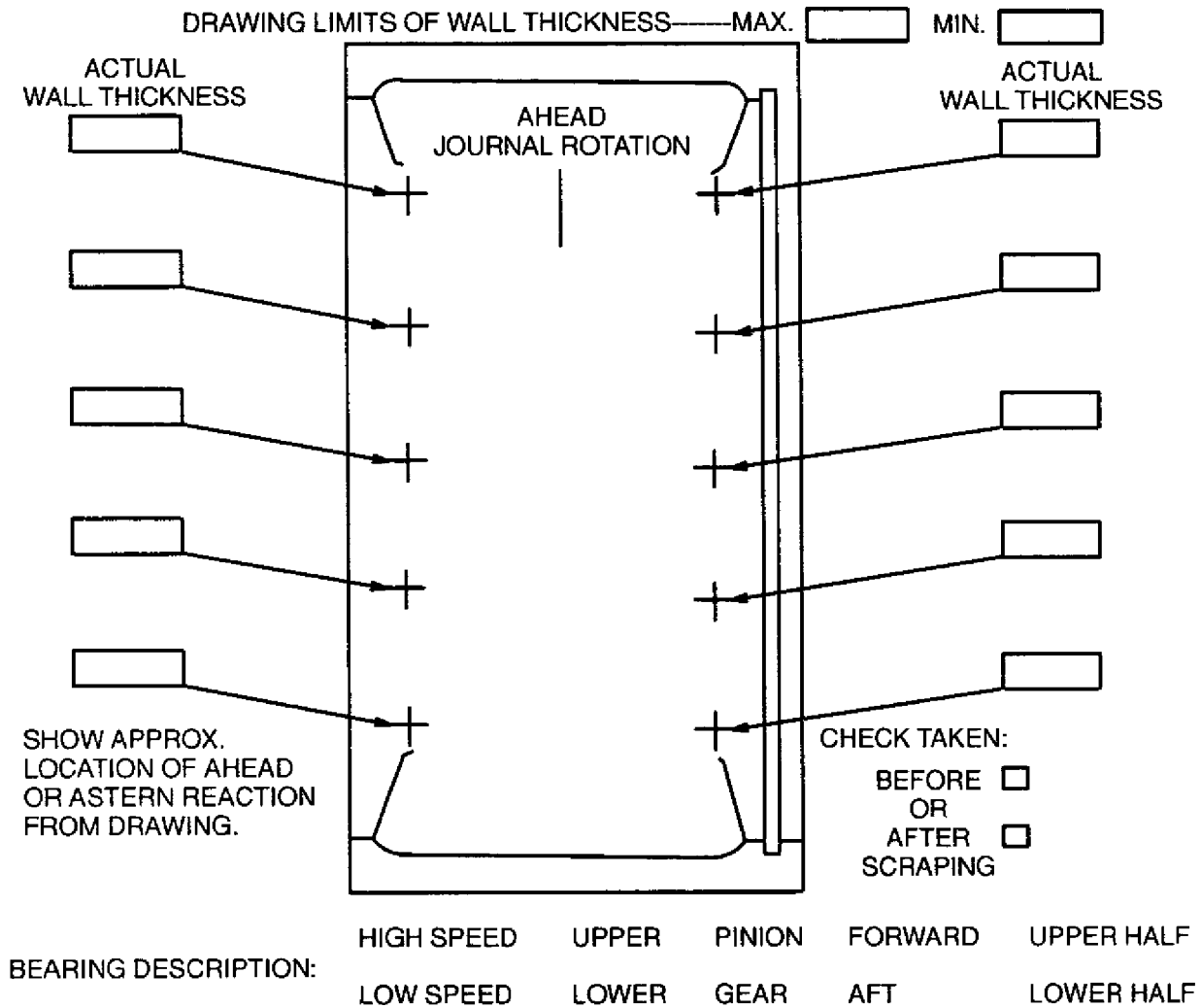
proper use of the scraper will suffice. Do not attempt to remove score marks. The contacting surfaces of stabilizing type bearings (e.g., pressure, tilting pad) should not be scraped because the designed bore tolerance must be maintained for satisfactory operation.

- i. In cases, when installing in the field, where it may be necessary to scrape bearings to obtain proper tooth contact, rescribe those bearings with the final wall thickness values.
- j. Spare bearings will normally be shipped without wall thickness scribe lines. This operation must be done when used in the field.
- k. It is important to perform bearing wall thickness measurements and scribing properly since the markings are used at a later date when checking for bearing wear or when replacing a wiped bearing journal to re-establish tooth contact.

241-4.3.7 REBABBITTING JOURNAL BEARINGS. Manufacturing bearing shells or backings is the largest part of bearing cost. This is especially true in the case of spherically seated bearings because of the complex machining operations required and the close tolerances. Bearings that are no longer serviceable because of surface damage or excessive clearance should be rebabbitted instead of replaced with new bearings whenever possible. The following general guidelines apply:

- a. **Limiting Outside Diameter and Inside Diameter Ratio for Rebabbitting.** Before a bearing shell is rebabbitted, inspect its condition and suitability. Relatively thin shell bearings (those having a ratio of shell outside diameter to bearing inside diameter (OD/ID) of 1.25) are not recommended for rebabbitting. This type bearing should normally be replaced because in most cases rebabbitting attempts will result in a faulty bond or excessive distortion.
- b. **Checks Before Rebabbitting.** A bearing shell considered suitable for rebabbitting should be inspected for dimensional conformance with the manufacturer's drawings and the condition of the seating surface. In some cases nicked and dented seating surfaces can be repaired; for example, bearing shells with removable pads that form the spherical diameter. A similar method of repairing shells without pads is to spread the shell slightly at the joint split and build up the joint face with weld to increase the outside diameter of the shell and permit remachining of the seating surface. Because this method is expensive, it should be restricted to emergency situations.

SHOW APPROXIMATE LOCATION OF THERMOCOUPLE (RTD) HOLE, DOWEL HOLES OR DOWELS, BUBBLER GROOVE OUTLETS, LOCK SLOTS, AND OIL INLET SLOTS.



BEARING DRAWING NO. _____ IDENTIFICATION NO. _____

SHIP _____ REDUCTION GEAR SERIAL NO. _____

REDUCTION GEAR _____ PORT STARBOARD _____

CHECKED BY: _____ DATE: _____

Figure 241-4-14 Bearing Wall Thickness and Contact Chart

- c. **Rebabbiting Procedure.** Bearing shells should be rebabbitted in accordance with DOD-STD-2188, **Babbitting of Bearing Shells**, which covers preparation of the bearing shell, casting the babbit, safety precautions, and bond testing. Although both static and centrifugal casting are generally acceptable for producing a satisfactory metallurgical bond, centrifugal babbit casting is preferred. Pay particular attention to special features when machining the bearing bore. Using the manufacturer's drawing as guidance, locate and machine all details such as elliptical bore, babbit relief, and grooving. The bore diameter can be altered to provide the proper clearance when the bearing is to be used with an undersized journal.
- d. **Bond Test.** Conduct bond tests in accordance with DOD-STD-2183, **Bond Testing, Babbitt Lined Bearings.**

241-4.3.8 REBUSHING MRG CASING BORES. On MRG's using rolling contact bearings, excessive rotation of bearing outer race may enlarge the bearing casing bore, causing misalignment of meshing elements. If enlargement of the bore is excessive, rebushing is required. Repair in accordance with **NSTM Chapter 244, Propulsion Bearings and Seals.**

241-4.3.9 ROLLING CONTACT. Information regarding rolling contact bearings is contained in **NSTM Chapter 244, Propulsion Bearings and Seals**, and is also available from commercial sources.

241-4.3.10 RTE AND THERMOCOUPLE INSTALLATIONS. When temperature detection devices are used in bearings, take extreme caution to avoid breaking wires. Check internal wires for grounds and continuity before replacing covers. Do not lift an MRG casing solely to replace an inoperable RTE or thermocouple.

241-4.3.11 JOURNAL REPAIR.

1. Examine condition of journals whenever bearings are removed.
2. Stone and polish or roll and polish journal if scored slightly.
3. Badly scored journals can be ground undersize, or plated with appropriate material (e.g., chrome, nickel) and then ground to size. The plating and grinding of gear journals involves considerable expense, delay of the ship, and the potential for additional problems due to machining errors or handling damage during repairs. For this reason journals are not to be ground or plated unless clearance (with a new bearing installed) is beyond the allowable wear limit or unless it has been documented that the scored journal has caused more than 0.002 inch of bearing wear per year. Bearing wear shall be measured by comparing crown thickness readings, which is the logical measure for judging journal conditions. Plating shall be in accordance with existing NAVSEA instruction.
4. If journals are machined, take precautions to maintain concentricity with teeth. Check balance after machining is completed. Balance to drawing requirements.

241-4.3.12 CHECKING END PLAY (AXIAL CLEARANCE) OF PIVOTED SHOE TYPE INTEGRAL THRUST BEARINGS.

241-4.3.12.1 Checking End Play While Running. When it is feasible to use it, the simplest method of checking end play is to use a suitable measuring instrument on any accessible part of the propeller shaft, while running the engine or turbine slowly ahead and astern. This would normally be done at the end of a run, when the ship is maneuvering to approach a pier, before the machinery and shaft are cold. The speeds should be slow to avoid adding deflections of bearing parts and housing to the actual end play, but they should be sufficient to overcome the rake of the shaft and ensure that the full end play is actually taken up. The method of applying this procedure will depend somewhat on the type of bearing, as follows:

- a. **Micrometer at Forward End of Shaft.** The end cover of the bearing at the forward end of the MRG case sometimes has a central hole through which a micrometer measuring device can be applied to detect the axial position of the end of the shaft. Using that device, take a measurement with forward thrust, and another with astern thrust. The difference between the two readings is the end play.

- b. **Indicator Aft on Shaft.** If the thrust bearing is at the forward end of the drive, but the end cover plate is not drilled, then a dial indicator may be mounted on a rigid support close to any convenient aft coupling flange. Sometimes the shaft has a shoulder turned on it for the purpose of applying a dial indicator. This arrangement may also be used at any convenient coupling flange or a shaft shoulder if the thrust bearing is mounted aft of the MRG.

241-4.3.12.2 Barring on Shaft Flange. If measuring end play while running is not feasible, the next choice is to move the shaft fore and aft at some convenient flange.

- a. If possible, move the shaft fore and aft while it is still warm. The indicator may be mounted as in paragraphs [241-4.3.12.1](#). Be sure that the shaft movement is free (e.g., oil not cold) and avoid excessive barring force, which would add deflections of metal parts (such as the bearing housing) to the actual end play.
- b. If the barring must be done cold, begin by rocking the shaft, by means of the turning gear, to break the oil film. After rocking the shaft, apply the bar. If possible, mount the bar so that it can follow the rocking motion from right to left. Bar forward until marked resistance to rocking shows that the oil film between the collar and shoes is squeezed out. Note the indicator reading, then bar the shaft aft, rocking it as before, and take the new reading. Repeat to obtain an average.

241-4.3.12.3 Barring by Means of Thrust End Plate. With a six or eight shoe bearing at the forward end of the MRG or electric motor and the power shutdown, the end play may be measured in the thrust bearing itself. First drain the oil, then use one of the following procedures:

- a. Ordinarily, the filler piece fits loosely in the housing bore, between the end cover plate and the forward thrust bearing base ring. It is ground to a thickness that leaves the desired end play. With housing top cover bolted down, remove the end cover and filler piece; then substitute a dummy filler at least 1/8 inch thicker than the regular filler. The dummy must be smooth and flat and of uniform thickness, accurately measured and recorded. With the dummy filler in the place of the regular filler, replace the end cover; then tighten the bolts first, the four opposites evenly all around, using a hand wrench. While tightening the bolts, rock the shaft by the turning gear, and stop tightening when there is a sharp increase in resistance to turning. At this point ease the bolts off slightly. Measure the air gap at several points between the end cover and the housing flange with feelers, and equalize the air gap all around with the cover bolts evenly tightened. From the thickness of the dummy filler, subtract both the thickness of the regular filler and the air gap. The remainder is the end play.
- b. Sometimes the filler is a flat ring between the end cover and the housing flange. In that case the forward base ring commonly butts directly against the end cover. Remove the filler ring and tighten the end cover plate against the base ring, using the turning gear and equalizing the air gap thus measured. The thickness of the filler ring will be the end play.
- c. Sometimes a permanent filler ring is used in the housing between the aft base ring and the adjacent end wall of the housing. The purpose of this filler ring is to accurately fix the axial position of the thrust shaft and set the axial clearance. If there is also a filler piece, or filler ring, at the forward end next to the end cover, the filler aft of after base ring is not to be altered for the purpose of checking the end play.
- d. If there is no other filler in the thrust housing except the one aft of the aft base ring, the end play can still be checked by making and using a dummy filler (paragraph [241-4.3.12.3a](#)) without disturbing the filler already there.
- e. A six and eight shoe bearing mounted on the aft end of a MRG case, with the shaft going through, can sometimes have the end play checked, as previously described. The end cover plate would be withdrawn aft, and a split dummy filler inserted between the cover plate and the aft base ring if the regular filler piece enters the housing bore. If the regular filler is a ring between the cover flange and the housing, it should be removed and the cover tightened against the base ring in the same manner as described for a bearing at the forward end of the gear housing. If a dummy filler is used, protect it for future use. The thickness should be stenciled on, not stamped on.

241-4.3.12.4 Measuring Inside a Two-Shoe Thrust Bearing. If end play of a two-shoe thrust bearing is to be measured inside the bearing (rather than with a dial indicator on the fore-and-aft shaft movement), the correct

method is to use a feeler between the thrust pin and the rounded pivot (shoe support) set into the back of each shoe. This should be done on the astern side only, with the housing cover lifted and the collar blocked or barred against the forward shoes. Ordinarily this is the only check necessary. The following precautions, however, should be noted:

- a. With any two-shoe thrust bearing solidly coupled to a diesel engine shaft, it is essential that the thrust collar be so positioned fore and aft that the engine crankshaft is correctly located in reference to the main and crank-pin bearing ends. Further, the thrust housing should be located to afford equal clearances, fore and aft, for thrust collar adjustment. Note these points in subsequent rechecking and resetting of end play.
- b. In large two-shoe thrust bearings there may be some brinelling between the shoe supports and the thrust pins (more on the ahead side). In time it may be necessary to readjust the ahead jacking screws. The safest procedure, therefore, is to start by checking the crankshaft clearances. If those clearances are incorrect, move the shaft endwise until they are correct. At that point, the shaft should be blocked and all the thrust pins run in until the shoes bear solidly and equally on the thrust collar. As the shoes make contact make fractional turns on the jacking screws until the oil film between shoes and collar stops yielding.
- c. If the astern shoes and thrust pins have been affected by brinelling, the use of feelers becomes uncertain. The astern jacking screws may then be backed accurately by any of the following methods:
 - 1 Note the pitch of the jacking screw threads. Use a protractor on the jacking screw head to get the required number of degrees of turn for the desired end play.
 - 2 Mount a dial indicator on a bracket, attached temporarily in place of the jacking screw lock wrench, with the indicator mushroom butting against the jacking screw head. The bracket must be parallel to the face of the jacking screw head, the mushroom square, and not too far from the jacking screw head center.
 - 3 Use a micrometer in place of the dial indicator. The above refers to the usual outside jacking screws. If the bearing has inside jacking screws, the procedure is as follows:
 - (a) Mark the exact position of the turning wrench when the jacking screw has been tightened. (A bar may be clamped in a raised position across the housing, and the wrench position marked on the bar.) Block the shaft and back the screw sufficiently to free the shoe. Lift the shoe out. Return the wrench to the marked position. Use a micrometer between the jacking screw and the thrust collar to back the jacking screw for the desired end play. Repeat for the other shoe. Wipe the shoes with clean rags before replacing them.
 - (b) Note the pitch of the jacking screw threads. Use a protractor on the jacking screw head to attain the required number of degrees of turn for the desired end play.

241-4.3.12.5 General Notes.

- a. End play checking of a six- or eight-shoe bearing must always be done with the housing upper half (housing cap) solidly bolted down; otherwise, the base rings could tilt under the freedom given by the leveling plates and give a false reading.
- b. Never try to measure the end play with feelers between collar and shoes. In a two shoe bearing the tilt of the shoes would make accurate measuring impossible. In a six- or eight-shoe bearing, the leveling plates would give unequally, again making accuracy impossible.
- c. Keep a log of the end play measurements and refer to it after each checking. The normal wear of a pivoted shoe type thrust bearing is negligible even with years of use. When new, there may be slight settling of the leveling plates of a six- or eight-shoe bearing or the thrust pins and jacking screws of a two-shoe bearing. Any noticeable increase in the end play indicates that the thrust shoe surfaces should be examined and repairs made if necessary.
- d. In any jacking operation, make sure that the weight and rake of the shaft do not affect the measurements.

241-4.3.12.6 Precautions.

- a. Do not bar the shaft forward and aft without first slightly rocking it to break the static film.

- b. Do not lift the housing cover of a six- or eight-shoe thrust to check end play. It must be firmly bolted down.
- c. Do not try to measure end play with feelers between collar and shoes.
- d. Do not treat the dummy filler of a six- or eight-shoe bearing carelessly. You will need to use it again.
- e. Do not bar carelessly. Leveling plates and housings can spring and give false readings if too much force is used.
- f. Do not start checking without being familiar with the preferred and alternative procedures for your particular bearing and operating conditions.
- g. Do not use pinch bars near the ends of the teeth to move the pinions or gears to determine axial movement.

241-4.4 GEAR MAINTENANCE.

241-4.4.1 BACKLASH. Backlash is the play between the surfaces of the teeth in the mesh measured at the pitch circle. On gears that have been recut or through hardened gears that have worn, the increased backlash does not affect operation or cause noise during ahead operation but may increase noise during reversals and during low power operation. Lack of backlash, on the other hand may cause noise, overloading, and overheating of the gears and bearings, and may even cause seizing and failure.

241-4.4.2 DAMAGE TO GEAR ELEMENTS IN HANDLING. Exercise great care when handling gears and pinions to prevent damage to the teeth. If any gear teeth are dented, the tooth surfaces around the dent will become raised, forming high spots. These raised surfaces or high spots must be removed by scraping, filing, or stoning. The tooth surfaces should be smoothed down with a carborundum stone. Only a skilled mechanic authorized by NAVSEA should attempt this work. The lube oil system must be thoroughly cleaned to remove any loose grit or flakes of steel that may have entered the system.

241-4.4.3 DAMAGE TO GEAR ELEMENTS BY FOREIGN PARTICLES. Pinion and gear teeth can be damaged by foreign particles in the lube oil system. These particles can scratch or dent tooth surfaces as they pass through the mesh, resulting in raised surfaces or high spots around the scratches and dents. These high spots must be removed, or they will track on their mating gear(s) causing further damage when the unit is operated under load. A damaged tooth can be heard when the MRG is spin tested. The frequency of the noise in hertz (cycles per second) will indicate which rotating element in the gear train has the damaged tooth. For a double reduction, locked train MRG, the damaged tooth may be on one of the four second reduction pinions or on one of the four first reduction gears. The frequency of the noise caused by the tooth damage can be used to locate the damaged rotating element. If the damage is small, however, examine all four rotating elements until the damaged tooth is located.

241-4.4.4 DETECTING DAMAGED TEETH. If the damage is slight and cannot be located by a thorough visual inspection, it may be easier to locate the damaged tooth by painting the pinion teeth with a thin coat of Prussian blue or equivalent metal marking compound (Artists yellow oil paint). After rotating the gears with the turning gear motor, high spots will shine through the metal marking compound.

241-4.4.4.1 If hones were made when the gears were new, they may also be used to locate high spots. Rub a thin coat of marking compound evenly on the gear teeth, coating about twenty teeth at a time. Using the proper hone for the helix you are investigating, rub the hone back and forth across the teeth about six times. The number of times the hone is rubbed across the teeth should be the same for all teeth. Remove the hone and examine the honed teeth for bright spots in the marking compound painted coat. When the high spot is found, remove it by scraping, stoning, or filing.

241-4.4.5 REPAIRING DAMAGED TEETH. When foreign particles enter the gear train, they can scratch the teeth if they are very small, and bend, dent, or crack the teeth if they are large. One bent or dented tooth will track on all mating teeth if permitted to operate. High spots that are formed from bent and dented teeth must be smoothed out by stoning or filing. The damaged portions of the teeth should only be dressed to prevent interference contact with the meshing teeth (e.g., removing a wire edge that is large enough to break off and pass through the mesh; also remove high spots). Gear teeth should not be touched with hand tools except in an emergency. Use only steel scrapers or a fine file, and take every precaution to remove all filings or abrasive material. Make no attempt to remove deep pitting or galling. Repairs to damaged teeth shall only be performed by a skilled mechanic authorized by NAVSEA.

241-4.4.5.1 Bearing Failure. If a bearing fails (wipes) on a gear or pinion, pinion to gear misalignment occurs and continued operation could cause tooth overloads and tooth breakage. Bearing failure is usually accompanied by babbitt in the SFI or PLO strainers. This allows the Engineering Officer time to stop the gear before serious damage occurs. The following data should be recorded after an MRG element bearing has wiped:

- a. Perform a static tooth contact check on the affected elements to record tooth contact and identify any misalignment.
- b. Measure axial float in the prime mover to MRG coupling to ensure that float is in accordance with the MRG technical manual.
- c. Measure axial float in the limiting intermediate coupling to ensure that float is in accordance with the MRG technical manual.
- d. Bearing cap bolt tightness should be checked before bearing disassembly to identify any loose fasteners.
- e. Measure thrust bearing clearances to ensure that clearances are in accordance with technical manual requirements.
- f. Magnetic particle check or dye penetrant check the affected elements for fatigue cracking. If magnetic particle inspection is used, take care to remove the magnetic powder from getting inside the MRG case.
- g. Upon completion of repairs, perform static and dynamic tooth contact checks in accordance with paragraphs [241-4.4.7](#) and [241-4.4.8](#) to ensure proper loading of MRG elements.

241-4.4.5.1.1 Gear Tooth Cracking or Breakage. When all cracked teeth are located, they should be removed to the point where the crack ends by cutting down from the top of the tooth to meet the crack and then breaking out the cracked portion of the tooth. Using hand tools (such as a rotary grinder, file, or handstones), remove all remaining sharp corners and high spots. Where the cracked portion was cut off, relieve the end so that at least 0.25 inch of the remaining tooth does not contact the mating gear. All broken or cracked teeth should be handled in the same manner. Trials following this type of repair call for inspections to be sure no proud portion of the broken tooth interferes with the mating gear.

241-4.4.5.2 Damage in Handling. Gears damaged in handling usually have flattened teeth. This means the tooth will be proud (raised metal) on the ahead and astern faces. It is difficult to remove these spots without damaging the adjacent part of the tooth. A small flat file will take off the high spot, and a handstone may be used to blend the bruised area into the surrounding tooth area. Use a small straight edge to check the accuracy of the repair. This repair should be performed when only a small portion of a gear tooth is damaged.

241-4.4.5.3 Tooth Crushing. When a tooth is crushed for 3 or more inches, relieving the surface properly with handtools is impractical. This is especially true for a double helical pinion with a large helix angle because the

teeth wind around the gear cylinder in a way that makes handwork impractical. Handtool correction of damaged teeth should be attempted only if the area is small, and it should be performed by NAVSEA authorized personnel who are experienced in such work.

241-4.4.5.4 Tracking. When foreign objects are trapped in a mesh, they tend to track every tooth on the mating rotating element. The mating element then reflects the tracking back on the element that has the foreign particle lodged in it. A foreign object lodged between two teeth is sometimes difficult to find. Sometimes a foreign object becomes trapped, marks the teeth, and then falls out. Each tooth should be thoroughly searched to locate the foreign object. The location of the object gives a clue as to where the maximum damage has occurred. When an object is lodged between two teeth, these two teeth will be damaged the most. The teeth of the mating element that see this object first have less damage because the foreign object will tend to flatten out and cause less interference. The damage to the mating element will now cause a weaker mark on the balance of the teeth of that element. Repairing this damage is very time consuming. File or stone the high spots on each tooth of each rotating element involved to remove the interference.

241-4.4.5.5 Severe Tracking. Occasionally a large foreign object (like a bolt, nut, or broken tooth) will catch in the mesh and track all the way around. If this occurs near the end of the helix of a gear, it may be temporarily repaired by machining off the pinion teeth to remove the affected area. All teeth affected by this failure should be examined for cracks. A report of findings and request for technical assistance shall be submitted to NAVSEA immediately.

241-4.4.5.6 Rusting. Gear tooth damage such as rust and corrosion is usually caused by excessive moisture in the lube oil. This moisture is usually caused by intermittent MRG operation without the purifier operating or by faulty purifier operation.

241-4.4.5.6.1 MRG case rust is usually caused by condensation that forms inside the case because of the location of hatchways that affect air circulation, inadequate cool down periods, improper oil purification, unusually cool engine rooms, lack of dehumidifier or lube oil circulation during shutdown periods, and improper venting.

241-4.4.5.6.2 When the MRG is being secured, the hot, humid atmosphere inside the MRG casings will cause water to condense on the cooler upper walls of the casing. This moisture causes rust unless precautions are taken to cool down the casing and oil at the same rate, thus preventing condensation. A cool down procedure when securing the MRG is given in paragraph 241-3.5. This procedure reduces oil temperature while the gears are rotating at standard speed, thus coating the case walls with relatively cool oil.

241-4.4.5.6.3 Also, directing cool air onto the MRG casings by fans or blowers will increase the rate at which rust forms inside the casing. When the MRG is operating, it is better to keep the casing warm than to cool it.

241-4.4.5.6.4 Rust in the MRG case, if left unchecked, will eventually flake and can enter the lube oil system. Rust accumulating in the lube oil will eventually be centrifuged in the couplings and scratch the working surfaces of the coupling teeth. The coupling teeth surfaces will clean themselves if the source of the moisture is eliminated. If the rust is heavy, it may be necessary to remove the rust scale with a crocus cloth. Do not attempt to rub away rust pits that extend below the working surface.

241-4.4.5.7 Worn Gear. There may be many ways to damage gear teeth, but in each case, any interfering metal must be removed. Badly worn gears, however, are best left alone unless replaced. Their operation will be noisy, and the rate of wear will increase with time; however, no amount of handwork will improve operation.

241-4.4.5.8 Heavy Loading. When a gear tooth is heavily loaded on the tip of the tooth, the bending stress will increase. Pitting or scoring in this area act as stress risers and can initiate cracks. The crack can also start at an inclusion in the steel. The crack will enlarge after additional load cycles and will eventually result in a broken tooth.

241-4.4.5.9 Pitting. Surface failure due to pitting is a fatigue failure. Gears that are misaligned usually show this type of failure because the teeth are not uniformly loaded (are locally overloaded) resulting in a tiny flake of metal popping out. The crack propagates in all directions until it reaches the surface, where a tiny flake of metal pops out.

241-4.4.6 TOOTH CONTACT. Gears that have shaft axes in parallel and uniform tooth contact will operate satisfactorily. Active pitting, tooth breakage, and uneven tooth contact indicate that corrective action may be required.

- a. For gears of 125 K factor or less, a satisfactory tooth contact is obtained when at least 80 percent of the axial length of the working face of each tooth is in contact, distributed over 100 percent of the face width less end relief.
- b. For gears above 125 K factor, tooth contact shall be at least 90 percent of the axial length of the working face of each tooth in contact, distributed over 100 percent of the face width less end relief.
- c. Scraping or stoning teeth to achieve contact is prohibited since tooth profile will be destroyed.
- d. Filing, honing or stoning to remove a local hump or deformation is permitted by an authorized OEM, NSWCCD, FTSCPAC, FTSCCLANT or NAVSEA technical representative.

241-4.4.7 TOOTH CONTACT DETERMINED BY STATIC CHECK. General Tooth Contact Information. Consult instruction manuals about required tooth contact. Some gears are cut with a very slight taper of the teeth (helix angle deviation) to offset the effects of torsional twist and bending. In such gearing full contact across the face will not be attained by static testing. For contact checking, rotating elements should be positioned in bearings at the full power reaction point.

241-4.4.7.1 Static Checking Method. For static tooth marking, apply a thin coat of Prussian blue to the pinion and contrasting marking compound to the gear teeth respectively (paragraph 241-4.4.9). Roll the gears (usually with the turning gear) with sufficient torque to cause metal contact between the meshing teeth. The Prussian blue on the pinion teeth will transfer to the contrasting compound on the gear teeth. Where two gears contact one pinion, inspect the markings on both gears.

241-4.4.7.1.1 The best static marking can be attained when sufficient torque is applied. This can be accomplished by positioning rotating elements to simulate bearing reaction in the operating condition. Apply a brake on one HS pinion and apply torque to the other HS pinion by operating the turning gear motor at full rated current.

241-4.4.7.2 Marking Compound Transfer Method. Apply a thin coat of Prussian blue to a band of five teeth on one element. Coat a similar band of five teeth on the mating element with contrasting marking compound (artists yellow oil paint works well). The coatings must be thin and even. Rotate the two bands into contact. A permanent record can be made of the tooth impression by applying scotch tape on a tooth and rubbing on the surface of the tape (paragraph 241-4.4.13). The sticky side of the tape will pick up the marking compound, and it can be placed on and adhered to white paper for future reference.

241-4.4.7.3 Static Check Precautions.

1. Continuously coat the turning gear worm with lube oil while applying torque.
2. Teeth shall be clean before marking compound is applied. Lubricating oil, if not removed, will smear the compound.
3. Bearing caps shall be installed securely when elements are rolled together.
4. If contact is not shown on one helix of a double helical element, move the pinion or gear axially to line up the apex.

241-4.4.8 TOOTH CONTACT DETERMINED BY OPERATION. Red DYKEM (made by DYKEM Co., 8505L Delport Drive, St. Louis, MO, 63114) is used to determine tooth contact for all operating conditions. Blue DYKEM is also used when required in conjunction with red DYKEM in applications where red DYKEM alone is not adequate to read the contact pattern. DYKEM is a lacquer based dye that is impervious to oil. It will eventually wear or wash off, particularly when operating at high oil temperatures (180 to 2005 F.) and when using inhibited oils. DYKEM must be applied in a thin coat and on a clean, dry surface, or it will chip off easily and give a false indication of contact. If properly and carefully applied, the dye will be 0.0001 to 0.0002 inch thick and will provide a good colored background for observing tooth contact markings. Any areas with mismatch that exceeds approximately 0.0001 to 0.0002 inch will not make contact. The dye will not wear away, but will remain on the teeth in these areas.

241-4.4.8.1 DYKEM Material List. The following materials have been used successfully by MRG OEM's for dynamic tooth contact checks in the fleet and are recommended:

a. **DYKEM Supplies:**

1. DX-296 DYKEM Layout Red (2 each, one pint bottles)
2. DSL DYKEM Staining Dark Blue (2 each, one pint bottles)

NOTE

Use only fresh fluid (within 1 year of date of manufacture) from a bottle that has not been previously opened. DYKEM company will provide the date of manufacture on the bottle if requested when ordered.

3. DYKEM Remover and Thinner #138 (4 each, one quart bottles)
4. DYKEM Marker (2 each, 1/2-ounce felt tip applicator)

b. **Industrial Supplies:**

1. Lint free cloth (1 dozen, 12x12-inch cloths)
2. Plastic containers, shallow, wide mouth, with lids (6 each, 8-ounce size)
3. 1/8-inch industrial felt (1 each, one square foot, cut into wiping pieces)
4. 4-inch paint brushes (2 each, gear safe)
5. Scotchbrite pads (6 each, 6x9-inch pads)
6. Lanyard material (50-foot length)
7. Denatured alcohol (2 gallons)

8. Paint bucket (2 each)

241-4.4.8.2 Recommendations. For most accurate results observe the following:

- a. Apply DYKEM to the gear teeth immediately preceding gear operation.
- b. If turning gear operation is required after DYKEM has been applied and before the test run, limit operation to astern rotation if possible; if not possible, minimize the time of operation.
- c. If the propulsion plant is to be operated after DYKEM has been applied and before the test run, minimize the time and torque of this operation.
- d. Tooth contacts should be inspected and recorded immediately following the prescribed power runs. It is recommended that the tooth contact patterns be recorded on a form that best represents helical orientations (e.g., apex leading, base leading) of the MRG elements.
- e. If the gear running tooth contact cannot be inspected and recorded immediately following the test run, minimize the time and torque of gear operation.
- f. If for any reason the DYKEM must be reapplied, apply it to a new area of teeth using this same procedure.

241-4.4.8.3 DYKEM Application Procedure. The following procedure is recommended for applying DYKEM to gear tooth elements:

1. Wait at least 2 hours from the time the lube oil system is shut down and the covers are opened before cleaning the gear teeth.
2. Inspect and rotate the gearing as required to determine that the teeth are free of old DYKEM and rust. When applied, DYKEM should be visible on all elements through the inspection cover openings at the same time.
3. Red DYKEM should be applied to a band of at least 5 teeth on each input pinion for single reduction MRG's, and on each HS gear and LS pinion for double reduction MRG's. If required, blue DYKEM should be applied to an adjacent band of at least 5 teeth on the same MRG elements. Use denatured alcohol, a bucket, and a paint brush to clean the band of 5 (10) teeth and enough adjacent teeth to prevent oil contamination of the band.
4. In the helix relief, at the center of each gear and pinion, mark the area (teeth) to be finish cleaned to which DYKEM will be applied. Mark the date. This marking should be done using the DYKEM felt tip marker.
5. Finish clean the defined teeth using soft, lint free cloths and DYKEM Remover and Thinner no. 138. Remark and date as in step 4, if required.
6. The Engineering Officer or his designated representative supervising the operation shall then check the cleanliness of the gear teeth using a clean, white, lint free 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 to apply DYKEM.
7. Pour the red DYKEM into a plastic container. Using a clean felt pad, apply a light, thin, uniform coat of red DYKEM to the entire tooth (both faces, root, and tip). Replace the pad as necessary to maintain a smooth and flexible pad surface. The DYKEM should not be diluted either by adding thinner to the DYKEM or by applying thinner to the felt pad.
8. The Engineering Officer or his designated representative shall inspect the DYKEMED teeth to ensure complete uniform coverage.

9. Allow the red DYKEM to dry at least 30 minutes before applying the blue DYKEM if required, or closing the inspection covers and starting the lube oil system. If a band of blue DYKEM is required, apply it commencing with step 6 above.

241-4.4.8.4 Operation for Determining Dynamic Tooth Contact. The following is general guidance for performing dynamic tooth contact checks.

241-4.4.8.4.1 Steam Turbine Powered Ships. Perform the following steps to evaluate dynamic tooth contact patterns on steam turbine powered ships:

1. Apply DYKEM to teeth in accordance with paragraph [241-4.4.8.3](#).
2. Operate at 50 percent ahead power for two hours and then examine and record tooth contact patterns.
3. Acceptable tooth contact at this power level should at least show a marking trend consistent with any helix angle correction in the tooth design, OEM prediction, or any predictions provided in the applicable technical manual. A qualified OEM, NSWCCD, FTSCPAC, FTSCCLANT, or NAVSEA technical representative should be present to evaluate the contact patterns and determine acceptability for full power. Contact patterns considered questionable but not obviously unacceptable should not preclude full power operation but should be investigated at a later time.
4. Operate at full ahead power for four hours and again examine and record the tooth contact patterns. For most designs, a satisfactory tooth contact pattern will meet the requirements in paragraph [241-4.4.9](#). Additional hours of full power operation may be recommended by the qualified gear representative if necessary to establish acceptable final contact patterns.
5. Operate at 50 percent astern power for one-half hour and examine and record tooth contact patterns.

241-4.4.8.4.2 Gas Turbine Powered Ships. Two different plant operating configurations can be used to dynamically check tooth contact patterns on gas turbine powered ships. The two configurations and procedures are as follows:

- a. Operate the propulsion plant(s) to be tested in the split plant configuration and perform the dynamic tooth contact check as follows:
 - 1 For each MRG to be tested, apply DYKEM in accordance with paragraph [241-4.4.8.3](#) to the appropriate teeth of the gear meshes to be checked.
 - 2 Operate at 50 percent split plant maximum ahead torque for two hours and then examine and record the tooth contact patterns.
 - 3 Acceptable tooth contact at this torque level should at least show a marking trend consistent with the MRG tooth design, OEM predictions, or any technical manual predictions. A qualified OEM, NSWCCD, FTSCPAC, FTSCCLANT, or NAVSEA technical representative should be present to evaluate the contact patterns and determine acceptability for full power. Contact patterns considered questionable but not obviously unacceptable should not preclude full power operation but should be investigated at a later time.
 - 4 Operate at split plant maximum ahead torque for two hours and again examine and record the tooth contact patterns marked on the driven elements. For most designs, a satisfactory tooth contact pattern will meet the requirements in paragraph [241-4.4.9](#). Additional hours of split plant maximum torque operation may be recommended by the qualified gear representative if necessary to establish acceptable final contact patterns.
 - 5 Reverse the split plant engine configuration in each plant and repeat [steps 2](#) through [4](#) above.

- b. The second plant configuration for performing dynamic tooth contact checks on gas turbine powered ships is with both plants operating and with all gas turbines on-line. The procedure is as follows:
- 1 Apply DYKEM to teeth in accordance with paragraph [241-4.4.8.3](#).
 - 2 Operate at 50 percent ahead full power torque for two hours and then examine and record tooth contact patterns.
 - 3 Acceptable tooth contact at this torque level should at least show a marking trend consistent with any helix angle correction in the tooth design, OEM prediction, or any predictions provided in the applicable technical manual. Qualified OEM, NSWCCD, FTSCPAC, FTSCCLANT or NAVSEA gear representative should be present to evaluate the contact patterns and determine acceptability for full power. Contact patterns considered questionable but not obviously unacceptable should not preclude full power operation but should be investigated at a later time.
 - 4 Operate at ahead full power torque for four hours and again examine and record the tooth contact patterns. For most designs, a satisfactory tooth contact pattern will meet the requirements in paragraph [241-4.4.9](#). Additional hours of full power torque operation may be recommended by the qualified gear representative if necessary to establish acceptable final contact patterns.
- c. On ships with a reversing reduction gear, operate at the design astern torque or the safe astern steering limit (whichever occurs first) for one-half hour and examine and record the tooth contact patterns.

241-4.4.8.4.3 Diesel Engine Powered Ships. Perform the dynamic tooth contact check as follows for diesel powered ships:

1. Apply DYKEM to teeth in accordance with paragraph [241-4.4.8.3](#).
2. Operate at 50 percent ahead full power torque for two hours and then examine and record tooth contact patterns.
3. Acceptable tooth contact at this torque level should at least show a marking trend consistent with the tooth design, OEM prediction, or any technical manual predictions. A qualified OEM, NSWCCD, FTSCPAC, FTSCCLANT, or NAVSEA gear representative should be present to evaluate the contact patterns and determine acceptability for full power. Contact patterns considered questionable but not obviously unacceptable should not preclude full power operation but should be investigated at a later time.
4. Operate at ahead full power torque for four hours and again examine and record the tooth contact patterns. For most designs, a satisfactory tooth contact pattern will meet the requirements in paragraph [241-4.4.9](#). Additional hours of full power torque operation may be recommended by the qualified gear representative if necessary to establish acceptable final contact patterns.

241-4.4.9 TOOTH MARKING. Typical good marking will consist of a broad contact band across the face width of the teeth, from the initial contact point near the root to the tip of the teeth. Elements cut with tip and root relief will show no contact for a short distance down from the tip or up from the root of the tooth. The locations of other markings that may be found by contact inspection are shown in [Figure 241-4-15](#).

- a. [Figure 241-4-15](#), view A indicates when a difference exists in helix angles between the pinion and gear. Load concentration may occur at:
1. The outer end of the ahead face and the inner end of the astern face.
 2. The outer end of the astern face and the inner end of the ahead face. This condition may occur on one helix when contact with the other helix is satisfactory.
- b. An error in parallelism in the plane containing the axis of the pinion and gear is shown in [Figure 241-4-15](#),

view B (Figure 241-4-16). Load concentration will occur on the ahead and astern faces at the same end (forward or aft end) of each helix. This same type of marking will occur on the first reduction pinion teeth whose helix angle has been modified to compensate for torsional twist and bending.

- c. The position of load concentration due to the misalignment of the pinion and gear axes is shown in Figure 241-4-15, view C (Figure 241-4-17). Load concentration will occur on both the helices at the same end (forward or aft ends) for the ahead face, and at the other end for the astern face.
- d. The location of marking under light load when teeth of second reduction pinions have helix angle modification is shown in Figure 241-4-15, view D.

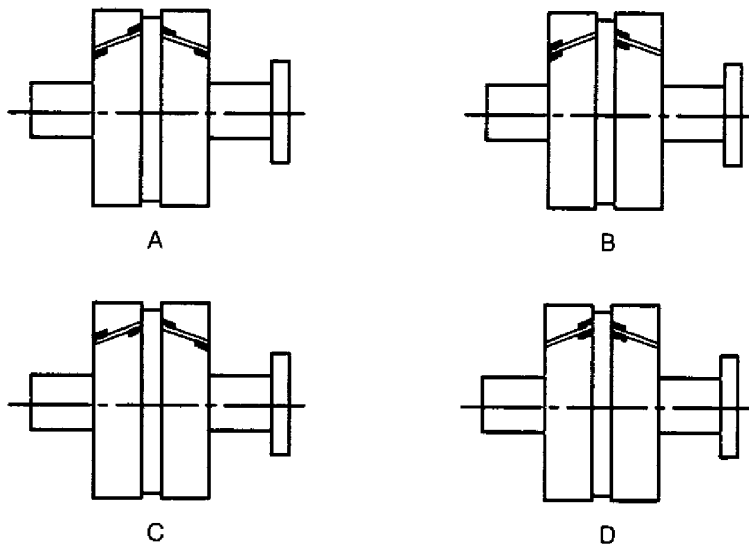


Figure 241-4-15 Locations of Tooth Markings by Contact Inspection

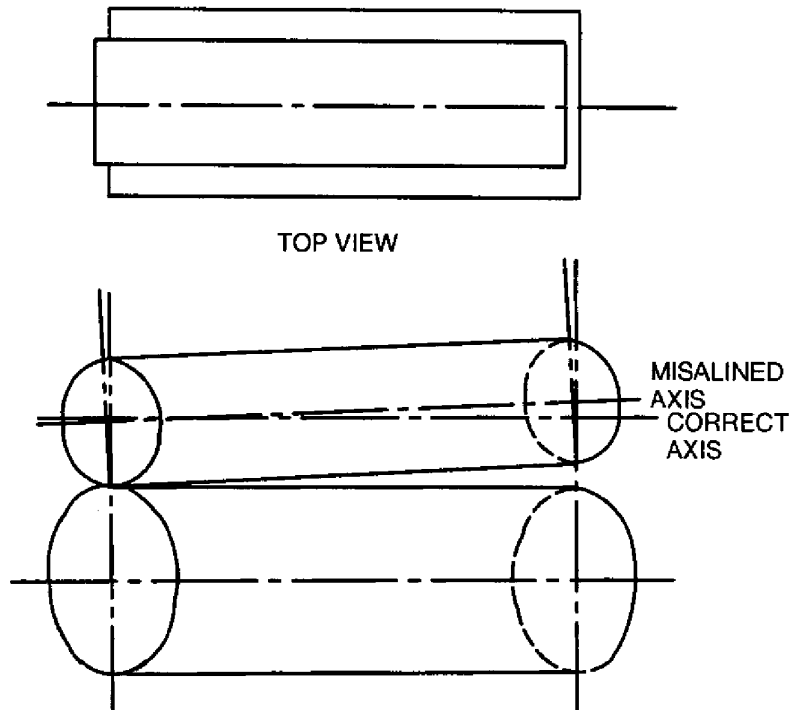


Figure 241-4-16 Misalignment in the Plane of the Centers (Parallel Misalignment)

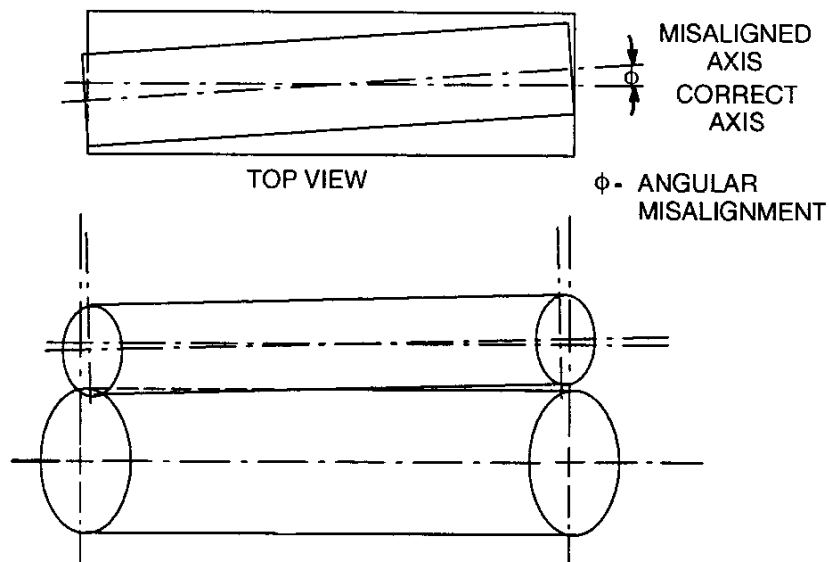


Figure 241-4-17 Misalignment Normal to the Plane of the Centers (Crossed Axes Misalignment)

241-4.4.10 CORRECTIVE ACTION.

- a. The condition shown in [Figure 241-4-15](#), view A can usually be corrected only by recutting. Where helix angle errors cause a load concentration ([Figure 241-4-15](#), view C), correction to improve tooth contact may consist

of casing realignment, bearing adjustment, or scraping of bearings so that the axes of the elements are out of plane. The amount of correction necessary should be determined by contact test.

- b. For the condition shown in [Figure 241-4-15](#), view B, realign the mating elements. For tapered teeth no corrective action is required.
- c. For the condition shown in [Figure 241-4-15](#), view C, realign the mating elements.
- d. For the condition shown in [Figure 241-4-11](#), view D, no correction is the required if teeth have helix angle modification. The teeth will show contact across the face when the MRG is operated at full power.
- e. **Precautions:**
 - 1 Realigning gears to correct tooth contact requires gear experts that are thoroughly familiar with such work.
 - 2 When a misaligned gear has pitted and has since stopped pitting, realignment will likely start the pitting process again.

241-4.4.11 RECORDING GEAR TOOTH DAMAGE. Photography provides a convenient means of making a permanent record of general tooth damage and failure; however, photographs may fail to show necessary detail. Other means, as described in the following paragraphs, have been successfully used to record tooth damage.

241-4.4.11.1 Casting Dental Stone Impressions from Silicone Rubber Molds. Rubber molds are made by pouring liquid room temperature vulcanizing (RTV) rubber directly onto clean gear tooth surfaces, using clay dams to confine the liquid until it cures. After the rubber sets, the mold is lifted from the gear. The sides and ends are cleaned and squared and then used to cast dental stone impressions of the gear teeth. The casts are made by pouring liquid dental stone into the mold, using dams to confine the liquid stone until it hardens. The stone cast is lifted from the rubber mold, cleaned, spray painted, and set aside to dry. The cast, an exact reproduction of the teeth, can be minutely examined and is a permanent record of the tooth condition at the time the mold was made. About ten dental stone casts can be made from each rubber mold before the mold begins to deteriorate.

241-4.4.11.1.1 RTV silicone rubber compounds with curing agents cure at room temperature to a tough rubber mold. No external heat is required, and no heat is released during curing. Curing times can vary from 30 minutes to 24 hours, depending on the type and quantity of curing agent used. Approximately 1 to 3 hours are required to make a mold, depending on variables such as curing time, mold size, advance preparations, and whether the gear is in or out of the MRG case. Working on the gear out of the case, the gear can be cleaned, a 6x8-inch dam can be made using prepared pieces of clay, and the liquid rubber mixed with the curing agent and poured, in about 1 hour. After a 1-hour curing time, the mold can be lifted. The total elapsed time is about 2 hours. Two molds (one of each helix of a double helical gear), could be made in about 3 hours total time.

241-4.4.11.1.2 Dental stone powder, mixed with water to a pourable consistency, is used to make the cast of the gear teeth. The dental stone releases some heat while curing and hardens in about 7 to 13 minutes. Approximately 1 hour is required to make a stone cast. This includes trimming and squaring the ends and sides of the rubber mold; building a dam around the mold; mixing, pouring, and curing the dental stone; squaring and dressing the cast; and spray painting. The cast may be made of the full length or any portion of a helix. When making a cast of the full length of a helix, the mold should be wide enough to include the full length of two adjacent teeth. A cast of a single tooth can also be made from the mold.

- a. **Making a Dental Stone Cast.** The following five general steps are required in making a dental stone cast:
 - 1 Obtain the materials listed in paragraph [241-4.4.11.1.2](#) so that they will be readily available.
 - 2 Prepare gear:
 - (a) Provide good light and staging, if required.
 - (b) With the gear shaft in a horizontal position, thoroughly clean a band of teeth located at the top of the gear.
 - (c) When working on the gear that is in the MRG case, protect all other portions of the MRG with canvas or other means to prevent materials from accidentally falling into openings in the casing.

- 3 Build a rectangular dam to confine the liquid rubber until it cures. Use blocks of clay to form the sides and ends of the dam.
- 4 Make the rubber mold:
 - (a) Add catalyst to the rubber and mix thoroughly.
 - (b) Pour mixture into the dam until it is approximately 1 inch over the tops of the teeth.
 - (c) Do not trap air when pouring liquid rubber into mold.
 - (d) Stroke a wooden spatula along the face of each tooth to release any trapped air. Do not lift the spatula above the surface of the liquid when moving from one tooth to another.
 - (e) Allow mold to cure until firm and resilient.
 - (f) Peel back and remove clay sides of dam; lift rubber mold from gear.
 - (g) Trim and dress ends and sides of mold using a sharp knife.
- 5 Make the dental stone cast:
 - (a) Place the rubber mold into a previously constructed wood or cardboard box, sized to suit the mold, with sides high enough to allow the teeth to be covered about 1 inch. If preferred, blocks of clay can be formed around the sides and ends of the rubber mold with sufficient height to allow the teeth to be covered about 1 inch.
 - (b) Add cold water to the dental stone powder and mix thoroughly until a pourable consistency is obtained. Pour into rubber mold, taking care not to trap air.
 - (c) Stroke a wooden spatula along the face of each tooth to release any trapped air. Do not lift the spatula above the surface of the liquid when moving from one tooth to another.
 - (d) When the stone cast sets, remove it from the mold and trim and dress sides.

NOTE

The stone can be more easily worked if removed from the rubber mold as soon as it sets.

- (e) Allow the dressed cast to set about 30 minutes and spray paint.

b. Materials:

- 1 Silicone rubber with catalyst. General Electric RTV II available in 1- and 10-pound cans
- 2 Dental stone. FSN 966520-00-557-7015 - 35-pound can
- 3 Modeling clay. Klean Klay Number 20 nondrying (nonoil bearing) - Art Chemical Products, Inc., Huntington, IN
- 4 Plastic bucket. 2-quart size (for mixing dental stone)
- 5 Plastic container. 1- or 2-quart size for water for mixing with dental stone
- 6 Box, wood or cardboard, sized to suit rubber mold and used to make the stone cast
- 7 Spatula for mixing catalyst into RTV rubber
- 8 Spatula for mixing dental stone
- 9 Small spatula, for use with rubber and for use with dental stone to stroke along face of teeth to release any trapped air
- 10 Pocket knife
- 11 Soft artist's brush
- 12 Stanley Surform Number 296 hand rasp for dressing dental stone
- 13 Sapolin Number 129 chromium effect spray paint.

NOTE

Experience has shown that it requires two 1-pound cans of silicone rubber to make a 6 x 8 x 1-inch (1 inch deep over tops of teeth) mold.

241-4.4.12 TIMING OF LOCKED TRAIN GEARS. Locked train gears require retiming only when new elements are installed; otherwise pinion and gear elements shall be installed using existing match marks. When retiming is required, it shall be accomplished by experienced OEM personnel (See [Figure 241-4-18](#), [Figure 241-4-19](#) and [Figure 241-4-20](#)).

- a. The timing procedure for a particular MRG is contained in the MRG technical manual.
- b. A rough check of the timing accuracy may be obtained by trying to insert feelers between the teeth of upper and lower meshes to determine if the teeth are contacting. When marking compounds are placed on the teeth before dock or sea trials, an indication of load division may be obtained by comparing upper and lower gear element markings after operation.

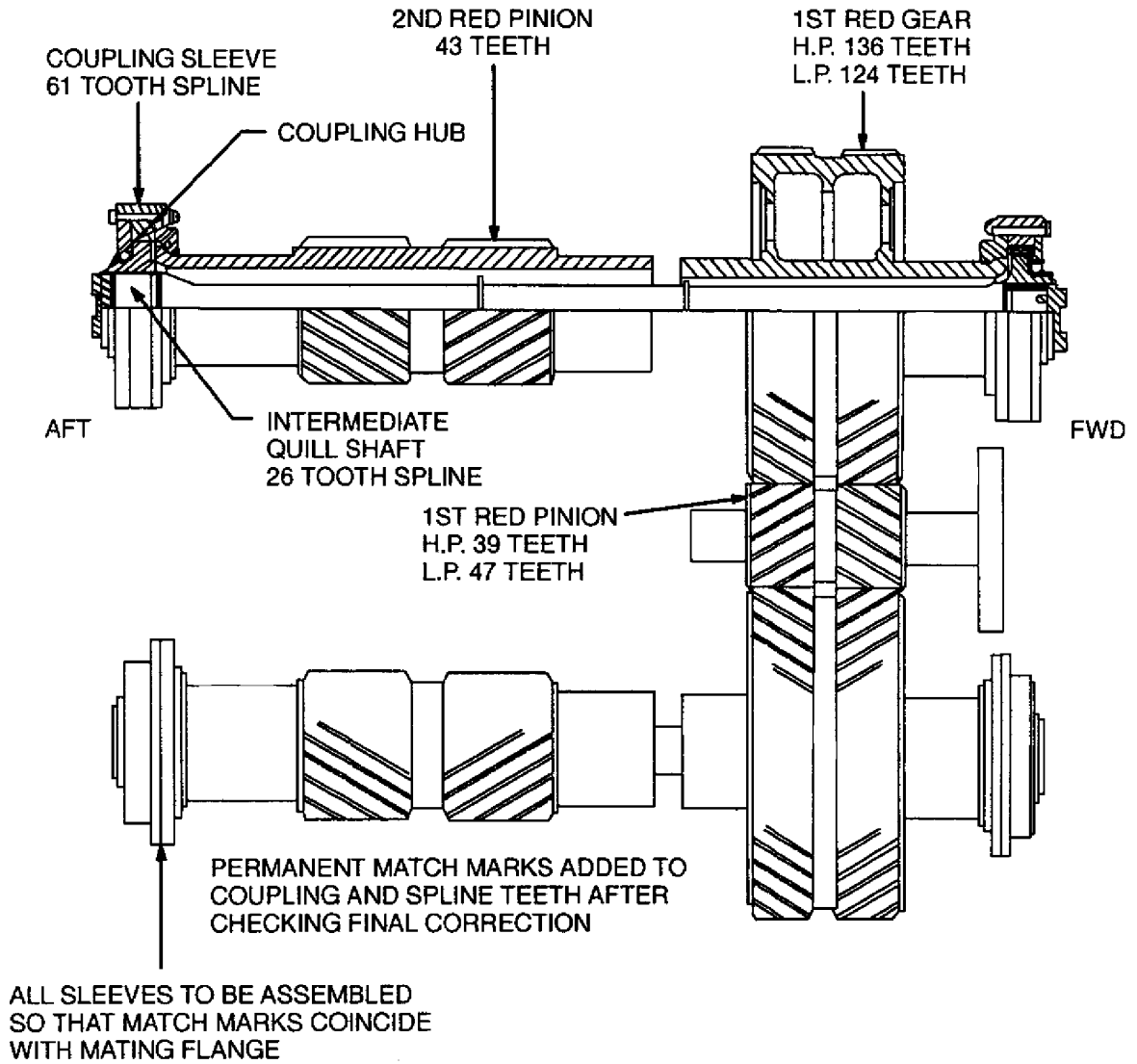


Figure 241-4-18 Typical Rotor Diagram

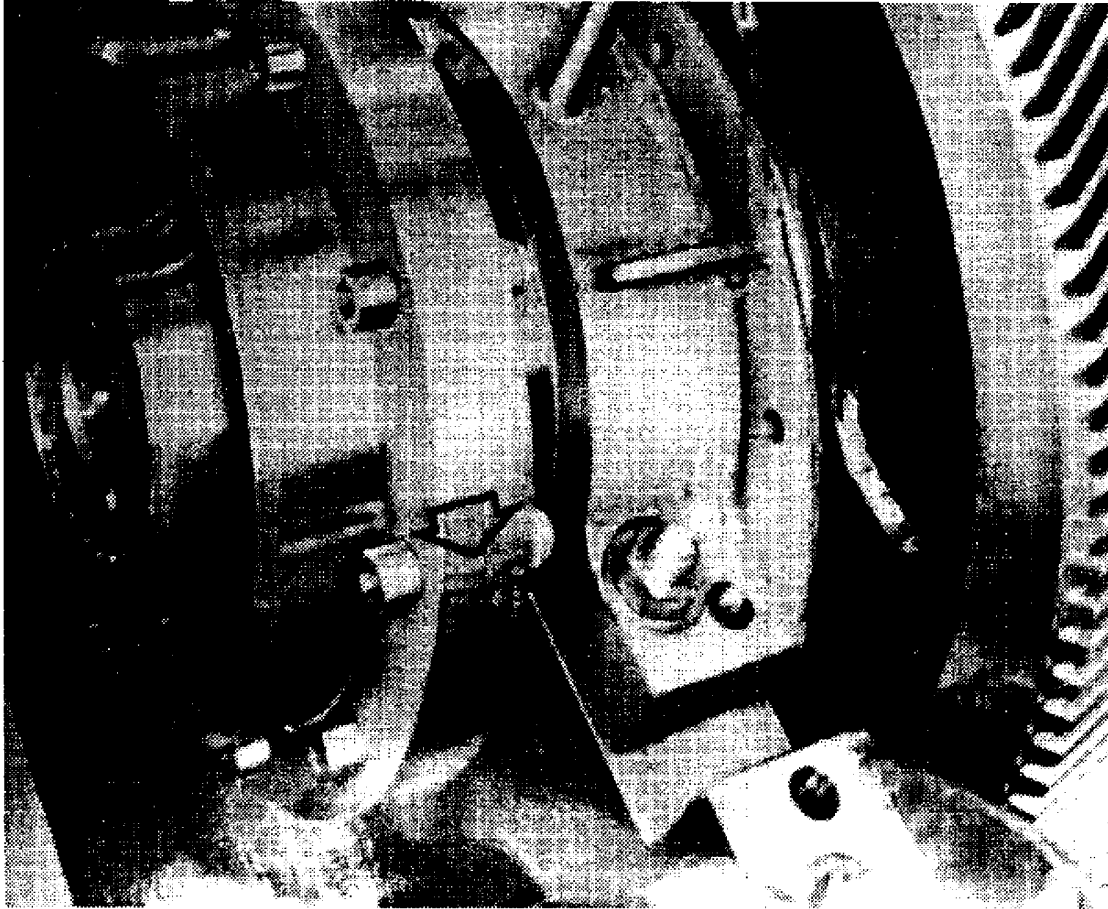


Figure 241-4-19 Intermediate Flexible Coupling Matchmarks

241-4.4.13 TOOTH WEAR.

- a. If proper tooth contact is attained when the gears are installed, there should only be slight tooth wear. Excessive wear cannot take place without metal-to-metal contact. Proper clearances, inspection for and removal of high spots, and an adequate supply of lubricating oil will prevent tooth wear.
- b. If the lubricating oil supply should fail and the teeth become scored, despite observing all precautions are observed, the gears must be thoroughly overhauled at the first opportunity.
- c. Pitting, particularly along the pitch line, may occur in the first few months of service. This pitting (often referred to as initial or corrective pitting) usually ceases after an initial wearing in period of varying length. The only corrective action required is to ensure that metallic flakes generated from the pitting are removed from the lubricating oil. Slight pitting does not affect operation of the gears.

241-4.4.14 TOOTH WEAR AND FAILURE.

- a. Wear may be defined as removal of metal from gear teeth.
- b. Normal wear may be defined as removal of metal from gear teeth at a rate that does not impair satisfactory operation of the gear.

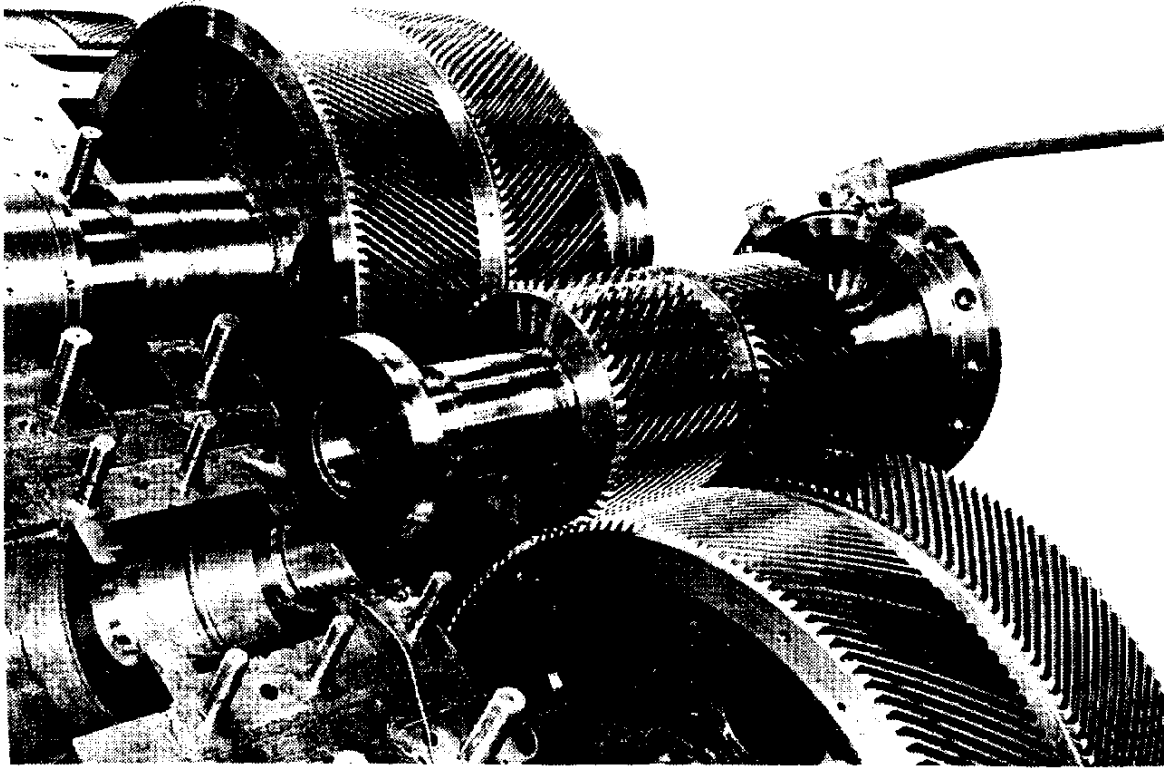


Figure 241-4-20 First Reduction Pinion Rolled Out for Adjusting Timing

- c. Pitting is a surface fatigue failure characterized by the removal of metal and the formation of cavities (pits). Pitting may occur in new units because of slight high spots. This pitting usually occurs near the pitch line and is called corrective or initial pitting because it redistributes the load by progressively removing the high contact spots. This pitting usually stops and no further trouble is experienced. Slight pitting does not affect operation of the gears. Overload conditions that cannot be corrected by initial pitting usually result in destructive pitting. Destructive pitting may progressively destroy the tooth profile, causing extremely rough operation and considerable noise. Often a bending crack will originate from a pit causing the tooth to break. Destructive pitting is shown in [Figure 241-4-21](#).
- d. Scoring is characterized by localized welding, and shows up as patches of radial scratches and tear marks, in the direction of sliding. Scoring for a few inches at the end of the helix is shown in [Figure 241-4-22](#). Scoring results from contact at the tooth tips because of insufficient tip relief or lack of lubrication.
- e. Dirt (debris) tracks are damaged to the gear tooth surface in the form of scratches and dents. They are caused by foreign particles passing through the gear mesh. The teeth are marked in the same location on each tooth ([Figure 241-4-23](#)). Dirt tracking may cause high contact spots. If prominent, these spots should be removed to avoid load concentrations that might cause pitting or tooth breakage.
- f. Wire edging is the gear tooth deformation caused by plastic flow of tooth surfaces. This results in a wire edge or fin at the tips of the gear teeth. If the fin is heavy, it shall be removed; otherwise, it may break off and pass through the mesh. Scoring, heavy pitting, and extreme wear are also shown in [Figure 241-4-24](#).
- g. Cracked teeth are normally caused by fatigue, but may also be caused by shock. The cracked teeth shown in [Figure 241-4-25](#) will break off with continued operation. Cracks are clearly shown by magnetic particle (powder) inspection.

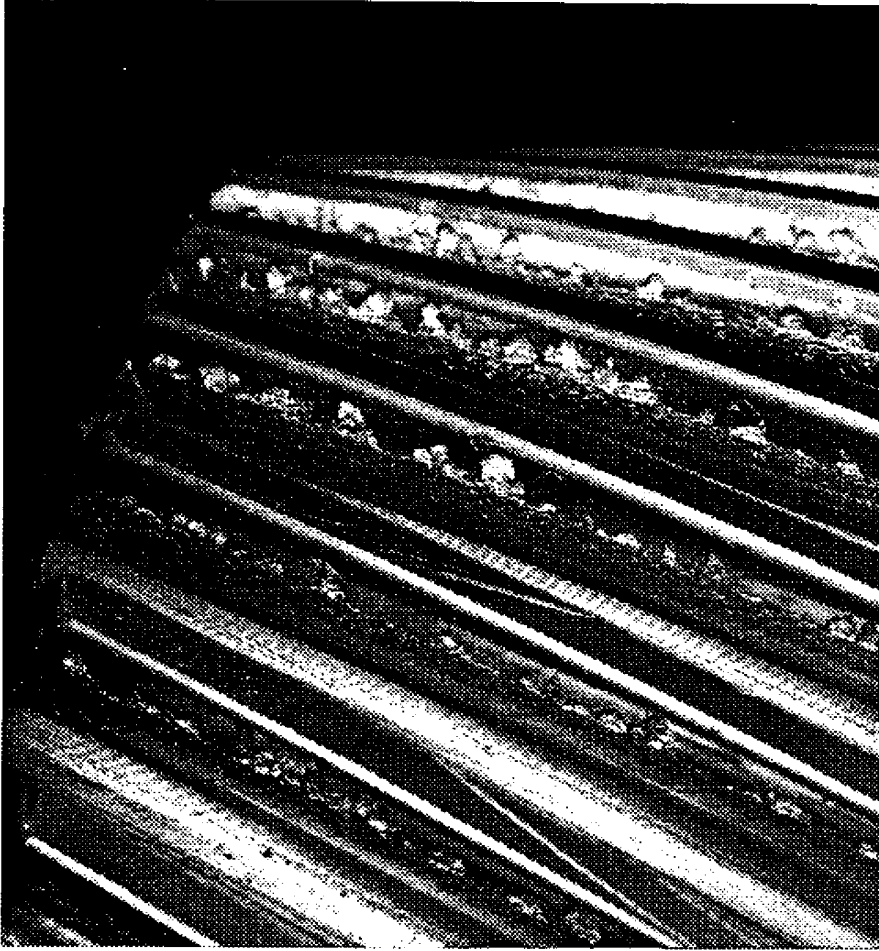


Figure 241-4-21 Progressive, Destructive Pitting

- h. Tooth fatigue breakage is caused by continued operation at a load that exceeds the fatigue strength of the material. Fatigue failure is progressive, usually starting as a short crack and then propagating. Characteristic oyster shell lines can usually be seen on the broken tooth. A typical broken tooth is shown in [Figure 241-4-26](#).

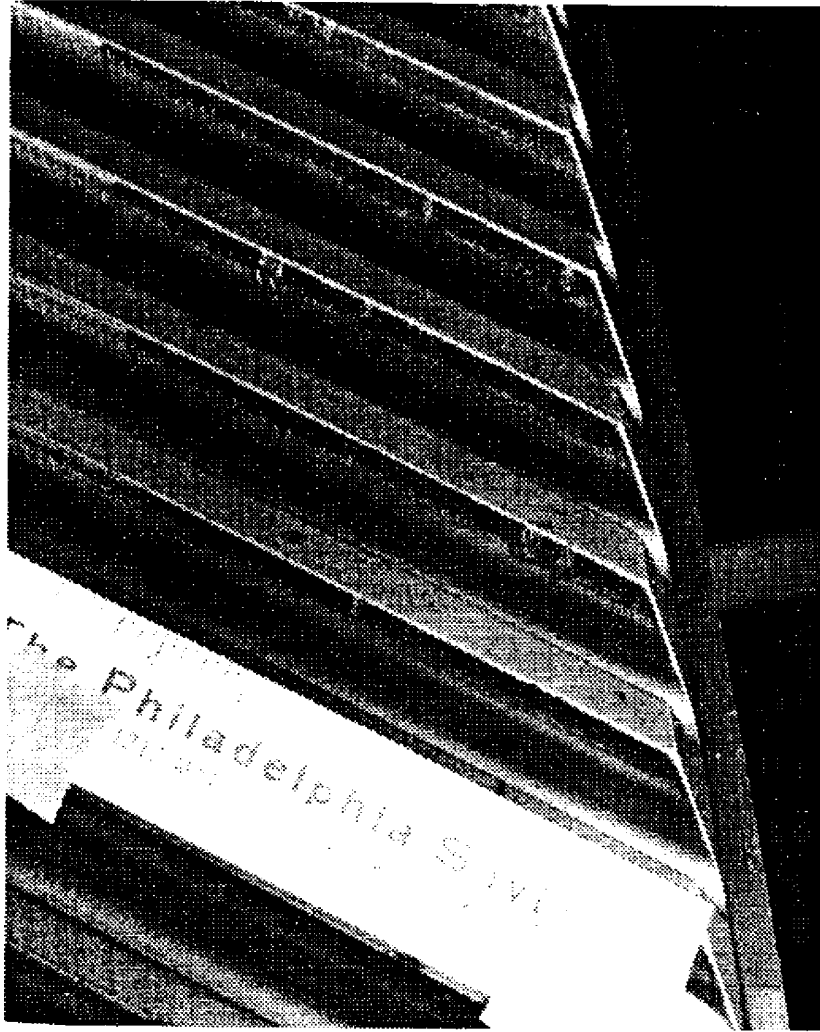


Figure 241-4-22 Scoring

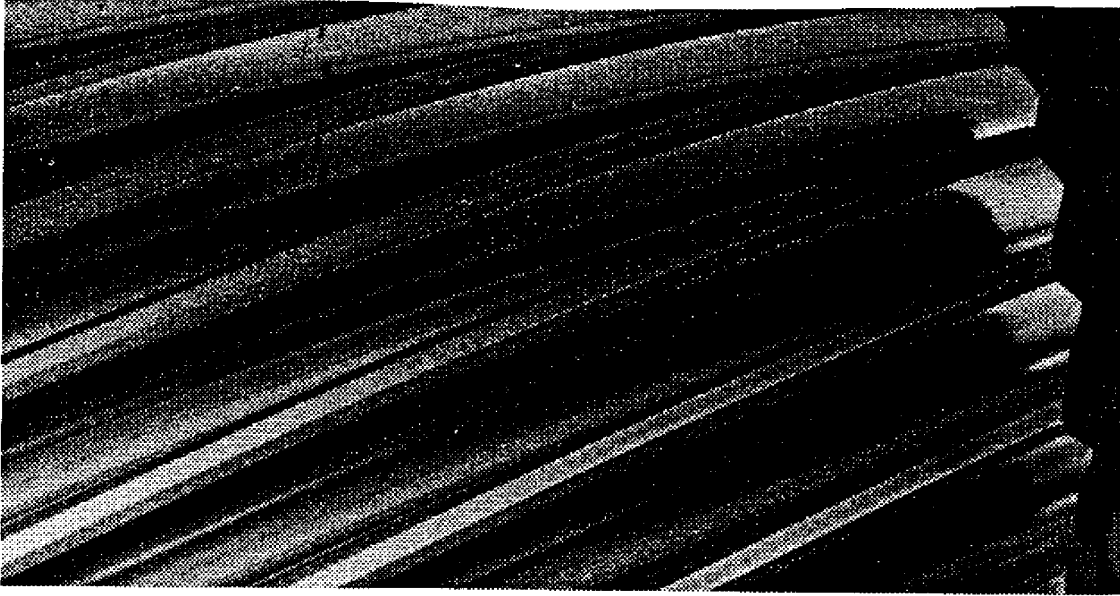


Figure 241-4-23 Dirt Tracking



Figure 241-4-24 Scoring, Heavy Pitting, and Extreme Tooth Wear

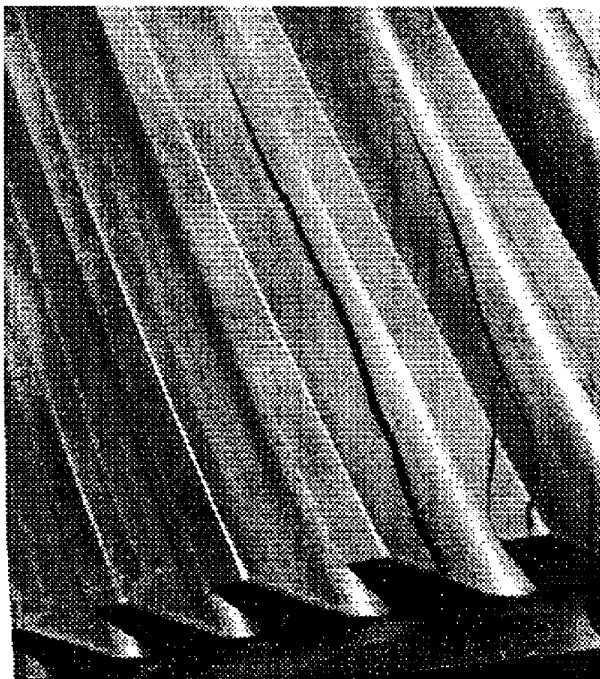


Figure 241-4-25 Cracked Teeth



Figure 241-4-26 Broken Tooth

241-4.4.15 ALIGNMENT. The gear train is aligned when the pinion and the gear are parallel. (The axes of the two shafts are in the same plane and everywhere are equal distance from each other.) In service the best indication of good alignment is good tooth contact.

241-4.4.16 ALIGNMENT CHECK. Because the alignment procedures can vary for different MRG's, the technical manual for a particular MRG unit will describe the equipment required and provide the procedure for determining the proper depth of mesh and parallelism for gear and pinion shafts.

241-4.4.16.1 Crown Thickness and Pin Check Methods.

- a. The length of tooth contact across the face of the gear teeth is the criterion for satisfactory alignment of reduction gears. When the gears are tested in the factory and satisfactory contact has been obtained, the ABCD and WXYZ pin check readings are scribed on the MRG casings for setting the lower casings. These readings

should be duplicated when the gear is installed in the ship. These readings will not change unless the ship is adversely affected by heavy weather or collides with another ship. At the same time the ABCD and WXYZ readings are scribed on the casing, crown thickness readings are scribed on the bearing shells. This makes it possible to install the gears in the ship and expect the same satisfactory gear tooth contact when it is operated. Each babbitted bearing shell of the MRG has a pressure bearing half and a nonpressure bearing half when referred to ahead operation. On some bearings the nonpressure half has a single radial scribe line at one end of the geometric center. The pressure half has three radial scribe lines at one end. The central scribe line is at the geometric center with a line on each side of the central scribe line, each at an angle of 45 degrees. The gear manufacturer places these marks in proper locations. The crown thickness is measured at these marks and is usually taken 1.25 inches in from the end of the shell. The wear on both the upper and the lower halves of the shell can therefore always be measured.

- b. The backlash on a pair of double helical gears is determined by the longitudinal movement of the gears. After the factory test, the longitudinal movement is measured and scribed on the end of the pinion. This measurement should be the minimum reading when compared with subsequent readings. Gear tooth and bearing wear will increase the backlash. The use of pinch bars near the ends of the gear teeth for moving the pinion or gears (to determine the longitudinal movement) is prohibited because it may damage the gear teeth.
- c. When the second reduction gear is larger than 48 inches in diameter and is of the double reduction type, the gear may have four holes drilled and reamed for use with ground pins or bars. Two of these holes will be on the forward end of the gear wheel, and two on the aft end. When the bar or pins are installed in the holes in the gear wheel, they will serve as a reference from which flatness readings of the lower MRG casing flange joint will be measured. These measurements were made in the gear manufacturer's shop, after satisfactory tooth contacts were obtained, to record the flatness condition of the lower casing flange joint. Readings taken on board ship should be within 0.002 inch of those taken in the shop (Figure 241-4-27).
- d. On single reduction gears having a second reduction gear pitch diameter of less than 48 inches, the lower MRG casing joint flatness reading for checking the warping or twisting of the casing are not required. On such gears, alignment is checked by measuring the bearing crown thickness and comparing these readings with the original readings scribed on the bearing shells adjacent to the scribe lines. The final check of alignment is to check the gear tooth contact with the gears torqued into the running position.

241-4.4.16.2 Alignment Check for Older Ships. Older ships may not be equipped for checking the lower MRG casing joint flatness condition, or the bearing crown thickness readings may not be scribed on the bearings. For these vessels check gear alignment by measuring the percentage of tooth contact. When new bearings are installed, the contact should be checked. The new bearing crown thickness should be measured and scribed on the bearing as indicated in paragraph 241-4.4.16.1.

241-4.4.16.3 Check of Alignment of MRG and Lineshaft. Poor alignment between the lineshaft and the MRG may be detected at the MRG. If the first lineshaft bearing is too high, the aft second reduction gear bearing may not be properly loaded. It is also possible for the aft second reduction gear to be statically loaded in the top half. During operation this gear may be noisy at a particular speed. That speed will be determined by the vertical components of the second reduction pinion loads. When the vertical components of load are high enough to bend the lineshaft and the second reduction gear shaft, the gear shaft will load in the bottom half of the aft bearing. At one speed, when the net vertical components of load misalignment forces plus weight are zero, the MRG may be noisy. The height of the first lineshaft bearing will determine the speed at which the noise will occur. This condition can also occur when the first lineshaft bearing is mounted too low. The forward second reduction gear bearing may be statically loaded in the top half.

241-4.4.16.3.1 Lineshaft misalignment can also occur in the athwartships direction. This condition will produce unequal static second reduction gear bearing reactions in the athwartships direction and result in shaft to bearing misalignment. Whenever the second reduction gear is misaligned in its bearings, the second reduction pinions will make poor tooth contact with the bull gear.

241-4.4.16.3.2 If the gear tooth contacts are poor, check the lineshaft to gearshaft alignment. Remove the coupling bolts, and break apart the coupling flanges. Measure shaft alignment with dial indicators. Compare these measurements with the design alignment requirements in the technical manual.

241-4.4.17 **ALIGNMENT CHECK AFTER GROUNDING OF PROPELLERS.** When a propeller strikes a submerged object or has grounded, a force from the turbine rotor inertia is transmitted from the pinions to the LS gear at the instant of contact. The magnitude of the force depends on the speed of the ship and how quickly the submerged object stops the propeller. The force may be sufficient to bend the shaft, bend or break gear teeth, or shear keys and loosen gears in the secondary train. In such cases check the concentricity and alignment of the gear. Visual and magnetic particle inspection (MPI) can be accomplished by qualified personnel to confirm that gear teeth have not been damaged.

241-4.4.18 **ALIGNMENT CHECK OF PRIME MOVER AND MRG.** Whenever the prime mover and MRG's are reassembled, it is imperative that the alignment of the pinion to prime mover shaft be checked. Measure alignment with a dial indicator.

241-4.4.19 **ALIGNMENT BETWEEN PRIME MOVER AND MRG PINION.** The most favorable alignment of the prime mover and MRG is concentricity at full power when at the proper operating temperature. The flexible coupling is designed to adjust for the transient condition of alignment as the machinery comes up to operating temperature. The two forms of misalignment seen between the prime mover and the driven shafts are angular and parallel offset ([Figure 241-4-28](#)).

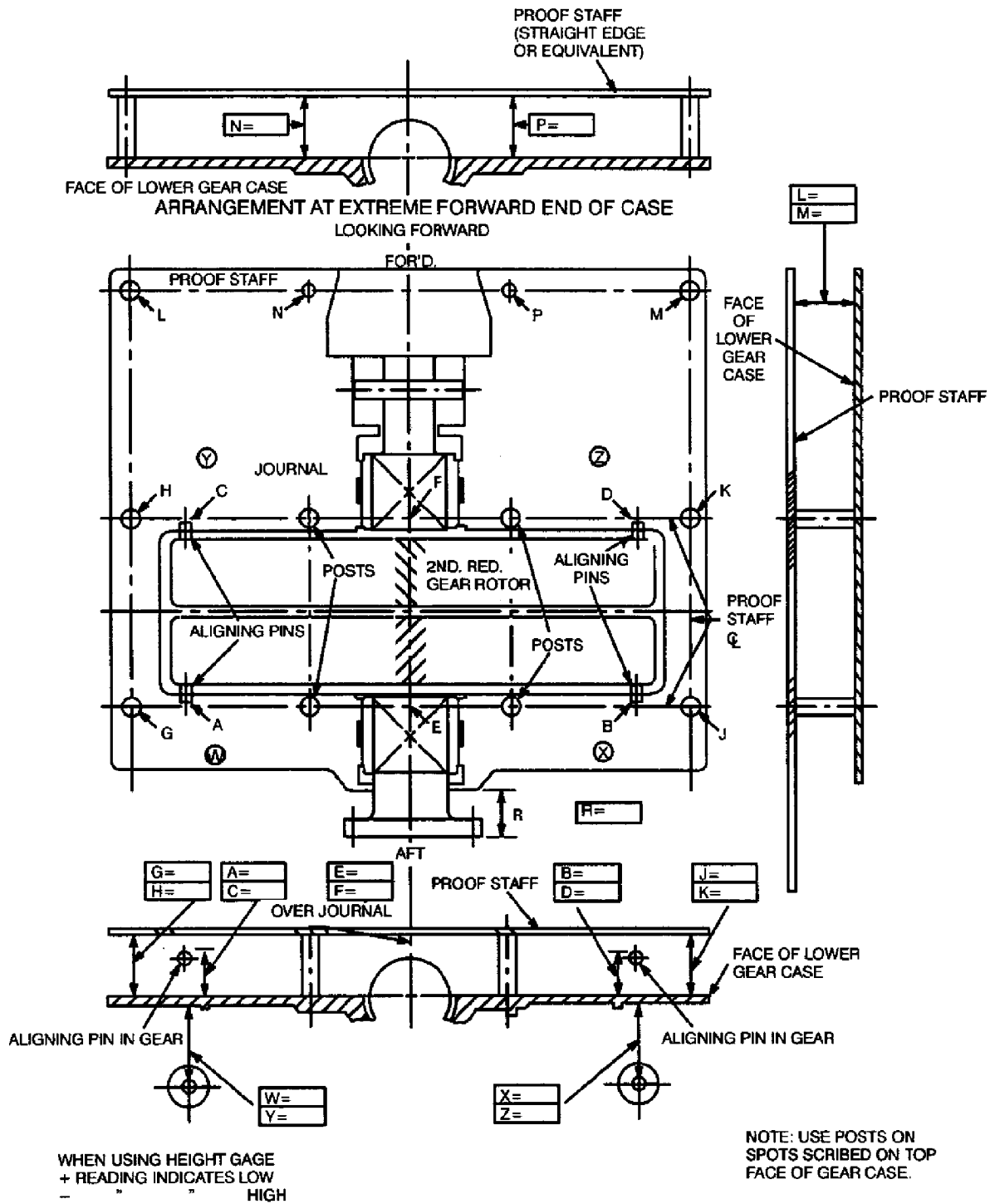
241-4.4.19.1 The objective of alignment is to locate the prime mover so that the axis of the spindle will be concentric with and parallel to the axis of the MRG pinion shaft or other component to which it is coupled during operation. Attaining this alignment is complicated because the prime mover casing, the MRG casing, and the foundation on which the prime mover and MRG are mounted all expand as they are heated from the cold condition to the hot running condition during operation. Another complication is that a turbine spindle is slightly higher in its bearings when running than when stationary. Also, the pinion shaft moves out of the stationary position when running because of the forces due to hydrodynamic oil film, tooth pressure, and gravity. It is, of course, necessary to know what these changes of position will be and to adjust for them by offsetting the prime mover shaft from the pinion when aligning the units in the cold stationary condition. The manufacturer provides these offset readings in the technical manual.

241-4.4.19.2 When checking alignment, first determine whether the flanges on the pinion and prime mover are true to the centerline of the shaft. This can be done by mounting an indicator so that the rider is running on the face of the flange or the outside diameter of the flange. Set the indicator to zero. With the thrust runner hard against the thrust bearing, rotate the shaft 360 degrees. The indicator should read zero at all positions from 0 to 360 degrees if the flange is true to the shaft centerline. If it does not read the same all the way around, the shaft is bowed or the flange is bent. This flange should be true to 0.0005 inch total indicator reading (TIR).

241-4.4.19.2.1 The horizontal and vertical offset are determined by indicating the outer diameter of the prime mover flange with an indicator mounted on the pinion and rotating the pinion on turning gear. Parallelism is determined by indicating the end face of the prime mover flange with a pair of indicators mounted on the pinion 180 degrees apart. Two indicators are used to compensate for the possible axial movement of the pinion as it is rotated during the process. A tripod support is necessary to mount the indicators so they may ride on the turbine flange. The tripod support, which is bolted to the pinion flange and on which the dial indicators are mounted, must be stiff enough to prevent deflection due to its own weight.

a. Determining Horizontal and Vertical Offset ([Figure 241-4-29](#)):

1. Mount indicator **A** on the tripod bolted to the pinion flange so that the indicator bears on the prime mover coupling hub (or coupling flange) periphery or outside diameter. Set the indicator to any desired value.
2. Rotate both the prime mover and pinion shaft through a complete revolution simultaneously and take readings every 90 degrees.



A TO F INCL. TO BE WITHIN .002" OF ORIGINAL READING
PROOF STAFF READINGS TO BE WITHIN + .001"

Figure 241-4-27 Alignment Reference Measurements (Erection Data)

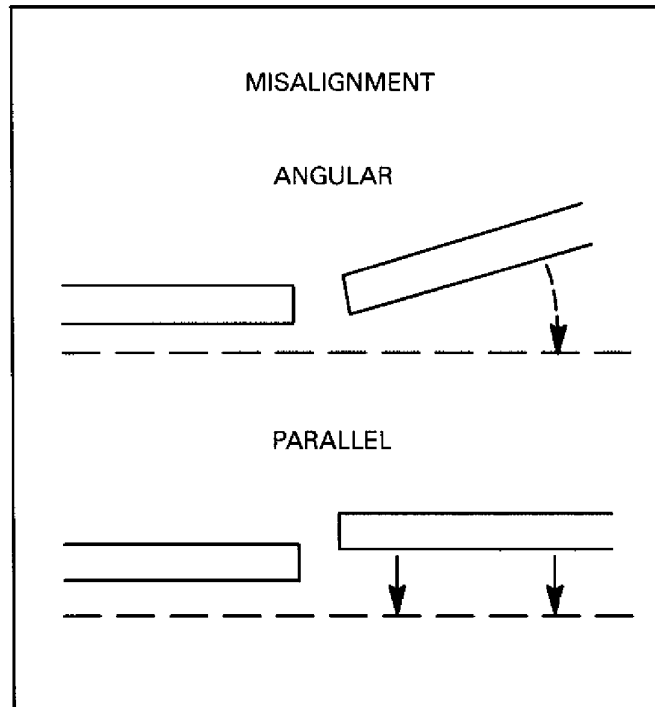


Figure 241-4-28 Misalignment Types

3. When the prime mover and gear shafts are concentric the indicator reading will be constant through a complete revolution. When the shaft axes are offset, the change in the indicator reading for 180 degrees rotation will be twice the offset in that plane.

A_0 = Indicator reading at top or 0 degree position

A_{180} = Indicator reading at bottom or 180 degree position

$$\frac{A_0 - A_{180}}{2} = \text{Vertical Offset}$$

- (a) If this value is positive, the prime mover is higher than the gear; if this value is negative, the prime mover is lower than the gear.

A_{90} = Indicator reading at 90 degree position

A_{270} = Indicator reading at 270 degree position

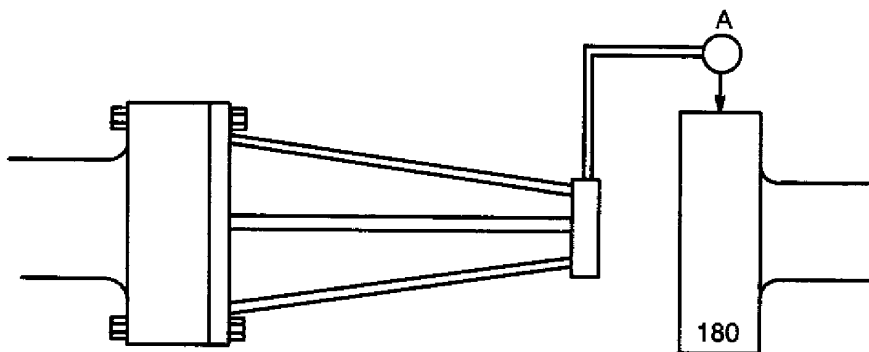
$$\frac{A_{90} - A_{270}}{2} = \text{Horizontal Offset}$$

- (b) If this value is positive, the prime mover is offset to the 90 degree point location; if this value is negative, the prime mover is offset to the 270 degree location.

b. Determining Parallelism:

- 1 Mount two dial indicators, **B** and **C**, on the tripod which is bolted to the pinion flange so that the indica-

tors bear against the face of the prime mover coupling hub (or coupling flange at points 180 degrees apart).



HORIZONTAL AND VERTICAL OFFSET

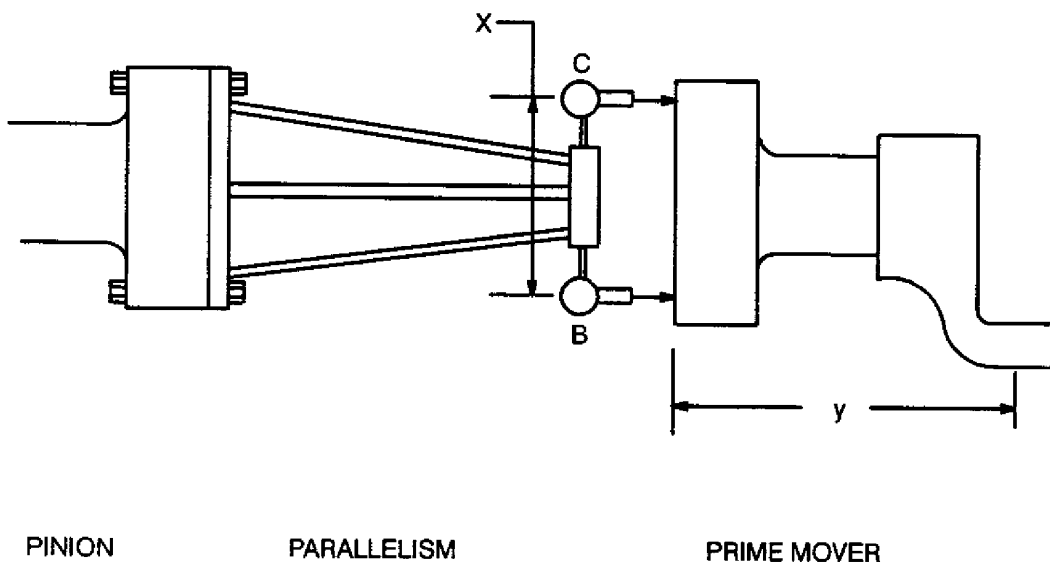


Figure 241-4-29 Alignment Measurements

- 2 Rotate both the prime mover and pinion shaft through a complete revolution simultaneously and take readings every 90 degrees, as indicated below. In taking these readings, each shaft should be held in an approximately fixed axial position by holding the thrust collar against the thrust bearing. The two indicator method will compensate for some axial movement due to the shafts floating in their thrust clearance.
- 3 Call the distance between indicators **X** inches. Call the distance from the centerline of the forward support feet (the location at which liners are fitted) to the coupling end face **Y** inches.
- 4 Call the B indicator reading B_0 and the C indicator reading C_0 for indicators in the vertical plane at the starting or 0 degree position. $B_0 - C_0 = Z_0$
- 5 Rotate both the prime mover and pinion shaft 180 degrees simultaneously and read the indicators. Indicator B reads B_{180} ; indicator C reads C_{180} for the indicators in the vertical plane at the 180 degree position. Then is the out of parallelism measurement in the vertical plane. If this value is positive, the

$$B_{180} - C_{180} = Z_{180}$$

$$\frac{Z_{180} - Z_0}{2}$$

Figure 5

coupling flanges are separated more widely at the top than at the bottom. If this value is negative, the coupling flanges are separated more widely at the bottom than at the top. If it is necessary to decrease the separation at the top to make this alignment parallel, the forward end of the prime mover should be raised to the amount:

$$\frac{Y(Z_{180} - Z_0)}{2X} \text{ inches}$$

- 6 Correction for parallelism in the horizontal plane is accomplished in a similar manner by taking indicator readings in the horizontal plane.
- 7 Call the B indicator reading B₉₀ and the C indicator reading C₉₀ for indicators in the horizontal plane at the 90 degree position. $B_{90} - C_{90} = Z_{90}$
- 8 Rotate both the prime mover and pinion shaft 180 degrees simultaneously and read the indicators. Indicator B reads B₂₇₀; indicator C reads C₂₇₀. $B_{270} - C_{270} = Z_{270}$
- 9 Normally there will be no requirement for introducing a cold angular misalignment in the horizontal plane, so $Z_{90} - Z_{270}$ should equal zero. If this value is not zero (or the value specified), correct by rotating the prime mover base in the horizontal plane in the following manner:
 - (a) Select as a pivot point either vertical support point on the prime mover base in line with the coupling.
 - (b) Mount an indicator to measure movement at the other prime mover vertical support point opposite the selected pivot point and in line with the coupling.
 - (c) Rotate the prime mover about the fixed point to achieve the proper alignment. The prime mover should be moved the amount: where **W** is the distance between the prime mover's vertical support points.

$$\frac{W(Z_{90} - Z_{270})}{2Y} \text{ inches}$$

- 10 Movements to correct offset may affect parallelism, and movement to correct non-parallelism may affect offset. A complete set of alignment readings shall therefore be taken each time the prime mover is moved. Take all measurements when the prime mover is correctly positioned. Make a final alignment check after the prime mover is bolted down.

241-4.4.20 FLEXIBLE COUPLINGS. A flexible coupling, either lubricated or nonlubricated type, fitted between the prime mover and MRG permits axial motion and expansion of rotors, and allows for some misalignment between the driver and pinion. Depending on the MRG internal configuration, a flexible coupling either dampens propeller thrust to the prime mover thrust bearing or supplements intermediate gear couplings in this function. Flexible couplings are installed with sufficient end float to allow for expansion and reasonable wear of thrust bearings.

241-4.4.21 INSTALLING FLEXIBLE COUPLINGS. The flexible coupling between the prime mover and the reduction gear is usually double ended to accommodate angular and parallel misalignment without causing adverse movement of the prime mover shaft and the HS pinion. It is supported on the prime mover side by the aft prime mover bearing and supported on the other end by the forward pinion bearing. The relative position between the shafts in these bearings determines coupling alignment and end float. For lubricated couplings, the

distance piece is supported by a good fit between the roots of the female teeth and the top land (outside diameter) of the male teeth. For nonlubricated couplings, the distance piece is supported by the diaphragms and disks.

241-4.4.21.1 Incorrect alignment can cause problems such as noise, vibration, pounding, excessive bearing wear, rapid tooth wear, or the distress of one or more diaphragms and disks of the coupling.

241-4.4.21.2 When couplings are installed, check spigot fits and indicate sleeves or hubs to ensure that they are running true. Remove burrs and dirt from flanges. Sleeves not in a plane with flanges may cause rapid tooth wear or distress of one or more diaphragms and disks of the coupling.

241-4.4.21.3 Misalignment may be caused by thermal expansion or distortion that results in the problems listed in paragraph 241-4.4.22. To correct for misalignment, adjust the cold alignment offsets or brace and strengthen the prime mover seating.

241-4.4.22 LUBRICATED COUPLING TOOTH WEAR. The various types of coupling tooth wear are illustrated as follows:

- a. **Severe Galling or Worm Tracking (Figure 241-4-30).**The coupling's axial movement is severely restricted. Replace coupling. Check alignment and lubrication. If light galling occurs, the coupling can be stoned and reinstalled.
- b. **Indenting (Figure 241-4-31).**The coupling's external teeth have formed a concave area in the internal teeth, preventing axial motion in either direction. Replace the coupling. If the indentation is not too deep, it may be removed by filing off both shoulders.
- c. **Knife-Edged Teeth (Figure 241-4-32).**Dirt mixed with oil collects at the roots of the coupling's female teeth and forms a lapping compound. This compound and the radial and axial motions slowly wear away the teeth. Sometimes the teeth are worn to knife edges. Replace the coupling.
- d. **Shouldering (Figure 241-4-33).**The coupling's axial movement is restricted. The shoulders should be removed by filing and stoning. Couplings that form a shoulder usually have teeth that are not surface hardened by carburizing, nitriding, induction hardening, etc.
- e. **Moderate Axial Scoring (Figure 241-4-34).**The coupling teeth have shouldered. The coupling can be salvaged by filing and stoning to remove the shoulder.
- f. **Severe Axial Scoring (Figure 241-4-35).**The coupling teeth have very rough surfaces that restrict axial movement. Pounding of the teeth is apparent. Replace the coupling.

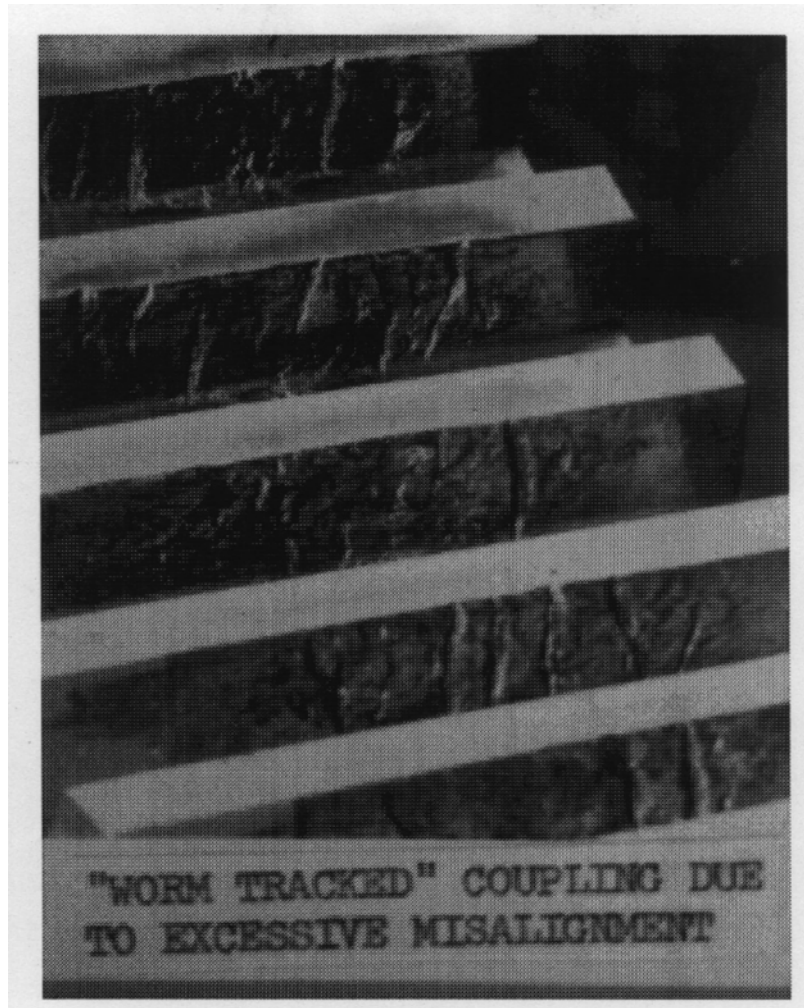


Figure 241-4-30 Severe Galling or Worm Tracking

241-4.4.22.1 Couplings can also collect enough dirt to restrict axial movement. A coupling packed with dirt has the same lack of axial motion as a coupling with a shoulder worn on the female teeth.

CAUTION

Do not blast (e.g., glass bead) clean surface hardened couplings as the blasting process can cause cracking of the hardened surface.

241-4.4.22.2 Repair damaged couplings whenever possible.

241-4.4.23 **NONLUBRICATED COUPLING DISTRESS.** Any type of distress or stress cracks in the coupling diaphragms and disks indicates excessive misalignment and will eventually lead to coupling failure if uncorrected. Check alignment and replace coupling diaphragms and disks.

241-4.4.24 **LUBRICATED COUPLING BACKLASH MEASUREMENT.** To determine backlash attach a dial indicator to the coupling sleeve or the sleeve oil dam. Install a projecting arm on the coupling distance piece that will extend out to the male teeth on the coupling distance piece. The pointer of the dial indicator should be about

the same radius as the pitch diameter of the coupling teeth. With the indicator pointer compressed against the projecting arm from the distance piece, rotate the sleeve or the distance piece back and forth (holding the other element stationary). The difference in the two readings corrected to the pitch diameter is the backlash at the teeth.

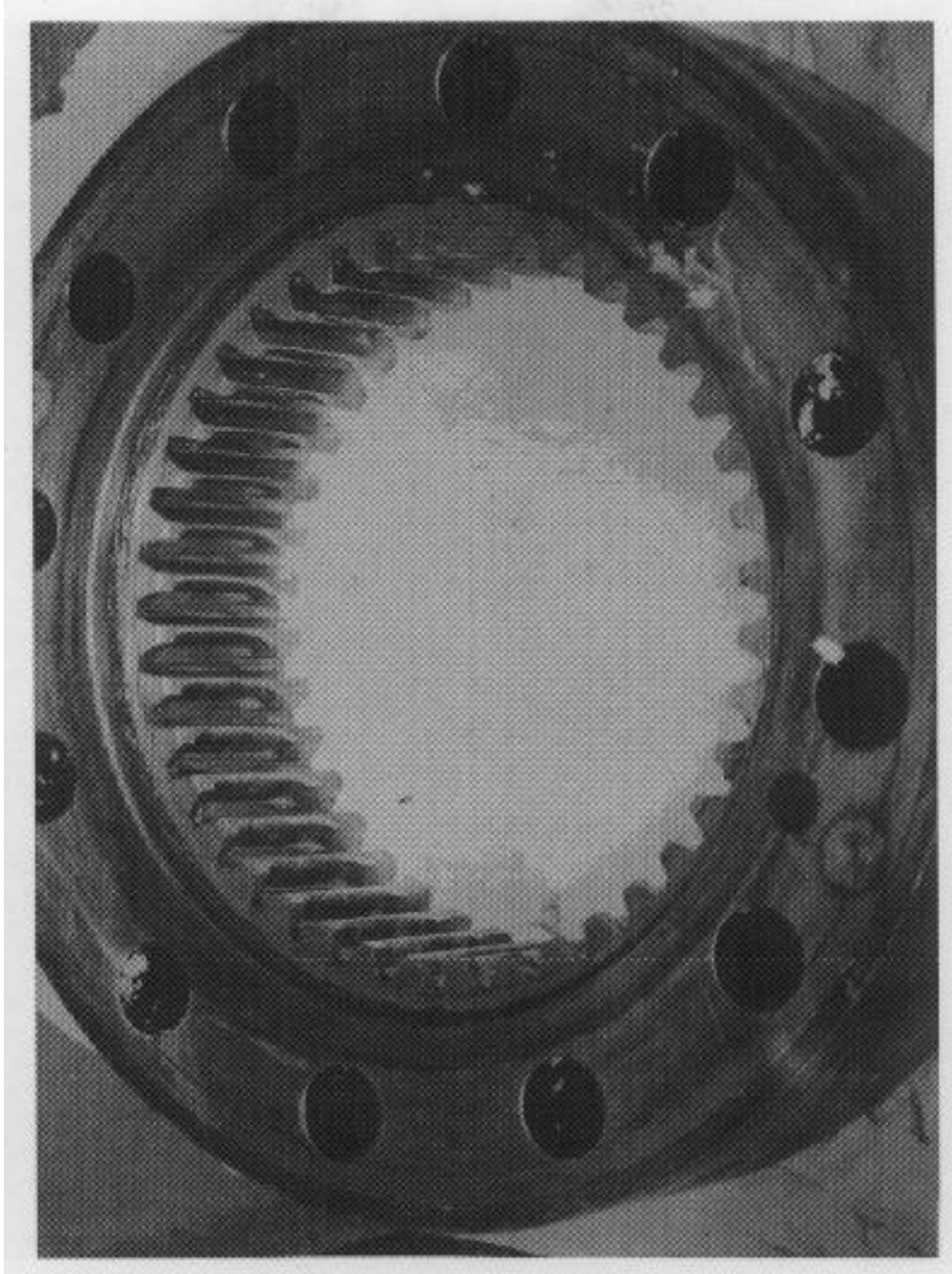


Figure 241-4-31 Indenting (Sheet 1 of 2)

241-4.4.25 LUBRICATED COUPLING TOOTH WEAR LIMIT.

- a. Replace couplings when the backlash is equal to the design backlash plus 20 percent of the male tooth design chordal tooth thickness for through hardened teeth and design backlash plus 50 percent of case thickness for surface hardened teeth. If information regarding tooth thickness is unavailable from the drawings, estimate the thickness by consulting the tables for spur gears.
- b. Coupling replacement may be required before it reaches maximum backlash. Reasons for early replacement are specified in paragraph [241-4.4.24](#).

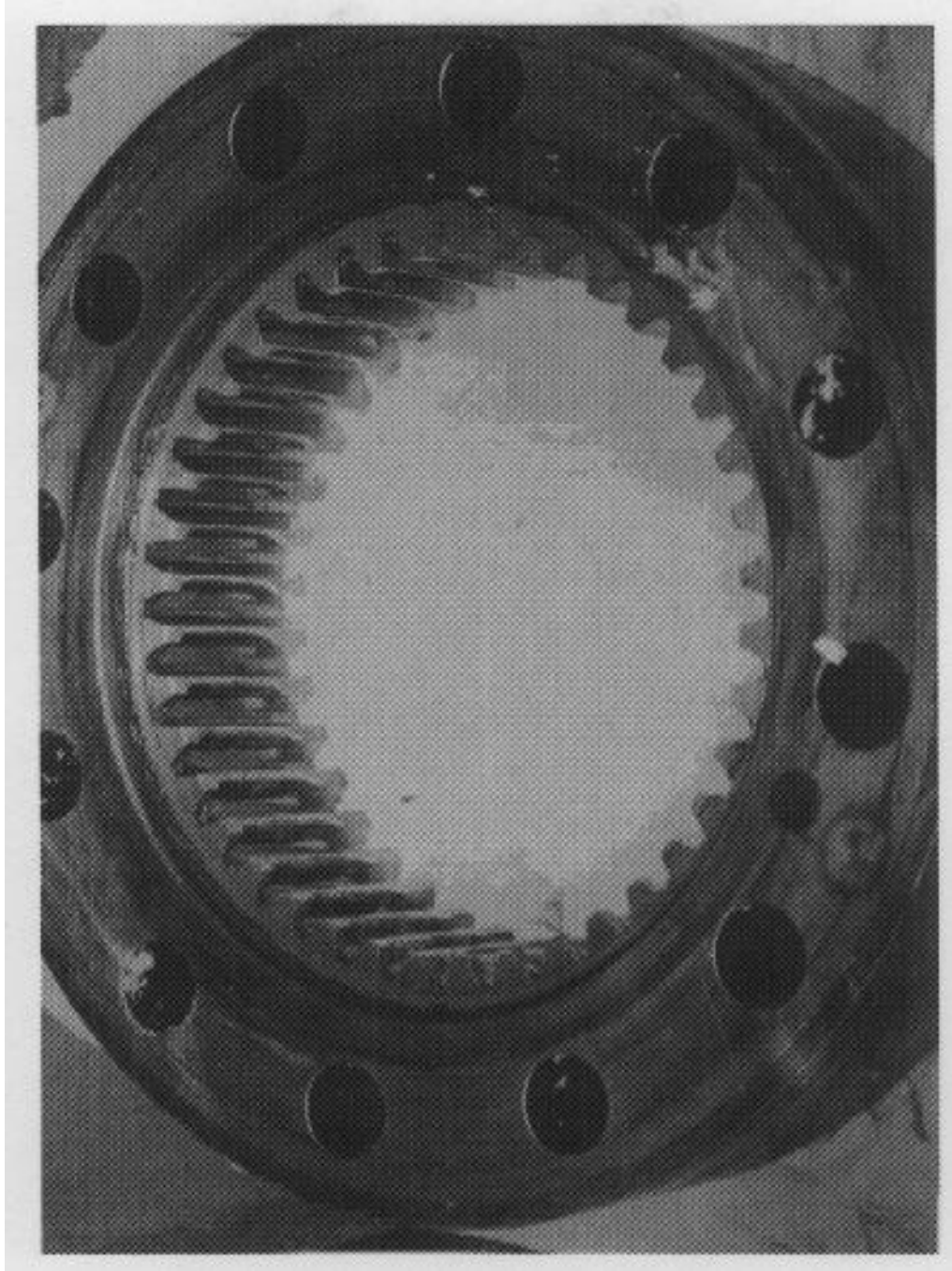


Figure 241-4-31 Indenting (Sheet 2 of 2)

- c. Couplings may be operated with a backlash in excess of maximum, under emergency conditions, if approved by the Type Commander or by NAVSEA. Replace such couplings, however, at the first opportunity.

241-4.4.26 COUPLING INSTALLATION PRECAUTIONS.

- a. For both lubricated and nonlubricated couplings, when a coupling must be replaced because of excessive wear, note the type of wear and take corrective action to minimize or eliminate its cause.
- b. For lubricated couplings, when the teeth wear to knife edges, two things should be done. First, inspect the coupling for dirt more often and operate the purifier more often to remove abrasive dirt. Second, check for undue vibration that may be caused by the prime mover or the MRG. Radial clearance between the ends of the male teeth and the roots of the female teeth should be checked when new couplings are installed. The drawings for these couplings will give the root clearance values.

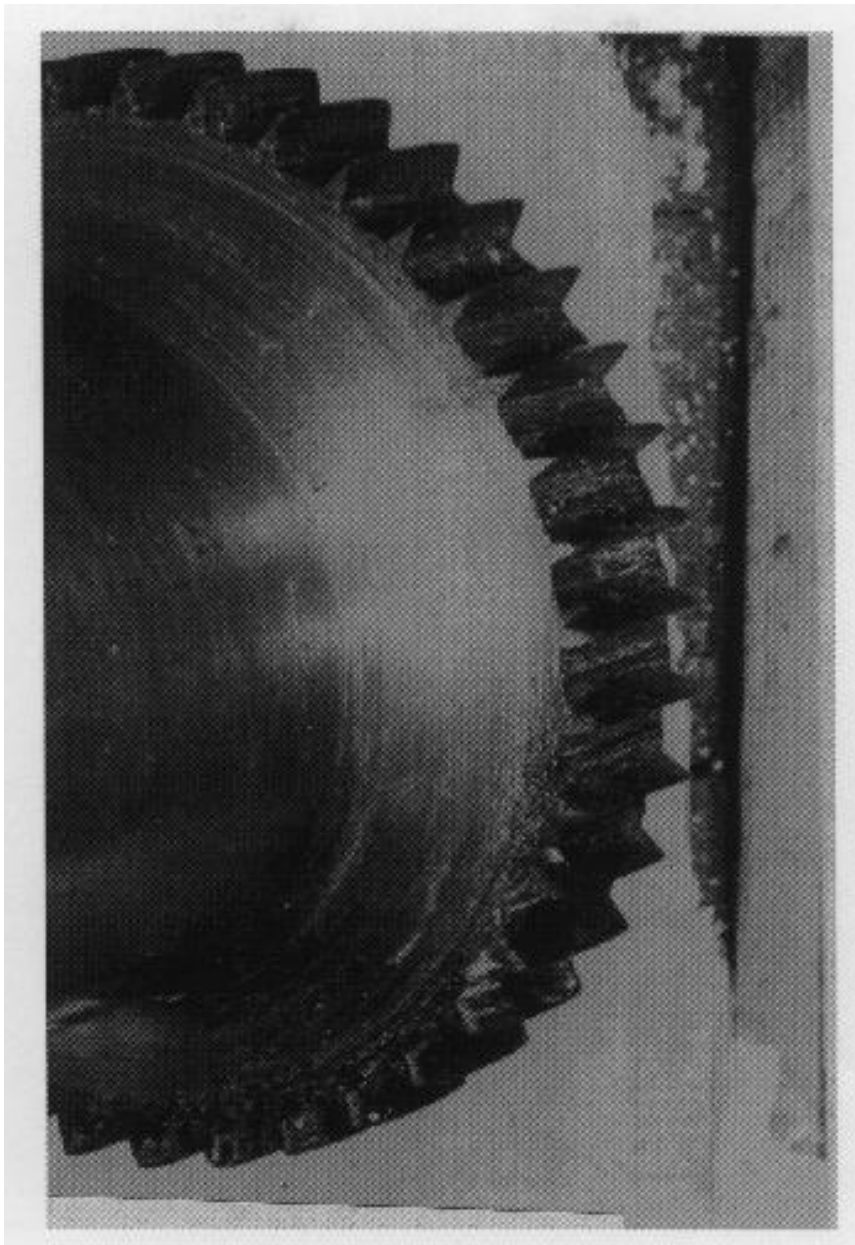


Figure 241-4-32 Knife Edged Teeth

- c. For lubricated couplings, determine that the lube oil sprays to the couplings are not clogged and are directing the oil properly.
- d. For both lubricated and nonlubricated couplings, remove dirt and burrs from the pinion and prime mover flanges.
- e. For lubricated couplings, use a dial indicator on the outside diameter of each sleeve to determine that the teeth are concentric with the mating flange.

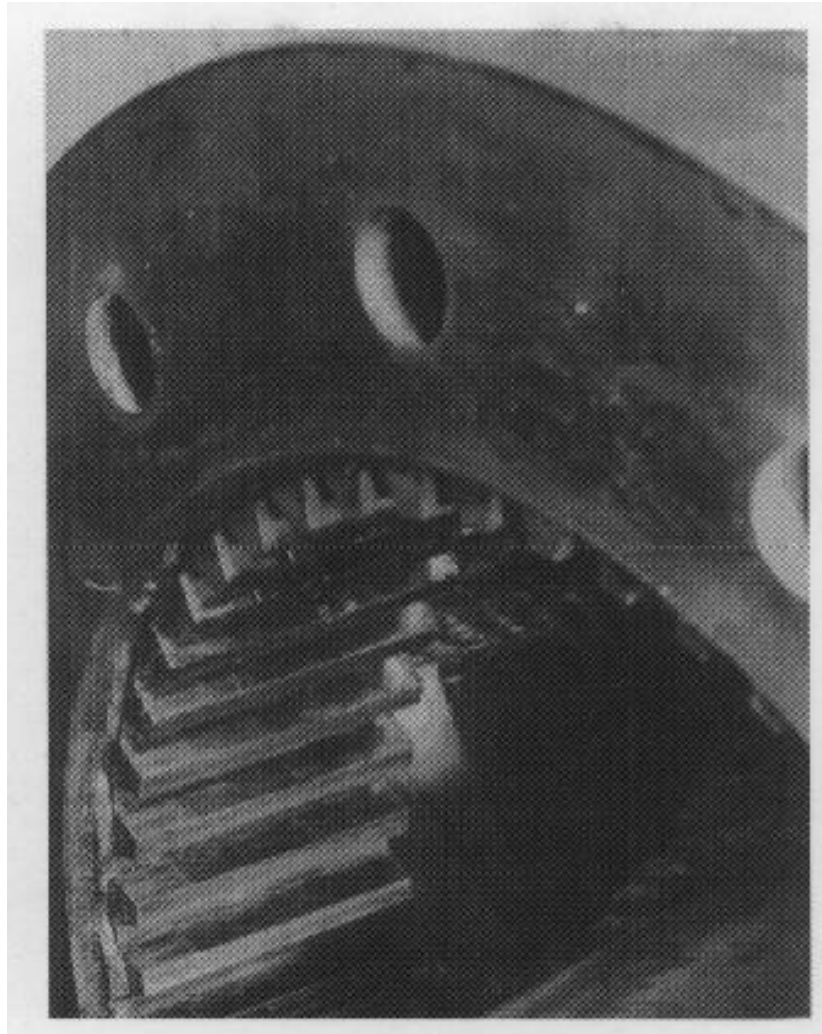


Figure 241-4-33 Shouldering

- f. For lubricated and nonlubricated couplings, use a dial indicator on the face of each sleeve to determine if it is running true.
- g. For lubricated couplings, if digging in of the tooth ends is apparent, check alignment.

241-4.4.27 COUPLING WITH SELF-CONTAINED LUBRICANT.

1. Examine couplings with self-contained lubricant, oil, or grease at 6-month intervals to determine tooth condition and lubricant levels. A substance similar to lapping compound is produced when fine steel particles are worn off the coupling teeth and mixed with the lubricant. This substance causes additional internal coupling wear and cannot be removed unless the coupling is disassembled and cleaned.

CAUTION

Do not blast (e.g., glass bead) clean surface hardened couplings as the blasting process can cause cracking of the hardened surface.

If excessive loss of lubricant is apparent, determine the cause and correct the condition.



Figure 241-4-34 Moderate Axial Scoring

2. Consult the coupling manufacturer's technical manual for the proper procedure for filling the coupling with lubricant.

241-4.4.28 TURNING GEARS. Inspect turning gears periodically to determine material condition. The condition of the turning gear can be determined by the ease or difficulty of engagement, tooth contact patterns, and bearing noises.

241-4.4.29 DISMANTLING MRG ASSEMBLIES. Note the following points when dismantling MRG's:

- a. The MRG cases and covers are split for easy removal and are provided with eyebolts or padeyes to attach slings.
- b. Determine if concealed bolts are used, and their location. When handling parts, take care to avoid damaging the gear teeth, bearings, shafts, thrusts, journals, and bolt threads.

- c. Take care to avoid damaging joint surfaces. Prevent burrs, or ridges, from forming; they will cause oil leaks. Use jacking bolts, if provided, to initially separate joints of MRG casing and covers. Scrape and clean joint flanges if a sealing compound has been used.
- d. To avoid delays in reassembly, mark all bolts, nuts, screws, and other small parts that have been removed and place them in buckets or other containers for safekeeping. Clean them before reassembly.
- e. Remove all oil pressure gages, sight flows, thermometers, thermocouples, and RTE connections where necessary, before lifting the casing.



Figure 241-4-35 Severe Axial Scoring

- f. If necessary, drain all the oil from the MRG cases and pump it from the drain tank to the settling tank.
- g. Remove all piping that will interfere with lifting or could be damaged.
- h. To exclude dirt, close all pipe openings with blind flanges or tapered wooden plugs only.
- i. Mark the ends of pinions and gear teeth, coupling bearings, etc. (or note existing marks), before dismantling to ensure that the parts are reassembled in the original position.
- j. When removing rotating elements, use extreme care to avoid damaging teeth and journal areas.
- k. When bearing caps have been removed, barring the gear may cause elements to fall out of bearing bores. This may occur in locked train gears where the split of the casing A-frame is at an angle from the horizontal or when rotating elements are lightweight. Install and secure bearing caps before pinions and gears are rotated.
- l. Rest the pinions and gears on their journals on wood blocks. When so supported, protect the journals by placing aluminum foil on the wood and grade A paper according to MIL-B-121, **Barrier Material, Greaseproofed, Waterproofed, Flexible**, placed on the journal. Soft metal, such as lead, with the grade A

paper, or pads or rollers of oil resistant hard rubber may be used in place of aluminum foil. When it is necessary to rest the pinions or gears on their teeth, let them rest on soft wood that is covered by oil resistant hard rubber.

- m. Gears removed from the MRG casing shall be protected against rusting by coating with a preserving oil according to MIL-L-3150, **Lubricating Oil, Preservative, Medium**. This oil provides adequate protection for 30 days. If gear elements are stored for more than 30 days but less than 60, recoat them with the oil. Gears that are expected to be stored for more than 60 days should be coated with grade 2 preservative. Remove preservatives before installing.
- n. After removing the pinions and gears, protect them against dirt by covering with a clean tarpaulin. Use the same precautions for the open gear case. Do not expose gears to the weather.

241-4.4.30 REASSEMBLING MRG's. In reassembling MRG's, perform the following steps:

1. Take crown thickness measurements of bearings. If bearings are renewed or scraped, check for proper tooth contact. If necessary, mark or correct crown thickness markings on replacement bearing(s).
2. Clean bearing shells thoroughly, including oil inlets and outlets. Remove high spots caused by dents on the outer diameter.
3. Bearing shells shall be properly fitted and shall not be turned end for end, which is likely to close off the oil inlets.
4. Remove high spots caused by burrs or dents in bearing bores. Clean the bores.
5. Strongbacks should not distort or misalign bearing shells. Take care to align oil passages correctly in shells, strongbacks, or housings to allow for proper operation of sight flow indicators.
6. Should the bearing surface of the thrust bearing collar become scratched, restore the surface with a very smooth oilstone and kerosene. The babbitt surfaces of the shoes shall be free from ridges and burrs.
7. Thoroughly clean all oil pipes, manifolds, and nozzles by blowing them out with dry air.
8. Check MRG casing and cover joints for burrs and dents. Remove high spots to attain an oiltight fit. Clean and dry joint surfaces. Material such as Permatex No. 2 or equivalent may be used for sealing casing joints. Take care to use a thin film. Excessive amounts of such sealing material at casing joints may fall into the MRG when bolting up and may impair the oil system.
9. Clean and dry the interior of the MRG casing before reassembling, and remove all tools, etc. If possible, hose down the casing and gear rotors with lube oil. The Engineering Officer shall personally inspect the casing and gears for loose material (tools, bolts, nuts, blocking, clothing, etc.) that may have been left in the casing. Inspections shall be made at the following times:
 - a Before lowering the gear wheels and pinions into place
 - b At the time of lowering the gears and pinions
 - c When closing the MRG covers. These inspections are invaluable for finding foreign objects in the MRG case that could cause damage to MRG elements and bearings.
10. Before replacing the pinions and gears, examine them for damaged or pitted teeth and damaged journals. Remove any nicks or burrs on the pinion or gear teeth by stoning. Stone or polish the shaft journals, if necessary. Remove preservative from gears and immediately cover with oil to prevent rust.
11. Take care when reassembling to ensure that bearing caps are tight. A loose bearing cap will permit misalignment of gearing.
12. Check the alignment and the clearance of the entire gear train. Record all adjustments and clearances.
13. Note the thrust bearing clearance and make the necessary adjustment.
14. Before connecting the prime mover and pinion shaft, check the alignment and make any necessary corrections.
15. The joint surfaces of the couplings must be free from burrs and dirt. Dial indicate the periphery (rim) and face to ensure that the coupling hub or sleeve is running true with the mating flange.

16. Do not interchange coupling bolts. These bolts must be equal weight to maintain correct rotational balance.
17. Install fastener locking devices on rotating and stationary parts as specified in the technical manual. Previously used fastener locking devices, such as cotter pins and tab type lockwashers, shall be replaced in kind before fitup. Self-locking threaded fasteners shall not have been threaded on an engaging part more than five times or, if five such engagements have been exceeded, shall not have lost more than 1/5 their original breakaway torque (refer to table III of MIL-N-25027). All fasteners shall be torqued to component technical manual specifications. If there are less than the required number of fasteners in the holding containers (paragraph 241-4.2.4c) to complete an assembly, do not draw replacements. Find the missing fasteners. Failure to find missing fasteners is sufficient cause to lift MRG covers to ensure that they are not adrift in the MRG casing.

SECTION 5

TESTS AND INSPECTIONS

241-5.1 GENERAL TEST AND INSPECTION INFORMATION.

241-5.1.1 OVERVIEW. The tests and inspections listed are the minimum requirements only. When defects are suspected or operating conditions indicate problems, the time between inspections should be shortened and ship's MRG technical manual should be referenced for inspections specific to ship's MRG design and installation. Where a preventative maintenance system is installed, shipboard preventative maintenance shall be conducted in accordance with the Maintenance Requirement Card (MRC).

241-5.1.2 ASSEMBLY AND DISASSEMBLY. An MRG should be assembled and disassembled in a shipyard under the guidance of trained personnel or the gear manufacturer's representatives. The Engineering Officer should be aware of any required or scheduled MRG maintenance to be performed during a particular overhaul.

241-5.1.3 ALIGNMENT. Alignment of MRG cases, lineshaft to MRG, lineshaft bearing, prime mover to MRG, and pinion(s) to gear(s) is best checked and corrected in a shipyard under the guidance of trained personnel.

241-5.1.4 SCHEDULING WORK. Opening the MRG cases while other work is being performed in the engine space is hazardous and should be avoided. The danger of foreign particles entering the case when the covers are lifted is high under normal conditions. The Engineering Officer should study the work to be performed in the engine spaces and avoid schedules that call for opening the cases while other work is in progress, especially work in progress over the MRG.

241-5.1.5 CLEANING MRG SUMPS. Whenever any part of a lube oil system is opened (such as a tank, pipe, or sump) foreign matter shall be prevented from entering the lube oil system components. If the MRG sumps are to be cleaned, it should be done after any work on the MRG is completed. Thoroughly inspect the MRG sump to ensure cleanliness and removal of foreign material before putting in clean or new oil (refer to NSTM Chapter 262, Lubricating Oils, Greases, Specialty Lubricants, and Lubricating Systems.)

241-5.1.6 LUBRICATING OIL. Used oil should be settled and centrifuged before returning it to the MRG sump. Even if new oil is used, exercise care to keep out rust and water. Condensate and rust may be in the new oil. Moisture in the new oil can cause rusting on the inside of the new oil drums; therefore, new oil must be centrifuged before putting it in the MRG sumps. Cloth bags placed in the strainer baskets after an overhaul is added protection against foreign particles passing through the gear meshes and bearings. Sometimes it is necessary to bypass the MRG case and gear sprays until the strainer bags show clean, then circulate oil through the bearings and gear meshes. With the proper temperature and pressure on the lube oil system, look for oil leaks in the lube oil system, at the bubblers, and at the thermometers. Inspect the lube oil gear sprays to be sure they are properly directed. Inspect all bubblers to be sure they are operating properly. Check the thermometers to be sure they are in the proper temperature range. Calibrate any thermometers that appear to be giving a faulty reading. Check the turning gear to be sure it can be engaged and disengaged. Check pressure gages to ensure proper pressure readings. Calibrate any pressure gage or resistance temperature element (RTE) that appears to be giving a faulty reading.

241-5.2 INSPECT FOR FOREIGN MATTER IN MRG CASING OR OIL LINES.

241-5.2.1 INSPECTION REQUIREMENTS. Before replacing an inspection plate, connection, fitting, or cover that permits access to the MRG casing, the Engineering Officer shall thoroughly inspect for foreign matter that may have entered or remains in the MRG casing or oil lines. This inspection shall include ledges, the undersides of ledges, pockets, and all gear teeth including those hidden by pinions or other obstructions. Use mirrors, periscopes or borescopes to view hidden areas. If work is being done by a naval shipyard or tender, a responsible officer from that activity shall also inspect. The inspections and the name of the officer or officers shall be entered in the engineering log.

241-5.2.1.1 Inspection of MRG's on ships being activated should be especially thorough, since MRG inspection ports are open to permit circulation of dehumidified air. Use mirrors or a video probe to inspect ledges that cannot be viewed directly. Also inspect the undersides of ledges.

241-5.2.2 CARE OF LUBRICATION SYSTEM.

- a. At anchor and underway, carry out the instructions of N STM Chapter 262 regarding the care and operation of the lubrication system.
- b. Carefully check strainers when MRG's are new or after they have been worked on. If large amounts of dirt are found, insert muslin bags into the strainer baskets.
- c. Check salinity of oil if oil sumps are located at the skin of the ship.
- d. Take weekly lube oil samples to detect presence of water and acid. Take samples from a low point in the lube oil system (refer to **NSTM Chapter 262** for sampling procedure).

241-5.3 INSPECTING MRG'S.

241-5.3.1 GENERAL. Perform the following tests and inspections of MRG's (if a preventive maintenance system has been installed, conduct preventive maintenance in accordance with the MRC's.)

241-5.3.2 WEEKLY. During MRG shutdown circulate lube oil through the system for 15 minutes weekly. The circulated lube oil shall be maintained at approximately the same temperature as the MRG and clutch casings. Circulate lube oil before and while jacking over the MRG. The propeller shaft shall be jacked 1-1/4 turns (to ensure repositioning of gear meshes).



If lube oil system is inoperative, hose down through inspection openings, but do not jack over the MRG (paragraph [241-3.5.2.7b.3](#)).

241-5.3.3 BI-WEEKLY. Visually inspect, through the uppermost inspection ports, the rotating elements and as much of the interior of the MRG case as practical for signs of rust. (On appendages, remove the uppermost bolted

cover to facilitate inspection of the interior and the rotating elements.) If rust is found, remove it in accordance with paragraph 241-3.5.2.7b.1. If rust is found during any later inspection, determine the cause and take corrective action.

NOTE

Always inspect gear elements before circulating lube oil. After circulation, the oil coating on the gear elements may hide rust spots.

241-5.3.4 QUARTERLY

1. Visually inspect and tap with a hammer holddown bolts, ties, and chocks to detect loose fastenings.
2. Remove inspection plates and inspect gears. Wipe off oil at different points, and note whether the surface is bright or already corroded or pitted. Note whether new areas are affected.
3. Move main gear shaft fore and aft to measure propeller thrust clearance (paragraph 241-4.3.12). Record the clearance.
4. Inspect the oil spray nozzles by visually noting the type of spray formed and if it is directed to the gear mesh properly. Clean and redirect the oil if the nozzles are not functioning properly.

241-5.3.5 SEMIANNUALLY

1. Check lubricant level of couplings with self-contained lubricant and replenish as required. (Refer to manufacturer's technical manual for replenishment procedure.)
2. Remove inspection plates and inspect gears. Wipe off oil at different points on the gear teeth and note whether the surface is bright or already corroded or pitted, and whether new areas are affected. Also note tooth contact patterns, and record on sample sheet the tooth material condition and contact observations for each inspection. Send inspection form to the Carderock Division, Naval Surface Warfare Center (NSWCCD) for review and retention.

241-5.3.6 ANNUALLY. Inspect coupling between prime mover and MRG.

1. Remove the minimum number of covers required to perform an external inspection of the coupling.
2. Inspect all accessible areas (end of teeth, oil collection grooves, lock rings, etc). Part of the sleeve teeth can be seen by sliding the distance piece toward the flange.
3. Check backlash and float (consult manufacturer's technical manual for allowable values). If the coupling is clean, a metallic ring should be heard when moving the distance piece axially to its extreme position when checking float.
4. If sludge or abnormal wear is indicated from step 2 or 3, remove the coupling for cleaning, further inspection, and repair or replacement, as necessary (paragraph 241-4.4.22).

NOTE

Do not blast (e.g., glass bead) clean surface hardened couplings as the blasting process can cause cracking of the hardened surface.)

5. Reassemble and recheck backlash and float, if necessary.

241-5.3.7 SHIPYARD OVERHAUL.

1. Perform the dynamic gear tooth contact check in accordance with paragraph 241-4.4.8 before the ship becomes available for overhaul. If any work that could affect MRG alignment was done on the MRG or any other propulsion component, perform another check after the overhaul. This check can also be done before any major ship maintenance.
2. Inspect condition and clearances of thrust shoes to ensure proper position of gears. Use dry compressed air to blow debris away from the thrust bearings after the inspection. Inspect thrust collar, nut, and locking device.
3. If the turbine coupling inspection indicated excessive wear, check alignment between pinions and turbines (paragraph 241-4.4.19).
4. Pump the oil out of the MRG sump, and clean the sump internally. Scrape off and dispose of hard rust deposits.
5. Inspect turning gear assemblies for proper operation and condition.
6. Protect against corrosion in accordance with paragraph 241-3.5.2.

241-5.3.8 UNSCHEDULED INSPECTIONS. If MRG covers are lifted for major repairs or corrective action (e.g. poor tooth contact or bearing performance), the following additional work should be considered.

CAUTION

Case covers may not be lifted without authorization from the Naval Sea Systems Command (NAVSEA). An open MRG case is a serious hazard to the main propulsion plant. Rags and tools dropped or left in gear cases while covers were lifted have caused serious and expensive casualties.

1. Inspect to determine condition of bearings, journals, and gear teeth exposed during the inspection. Record the crown thickness readings of the exposed pinion and gear bearings.
2. Check exposed intermediate coupling, connecting shaft, and clutch bolts for tightness.
3. Record prime-mover-to-MRG alignment readings. This should be accomplished with the ship waterborne and the propulsion plant ready to operate.
4. The inspections conducted and the name of the inspector(s) shall be entered in the Engineering Log. Retain a copy of all measurements and readings for future reference.

5. The ship's MRG technical manual shall be referenced for additional inspections based on repair efforts or applicable corrective action.

241-5.3.9 TRIALS. Conscientiously observing the instructions in this chapter and correcting defects disclosed by regular tests and inspections should ensure that the MRG's are ready for full power at all times. The general opening of MRG cases, bearings, and thrust bearings immediately before trials is to be discouraged, as more harm may be done than good.

- a. **Before Trials.** In addition to inspections that may be directed by proper authority, remove the inspection plates, and examine the tooth contact and the condition of the teeth. The use of red and blue DYKEM in determining tooth contact under operating conditions is specified in paragraph [241-4.4.8](#).
- b. **Dock Trials.** Operate propulsion machinery to the maximum practical power attainable. Determine whether main element tooth contact is satisfactory.
- c. **Sea Trials.** At the first sea trial, determine proper tooth contact of main pinions and gears and conducting operational tests. Perform the following tooth contact checks in accordance with paragraphs [241-4.4.7](#), [241-4.4.8](#)
- d. **After Trials.** In addition to inspections that may be directed by the proper authority, remove the inspection plates and examine the tooth contact and the condition of the teeth to note changes that occurred during the trial. Running at high power will, in a few hours, show improper contact or abnormal wear that would not show up in months running at lower power. Check and record the main thrust clearance before completing trials (paragraph [241-4.3.12](#)).

SECTION 6

PRECAUTIONS, REPORTING PROCEDURES, AND MRG CASUALTY GUIDANCE

241-6.1 SPECIAL PRECAUTIONS.

241-6.1.1 Always observe the following precautions when operating Main Reduction Gears (MRG's):

- a. In case of churning or emulsification of the oil in the MRG case, slow or stop the MRG until the defect has been remedied (paragraph 241-3.2.4).
- b. If for any reason, the supply of lubricating oil to the MRG fails, stop the propeller until the cause has been located and remedied. Do not operate the MRG's until the normal supply has been restored.
- c. When bearings are known to have been overheated, do not operate the MRG, except in cases of extreme emergency, until the bearings have been examined and the defects remedied.
- d. The temperature of oil discharged from a bearing shall not exceed 180° F or a 50° F rise above the cooler outlet temperature, whichever is less (unless otherwise stated in the applicable technical manual or waived the Naval Sea Systems Command (NAVSEA) on a case-by-case basis) (paragraph 241-3.4.5).
- e. When salt water is found in the PLO system, take immediate corrective action to locate and seal off the source of the contamination, remove the contaminated oil, follow the casualty control procedures provided in paragraph 241-6.4 for MRG salt water contamination. and refill with clean oil. Technical assistance from FTSCCLANT, FTSCPAC, NSWCCD, or NAVSEA should be initiated immediately to ensure complete corrective action is followed and witnessed. Delay in responding to salt water contamination can damage and reduce the service life of the MRG.
- f. Lubricating oil shall be furnished to the propulsion machinery of a trailed shaft when a ship is underway.
- g. When the turning gear or shaft lock is engaged to lock a shaft, the throttles shall be secured by a chain and lock. This key shall be the responsibility of the Engineering Officer (paragraph 241-3.5.1.3).
- h. Do not use pinch bars near the ends of teeth to move the pinions or gears to determine either axial movement (paragraph 241-4.3.12.6) or backlash (paragraph 241-4.4.16.1b).
- i. If gear tooth damage occurs, do not operate the MRG's, except in cases of emergency. Take care to prevent metallic debris from entering the lubricating system (paragraph 241-3.2.2).
- j. Investigate unusual noises or vibration immediately. Operate the MRG's with caution until the cause has been discovered and remedied (paragraph 241-3.4.4).
- k. No inspection plates, connection, fitting, or cover that permits access to the MRG casing shall be removed without specific authorization from the Engineering Officer (paragraph 241-4.2.2).
- l. Inspection plate joints shall be paint free.
- m. When MRG cases, MRG sumps, and lube oil lines which terminate the MRG cases are open, take extreme care to prevent foreign objects from entering. Establish a clean area around the opening with all personnel entering the space signing in and out. Establish a tool log to record all tools and materials entering and exiting the space. Establish a clean area with overhead protection to prevent objects from falling into the case. Do not leave MRG covers open. Close each cover when access is no longer required. Remove shirt if it has buttons or other fasteners that may fall off or be pulled off. If the shirt is not taken off, remove all articles from pockets. Remove all articles from trouser pockets, and remove belt if used. If eye glasses are necessary, fasten with cord behind head. Wear contact lenses only if necessary. Remove wristwatch and any jewelry from fingers, wrists and ears. Any equipment used in the inspection (flashlight mirror, etc.) is to be attached

to user by a cord. Take any other measures to **ensure objects do not fall into the MRG case**. The openings shall never be unattended without establishing a clean area and posting a security watch. An opened gearcase cannot be left unattended. A constant security watch must be maintained in the immediate vicinity of an open gearcase. When Ships Force is responsible for the security watch, the watch shall be a responsible PO, E-5 or above. Before closing cases, perform the inspections required by paragraph [241-5.2](#).

- n. Carefully inspect lifting devices before using and be careful to not overload.
- o. Keep naked lights away from vents while MRG's are in use, because the oil vapor may be explosive (paragraph [241-3.2.7](#)).

241-6.2 REPORTS.

241-6.2.1 When failure occurs or replacement is necessary, report the failure or replacement as specified by NAVSEA. For active ships, the commanding officer shall furnish the report; for inactive ships, the industrial manager. In addition, furnish letter reports to NAVSEA when any of the following items occur:

- a. Deficiencies occurring during the warranty period
- b. Broken teeth
- c. Active deterioration of the tooth surface, such as pitting
- d. Replacement of gear elements or couplings
- e. Design deficiency
- f. Repetitive bearing wipes
- g. Bearings normally operating higher than a maximum of 180° F oil discharge temperature or a 50° F rise above the oil cooler outlet temperature, as read by thermometer (unless otherwise stated in the applicable technical manual or waived by the Naval Sea Systems Command (NAVSEA) or a case by case basis) (paragraph [241-3.4.5](#)).

241-6.2.2 The report should identify the part by manufacturer's drawing and piece number, or technical manual figure and piece number. Report the exact nature and extent of the casualty, using sketches or photographs when it is necessary to illustrate the deficiency clearly. List all markings stamped (by the manufacturer) on defective parts. If known, provide the number of miles steamed and the length of time a part has been installed. When high bearing temperatures are being reported, provide information about the operating condition of the plant, including lube oil pressure and temperature from the cooler and history of the particular bearing.

241-6.3 MRG CASUALTY GUIDANCE.

241-6.3.1 In the event of an MRG casualty, technical assistance from Regional Maintenance Centers, NSWCCD, or NAVSEA shall be initiated immediately to ensure potential MRG damage is limited, proper investigative actions are accomplished, and the necessary corrective actions are developed and performed.

241-6.4 MRG SALT WATER CONTAMINATION GUIDANCE

Presence of water in the lube oil is indicated by high lube oil level in the gear sump (NSTM 262, paragraph [262-3.10.2 LEAKAGE](#)). This casualty can be caused by a misaligned lube oil system or by a ruptured lube oil cooler tube. As soon as it is evident that the lube oil is contaminated with sea water, quick action is required to

determine the level of contamination and the necessary corrective action before chlorides from the sea water are deposited on the gear teeth. The chlorides will accelerate corrosion of gear teeth causing damage to the gear tooth profile. Surface corrosion could lead to pitting, resulting in potential torque and speed restrictions and reduced service life of the MRG. Scope of the corrective action will be determined by the extent of the sea water contamination.

241-6.4.1 Extent Of Contamination The extent of sea water contamination can be classified into categories. The procedure to remove the contamination will vary for each classification.

- a. Minimal contamination: Sea water entered the lube oil system but was not circulated through the MRG. A low risk of contamination exists.
- b. Severe contamination: Sea water entered the lube oil system and was circulated through the MRG; or sea water entered the MRG through a casualty in the space (i.e. flooding of the engine room). A high risk of contamination exists.

241-6.4.1.1 MINIMAL CONTAMINATION

- a. Remove existing contaminated lube oil from MRG sump. This oil will not be re-used; however, a sample must be retained for lube oil analysis.
- b. Open lube oil sump and hand wipe all accessible areas using lint free rags. Upon completion, the Chief Engineer (CHENG) or assigned individual will close out sump and secure access covers.
- c. Fill lube oil sump to minimum level with new lube oil. Lube oil must conform to requirements of NSTM Chapter 262, Lubricating Oils, Greases, Specialty Lubricants and Lubrication Systems.
- d. Install muslin or nylon filter bags in main lube oil strainer. Operate system lube oil pumps (high level, if applicable) for (12) hours. Rotate turning gear one complete shaft revolution every (30) minutes in forward direction. Shift, inspect and clean lube oil strainers (SICLOS) every (4) hours.

241-6.4.1.2 SEVERE CONTAMINATION

- a. Testing for chlorides needs to be completed. The preferred method for chloride level measurement is the Bresle method (ISO 8502-9, Field Method for the Conductometric Determination of Water-Soluble Salts). The SCM 400 Salt Contamination Meter and the Chlor*Test kit are authorized alternatives.

NOTE

If chloride testing cannot be completed immediately, complete the requirements for MINIMAL CONTAMINATION given in paragraph [241-6.4.1.1](#) before proceeding in order to minimize contamination until the testing can be completed.

- b. Take several chloride swipes for evaluation. Swipes shall be a representative sample of the entire MRG, including different areas of the gear/pinion elements and casing. Each swipe must be identified for future trending purposes and swipe area must be (4) square inches where possible.
- c. If the chloride level is less than 0.02 mg/ 25 square cm and there are no visible signs of chloride oxidation then de-ionized water wash is not necessary; proceed with the requirements for MINIMAL CONTAMINATION.

TION given in paragraph 241-6.4.1.1. If it exceeds this limit high pressure feed water lance is required in accordance with S6300-AE-MMA-010, Water Jet, Model WBD-150N Operation Maintenance, Repair and Overhaul Procedures. Feed Water must be tested prior to lancing to ensure chloride levels meet boiler feed water specifications per NSTM Chapter 220 Volume 2, Boiler Water/Feed Water Test and Treatment.

- d. Open all inspection/access covers and high pressure feed water lance gear elements/casing with a nozzle pressure of 500 PSI - 800 PSI. Direct lance evenly onto all gear teeth to remove oxidation from gear tooth profiles. Lance 100 percent of gear elements, casing and sump, including the over head areas.

NOTE

Do not direct high pressure lance at bearing ends or RTD wiring. Maintain feed water lance temperature between 150 and 180 degrees Fahrenheit.

- e. The turning gear may be rotated until 2-1/2 main shaft turns are achieved. Ensure all gear elements are thoroughly cleaned.

NOTE

For turning gears without a dedicated oil sump, open first and second reduction turning gear covers and spray lube oil on worm and worm gear for every rotation of the main shaft.

- f. During the lancing process, maintain an empty sump using a temporary evacuation pump and perform water analysis for chloride levels for feed water being extracted from sump. Samples should be taken every quarter turn of the main shaft. Typically, the lancing process is completed after one main shaft revolution.
- g. Once a full feed water lance has been completed immediately coat all gear elements and accessible casing areas with lube oil.
- h. Ship's low pressure air (not to exceed 125 PSI) can be used to augment the removal of standing water in voids and pocket areas.

NOTE

Do not direct air pressure on bearing ends, sight flow indicator tubes, RTD wiring/epoxy filled groves.

- i. Clean the sump. Hand wipe and remove all standing water. Close out sump.
- j. Fill main lube oil sump with new lube oil. Operate lube oil system with ship's installed pumps on high (if applicable) and muslin or nylon filter bags installed in main lube oil strainer. Clean and operate the main lube oil purifier sump to sump. Maintain lube oil temperature at normal operating temperature. Rotate tuning gear for two minutes every hour. Continue this process until water content is less than 0.1 percent.
- k. When lube oil analysis indicates water content is less than 0.1 percent, conduct a dock trial not to exceed 60 minutes at maximum allowable shaft RPM not to exceed 50% of full power. The dock trial may be conducted without clear and bright lube oil; however water content must be less than 0.1 percent. Ensure lube oil temperatures are at normal underway levels.

- l. Upon completion of dock trials, continue lube oil purifier and turning gear operations until clear and bright criteria and muslin bag inspections meet requirements of NSTM Chapter 262, Lubricating Oils, Greases, Specialty Lubricants and Lubrication Systems.
- m. Muslin or nylon filter bags may be removed from the main lube oil strainer once all acceptance parameters have been met. However, the use of muslin or nylon bags until after the first underway period is recommended. It is imperative the dehumidifier is operated per NSTM Chapters 241 and 262 maintaining 30-35 percent relative humidity. If the dehumidifier is unable to maintain correct relative humidity, action must be taken to troubleshoot and repair the unit. Meanwhile it is recommended that the lube oil system be aligned and operated at high speed for (4) hours every (48) hours.
- n. Perform Main reduction Gear and lube oil system flush as outlined in NSTM 262, paragraph 262-3.8.3.1 *Initial Flush (Piping Only - Bearings and Components Jumpered)* and paragraph 262-3.8.3.2 *Final Flush (Piping, Bearings, and Components Included in Flushing Loop)* or 262-3.8.4 *REDUCTION GEAR SYSTEMS USING MIL-L-9000 (MS 9250) AND MIL-L-2104 (15W40) OIL* depending upon the type of oil used in the system.

APPENDIX A**TECHNICAL MANUAL DEFICIENCY/EVALUATION REPORT (TMDER)****NOTE**

Ships, training activities, supply points, depots, Naval Shipyards, and Supervisors of Shipbuilding are requested to arrange for the maximum practical use and evaluation of NAVSEA technical manuals. All errors, omissions, discrepancies, and suggestions for improvement to NAVSEA technical manuals shall be reported to the Commander, NAVSURFWARCENDIV, 4363 Missile Way, Port Hueneme, CA 93043-4307 on NAVSEA/ SPAWAR Technical Manual Deficiency/Evaluation Report (TMDER), NAVSEA Form 4160/1. To facilitate such reporting, print, complete, and mail NAVSEA Form 4160/1 below or submit TMDERS at web site <https://nsdsa.nmci.navy.mil>. All feedback comments shall be thoroughly investigated and originators will be advised of action resulting therefrom.

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