

NAVAL SHIPS' TECHNICAL MANUAL FOR

CHAPTER 233

DIESEL ENGINES

THIS CHAPTER SUPERSEDES CHAPTER 233 DATED 31 AUGUST 1998

DISTRIBUTION STATEMENT C: DISTRIBUTION AUTHORIZED TO U.S. GOVERNMENT AGENCIES AND THEIR CONTRACTORS; ADMINISTRATIVE AND OPERATIONAL USE (1 JANUARY 2005). OTHER REQUESTS FOR THIS DOCUMENT WILL BE REFERRED TO THE NAVAL SEA SYSTEMS COMMAND (SSES 932).

WARNING: THIS DOCUMENT CONTAINS TECHNICAL DATA WHOSE EXPORT IS RESTRICTED BY THE ARMS EXPORT CONTROL ACT (TITLE 22, U.S.C., SEC. 2751, ET SEQ.) OR EXECUTIVE ORDER 12470. VIOLATIONS OF THESE EXPORT LAWS ARE SUBJECT TO SEVERE CRIMINAL PENALTIES. DISSEMINATE IN ACCORDANCE WITH PROVISIONS OF OPNAVINST 5510.161, REFERENCE (JJ)

DESTRUCTION NOTICE: DESTROY BY ANY METHOD THAT WILL PREVENT DISCLOSURE OF CONTENTS OR RECONSTRUCTION OF THE DOCUMENT.

1 OCT 2005

REVISION RECORD

REVISION NO.	DATE	TITLE AND/OR BRIEF DESCRIPTION/PREPARING ACTIVITY
3	1 OCT 2005	THE FOLLOWING WAS CHANGED: SECTION 4: ADDED PARA CONCERNING KEEPWARM SYSTEMS AND PROVIDED TABLE WITH TEMPERATURE LIMITS. DDED PARA CONCERNING NAVY POLICY WRT ENGINE EMISSIONS CHANGED DRYDOCKING GUIDANCE SECTION 6: MADE CHANGES TO THE ENGINE PRESERVATION GUIDANCE. PLAN TO SUBMIT PMS CHANGES SO THAT NSTM AND PMS CONCUR. (NAEEMAH, THIS IS AN OPEN FEEDBACK FROM THE FLORIDA. I WILL FORWARD THE PMS CHANGES TO YOU NEXT WEEK.) SECTION 7: ADDED PARA CONCERNING SUBSTITUTE FUELS. SECTION 8: CHANGES TO THE LUBE OIL CONDEMNING LIMITS TABLE. SECTION 10: CHANGES TO THE JACKETWATER INHIBITOR TABLE, WHAT IS AUTHORIZED FOR SHIP CLASSES SECTION 13: CHANGES TO THE LUBE AND FUEL OIL LEAKAGE GUIDANCE PARAGRAPH(S) 233-1.2.1, 233-3.2.2, 233-3.2.3, 233-3.4.1, 233-3.4.2, 233-3.4.3, 233-3.4.4, 233-3.4.5, 233-3.4.6, 233-3.5, 233-3.5.1, 233-3.6, 233-3.6.1, 233-3.6.4, 233-3.6.5, 233-3.7.2, 233-3.7.4, 233-3.7.5, 233-3.7.6, 233-3.8, 233-3.8.1, 233-3.8.1.1, 233-3.8.1.6, 233-3.8.2.2, 233-3.8.2.7, 233-3.10.1, 233-4.2.2, 233-4.5.1, 233-4.6.1, 233-4.7.2, 233-4.16.2, 233-4.17, 233-4.18, 233-4.18.1, 233-4.18.2, 233-4.18.3, 233-4.18.4, 233-4.18.5, 233-4.18.6, 233-4.19, 233-4.19.1, 233-4.20, 233-4.20.1, 233-4.20.2, 233-4.21, 233-4.21.1, 233-4.22, 233-4.22.1, 233-4.22.2, 233-5.2.4, 233-5.8.1, 233-5.10.3, 233-5.10.6, 233-5.13.1, 233-5.13.2, 233-5.13.3, 233-5.18.1, 233-5.22.1, 233-5.22.6.1, 233-5.22.6.3, 233-5.22.6.4, 233-5.24.3, 233-5.24.4, 233-5.24.6, 233-5.25.1, 233-5.25.4, 233-5.25.11, 233-5.25.16, 233-5.26.1, 233-5.26.3, 233-5.28, 233-5.28.3, 233-5.29.1, 233-6.1.1, 233-6.2.1, 233-6.3, 233-6.3.1.1, 233-6.3.2, 233-6.3.3, 233-6.4.1, 233-6.4.1, 233-6.5, 233-6.6.1, 233-6.8.1, 233-6.10.1, 233-6.11.1, 233-6.11.2, 233-6.11.3, 233-6.12.2, 233-6.13.1, 233-6.14.1, 233-6.14.2, 233-6.15.1, 233-6.17.2, 233-6.18.1, 233-7.1.1, 233-7.2.1, 233-7.3.1, 233-7.4, 233-7.5, 233-7.6, 233-7.6.1, 233-7.6.2, 233-7.6.3, 233-7.6.4, 233-7.6.5, 233-7.7, 233-7.7.1, 233-7.8, 233-7.8.1, 233-7.8.2, 233-7.8.3, 233-7.8.4, 233-7.9, 233-7.9.1, 233-7.10, 233-7.10.1, 233-7.10.2, 233-7.10.3, 233-8.6.2, 233-8.6.3, 233-8.6.4, 233-8.8.4, 233-8.10.1, 233-8.11.1, 233-8.14.1, 233-8.14.2, 233-8.14.3, 233-8.14.4, 233-8.19.1, 233-8.20, 233-8.21.2, 233-8.21.3, 233-8.21.6, 233-8.21.11, 233-8.21.13, 233-8.21.14.2, 233-8.21.15, 233-8.21.16, 233-8.21.17, 233-9.5.1, 233-9.6, 233-9.7, 233-9.7.1, 233-10.2.1, 233-10.3.1, 233-10.7.1, 233-12.1, 233-12.1.1, 233-12.1.2, 233-12.2.2, 233-12.2.3, 233-12.2.4, 233-12.2.5, 233-12.3.3, 233-12.5, 233-12.5.1, 233-12.5.2, 233-12.5.3, 233-13.1.2, 233-13.6.1, 233-13.6.2, 233-13.6.4, 233-13.7.1, 233-13.8.4, 233-13.8.5, 233-13.13.2, 233-13.13.3 AND 233-13.13.4 TABLE(S) , 233-3-1., 233-3-2., 233-3-3., 233-4-1., 233-4-2., 233-8-1., 233-8-2., 233-8-3. AND 233-10-1. FIGURE(S) 233-5-1. AND 233-12-1.

TMDERS INCORPORATED: R21001-02-CL01, N65540-04-TC12

TABLE OF CONTENTS

Chapter/Paragraph	Page
233 DIESEL ENGINES	233-1
SECTION 1. INTRODUCTION	233-1
233-1.1 FAMILIARITY WITH DETAILS	233-1
233-1.2 INSTRUCTIONS AND MANUALS TO BE CONSULTED	233-1
233-1.3 SAFETY PRECAUTIONS	233-2
SECTION 2. APPLICATION OF INSTRUCTIONS	233-3
233-2.1 GENERAL INFORMATION	233-3
SECTION 3. OPERATION	233-4
233-3.1 GENERAL	233-4
233-3.2 PREPARATION FOR STARTING DIESEL ENGINES AFTER MAJOR REPAIRS, OVERHAUL OR LONG IDLE PERIODS	233-4
233-3.3 STARTING PROCEDURES	233-7
233-3.4 RUNNING IN NEW AND OVERHAULED ENGINES	233-7
233-3.5 GENERAL RUN-IN PROCEDURE	233-8
233-3.6 METHOD OF CHECKING BEARINGS AND BUSHINGS	233-9
233-3.7 METHOD OF CHECKING PISTON RINGS	233-10
233-3.8 PRECAUTIONS AND UNUSUAL CIRCUMSTANCES	233-10
233-3.8.1 HELPFUL POINTS DURING RUN-IN	233-10
233-3.8.2 CRANKCASE PRESSURE OR VACUUM	233-11
233-3.9 READING THE MANOMETER	233-13
233-3.10 MANOMETER CONVERSION DATA	233-13
SECTION 4. OPERATION AND OPERATING LIMITATIONS	233-14
233-4.1 RATINGS	233-14
233-4.2 OPERATION OF DIESEL ENGINES	233-14
233-4.3 DETERMINING ENGINE TORQUE AND HORSEPOWER	233-14

TABLE OF CONTENTS - Continued

Chapter/Paragraph	Page
233-4.4 EXHAUST BACK PRESSURE	233-15
233-4.5 FIRING PRESSURES	233-17
233-4.6 FACTORS AFFECTING SHAFT HORSEPOWER	233-17
233-4.7 FACTORS AFFECTING SHIP SPEED	233-18
233-4.8 EFFECTS OF FOULING	233-18
233-4.9 TRIM	233-19
233-4.10 PROPELLER BEARINGS AND SHAFTING	233-19
233-4.11 EFFECTS OF OPERATION IN SHALLOW WATER	233-19
233-4.12 OPERATION IN HEAVY SEAS	233-19
233-4.13 COLD WEATHER STARTING AND OPERATION	233-19
233-4.14 FUEL IGNITION AT LOW TEMPERATURES	233-20
233-4.15 STARTING AIDS	233-20
233-4.16 STARTING TECHNIQUES FOR DIESEL ENGINES	233-22
233-4.17 KEEPWARM SYSTEMS FOR DIESEL ENGINES	233-23
233-4.18 MINIMIZING EXHAUST SMOKE AND EMISSIONS	233-24
233-4.19 DIAGNOSING ENGINE PROBLEMS BY EXHAUST SMOKE	233-25
233-4.20 OPTIMIZING ENGINE PARAMETERS	233-26
233-4.21 OPERATING ENVELOPE	233-27
233-4.22 OPERATING DIESEL ENGINE DURING THE DRYDOCKING EVENT	233-27
SECTION 5. MAINTENANCE	233-29
233-5.1 INTRODUCTION	233-29
233-5.2 OVERHAUL PROCEDURES	233-29
233-5.3 FUEL INJECTORS AND PUMPS	233-30
233-5.4 EQUALIZING THE LOAD BETWEEN CYLINDERS	233-30

TABLE OF CONTENTS - Continued

Chapter/Paragraph	Page
233-5.5 CYLINDER HEADS	233-30
233-5.6 LINERS	233-30
233-5.7 INTAKE AND EXHAUST VALVES	233-31
233-5.8 CYLINDER RELIEF VALVES	233-32
233-5.9 PYROMETERS	233-33
233-5.10 PISTONS AND RINGS	233-33
233-5.11 PISTON PINS	233-36
233-5.12 BALL OR ROLLER BEARINGS	233-36
233-5.13 PRECISION OR BABBITT BEARINGS	233-36
233-5.14 SHAFT JOURNAL INSPECTION	233-36
233-5.15 SCRAPING OF JOURNAL BEARING	233-37
233-5.16 GEARS	233-37
233-5.17 TIMING	233-38
233-5.18 GOVERNORS	233-38
233-5.19 PUMPS	233-38
233-5.20 COUPLINGS AND UNIVERSALS	233-38
233-5.21 CRITICAL SPEEDS AND VIBRATION TORSIONAL DAMPERS	233-38
233-5.21.1 CRITICAL SPEEDS.	233-38
233-5.21.2 TORSIONAL VIBRATIONS.	233-38
233-5.22 REDUCING OR ELIMINATING TORSIONAL VIBRATIONS	233-39
233-5.22.1 FLYWHEELS.	233-39
233-5.22.2 GENERAL.	233-39
233-5.22.3 ATTACHING FLYWHEEL TO CRANKSHAFT.	233-39
233-5.22.4 FLYWHEEL MAINTENANCE.	233-39
233-5.22.5 COUNTERWEIGHTS.	233-39
233-5.22.6 VIBRATION DAMPERS.	233-40
233-5.23 VIBRATION DAMPER MAINTENANCE	233-44
233-5.24 ENGINE ALIGNMENT	233-44

TABLE OF CONTENTS - Continued

Chapter/Paragraph	Page
233-5.25 CRANKSHAFT DEFLECTION	233-45
233-5.26 CRANKCASE, FOUNDATION AND FRAME REPAIR	233-49
233-5.27 WELDING ON ROTATING MEMBERS	233-51
233-5.28 WELDING RESTRICTIONS AND CHROME PLATING OF CRANKSHAFTS . .	233-52
233-5.29 DIESEL ENGINE MOUNTED PIPING MATERIALS	233-52
SECTION 6. CORROSION PREVENTION	233-53
233-6.1 PROTECTION AGAINST CORROSION FOR ENGINES TEMPORARILY INACTIVE	233-53
233-6.2 ENGINES TEMPORARILY INACTIVATED	233-53
233-6.3 PRESERVATION OF DIESEL ENGINES TEMPORARILY INACTIVATED ONBOARD U.S. NAVY COMMISSIONED SHIPS, SMALL CRAFT AND BOATS	233-53
233-6.3.1 GENERAL.	233-54
233-6.3.2 MATERIALS REQUIRED	233-54
233-6.3.3 APPLICATION OF MIL-L-21260	233-54
233-6.4 PRECAUTIONS DURING PRESERVATION	233-58
233-6.4.1 GENERAL.	233-59
233-6.5 STARTING DIESEL ENGINES AFTER PRESERVATION WITH MIL-L-21260 . .	233-60
233-6.6 ENGINES TO BE STORED	233-62
233-6.7 NEW ENGINES	233-62
233-6.8 OVERHAULED ENGINES	233-62
233-6.9 USED ENGINES	233-63
233-6.10 INITIAL RECEIPT INSPECTION	233-63
233-6.11 CORROSION PREVENTION COMPOUNDS	233-63
233-6.12 GRADES OF COMPOUNDS AND DESCRIPTION	233-64
233-6.13 APPLICATION OF COMPOUNDS	233-65
233-6.13.1 APPLICATION.	233-65
233-6.13.2 APPLICATION PRECAUTIONS.	233-65
233-6.14 PRESERVATION OF DIESEL ENGINES BY MOTORING	233-66

TABLE OF CONTENTS - Continued

Chapter/Paragraph	Page
233-6.15 LAYING UP DIESEL ENGINES WHEN MOTORING IS NOT POSSIBLE	233-67
233-6.16 STARTING DIESEL ENGINES AFTER PRESERVATION WITH COMPOUNDS . .	233-69
233-6.17 TREATMENT AFTER IMMERSION IN SEAWATER	233-70
233-6.18 IMMEDIATE REUSE FOLLOWING IMMERSION	233-70
233-6.19 ENGINES AND PARTS FOR DELAYED REPAIR	233-71
SECTION 7. DIESEL FUEL OIL	233-72
233-7.1 FUEL SPECIFICATIONS	233-72
233-7.2 NAVAL DISTILLATE FUEL (DIESEL FUEL MARINE) (DFM)	233-72
233-7.3 JET PROPULSION FUEL	233-72
233-7.4 ACCEPTABLE SUBSTITUTE FUELS	233-72
233-7.5 TEMPERATURE CONSIDERATION AND FUEL USE	233-73
233-7.6 FUEL CONTAMINATION	233-73
233-7.7 CENTRIFUGES, FILTERS AND COALESCERS	233-73
233-7.8 SUPPLEMENTAL FUEL ADDITIVES	233-74
233-7.9 SPRAY SHIELDS (FLANGE SHIELDS)	233-74
233-7.10 PRECAUTIONS	233-74
SECTION 8. LUBRICATING OILS	233-76
233-8.1 INTRODUCTION	233-76
233-8.2 FRICTION REDUCTION	233-76
233-8.3 HEAT DISSIPATION	233-76
233-8.4 CORROSION PREVENTION	233-76
233-8.5 LUBRICATION SYSTEM REQUIREMENTS	233-77
233-8.6 GOVERNMENT SPECIFICATION LUBRICANT	233-77
233-8.6.1 GENERAL.	233-77
233-8.6.2 MIL-L-2104 15W-40.	233-77
233-8.6.3 MIL-L-9000 SERIES.	233-77

TABLE OF CONTENTS - Continued

Chapter/Paragraph	Page
233-8.6.4 MIL-L-2104 10W.	233-77
233-8.7 USE OF UNTESTED LUBRICANTS	233-77
233-8.8 SUPPLEMENTAL LUBRICATING OIL ADDITIVES	233-77
233-8.9 PHYSICAL, CHEMICAL, AND PERFORMANCE CHARACTERISTICS	233-78
233-8.10 INTERNAL COMBUSTION ENGINE LUBRICANTS	233-78
233-8.11 FORCED LUBRICATION SYSTEM	233-79
233-8.11.1 COMPONENTS OF A DIESEL ENGINE FORCED LUBRICATION SYSTEM	233-79
233-8.12 DIESEL ENGINE LUBRICATION SYSTEM	233-79
233-8.13 SPRAY SHIELDS (FLANGE SHIELDS)	233-80
233-8.14 CENTRIFUGAL PURIFIERS	233-80
233-8.15 LUBRICATING OIL MAINTENANCE	233-80
233-8.16 MIL-L-9000 USE IN DIRTY ENGINES	233-80
233-8.17 CHANGE IN COLOR OF OIL	233-81
233-8.18 DRAIN PERIODS	233-81
233-8.19 CONDEMNING LIMITS	233-82
233-8.20 SHIPBOARD TESTING	233-82
233-8.21 POST-OVERHAUL OR REPAIR, LUBE OIL SYSTEM INTENSIVE CLEANING .	233-83
233-8.21.1 GENERAL.	233-83
233-8.21.2 SOAKING.	233-83
233-8.21.3 FLUSHING.	233-85
233-8.21.4 QUALIFICATION.	233-85
233-8.21.5 EXEMPTIONS.	233-85
233-8.21.6 ENGINES THAT REQUIRE HOT OIL FLUSHING.	233-85
233-8.21.7 PROCEDURE.	233-86
233-8.21.8 EXTERNAL FLUSHING PROCEDURE FIRST OPERATION.	233-86
233-8.21.9 INTERNAL AND EXTERNAL FLUSHING PROCEDURE - FINAL FLUSH.	233-86
233-8.21.10 FLUSHING MEDIUM.	233-86
233-8.21.11 FLUSHING EQUIPMENT.	233-88
233-8.21.12 FLUSHING PREREQUISITES.	233-89
233-8.21.13 EXTERNAL FLUSHING PROCEDURE.	233-90
233-8.21.14 FINAL FLUSHING PROCEDURE	233-91

TABLE OF CONTENTS - Continued

Chapter/Paragraph	Page
233-8.21.15 POST-FLUSH CLEAN UP.	233-93
233-8.21.16 ENGINE RUN AFTER COMPLETION OF FLUSHING	233-93
233-8.21.17 WATER CONTAMINATION FLUSH.	233-95
SECTION 9. FILTERS AND STRAINERS	233-97
233-9.1 FUNCTION AND DESCRIPTION	233-97
233-9.2 FUEL OIL STRAINERS	233-97
233-9.3 MAINTENANCE OF FUEL OIL STRAINERS	233-98
233-9.4 LUBRICATING OIL STRAINERS	233-98
233-9.5 LUBRICATING OIL FILTERS	233-99
233-9.5.1 FULL FLOW FILTERS.	233-99
233-9.5.2 BYPASS FILTER SYSTEM.	233-99
233-9.6 FUEL OIL FILTERS.	233-99
233-9.7 FILTER REPLACEMENT	233-99
SECTION 10. COOLING WATER SYSTEMS	233-100
233-10.1 ENGINE COOLANT	233-100
233-10.2 EFFECTS OF UNTREATED COOLANT	233-100
233-10.3 WATER	233-100
233-10.4 WATER IMPURITIES	233-100
233-10.5 HARDNESS	233-100
233-10.6 CHLORIDE AND SULFATE	233-100
233-10.7 IMPURITIES IN SHORE WATERS AND SEAWATER	233-101
233-10.8 WATER REQUIREMENTS	233-101
233-10.9 INITIATING COOLANT TREATMENT	233-101
233-10.10 FRESH FILL AND TREATMENT OF COOLING SYSTEMS	233-102
233-10.11 SAMPLING	233-103
233-10.12 SAMPLING FREQUENCY	233-103

TABLE OF CONTENTS - Continued

Chapter/Paragraph	Page
SECTION 11. SPARE PARTS AND ALLOWANCE LISTS	233-104
233-11.1 GENERAL	233-104
233-11.2 REPAIR PARTS	233-104
233-11.3 ALLOWANCE LISTS	233-104
233-11.3.1 INTRODUCTION.	233-104
233-11.3.2 PURPOSE.	233-104
233-11.3.3 COORDINATED SHIPBOARD ALLOWANCE LIST (COSAL).	233-104
233-11.4 RESPONSIBILITIES	233-105
233-11.4.1 SUPPLY OFFICERS.	233-105
233-11.4.2 TECHNICIANS.	233-105
233-11.5 TURN IN REPAIRABLE ITEMS	233-105
SECTION 12. INSPECTIONS, RECORDS, AND REPORTS	233-106
233-12.1 BOARD OF INSPECTION AND SURVEY REQUIREMENTS	233-106
233-12.2 DIESEL ENGINE INSPECTORS AND DIESEL INSPECTION REPORTS	233-106
233-12.3 SHIPS' MAINTENANCE AND MATERIAL MANAGEMENT (3-M) SYSTEM	233-106
233-12.4 OPERATING RECORDS	233-109
233-12.5 DIESEL ENGINE PERFORMANCE TEST	233-109
SECTION 13. SAFETY PRECAUTIONS	233-110
233-13.1 GENERAL INSTRUCTIONS	233-110
233-13.2 CRANKCASE EXPLOSIONS	233-110
233-13.2.1 DEFINITION OF CRANKCASE EXPLOSIONS.	233-110
233-13.3 CRANKCASE RELIEF VALVES	233-111
233-13.4 UNINTENTIONAL ROTATION OF AN ENGINE	233-112
233-13.5 CYLINDER RELIEF VALVES	233-112
233-13.6 OVERHEATED ENGINE	233-112
233-13.7 INTAKE AIR	233-113
233-13.8 CLEANLINESS	233-113

TABLE OF CONTENTS - Continued

Chapter/Paragraph	Page
233-13.9 SUBMARINE ENGINES	233-113
233-13.10 OVERSPEED TRIPS AND OVERSPEED GOVERNORS	233-113
233-13.11 PREVENTION OF FIRES IN MACHINERY SPACES	233-114
233-13.12 DIESEL ENGINE CASUALTY CONTROL PROCEDURES	233-114
233-13.13 DIESEL ENGINE LUBE AND FUEL OIL LEAKAGE GUIDANCE	233-115
233-13.14 DISCHARGE OF HALON IN DIESEL ENGINE SPACE	233-115

LIST OF TABLES

Table	Title	Page
■ 233-3-1.	MAIN PROPULSION RUN-IN SCHEDULE	233-6
■ 233-3-2.	SHIP SERVICE AND EMERGENCY GENERATOR RUN-IN SCHEDULE	233-7
233-3-3.	PRESSURE CONVERSION DATA	233-13
233-4-1.	TEMPERATURE LIMITS FOR MEDIUM AND HIGH SPEED DIESEL ENGINES	233-20
■ 233-4.2.	TEMPERATURE LIMITS FOR KEEPWARM SYSTEMS	233-23
233-8-1.	DIESEL ENGINE LUBRICATING OILS	233-78
233-8-2.	TESTS TO DETERMINE OIL CONDEMNING LIMITS	233-81
■ 233-8-3.	DROP ROD TEST KIT	233-81
233-10-1.	INHIBITOR TREATMENTS AUTHORIZED FOR DIFFERENT SHIP CLASSES .	233-102

LIST OF ILLUSTRATIONS

Figure	Title	Page
233-4-1.	Diesel Engine Operating Curve Main Propulsion and Generators	233-16
233-5-1.	Normal Rate of Pressure Drop Across Compression Rings	233-35
233-5-2.	Typical Counterweight Assembly	233-41
223-5-3.	Vibration Damper on Free End of Crankshaft	233-42
223-5-4.	Gear Type or Hydraulic Type Vibration Damper	233-43
233-5-5.	Out-of-Line Crankshaft Deflection	233-47
233-5-6.	Mounting the Crankshaft Deflection Gage	233-48
233-5-7.	Angular Position for Taking Crankshaft Deflection	233-50
233-5-8.	Sketches of a Relative Crankshaft Shape	233-51
233-8-1.	Typical Flushing Diagram of the External Lube Oil System	233-87
233-8-2.	Typical Flushing Diagram of the Internal and External Lube Oil System	233-88
233-12-1.	Sample Diesel Inspection Maintenance Requirement Card	233-108

CHAPTER 233

DIESEL ENGINES

SECTION 1.

INTRODUCTION

233-1.1 FAMILIARITY WITH DETAILS

233-1.1.1 Modern diesel engines cover a wide variety of makes, models and power ratings. It is essential that the applicable NAVSEA Technical Manual, Planned Maintenance System (PMS), Technical Repair Standards (TRS's), Engineering Operating Sequencing System (EOSS), Navy Maintenance Policies and courses of instruction at Naval or manufacturers' training schools shall be strictly adhered to during preventive maintenance and repairs. Technical documentation and training course instructions shall be followed to maintain the highest degree of Fleet readiness. All personnel involved in the operation, maintenance, minor and major repairs should be thoroughly familiar with details of the engine(s) under their care. This is the only method of ensuring reliable diesel engines in the Navy.

233-1.2 INSTRUCTIONS AND MANUALS TO BE CONSULTED

233-1.2.1 Diesel engines used by the Navy vary to such an extent that detailed maintenance, repair and operating instructions cannot be covered in this chapter; only general principles are given. The applicable NAVSEA Technical Manual is supplied for each engine providing comprehensive information for that particular make, model and application. Personnel involved in maintenance and operation shall be familiar with the following instructions and training manuals.

- a. NAVEDTRA 10085, **Tools and Their Uses** .
- b. NAVEDTRA 12001, **Fireman**
- c. NAVEDTRA 10541, **Engineman 3 and 2**
- d. NAVEDTRA 10543, **Engineman 1 and C**
- e. NAVEDTRA 10625, **Diesel Engines**
- f. NAVEDTRA 12204, **Machinery, Repairman 3 and 2**
- g. NAVEDTRA 10531, **Machinery, Repairman 1 and C**
- h. NAVEDTRA 10883, **Fundamentals of Petroleum**
- i. NAVEDTRA 10992, **Engineering Administration**
- j. NAVEDTRA 10507, **Principles of Naval Engineering**
- k. OPNAVINST 9233.1, **U.S. Navy Diesel Engine Inspection and Inspector Training and Certification Program**.
- l. NAVSEA Handbook S9233-CJ-HBK-010, **U.S. Navy Diesel Engine Inspector Handbook**, Part 1, Inspection Procedures.

- m. NAVSEA Handbook S9233-CJ-HBK-020, **U.S. Navy Diesel Engine Inspector Handbook** Part 2, Technical Information.
- n. **Allowance Parts List (APL)**
- o. OPNAVINST 5100 Series, **Navy Safety Precautions for Forces Afloat**.
- p. MIL-HDBK-267, **Guide for Selection of Lubricants and Hydraulic Fluids for Use in Shipboard Equipment**.
- q. OPNAVINST 5090.1, **Environmental and Natural Resources Protection Manual**.

233-1.2.2 Other NSTM chapters cover related equipment and subjects, such as bearings, shafts, pumps, firefighting, and lubrication. Consult specific chapters for the related equipment.

233-1.3 SAFETY PRECAUTIONS

233-1.3.1 All personnel involved in diesel engine operation, maintenance and repair shall be familiar with the requirements in [Section 13](#), the **Navy Safety Precautions for Forces Afloat** OPNAVINST 5100 series, and cautions and warnings stated in the PMS and Maintenance Requirement Cards (MRC's). These safety procedures, warnings, and cautions are mandatory for all involved personnel and may be used to augment formal safety regulations.

SECTION 2.

APPLICATION OF INSTRUCTIONS

233-2.1 GENERAL INFORMATION

233-2.1.1 Because of the wide variations in the modern diesel engine makes, models, power ratings, applications, installations and the difference in the diesel support systems, these instructions are general in nature. These instructions apply to all ship classes with diesel engines and applications from main propulsion, electrical generation, small craft and boats.

233-2.1.2 Detailed procedures for operation, maintenance, minor and major repairs are given in the applicable NAVSEA Technical Manual, Planned Maintenance System (PMS), Technical Repair Standard (TRS) and Engineering Operating Sequencing System (EOSS).

233-2.1.3 Detailed preventive maintenance actions for each diesel engine on active ships are addressed in the PMS of the Maintenance, Material, and Management System (3-M). The primary objective of the ship's 3-M System is to provide for managing maintenance and maintenance support in a manner which will ensure maximum diesel engine operational readiness. When implemented and properly used the 3-M System provides for the orderly scheduling of a preventive maintenance plan along with the required reporting and dissemination of significant maintenance related information.

233-2.1.4 The 3-M System specifies the planning, scheduling, and management of resources (men, material, and time) for those actions which contribute to the uninterrupted functioning of equipment within its design characteristics. It defines uniform maintenance standards, based on engineering experience, and prescribes simplified procedures and management techniques for the accomplishment of maintenance. Through the 3-M System, each ship, each department, and each supervisor is provided with the tools to plan, schedule and control shipboard planned maintenance effectively. The 3-M System is expressly designed to accomplish the following:

- a. Reduce complex maintenance to simplified procedures easily identified and managed.
- b. Define the minimum planned maintenance required, schedule and control its performance, describe the methods and tools to be used, and provide for detection and prevention of impending casualties.
- c. Forecast and plan manpower and material requirements.
- d. Plan and schedule maintenance tasks.
- e. Estimate and evaluate material readiness.
- f. Detect areas requiring additional or improved personnel training or improved maintenance techniques or actions.

233-2.1.5 Specifics of the 3-M System are contained in the **Ship's Maintenance and Material Management (3-M) Manual**, OPNAVINST 4790.4. When conflict and or discrepancies exist between PMS and the applicable NAVSEA Technical Manual, the PMS System prevails.

SECTION 3. OPERATION

233-3.1 GENERAL

233-3.1.1 It is important that careful preparation be made before a diesel engine is started after it has been overhauled, after major repairs or after long idle periods (30 day or more). Procedures to be followed are described in [paragraphs 233-3.2](#) through [233-3.2.3](#).

233-3.2 PREPARATION FOR STARTING DIESEL ENGINES AFTER MAJOR REPAIRS, OVERHAUL OR LONG IDLE PERIODS

233-3.2.1 Check all pipe connections for tightness and ensure that all of the diesel engine support systems are correctly installed and free of contamination. When any part of the engine or associated support systems are opened for preventive or corrective maintenance, caution shall be taken not to allow any contamination enter into the diesel engine or support systems. If major repair work was accomplished to the engine or casualties in which particles from the failed components have been circulated in the lube oil system, external and internal hot lube oil flushing shall be accomplished. The exception to this is small high speed diesel engines (i.e., Waukesha, Isotta Fraschini, some models of Caterpillar engines and, Detroit Diesel 53, 71 and 92 series).

NOTE

The best procedure is to plan and conduct the work in such a way that contaminants will not enter the system.

233-3.2.2 Lube oil flushing guidance for use after long idle periods (storage), major and minor repairs, overhaul, and dirty lube oil systems is given in [Section 8](#). Detailed flushing and cleaning procedures for the closed jacketwater cooling systems are given in NSTM Chapter 220, Volume 3, Corrosion and Contamination Control for Diesel Engine Cooling Water Systems.

233-3.2.3 General procedural steps to be taken to prepare the engine for starting after major repairs, overhaul or long idle periods are as follows:

1. Examine all piping systems, fittings, packing glands, pumps and joints for leaks in the jacketwater system, lube oil system, fuel oil system and the air starting system.
2. Jacketwater cooling system shall be filled and chemically treated in accordance with Planned Maintenance System (PMS) and NSTM Chapter 220, Volume 3, Corrosion and Contamination Control for Diesel Engine Cooling Water Systems.
3. Verify the flow of jacketwater through all cooling spaces and thoroughly vent the jacket cooling water system with vent valves if provided.
4. Fill the lube oil sump to the proper level.
5. A lube oil sample shall be taken prior to starting the diesel engine following overhaul, major repairs, long idle periods and lube oil flushing. Lube oil samples shall be taken in accordance with [Table 233-3-1](#) or

233-3-2 and PMS during engine run-in and or break in of an overhauled engine, major repairs or replacing any power producing components (i.e., cylinder liners, rings, pistons, bearings, main and connecting rods, piston pins, piston pin bushings and crankshaft).

6. Oil and or grease all external working surfaces (i.e., fuel pump, fuel control linkage, governor control links, rods and etc.).
7. The diesel engine lube oil system shall be primed before starting and before the engine is turned over (by hand or by a motor driven jacking gear) prior to starting. Priming of the engine should continue only until a slight pressure is registered on the engine lube oil pressure gage or until oil is observed at each main bearing.

WARNING

During visual inspection, if it is found that lubricating oil is not reaching all parts of the system, the cause shall be located and corrected before proceeding with the starting of the engine.

CAUTION

On opposed piston engines, the priming pump shall not be run for any greater time than is actually required to produce lube oil flow at the last main bearing on the upper crankshaft. Excessive lube oil priming may result in lubricating oil filling the upper pistons, allowing a certain amount of lube oil to reach the air receiver and also enter the combustion space which may cause hydraulic lock. Extreme caution shall be exercised to avoid this condition. Before the engine is started after a prolonged shutdown (30 day or more), the air receiver and blower discharge passages shall be inspected and accumulated lube oil removed.

CAUTION

Care should be taken to ensure that turbochargers, blowers and generators are not flooded by excessive priming.

NOTE

For engines without a prelube system, the turbocharger, blower and so forth, shall be prelubed by hand before starting.

8. Inspection and hand hole covers should be removed and a visual check be made to ensure that lubricating oil is reaching all points of the system that are visible, main and connecting rod bearings, camshaft bearings, blowers, turbochargers, rocker arms, pistons and piston pins.
9. Ensure hydraulic governors are filled to the proper level and with the correct fluid. Set governor speed at idle or minimum speed.
10. Ensure all timing events and clearances are correct (i.e., pumps, air starting cam, camshafts, intake and exhaust valves, fuel injection nozzles, injectors etc.)

11. Clean all fuel and lube oil strainers, replace all filters in the lube oil and fuel oil system.
12. Ensure fuel oil service tank is filled and free of water and sediment.

WARNING

Do not bypass installed engine starting systems. Never use unauthorized starting equipment.

13. Inspect air starting system for integrity and clearances and take appropriate actions to correct any deficiencies found.
14. If the engine is equipped with an electric starter, inspect the battery and starter terminals. Inspect all the battery cable connections and battery electrolyte specific gravity. Correct any deficiencies found.
15. Bar engine 1-1/2 revolutions by hand before starting to check for binding.

Table 233-3-1. MAIN PROPULSION RUN-IN SCHEDULE

STEP	% RATED SPEED	% RATED LOAD	DURATION (MINUTES)	CHECKS
1	IDLE	0	1	B, C
2	IDLE	0	5	B
3	IDLE	0	10	B
4	20% ABOVE IDLE	0	10	B
5	30% ABOVE IDLE	0	10	B
6	40% ABOVE IDLE	0	15	B
7	50% ABOVE IDLE	0	15	B
8	75% ABOVE IDLE	0	15	B
9	85% ABOVE IDLE	0	15	B
10	FULL RATED SPEED	0	15	A,B,C
11	AS REQUIRED	25%	30	A, C
12	AS REQUIRED	37.5%	60	A, C
13	AS REQUIRED	50%	60	A, C
14	AS REQUIRED	62.5%	120	A, C
15	AS REQUIRED	75%	120	A, C
16	AS REQUIRED	87.5%	120	A, C
17	100%	100%	240	A, C
18	PERFORMANCE TEST AS REQUIRED BY PMS TO ESTABLISH BASE LINE DATA.			
A = CHECK PISTONS, RINGS AND CYLINDERS; B = CHECK BEARINGS FOR OVERHEATING; C = SAMPLE LUBE OIL.				
NOTE ENGINE LOAD MAY VARY ±5%				

Table 233-3-2. SHIP SERVICE AND EMERGENCY GENERATOR RUN-IN SCHEDULE

STEP	% RATED SPEED	% RATED LOAD	DURATION (MINUTES)	CHECKS
1	IDLE	0	1	B, C
2	IDLE	0	5	B
3	IDLE	0	10	B
4	20% ABOVE IDLE	0	10	B
5	30% ABOVE IDLE	0	10	B
6	40% ABOVE IDLE	0	15	B
7	50% ABOVE IDLE	0	15	B
8	75% ABOVE IDLE	0	15	B
9	100%	0	15	A, B, C
10	100%	25%	15	A, C
11	100%	37.5%	30	A, C
12	100%	50%	60	A, C
13	100%	62.5%	60	A, C
14	100%	75%	120	A, C
15	100%	87.5%	120	A, C
16	100%	100%	240	A, B, C
17	PERFORMANCE TEST AS REQUIRED BY PMS TO ESTABLISH BASE LINE DATA.			
A = CHECK PISTONS, RINGS AND CYLINDERS; B = CHECK BEARINGS FOR OVERHEATING; C = SAMPLE LUBE OIL.				
NOTE				
ENGINE LOAD MAY VARY ±5%				

233-3.3 STARTING PROCEDURES

233-3.3.1 All engines on board Navy ships are started in accordance with local prepared starting procedures, Engineering Operating Procedures (EOP) or Engineering Operating Sequencing System (EOSS) and the applicable NAVSEA Technical Manual.

CAUTION

The low lube oil pressure and fresh water high temperature alarms circuit shall be operable immediately after starting the engine.

233-3.4 RUNNING IN NEW AND OVERHAULED ENGINES

233-3.4.1 When the wearing parts of an engine have been renewed during an overhaul, or as the result of a casualty, the wearing surfaces of the engine parts shall be allowed to run-in, or properly match with their mating surfaces, before full speed and load are applied to the engine. Engine parts are made to certain dimensions and are designed to be operated under specific conditions. Improper installation of a small part can put an engine out of commission just as surely as if a larger part were involved.

233-3.4.2 When gears or bearings of gear trains are renewed, proper installation and adjustments are critical. If proper alignment, clearances, and lubrication are attained at installation and maintained during the initial engine operation, the new parts will run-in without any rework.

233-3.4.3 Proper installation and adjustment are critical for main and connecting rod bearings. If rod and main bearings are clean, properly installed, and are provided with proper lubrication, their surfaces can be run-in relatively fast. An engine load is not required for run-in of bearings. The first few minutes of engine operation will usually determine the success or failure of main or connecting rod bearings. Run-in of piston rings and cylinder liners requires a gradual increase to 100% load. Properly seating of piston rings requires high cylinder pressures.

CAUTION

If full load is applied too quickly to an engine having new rings or liners installed, there is a risk of galling pistons, scoring liners, or even piston seizure. On the other hand, if the engine is operated for long periods during the run-in at little or no load, cylinder surfaces will glaze and the wear in action of the rings will cease before a tight seal is established.

233-3.4.4 If engine is not properly run-in, later application of heavy loads will result in excessive blow-by, which will cause the rings to stick and clog the ring lands with carbon. The rings will never seal properly, crankcase pressure and lube oil consumption will be high and compression pressure crankcase vacuum will be low.

233-3.4.5 Most engine manufacturers furnish a recommended run-in schedule for their engines as used in specific applications. These schedules vary with the manufacturer, engine model, engine application and even variations of the same model when significant changes have been made in material or design.

233-3.4.6 When a newly overhauled engine is run-in, the manufacturer's schedule should be followed if available. If the manufacturer's schedule is not available or detailed enough, [Table 233-3-1](#) or [233-3-2](#) and [paragraphs 233-3.5](#) through [233-3.7.5](#) shall be used.

233-3.5 GENERAL RUN-IN PROCEDURE

233-3.5.1 A diesel engine run-in schedule has two distinct phases.

- a. The first phase is running in at no load, which is primarily for the purpose of mating of new main and connecting rod bearings with their journals and connecting rod bushings with their pins. No appreciable seating of piston rings will occur during this phase.
- b. The second phase is running in under progressively higher loads, which gives the higher cylinder pressures and temperatures necessary for successful seating of new piston rings. Some wearing in of new main and connecting rod bearings and bushings is incidentally accomplished while running in under load, but the danger of failure of these parts decreases when the first phase is finished.

233-3.6 METHOD OF CHECKING BEARINGS AND BUSHINGS

WARNING

When the crankcase is opened for inspection or repairs, the starting system shall be de-energized and or deactivated and tagged out of service in accordance with current shipboard and or shore tag out instructions.

233-3.6.1 The lubricating oil temperature shall be maintained at 48.9° C (120° F) or below during bearing checks. The running in of bearings and bushings can be checked in larger engine installations by feeling for abnormal heat. If a bearing is not properly installed or is not getting enough lubricating oil for some reason, it will immediately heat up. The same holds true for the connecting rod bushings. After the engine is secured, overheating caused by improper wearing in of the piston pin and bushing can be felt by reaching along the connecting rod and into the piston. The checks which should be made at the end of each no load run on engines with crankcase inspections covers are as follows:

1. Feel the edge of each connecting rod bearing and each connecting rod cap.
2. Feel the sides of each main bearing cap and saddle of each main bearing.
3. Reach along each connecting rod and feel the rod eye and bushings.

233-3.6.2 As the engine continues to operate, all parts will grow warmer. The temperatures of adjacent similar parts of the engine can be felt and compared to determine if any parts are overheating. An explosion proof light should be used in the crankcase to provide for a good visual inspection of all areas.

233-3.6.3 In the case of aluminum bearings which are overheating, serious damage to the bearing can be determined by a close inspection of the sides of the bearing shell, which are visible with the bearing installed. If the bearing has failed, beads or blisters will be visible on the sides of the bearing. If this condition is found, the bearing shall be removed and renewed, observing the crankshaft cleaning precautions normally exercised during this procedure. Consult the applicable NAVSEA Technical Manual.

233-3.6.4 When an engine is checked following any run and a part is found to be overheating, the engine shall again be operated at the same speed and load previously used, with periodic inspection stops, until the temperature of the hot parts cools to approximately that of similar parts. If the affected parts fails to cool before the particular run has been repeated, the parts shall be removed and inspected to determine cause for overheating, and replaced or repaired in accordance with established procedures and the last run-in shall be repeated.

233-3.6.5 A slight temperature variance of similar parts are to be expected during a run-in and a run should not be repeated merely because some parts are slightly hotter than others. As a part wears in, its temperature will approach that of other similar parts.

233-3.6.6 Insufficient lubrication to any bearing or bushing, improper installation of bearings or bushings, or defective bearings or bushings normally will be indicated by a noticeable overheating of the affected part by the end of the 15 minute run at 40 percent speed, no load. A major deficiency such as a complete lack of lubrication to any part usually will be detected by a noticeable overheating of the part after the initial 1 minute run at no load.

233-3.7 METHOD OF CHECKING PISTON RINGS

233-3.7.1 Two methods are used to check the seating of piston rings, visual inspection and operational parameters. Both methods should be used for checking the progress of seating of piston rings where possible.

233-3.7.2 In most two cycle engines, the seating of rings can be observed by visual inspection. The seating surface of a ring which has not seated will have a dull appearance and may have areas of black carbon where blow-by is occurring. When seated properly rings will have a shiny surface. Grooved face rings will have a shiny surface, except for dark circumferential lines indicating the small machined grooves.

233-3.7.3 In four cycle engines, visual inspection of ring condition is not practical. Crankcase pressures, engine exhaust color, compression pressures, firing pressures and lube oil consumption shall be observed to determine progress of piston ring seating. These conditions should also be observed in the case of two cycle engines and coordinated with the results of visual inspection of the rings.

233-3.7.4 As an example, if the crankcase vacuum of an engine is normally 1/2 to 1 inch of water vacuum, the vacuum immediately after an overhaul would probably be 0 or slightly on the pressure side. As the run-in (under load) continues, the pressure should diminish and gradually the normal vacuum for the engine will be obtained. The engine exhaust will gradually clear and the crankcase vacuum will return to normal as the run-in process is completed.

NOTE

Some makes and models of diesel engines are designed to run with a crankcase pressure instead of a vacuum. Consult the applicable NAVSEA Technical Manual.

233-3.7.5 An engine performance test shall be conducted in accordance with PMS after the run-in period is totally completed. An engine performance test is conducted to see if compression pressures, firing pressures and other operating parameters are within design specifications, the engine load is balanced correctly and to initiate a baseline for engine performance data.

233-3.7.6 Lube oil consumption is higher than normal during the run-in period. Lube oil consumption on board ship is very difficult to accurately measure, as a result lube oil consumption is estimated.

233-3.8 PRECAUTIONS AND UNUSUAL CIRCUMSTANCES

WARNING

When the crankcase is opened for inspection or repairs, the starting system shall be de-energized and or deactivated and tagged out of service in accordance with current shipboard and shore instructions.

233-3.8.1 HELPFUL POINTS DURING RUN-IN

- a. Chrome plated rings or liners require higher cylinder pressures for successful ring seating.
- b. Engine run-in or break-in shall be accomplished using the lubricating oil used during normal engine operation. (So called break in oils shall not be used.)
- c. Introduction of abrasive elements through the air intake is not authorized.
- d. Where new rings are to be installed in old liners that are glazed, the glaze shall be broken by honing, with the exception of chrome plated liners, before installing new rings, or the rings may not seat.

NOTE

Fairbanks Morse diesel engines cylinder liners are usually not honed during engine overhaul.

- e. Lube oil temperatures shall be maintained at or near 48.9° C (120° F) during the no load run-in to facilitate feeling of parts for heat.
- f. Lube oil and jacketwater temperatures shall be maintained at their normal operating values during the run-in under load.
- g. If any monitored operating temperatures go above normal during a specific step of the run-in, other conditions being normal, the speed or load shall not be increased until temperatures have returned to normal. In extreme cases, the speed or load may have to be dropped to the previous step and the run repeated before the engine can satisfactorily accept the increased speed or load required by the next step of run-in.

233-3.8.1.1 [Tables 233-3-1](#) and [233-3-2](#) provide run-in schedules for main propulsion and generator sets.

233-3.8.1.2 If unusual noises, conditions and alarms are encountered, shut engine down immediately. Throttle station shall be manned at all times for this specific purpose.

233-3.8.1.3 After completion of steps 1 through 9 in [Table 233-3-1](#) or [233-3-2](#), temperature should be allowed to reach normal operating values. Feel the parts in Steps 1 through 9 in [Tables 233-3-1](#) and [233-3-2](#) to determine the temperature of the parts. Do not attempt to feel parts after steps 9 through 16 in the tables; the parts will be too hot to touch. Parts should be inspected visually with an explosion proof light. Look for missing cotter pins, loose nuts, blistered aluminum bearings, purple or blue parts (previously shiny), metal particles, or anything unusual.

233-3.8.1.4 Diesel engine log readings shall be recorded every 15 minutes during run.

233-3.8.1.5 If a problem is encountered during any one of the steps of [Table 233-3-1](#) or [233-3-2](#), the previous step shall be repeated until the engine can accept the next higher load and speed.

233-3.8.1.6 Filters, strainers and temporary muslin or polyester bags, if installed, shall be cleaned or renewed after the run-in.

233-3.8.1.7 All overhaul, and break in and overhaul logs shall become a part of the repair package for future reference.

233-3.8.2 CRANKCASE PRESSURE OR VACUUM

NOTE

Some makes and models of diesel engines are designed to run with a crankcase pressure instead of a vacuum. Consult the applicable NAVSEA Technical Manual.

233-3.8.2.1 An engine operating with a crankcase vacuum has effectively created a situation whereby the greater pressure is external to the engine and this pressure aides in holding back oil that would leak if the pressure was equal on both sides of the cover. This vacuum is maintained by various means depending on engine manufacturer. Some engine models obtain a vacuum by a motor driven centrifugal air pump and others obtain a vacuum by an air eductor arrangement from the blower or turbocharger.

233-3.8.2.2 A crankcase vacuum system aids in reducing lube oil contamination caused by the blow-by from the combustion chamber past the piston and rings into the crankcase. Since the blow-by consists of products of combustion, partially burned fuel and air and some liquid or gaseous fuel, these contaminates are deposited in the oil. The vacuum system tends to remove some of the contaminates while they are airborne in the crankcase, thus aiding in the reduction of lube oil contamination.

NOTE

Do not use mercury in manometers, use water with an approved manometer dye.

233-3.8.2.3 If crankcase vacuum decreases (an increase in crankcase pressure) the engine operator should investigate the problem by first ensuring the engine crankcase vacuum U-tube manometer is working properly. The manometer should be mounted on the engine or adjacent to the engine with as short a run of tubing to the crankcase as is practical. The tubing should be examined to ensure it is not crimped or punctured which would give false crankcase readings. The manometer should be mounted higher than its crankcase connection and the tubing should be run as straight as is practical with a continuous up slope from the crankcase to the manometer. The tubing should not contain any loops, kinks or sharp bends which would trap lube oil and prevent the manometer from operating.

233-3.8.2.4 All precautions shall be taken for the engine so that the installed system can pull a vacuum in the crankcase. A crankcase vacuum will never be realized if air is allowed to enter the crankcase.

233-3.8.2.5 The vacuum system should be examined to ensure it is working properly. If the system is equipped with any filters or baffles, they should be cleaned and installed correctly. Lube oil sump level should be checked to ensure it is not higher than required. If an engine is equipped with a vacuum breaker/limiter ensure it works properly before and during engine operation.

233-3.8.2.6 If an engine has an orifice installed in the vacuum system to maintain a specified vacuum at rated load and speed, the orifice hole should be cleaned and free of any debris. Special attention shall be given to the gaskets on both sides of the orifice plate to ensure they do not obstruct the orifice opening.

233-3.8.2.7 The orifice shall not be adjusted to increase vacuum since doing so would cover up the actual problem and indications would be that the engine and vacuum systems are working properly, when in fact a problem

actually exists. When an engine has been overhauled and after the run-in is completed, the orifice size should be adjusted to achieve the maximum crankcase vacuum listed in the applicable NAVSEA Technical Manual and PMS for full load and speed.

233-3.9 READING THE MANOMETER

233-3.9.1 The total reading is obtained by adding the readings from both tubes. For instance, if one reading is 2 inches above zero, the other 2.2 inches below zero, the reading would be 4.2 inches. The readings in both legs may be different either due to incorrect zero adjustment or due to a slight difference in the bore of the glass tube. By adding the two readings, both sources of error are eliminated. Pressure is indicated if the side that is vented to the atmosphere is higher; vacuum if it is lower than the side that is connected to the engine crankcase.

233-3.10 MANOMETER CONVERSION DATA

233-3.10.1 Manometer pressure conversion table, refer to [Table 233-3-3](#).

Table 233-3-3. PRESSURE CONVERSION DATA

PRESSURE CONVERSION DATA	
1 INCH WATER	0.0735 INCHES MERCURY
1 INCH WATER	0.0361 LBS PER SQ IN
1 INCH WATER	0.578 OZ PER SQ IN
1 INCH MERCURY	0.491 LBS PER SQ IN
1 INCH MERCURY	13.6 INCHES WATER
1 LB PER SQ IN	27.7 INCHES WATER
1 OZ PER SQ IN	1.73 INCHES WATER
1 LB PER SQ IN	2.036 INCHES MERCURY

NOTE

Do not use mercury in manometers, use water with an approved manometer dye.

SECTION 4.

OPERATION AND OPERATING LIMITATIONS

233-4.1 RATINGS

233-4.1.1 The rated power of an engine is normally the nameplate rating and is the horsepower or kilowatt output safely obtained from an engine in good operating condition at rated speed and under specified ambient conditions. For most main propulsion installations the rated horsepower of the engine corresponds to the engine horsepower at the full power trial condition.

233-4.2 OPERATION OF DIESEL ENGINES

233-4.2.1 The service life and maintenance requirements of any diesel engine are greatly influenced by the speeds and load factors imposed by the user during its operation. In some cases, the particular requirements of the installation or the mission require that the installed diesel(s) be operated much of the time at speeds and loads either higher or lower than would be desirable from the standpoint of best economy, least maintenance, and longest life.

233-4.2.2 For most installations and circumstances, the user has considerable choice of the speed and load factors which can be used to accomplish the mission. When economy, maintenance requirements, and engine life are important factors, it is recommended that the user consider the following:

- a. An engine operated at full rated (nameplate) power output will require more maintenance and more frequent overhauls than the engine would require if the load were reduced to about 80 percent of full load and the speed reduced to about 90 percent of full rated speed. If the application does not permit a speed reduction (as in an alternating current generator), a reduction in load will still be advantageous to reduce maintenance requirements.
- b. It is not desirable to load a diesel engine to full torque output for extended periods at less than about 2/3 of full rated speed.
- c. Do not idle diesel engines unnecessarily for long periods of time. Extended operation at any speed at less than 60 percent of full load torque (or BMEP) will develop problems with carbon formation, lube oil dilution, oil carry over to the exhaust system, premature engine overhaul and other problems relating to incomplete combustion. Operation at full rated speed and no load, or very little load, will develop these problems to the maximum degree.
- d. [Figure 233-4-1](#) illustrates some of the recommended operating limits and illustrates the area of speed load combinations which are preferred for most installations to produce the least engine maintenance and the most effective engine utilization.

233-4.3 DETERMINING ENGINE TORQUE AND HORSEPOWER

233-4.3.1 Compliance with the recommendations of [paragraph 233-4.2.2](#) requires that the operator have some reasonably accurate measure of the power being developed by the engines under various operating conditions. In most cases the operator has, or can develop, this information by using equipment and information at hand.

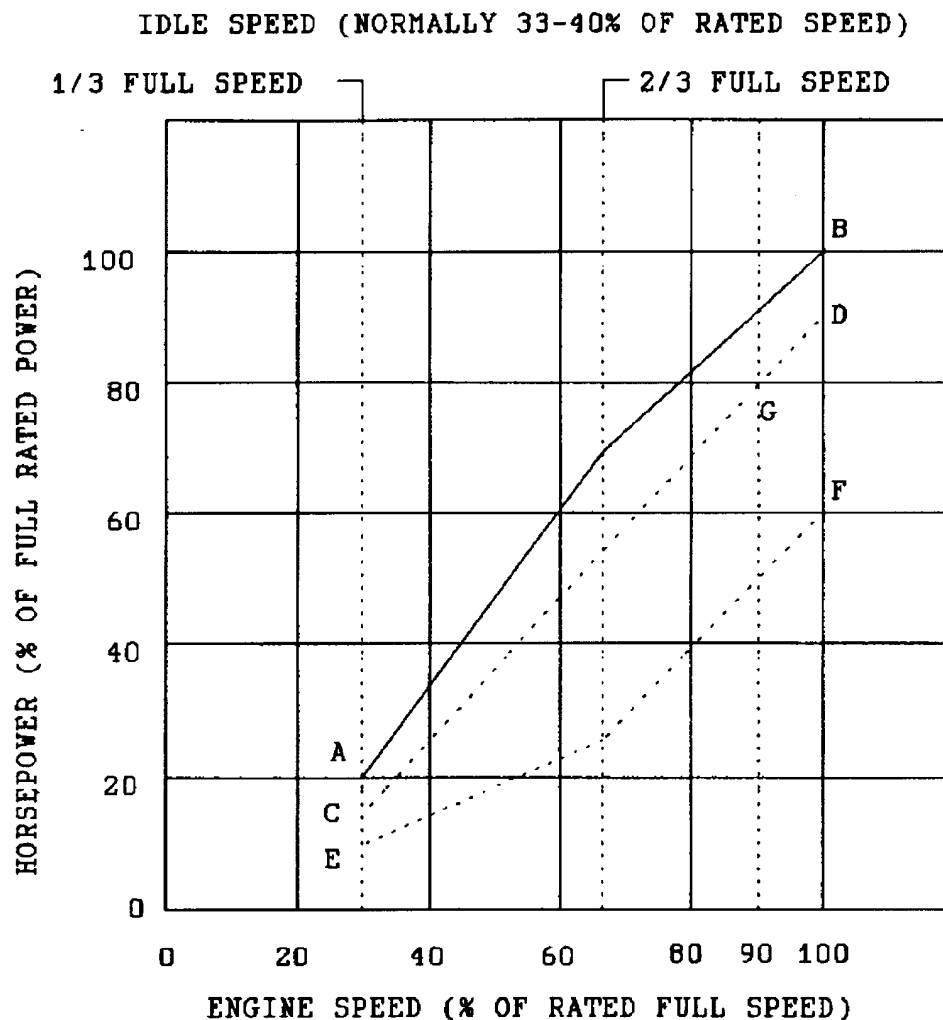
233-4.3.2 If the engine drives an electric generator, the engine output can be accurately measured through use of the meters indicating kilowatt output of the generator, modified to reflect the efficiency of the machine.

233-4.3.3 If the engine drives a propeller connected through a reduction gear, the power output of the engine is obtained from curves of propeller speed versus power requirements or measured directly with torque meters and tachometers. Condition of the hull shall be a factor when determining engine power output.

233-4.4 EXHAUST BACK PRESSURE

233-4.4.1 The results of high exhaust back pressure are detrimental and include the following:

- a. Higher exhaust temperatures.
- b. Less air supplied for combustion.
- c. Dirty exhaust.
- d. Less available power



A. FULL POWER OPERATION SHOULD NOT EXCEED THE LIMITS OF CURVE A-B

B. WHERE ENGINE WEAR AND MAINTENANCE COSTS ARE IMPORTANT CONSIDERATIONS, LIMIT ENGINE LOAD AND SPEED COMBINATIONS WITHIN AREA BOUNDED BY C-G-D AND E-F.

C. WHERE FEASIBLE, LIMIT ENGINE SPEED TO 90 PERCENT OF FULL SPEED AND AS CLOSE AS POSSIBLE TO LINE C-G FOR OPTIMUM OPERATION. OPERATION AS MAY BE NECESSARY OUTSIDE ABOVE OPTIMUM AREA, BUT WITHIN UPPER LIMIT CURVE A-B PROVIDES SAFE OPERATION ALTHOUGH ENGINE MAINTENANCE REQUIREMENTS WILL BE INCREASED.

D. ALTERNATING CURRENT DIESEL GENERATOR SETS SHOULD NOT BE OPERATED BELOW 60 PERCENT LOAD FOR EXTENDED PERIODS OF TIME.

E. IF MAIN PROPULSION AND GENERATOR ENGINES ARE OPERATED BELOW CURVES E TO F PROBLEMS WITH OIL CARRYOVER, INCOMPLETE COMBUSTION AND CARBON DEPOSITS WILL INCREASE.

Figure 233-4-1. Diesel Engine Operating Curve Main Propulsion and Generators

233-4.4.2 The exhaust system shall be kept free of unnecessary restrictions to keep the exhaust back pressure below design limits. Precautions should be taken to prevent accumulation of excessive carbon, oil, and water in the mufflers.

233-4.5 FIRING PRESSURES

233-4.5.1 The firing pressure in any cylinder should never be allowed to exceed the limit given by Planned Maintenance System (PMS) or the applicable NAVSEA Technical Manual. The results of allowing the firing pressure to exceed the established limits specified include the following:

- a. Increased stresses in the cylinder heads, cylinder liners, pistons and crankshaft.
- b. Higher cylinder temperatures.
- c. Dirty exhaust.
- d. A tendency to burn up the injector nozzle tips.
- e. A tendency to pound out bearing material.
- f. A tendency to cause ring failure and piston seizure.

233-4.6 FACTORS AFFECTING SHAFT HORSEPOWER

233-4.6.1 On all types of diesel propelled ships, the percentage of engine horsepower (HP) available at the propeller depends on the type of connection between the engines and the propeller. Types of drives and the approximate relation between engine horsepower and power output to the propeller or shaft horsepower (SHP) are listed below.

- a. Engines that are connected directly to the propeller shaft, $\text{Shaft HP} = \text{Engine HP}$ less a loss due to engine and line shaft bearing friction. A loss of less than 0.75 percent.
- b. Engines that are connected to the propeller shaft by flexible couplings (sometimes part of the clutching mechanism when engaged) $\text{Shaft HP} = 0.985 \times \text{Engine HP}$.
- c. Engines that are connected to the propeller shaft through attached reduction gears, $\text{Shaft HP} = \text{Engine HP}$. In this case the gears are considered to be an integral part of the engine.
- d. Engines that are connected to the propeller shaft by generator and motor, $\text{Shaft HP} = \text{Engine HP} \times \text{generator efficiency} \times \text{motor efficiency}$.
- e. Engines that are connected to the propeller shaft by generators, motors, and reduction gears, $\text{Shaft HP} = \text{generator efficiency} \times 0.98 \times \text{Engine HP}$.

NOTE

For generator set applications the electrical output in kilowatts is $Kw = 0.746 \times \text{Shaft HP}$.

- f. Engines that drive an alternating current (AC) generator, to verify kilowatts load (kW) use the following formula:

$$kW = \frac{1.732 \times V \times A \times pf}{1000}$$

(V) = Volts

(A) = Amps

(pf) = Power Factor

(kW) = Kilowatts

NOTE

1.732 is the square root of 3, for 3 phase generators.

NOTE

If a power factor (pf) meter is not installed use 0.8.

233-4.7 FACTORS AFFECTING SHIP SPEED

233-4.7.1 At present three general types of propellers are used on diesel propelled ships:

- a. Fixed pitch fixed diameter.
- b. Controllable reversible pitch-fixed diameter.
- c. Cycloidal propeller.

233-4.7.2 At any given hull displacement, when the propeller pitch is fixed, the power required for propulsion increases exponentially as the cube of the shaft speed. The horsepower is represented by a cubic curve derived from the shaft speed and propeller constants.

233-4.7.3 Fixed pitch propellers are designed to absorb rated horsepower at rated engine revolutions per minute (RPM) at either trial or design displacement.

233-4.7.4 With controllable pitch propellers, it is possible to operate under different conditions of displacement of ship resistance at the same engine RPM and power by varying the pitch of the propeller. Operation of engines connected to controllable pitch propellers should be in accordance with the applicable NAVSEA Technical Manual and Engineering Operating Sequencing System (EOSS) if applicable.

233-4.8 EFFECTS OF FOULING

233-4.8.1 Marine growth (fouling) on the propeller sides and the bottom of the ship and in the raw water piping has a very significant effect on the operation of diesel engines. The amount of fouling is dependent primarily upon three factors:

- a. The first factor is the number of days the ship has been operating after having the bottom cleaned and painted.
- b. The second factor is the temperature of the water and the locality in which the ship is operating. In tropical seas the marine growth rate is up to six times as much as in the North Atlantic.
- c. The third factor is the amount of idle time at the dock and at anchor.

233-4.9 TRIM

233-4.9.1 Care should be taken to ensure that the ship will always be trimmed as close to the designed trim as possible. Improper trim conditions can result in the following:

- a. Engines will be overloaded.
- b. The efficiency of the propulsion plant will be reduced.
- c. At any given shaft speed the ship will not attain the maximum speed when the ship is not properly trimmed.

233-4.10 PROPELLER BEARINGS AND SHAFTING

233-4.10.1 **NSTM Chapter 245, Propellers** , should be consulted for detailed information concerning installation and maintenance of propeller shafts and bearings. Improperly adjusted bearings and misaligned shafting will result in increased shaft horsepower requirements at a given ship speed and may result in accelerated wear in the engine and gears.

233-4.10.2 It is very important for the most efficient operation of the ship that the propellers be free of all foreign matter and nicks on the blade edges and that the designed pitch of the propellers is maintained at all times.

233-4.11 EFFECTS OF OPERATION IN SHALLOW WATER

233-4.11.1 The power required for operation in shallow water will increase. On electric-drive ships it is necessary only to limit the engine output as shown by [Table 233-4-1](#). For extended operation in shallow water, it may be necessary to limit engine speed to 90 percent of maximum speed.

233-4.12 OPERATION IN HEAVY SEAS

233-4.12.1 During operation in heavy seas, the power requirements at any given shaft RPM fluctuate considerably. The rated horsepower is intermittently exceeded when trying to maintain this rating.

233-4.13 COLD WEATHER STARTING AND OPERATION

233-4.13.1 For cold weather operations the fresh water system shall be protected in accordance with [Section 10](#) and PMS.

233-4.13.2 For fuel requirements in cold weather refer to [Section 7](#).

233-4.13.3 For lubricating oil requirements in cold weather refer to [Section 8](#).

233-4.14 FUEL IGNITION AT LOW TEMPERATURES

233-4.14.1 A diesel engine depends on the heat of compression in the cylinder to ignite its fuel. In theory, this temperature in the cylinder depends only on the compression ratio and the temperature of the air entering the cylinder. When the outside air temperature drops 10°, the temperature at the end of the compression stroke may drop as much as 20°.

233-4.14.2 Some important factors in starting engines are beyond the control of the operator, such as compression ratio, combustion chamber design, and the type of cranking system. In general, 4 stroke cycle engines can be started more easily than 2 stroke cycle engines due to better scavenging.

233-4.14.3 The use of starting aids is required to start almost any diesel engine at sub zero temperatures. Starting aids authorized are listed in [paragraph 233-4.15](#).

Table 233-4-1. TEMPERATURE LIMITS FOR MEDIUM AND HIGH SPEED DIESEL ENGINES

EXHAUST TEMPERATURES: IN NORMAL OPERATION: CYLINDER EXHAUST GAS TEMPERATURES SHALL NOT BE ALLOWED TO EXCEED THE MAXIMUM LIMIT(S) GIVEN IN PMS, EOSS OR THE APPLICABLE NAVSEA TECHNICAL MANUAL. UNLESS OTHERWISE STATED IN PMS, EOSS OR THE APPLICABLE NAVSEA TECHNICAL MANUAL, THE EXHAUST TEMPERATURE VARIATION AMONG THE CYLINDERS IN THE SAME ENGINE BANK AT FULL LOAD AND AT RATED SPEED SHALL NOT EXCEED 150° F. THE SAME LIMIT APPLIES BETWEEN ENGINE BANKS AND ALSO FROM ENGINE TO ENGINE IN TANDEM SETS. TO MEET THIS LIMIT, FUEL RACKS, INJECTORS OR ASSOCIATED LINKAGES ARE NOT TO BE ADJUSTED OUTSIDE THE APPLICABLE NAVSEA TECHNICAL MANUAL REQUIREMENTS.			
	Minimum	Preferred	Maximum
FRESH WATER TEMPERATURE FROM ENGINE	68.3° C(155° F)	76.7° C(170° F)	85° C(185° F)
LUBRICATING OIL TEMPERATURE FROM ENGINE	71.1° C(160° F)	82° C(180° F)	93.3° C(200° F)
SEAWATER	N/A	N/A	N/A
NOTE SOME HIGH SPEED DIESEL ENGINES (1,800 AND HIGHER) HAVE OPERATING OIL OUTLET TEMPERATURES AS HIGH AS 107.2° C (225° F)			

233-4.14.4 When the ambient temperature drops, starting becomes more difficult, cranking speed is reduced because of reduced battery efficiency and the increase in engine oil viscosity. Cold cylinder walls cool the incoming air, lowering the air charge temperature which further inhibits combustion.

233-4.15 STARTING AIDS

233-4.15.1 There are several types of starting aids for use in cold-weather operation. The majority of the starting aids assist by adding heat to the air in the combustion chamber, or by adding a volatile, easily combustible fluid, such as diethyl ether, to the intake air.

233-4.15.2 Starting aids vary according to engine application, equipment installed, and harshness of the environment. Starting aids used in cold weather are in these general categories:

- a. Heating the engine coolant.
- b. Heating the engine oil.
- c. Heating the intake air.
- d. Heating the battery.
- e. Using special fuels, such as diethyl ether in minute amounts.

WARNING

Do not use diethyl ether with air inlet preheaters.

WARNING

These fluids shall be handled with care since they are highly flammable, and a mixture of the vapors with air is explosive. Prolonged exposure may cause death. Particular care shall be taken that fumes do not collect in the bilges of small craft. Exposure to the fumes should be avoided in any confined space because they will cause unconsciousness and may, under prolonged exposure, cause death.

CAUTION

Use only approved starting aids.

233-4.15.3 Depending on the installation, starting aids are often used in combination but diethyl ether is never used with air inlet preheaters because of the high volatility of the ether. Consult the applicable NAVSEA Technical Manual for special starting requirements for a particular engine.

233-4.15.4 The most effective starting fluid is diethyl ether.

CAUTION

Never use bulk ether from cans.

233-4.15.5 When diethyl ether is furnished for use as a starting fluid, it is usually compounded with a small amount of low pour point lubricating oil for top cylinder lubrication, and a trace of alcohol to prevent moisture freezing in the supply line.

WARNING

Explosion will occur if steel pressure primer bulbs are heated above 315.5° C (600° F).

CAUTION

Repeated use of ether, or an excessive application of ether on any one start, can cause damage to the engine.

233-4.15.6 Diethyl ether starting fluid can be obtained in steel pressure primer bulbs. The introduction of a small amount of fluid into the intake before cranking the engine will facilitate starting. The use of excessive amounts should be avoided because it may backfire through the air intake, or detonate in the engine cylinder, causing mechanical damage to the engine.

233-4.15.7 The steel pressure primer bulbs are pressurized with a flammable gas at approximately 250 psig and they will withstand rough handling without breaking, but will explode if heated above 315.5° C (600° F). The primer bulbs shall be used in a pressure primer discharger which pierces the end seal on the bulb and permits the pressurizing gas to force the fluid through a connecting tube to a spray nozzle in the engine air intake system. The primer discharger is designed to prevent spillage or leakage of the fluid. Occasional difficulty will be experienced with the primer discharger because of choking of the screen in its base caused by black iron oxide which comes from inside the pressure primer bulbs. Periodic cleaning of the screen will be required.

CAUTION

Do not inject too much ether or the engine may be damaged because of high cylinder pressure.

233-4.15.8 The amount of ether type starting fluids required for a given engine can be determined only by trial and error. It may be said that the quantity of fluid required is roughly proportional to engine displacement and increases rapidly as the temperature falls below -17.7° C (0° F). Care should be exercised not to inject too much ether or the engine may be damaged because of high cylinder pressures. At sub-zero temperatures, starting is improved if a minute amount of the fluid used is sprayed into the intake manifold before starting to crank the engine.

233-4.16 STARTING TECHNIQUES FOR DIESEL ENGINES

233-4.16.1 Cylinder temperature also depends on the cranking speed. Since cranking speeds for most engines are less than 200 RPM, the engines operate in a range where a small increase in cranking speed may cause a relatively large increase in combustion chamber temperature. This will make starting much easier.

■ 233-4.16.2 In general, engines start most readily when the throttle (fuel injector rack) is slowly opened to the full fuel position during cranking.

233-4.16.3 At low temperatures, it is usually necessary to operate an engine at a fast idle speed even though this may cause rapid wear of bearings, piston rings, and cylinder walls. The engine speed should be reduced to normal idle as soon as possible.

233-4.17 KEEPWARM SYSTEMS FOR DIESEL ENGINES

233-4.17.1 **KEEPWARM SYSTEMS.** A keepwarm system is an optional auxiliary heating system, the intent of which is to allow for more favorable thermal conditions to be present during engine start up than would otherwise be found in a cold engine. Emergency diesel generators, because they are designed to automatically start up and accept load within a matter of seconds, usually come equipped with a keepwarm system in an attempt to keep engine wear to a minimum. A keepwarm system maintains the temperature of the power assembly components closer to the temperatures that they will attain during engine operation, thereby reducing the rate of thermal expansion of those components during start up. Lube oil viscosity is also lowered by the increased lube oil temperature produced by the keepwarm system. Less viscous lube oil flows more rapidly and easily to all moving components within the engine. This improved lube oil flow decreases engine component wear during start up.

233-4.17.2 Although there are different configurations available, keepwarm systems essentially keep the engine block at a temperature significantly above the ambient temperature by heating either the engine jacketwater or the engine lube oil (or both) and allowing the conductive heat transfer process to take place. Electric immersion heaters are most often used as the source for preheating the jacketwater/lube oil. They can be installed in tanks external to the engine, in freeze plug openings, in drain plugs, or directly in the oil sump. Oil can be circulated by a small positive displacement pump and some systems utilize natural circulation caused by the temperature differences in the water being heated. A heat exchanger can be used to more efficiently transfer heat from the fluid being directly heated (usually the jacketwater) to the fluid not being directly heated (usually the lube oil).

233-4.17.3 This equipment keeps the entire engine block warm while the engine is shut down. When the engine starts up, the keepwarm system should be secured. Although, most keepwarm systems are designed to perform this task automatically. Some crankcase explosions have been caused by oil heaters that were operating while the engines were running or that remained energized with the circulating pump secured.

233-4.17.4 Temperature limits for keepwarm systems are listed in [Table 233-4-2](#).

Table 233-4.2. TEMPERATURE LIMITS FOR KEEPWARM SYSTEMS

Fluid	Minimum Temp	Preferred Temp	Maximum Temp
Lube Oil	100° (F) 37.7° (C)	110° (F) 43.3° (C)	120° (F) 48.8° (C)
Jacketwater	105° (F) 40.5° (C)	120° (F) 48.9° (C)	140° (F) 60.0° (C)

233-4.17.5 Attempting to maintain these fluids at temperatures above those listed in [Table 233-4-2](#), becomes difficult and expensive due to heat loss in typical ambient conditions. Do not operate the keepwarm system above the limits specified in EOSS, PMS, NAVSEA Technical Manuals, [Table 233-4-2](#) or other approved operating procedures. Operating above these limits can cause condensation within the engine and result in rust formation on interior surfaces.

233-4.18 MINIMIZING EXHAUST SMOKE AND EMISSIONS

233-4.18.1 The normal exhaust smoke opacity for engines in good condition operating under normal load and warmed up is well below Ringleman Number One. However, even a good engine can produce smoke during warm up. Excessive idling causes smoke from any diesel engine. Any new or overhauled engine can produce smoke until the run-in procedure has been completed.

233-4.18.2 In order to minimize exhaust smoke the following actions are recommended:

1. Strictly adhere to maintenance requirements as specified in the applicable NAVSEA Technical Manual and PMS requirements.
2. Conduct performance test in accordance with PMS to identify potential problems which will contribute to poor combustion and engine operation.
3. Whenever a cold engine is started, idle the engine until the lube oil temperature reaches 35° C (95° F). Then apply a light load (approximately 20 to 30 percent). When the lube oil temperature reaches 48.9° C (120° F), apply a normal operating load (60 percent or greater).

CAUTION

Do not operate a warm engine for any length of time at less than 60 percent load. Avoid prolonged idling (in excess of 5 minutes) of a warm engine. Combustion at low or no load is incomplete and may cause heavy carbon deposits which will foul the valves, valve stems, intake and exhaust ports, and the piston rings as well as the exhaust system.

4. Operate a warm engine at between 60 and 80 percent of full load to the maximum extent possible.
5. To secure a warm engine remove the load and slowly reduce RPM to the idle speed. Then run at the idle speed for three to five minutes and then shutdown.
6. When a multiple engine arrangement is provided so that various engine combinations may be used, select a combination that operates fewer engines at higher loads for low speed or low power operation. Consistent with the need for split plant operation to ensure maximum reliability, make every effort to maintain the load between 60 and 80 percent of full load. Refer to **NSTM Chapter 320, Electric Power Distribution Systems**, for information on split plant operations.
7. Never operate diesel engines at an overload except in the case of an emergency. If conditions indicate that the engine is overloaded, reduce the load immediately. Overload may be indicated by high exhaust temperatures, smoky exhaust, and high firing pressures.

233-4.18.3 Exhaust emissions regulated by the Environmental Protection Agency (EPA) and state/local regulatory agencies include nitrous oxides (NO_x), hydrocarbons (HC), carbon monoxide (CO), airborne particulate matter (PM), and visible smoke. Typically, high combustion temperatures increase NO_x and incomplete combustion yields HC, CO, CO₂, and PM. Federal and state emission regulations have become increasingly stringent and now require the reduction of emissions from all types of internal combustion engines. Although the U.S. Navy's combatant ships are covered by the National Security Exemption for EPA CAAA regulations and Public Vessel Exclusion for the MARPOL 73/78 Convention, OPNAVINST 5090.1B, Change 2, 19-4.3.1 states that "Navy ships shall comply with applicable Federal, State, and local regulations governing air pollution emissions." Therefore, the use of the EPA National Security Exemption and the MARPOL 73/78 Public Vessel Exclusion

shall be restricted to vessels where it can be shown that use of environmentally compliant engines would impair the ability of the vessel to meet Top Level Requirements. Application for either exemption should be discussed with the Naval Sea Systems Command and submitted formally to this command.

233-4.18.4 Commercially-available, environmentally-compliant marine engines shall be procured, installed, operated, and maintained for US Navy new construction ships, service craft and small boats. Replacement engines on existing US Navy vessels, if not the same engine model that is being removed, shall be compliant with environmental laws in place at the time of replacement. Engines on existing vessels that are upgraded to increase power, improve fuel economy, or otherwise receive configuration modifications that could effect exhaust emissions shall also be brought into compliance with environmental laws in place at the time of upgrade. Exceptions to these requirements shall only be made when Naval Sea Systems Command has determined on a case-by-case basis that a National Security Exemption or a Public Vessel Exclusion is required for operational requirements to be met.

233-4.18.5 For the rebuilding of marine engines, the EPA requires specific record-keeping procedures for all EPA-compliant engines produced in 2004 and beyond. The Naval Sea Systems Command shall ensure that Navy engine rebuild facilities implement these procedures to document the rebuilding or remanufacturing of marine engines. The incorporation of these procedures into maintenance documentation (technical manuals and the Periodic Maintenance System (PMS)) will be conducted by the Naval Sea Systems Command. Required records shall include the following information and be maintained for at least two years:

- a. Hours of use accumulated on the engine at the time of rebuild,
- b. List of replacement parts used,
- c. Engine parameter adjustments,
- d. Design element changes, and
- e. Description of work performed on the engine or related system.

Technical documentation shall include instructions that require the reporting of any emission control equipment modification to the Naval Sea Systems Command equipment manager.

233-4.18.6 Where a particular locale cannot achieve the air quality standards of the Clean Air Act (is not in attainment with Clean Air Act air quality standards), State Implementation Plans will require “conformity.” In order to achieve conformity, US Navy ships, Commands, and facilities located in that locale may be required to reduce certain regulated air pollutants. In that event, emission control technologies certified by the EPA and approved for implementation by the Naval Sea Systems Command, may be retrofitted on existing engines. The extent of the retrofitting will depend upon the projected life of the candidate diesel engine. Shore activities and naval bases developing the requisite regional conformity plan will typically implement less costly hardware retrofit technologies on diesel engines nearing the end of their useful life and more costly hardware retrofit technologies, yielding greater emission reductions, for those engines with a greater portion of their useful life remaining. Information regarding whether retrofit technology has been certified and approved for use on Naval Vessels shall be obtained from NAVSEA. NAVSEA will ensure that the approval process for retrofit technology installation includes consensus from the TYCOM’S and the NAVSEA Program Executive Office (PEO).

233-4.19 DIAGNOSING ENGINE PROBLEMS BY EXHAUST SMOKE

233-4.19.1 The major contributors to exhaust smoke emissions are as follows:

a. Blue smoke

1. Worn or stuck piston rings.
2. Worn cylinder liners.
3. Worn valve guides.
4. Cracked pistons.

b. Black or gray smoke

1. Incompletely burned fuel.
2. Improper grade of fuel.
3. High exhaust back pressure.
4. Restricted air inlet.
5. Malfunctioning turbocharger.
6. Improperly timed injectors.
7. Faulty injectors.
8. Engine overload, cylinders not balanced.
9. Low compression.

c. White smoke

1. Cold air intake.
2. Light load operations.
3. Air in fuel lines.
4. Insufficient diesel fuel.
5. Water in the diesel fuel.
6. Operation at low jacketwater temperature.

233-4.20 OPTIMIZING ENGINE PARAMETERS

233-4.20.1 The diesel engine general mechanical condition shall be maintained to ensure the power output from individual cylinders are equal at rated load and speed. To obtain equal load distribution among the individual cylinders, the clearances and tolerances, and the general condition of all parts that affect the cycle (intake, compression, power, and exhaust) shall be maintained so variations between individual cylinders are at a minimum.

233-4.20.2 To obtain equal load distribution, the following conditions should be as nearly equal as is possible for all cylinders:

- a. Compression pressure.
- b. Firing pressure.
- c. Cylinder exhaust temperatures.
- d. Fuel rack and governor power position.
- e. Fuel injection timing.
- f. Quantity of fuel injected.

- g. Intake and exhaust valve timing and lift.
- h. Fuel injector popping pressures.

233-4.21 OPERATING ENVELOPE

233-4.21.1 Paragraphs 233-4.2 through 233-4.2.2 address recommended operating limits when not specifically addressed by the applicable NAVSEA Technical Manual, PMS, Engineering Operating Sequencing System (EOSS). Table 233-4-1 and paragraph 233-4.1.1 illustrate the area of speed and load combination which are preferred for the least maintenance, the most effective and efficient engine utilization with the least amount of exhaust smoke.

233-4.22 OPERATING DIESEL ENGINE DURING THE DRYDOCKING EVENT

NOTE

Main Propulsion Diesel Engines (MPDE's) shall not be operated during the dry-docking event.

WARNING

Operating the diesel engine during the drydock event while the hull is partially resting or resting on the blocks has the potential to cause damage to the engine's main and thrust bearings, engine block and to the engine's gear train due to hull distortions transmitted to the engine foundation.

233-4.22.1 Diesel engines driving generators may be operated during the drydock event. However, as a result of the above warning, the following precautions are recommended:

NOTE

The drive end crankwebs are the most susceptible to deflections caused by misalignment of the engine. If the drive end crankweb is within specifications it is not necessary to take deflection readings on the other crankshaft webs.

- a. Diesel engines may be used as a primary or backup source of electrical power when entering or exiting drydock and while the ship is still totally afloat provided crankshaft deflections and thrust readings are taken prior (up to 96 hours) to the docking or undocking event and are within specifications.
- b. Diesel engines may be used as a primary or backup source of electrical power when entering drydock until just prior to the ship's hull contacting the blocks. At this point, the diesel engine should be secured until the ship is completely resting on the blocks.
- c. While the hull is resting on the blocks, diesel engines may be used as a backup source of electrical power, or

temporarily as a primary source of electrical power, provided crankshaft deflections and thrust readings taken after the ship has been docked are within specifications.

- d. When the ship is to be refloated, the diesel should remain secured until the ship is completely afloat and crankshaft deflections and thrust readings taken after the ship is completely afloat, are within specifications.
- e. The recommendations provided in [paragraphs 233-4.22.1.a](#) through [233-4.22.1.d](#) do not apply to Aircraft Carrier EDG engine applications as drydock block loading has a negligible effect on the generator set foundations or engine-to-generator alignment.

233-4.22.2 The following general guidance regarding diesel engine operation during the drydocking event is provided and is applicable to all diesel engines driving generators:

- a. Do not operate the diesel engine if there is any question concerning whether engine and driven unit are within alignment specifications.
- b. Do not operate the diesel engine without concurrence of the repair activity.
- c. The repair activity shall confirm that there are no hazards associated with the operation of the diesel engine because of the ships location on the blocks.
- d. Operate the diesel engine only for the minimum amount of time needed to support current need.
- e. Do not operate the diesel engine when sandblasting, extensive grinding, or other dust producing activities are in progress.
- f. The atmosphere in the drydock and inside the ship shall be monitored for carbon monoxide while the engine is operating.
- g. Ensure that there is unobstructed path for inlet air and engine exhaust to prevent injuries or damage caused by excessive pressure or vacuum.
- h. Ensure that all engine safety and monitoring devices are operational and that pressures and temperatures remain within normal operating ranges.
- i. Ensure that the drydock system which supplies cooling water to the diesel seawater system will not over pressurized and damage its components. The maximum allowable system pressure is 80 psi.
- j. During operation of the diesel engine if any temperatures or pressures are out of specification the diesel engine shall be secured immediately.

SECTION 5.

MAINTENANCE

233-5.1 INTRODUCTION

233-5.1.1 To keep a diesel engine in reliable operating condition, it is necessary to follow an intelligently planned procedure of periodic inspection and adjustments. With such a procedure, early failure, maladjustment, or excessive clearance of wearing parts may be detected and corrected before any serious casualty results. Planned Maintenance System (PMS), Maintenance Requirement Cards (MRC's) provide intelligently planned procedures.

233-5.2 OVERHAUL PROCEDURES

233-5.2.1 The Navy uses so many models of diesel engines, it is not possible to specify any detailed overhaul procedure in this section. Several general rules apply to all engines and shall be followed.

233-5.2.2 Detailed repair procedures are listed in the applicable NAVSEA Technical Manual, Technical Repair Standards (TRS), and the PMS. Consult the applicable NAVSEA Technical Manuals, TRS's and MRC's prior to proceeding with any repair work. Particular attention should be paid to installation tolerances, wear limits, and adjustments.

233-5.2.3 Observe the highest degree of cleanliness in handling engine parts. Engines have been completely destroyed by the presence of abrasive and other foreign objects which have been carelessly left in the engines after overhaul. Ensure that any engine assembled for post-repair running is free of foreign matter prior to running. Too much emphasis cannot be given to the necessity for maintaining engines that are clean both internally and externally. Dirt entering the engine during overhaul causes increased wear and poor operation. It is essential that all repair work be done under clean conditions. When overhaul or repair of precision parts and surfaces is required, the parts and the surfaces should be thoroughly cleaned and wrapped in a clean lint-free cloth or suitable paper. The parts should then be stored in a dry place until reinstalled. During installation, parts should be wiped with a lint-free cloth and coated with clean lubricating oil, where applicable. When removing or installing parts such as pistons, connecting rods, camshafts, and cylinder liners, care shall be taken to ensure that the parts, new or used, are suitable for use. Precautions shall also be taken to keep dirt and other foreign material in the surrounding atmosphere from entering the engine while it is being overhauled. During shipyard overhaul periods, the engine(s) shall be protected from grit producing work procedures (i.e., welding, sandblasting, grinding, painting, etc).

233-5.2.4 Before starting repair work, ensure that all required tools and spare parts are available. Plan ahead for repair periods so everything needed is available to ensure successful and expeditious completion of the work.

WARNING

Never attempt to bar the engine over by hand without first de-energizing and deactivating the starting system and tagging out of service in accordance with current shipboard and shore tag out instructions.

233-5.2.5 Keep records of repairs, including measurements of used parts that are to be reused. Measurement of qualified new parts is not always required. All clearances and tolerances are to be in accordance with the applicable NAVSEA Technical Manual, PMS, and TRS's. All measurements shall become part of the engine overhaul or repair package for future reference.

233-5.2.6 Do not test an overhauled diesel engine above name plate rating or rating listed in the applicable NAVSEA Technical Manual. Engines are normally tested to 100 percent load only. Modern generator sets have a single rating with no stated overload requirement. Overload testing is neither required nor desirable for generator applications.

233-5.3 FUEL INJECTORS AND PUMPS

233-5.3.1 Fuel injectors, injector nozzles and high pressure fuel pumps should not be disassembled unless defective operation is indicated. The applicable NAVSEA Technical Manual, PMS, and TRS's provide instructions for servicing and adjusting fuel injection equipment and shall be strictly adhered to. Absolute cleanliness is of paramount importance. Only qualified shops and repair facilities shall overhaul and calibrate fuel injection equipment. All fuel injection parts shall be inspected for fit, form and function prior to installation.

233-5.4 EQUALIZING THE LOAD BETWEEN CYLINDERS

CAUTION

Fuel rack settings are not to be adjusted merely to equalize exhaust temperature differences.

233-5.4.1 Procedures for equalizing the load between cylinders and engines are found in the applicable NAVSEA Technical Manual and PMS. Before attempting to equalize cylinders and engines, ensure all injectors and high pressure fuel pumps are properly assembled and calibrated.

233-5.5 CYLINDER HEADS

233-5.5.1 Cylinder heads shall be inspected for cracks, pitted surfaces and excessive carbon deposits at overhaul. Cylinder head repairs are to be in accordance with the applicable NAVSEA Technical Manual, PMS, and TRSs.

233-5.5.2 Improper installation of cylinder head assemblies or component parts can result in permanent damage to cylinder heads, engine block, pistons, cylinder liners and turbochargers.

233-5.5.3 Proper cylinder head maintenance is nothing more than the application of good work procedures guided by the applicable NAVSEA Technical Manual, PMS and TRS's.

233-5.6 LINERS

233-5.6.1 Most diesel engines are designed to use replaceable cylinder liners. Some engine designs use a dry cylinder liner inserted into the bores of the cylinder block. In such designs, the cooling water does not directly

contact the cylinder liner. Many engines use designs of replaceable cylinder liners where some portion (or even the entire liner's outer surface) may be in direct contact with the cooling water. These wet liner designs shall employ a sealing system to prevent leakage of water into the engine.

233-5.6.2 Wet liners are positioned in the block by a loose or light interference fit, with sealing surfaces at the top and bottom of the liner. The seals are usually O-rings. An interference fit at the bottom stabilizes the liner to reduce high frequency vibration that can induce cavitation on the water side of the liner. Liner O-ring seals and liners are installed in accordance with the applicable NAVSEA Technical Manual, PMS, and TRSs.

233-5.6.3 If applicable always pressure test the engine after replacing liners and before installing pistons and heads. When a sealing surface is disturbed, always use a new O-ring or gasket.

233-5.6.4 Liners will usually wear at the greatest rate in an area 90 degrees to the crankshaft and in the direction of piston thrust.

CAUTION

Engine cylinder liners shall never be stacked or stored on their sides. They will become out of round and be unserviceable.

233-5.6.5 Liners shall be well coated with preservative oil or grease and stored vertically on end only.

233-5.6.6 Liners should be carefully inspected and measured for wear, cracks and corrosion at each overhaul if they are to be reused. Wear limits and installation of liners shall be in accordance with the applicable NAVSEA Technical Manual, PMS, and TRSs.

NOTE

The cylinder liners of Fairbanks Morse engines are not usually honed during engine overhaul because this is not recommended by the manufacturer.

233-5.7 INTAKE AND EXHAUST VALVES

233-5.7.1 Intake and exhaust valves should be carefully inspected in accordance with the applicable NAVSEA Technical Manual, PMS, and TRS's. When replacing a valve in the cylinder head, extreme care shall be taken to ensure valve keepers and spring retainers are properly assembled. A valve dropping into the cylinder may cause catastrophic engine damage.

WARNING

Sodium is dangerous when in contact with the atmosphere and explosive when in contact with water.

WARNING

Do not sectionalize sodium-filled valves for training or other purposes. Personal injury may result.

CAUTION

Sodium-filled exhaust and intake valves, when no longer serviceable, should be disposed of in accordance with current instructions and regulations.

233-5.7.2 Sodium-filled engine poppet valves are provided with a chamber formed by the hollow stem and extending well up into the valve head. The chamber contains a sodium salt which changes to a liquid as it is heated and provides a more rapid flow of heat from the valve head to the stem than would be possible in a solid stem valve.

233-5.7.3 Sodium-filled valves may be serviced or cleaned, or the seat may be refaced in the normal manner. Extreme care shall be exercised to prevent personnel from accidentally grinding into the hollow sodium-filled portion of the valve or otherwise exposing the sodium to the atmosphere or moisture. Precautions which shall be observed when handling valves of this type are as follows:

- a. Store valve in a dry place.
- b. Exercise care in handling and servicing, so stems are not broken.
- c. If chamber is found to be cracked, or inadvertently opened, submerge the valve in kerosene and keep it submerged until the valve can be disposed of properly.

233-5.7.4 Not all sodium-filled valves are marked for identification. They can be identified by number and usually are constructed with a much larger diameter valve stem than is common for solid stem valves. If any doubt exists in identifying sodium-filled valves, treat the valve as being sodium-filled and handle accordingly.

233-5.8 CYLINDER RELIEF VALVES

CAUTION

Cylinder relief valves shall never be locked closed except in cases of emergency.

233-5.8.1 Cylinder relief valves shall be set in accordance with the applicable NAVSEA Technical Manual and PMS. Repeated lifting of cylinder relief valves while the engine is running indicates that the spring has become weakened, ignition or fuel injection occurs too early, or the engine is being over fueled by faulty fuel injection equipment.

233-5.9 PYROMETERS

233-5.9.1 Pyrometers used for measuring exhaust temperatures are taken for granted and not thoroughly understood. Pyrometers are one of the most important gages on the engine. Accurate exhaust temperature readings can help identify an engine problem.

233-5.9.2 The engine pyrometer exhaust temperature measuring system consists of three parts; the thermocouples, the pyrometer and the wiring that connects the thermocouples and the pyrometer together. The thermocouples, located in a protective sleeve (tubing), convert the heat that the tip of the tubing is in contact with into an electrical signal (in millivolts) that is proportional to the temperature. The pyrometer indicates the temperature by measuring this electrical signal. The wiring is made of a low resistant type and typically has a multipoint switch inline that allows one pyrometer to measure several thermocouple outputs.

233-5.9.3 The engine pyrometer exhaust temperature measuring system requires little maintenance. All maintenance is in accordance with the applicable NAVSEA Technical Manual and PMS.

233-5.9.4 Problems with the engine pyrometer exhaust temperature measuring system include the following:

- a. Thermocouple's protective tubing becomes coated with carbon (decreasing accuracy and slowing response time), the tubing is installed into exhaust manifolds at different lengths, or the thermocouple has broken away from its protective tubing.
- b. Pyrometer is out of calibration, is calibrated wrong, or its external resistor is not the correct resistance for the installation.
- c. The wiring between the thermocouple and the pyrometers is the wrong material, the leads are not connected properly (or polarity is reversed), the lengths of the wiring are not equal between different thermocouples, the junctions in the wiring are loose or corroded, the wiring itself is brittle and broken, or the multipoint switch connections are loose or corroded.
- d. For those installations whose multipoint switches include an amplifier (to boost the current over long distances), these amplifiers are adjusted wrong.

233-5.10 PISTONS AND RINGS

233-5.10.1 Piston ring replacement is probably the most prominent reason for engine overhaul. Piston rings are designed for three basic purposes:

- a. To seal the compression and combustion pressures within the cylinder.
- b. To transfer heat from the piston to the liner.
- c. To meter the required lubricating oil to the liner and rings.

233-5.10.2 Piston rings are subjected to the adverse and varied conditions of extreme heat, pressure loading, dirt, and marginal lubrication.

233-5.10.3 Piston rings function as a team. If any one ring fails on the same piston, the pressure affecting rings further from the combustion chamber will be changed. Oil rings control the oil on the cylinder liner walls but

must control the amount distributed. If the oil control is too stringent, high cylinder liner and ring wear will result. If too much oil is distributed by the rings, the oil may reach the combustion space and burn, causing smoky exhaust and forming carbon deposits in the ring grooves.

233-5.10.4 Too much oil has an adverse effect on proper operation of compression rings and can lead to ring breakage or flutter. When it is determined that one or more rings on a piston are in need of replacement, all the rings on the affected piston shall be replaced. Replacing only the most severely worn rings will result in continued marginal performance and more frequent down time for ring servicing.

233-5.10.5 With a properly functioning set of compression rings with open gaps, the pressure drop across each ring is approximately 1/2 the pressure above the ring. The pressure drop is illustrated in [Figure 233-5-1](#).

233-5.10.6 If one ring fails or is excessively worn, the additional load is transferred to the lower compression rings and may over pressurize the oil control rings.

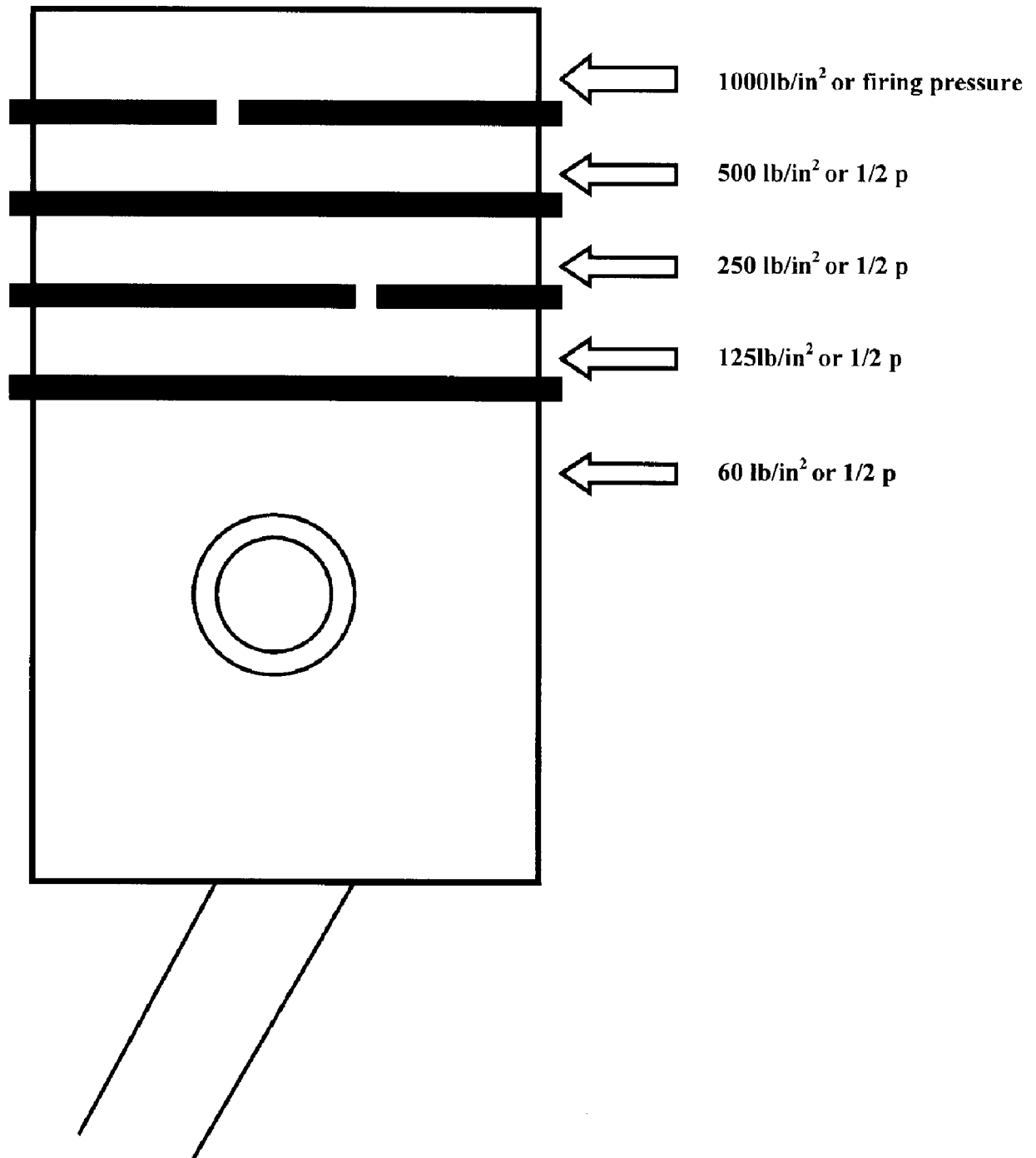


Figure 233-5-1. Normal Rate of Pressure Drop Across Compression Rings

233-5.10.7 Normally all rings on one piston will be replaced when one of the rings needs replacement. Single ring replacement is not recommended except in emergencies.

233-5.10.8 Piston, piston ring lands and grooves shall be cleaned before installing new rings. New rings that are installed in piston ring grooves that are stepped due to excessive wear will rapidly wear the new rings.

233-5.10.9 Ring replacement shall be in accordance with the applicable NAVSEA Technical Manual, PMS or TRS.

233-5.11 PISTON PINS

CAUTION

Under no circumstances are piston pins to be cleaned with sandpaper or emery cloth or filed to remove surface defects. Replacement of pin is required.

233-5.11.1 Piston pins shall be rejected if they have any surface defects, nicks, burrs, etc.

233-5.12 BALL OR ROLLER BEARINGS

233-5.12.1 Ball or roller bearings should be renewed only when the bearings or races are definitely known to be pitted, fatigued, or worn. Frequently, fresh lubrication is all that is required after a thorough cleaning has removed gummed lubricating oil or grease. For further information see the applicable NAVSEA Technical Manual, PMS, and **NSTM Chapter 244, Propulsion Bearings and Seals** .

233-5.13 PRECISION OR BABBITT BEARINGS

233-5.13.1 Babbitt bearings should be renewed only when wiped, worn beyond allowed limits, honeycombed to such an extent that complete failure is imminent, or when bearing material is broken loose from the shell.

233-5.13.2 Circumferential scratching and grooving, often noted during inspections, are caused by dirt in the lubricating oil. Every effort shall be made to ensure that such dirt is eliminated.

233-5.13.3 Surface marks such as scratches or grooves do not affect performance, but will reduce bearing life. A worn-in operating bearing may have much greater inherent reliability than a new bearing.

233-5.14 SHAFT JOURNAL INSPECTION

233-5.14.1 Shaft journals are machined to be round and smooth. Deviation from this original configuration will impair bearing operation. Most journal surface should be bright and shiny. Circumferential grooving caused by dirt and abrasive material reduces the area in contact with the bearing, impairs the oil film, and damages or removes the babbitt. Slight circumferential grooving is acceptable. When grooving is considerable, journal repair is required. Unacceptable conditions are considerable or heavy circumferential grooving, blackened surface, a rough, pitted, or burred surface, and babbitt deposits.

NOTE

Flat spots are caused by excessive use of stones, scrapers, and abrasives. Do not work journals by hand. When required, only experienced personnel should perform hand operation.

233-5.15 SCRAPING OF JOURNAL BEARING

233-5.15.1 Hold scraping to a minimum. Never scrape bearings to alter the basic surface geometry or to change the effective bearing clearance. Bearings are manufactured to precise tolerances and, in general, should require no scraping or fitting during installation. Bearings usually show a polished area of babbitt over the bottom central 10 to 60 degrees of arc. This does not mean that the shaft does or should contact the bearing over this arc at any one time. What does happen is that, at low shaft speeds, the oil film between the journal and bearing is thin, proportional to speed. Because the oil film is thin, the shaft tends to polish off babbitt aspirates (irregularities) at the bottom dead center and for as much as 30 degrees in the direction of journal rotation.

233-5.15.2 Scraping a bearing to obtain a uniform blued contact is undesirable. It destroys the bearing arc by producing a bearing surface with the same curvature radius as the journal. When the journal and bearing have the same curvature radius, the clearance over the arc is zero, preventing the oil film from forming and causing the bearing to have no load capacity. Scraping to blend a generous clearance at the wings or parting line into the bottom 60 degree contact area is also undesirable because it shortens the active bearing arc, raises the running temperature of the bearing, and reduces the minimum oil film thickness.

233-5.15.3 Since the attitude angle of the bearing (that is, the location of the point of minimum film thickness) usually exceeds 30 degrees at full power, in an area relieved by scraping, the shaft is forced to run at its worst operating point. Such operation is undesirable.

233-5.15.4 Use scraping to accomplish the following:

- a. Blend or smooth the edges of all oil grooves as required to produce a smooth junction, but only over narrow areas, such as at a chamfer.
- b. Remove high spots anywhere on the bearing surface, but only to reduce them to match the surrounding surface profile.

233-5.15.5 Modern day diesel engines use precision bearings. Consult the applicable NAVSEA Technical Manual, PMS, TRS and **NSTM Chapter 244, Propulsion Bearings and Seals**.

233-5.16 GEARS

233-5.16.1 Gears should not be renewed merely because of initial pitting of teeth. If the wearing area on the teeth show that alignment is correct, the gears can be used until wear and backlash becomes excessive for the service required, or the pitting extends to the point of possible tooth failure. In certain cases, gear tooth pitting does not continue after the wearing surfaces are well worn in following the first few hundred hours of operation. Such gears may be retained in service, provided all operating requirements are met and the gear is inspected at regu-

lar intervals. Particular attention should be given to the tightness of a gear on its shaft because loose gears cause early failure. In addition, inspect for cracking and chipping of the teeth. For further information consult the applicable NAVSEA Technical Manual, PMS, and TRS.

233-5.17 TIMING

233-5.17.1 It is absolutely essential that the engine be correctly timed in accordance with the applicable NAVSEA Technical Manual and PMS. Any deviation from the timing instructions will result in loss of power and be detrimental to the engine.

233-5.18 GOVERNORS

233-5.18.1 When normal governor adjustments do not give the response desired, the hydraulic governors and mechanical governors should be removed and sent to a repair activity for cleaning, overhaul, and recalibration. A spare governor should be on hand or provided so the engine can be operated during governor overhaul periods and PMS procedures.

233-5.19 PUMPS

233-5.19.1 The provisions of **NSTM Chapter 503, Pumps**, apply in general to engine pumps. Pumps shall be checked for wear and corrosion at time of each overhaul in accordance with the applicable NAVSEA Technical Manual and PMS. Weep holes on some pumps assist the operator to determine seal integrity. When the operating fluid drips or runs from the weep hole, seal failure is evident and replacement is required.

233-5.20 COUPLINGS AND UNIVERSALS

233-5.20.1 Small boat engine couplings and universals shall be visually inspected daily prior to engine operation. Ensure that no excessive run out exists and that all fasteners or locking devices are secure. When propulsion engine vibration is experienced, alignment, coupling and universals should be inspected in accordance with the applicable NAVSEA Technical Manual and PMS.

233-5.21 CRITICAL SPEEDS AND VIBRATION TORSIONAL DAMPERS

233-5.21.1 **CRITICAL SPEEDS.** Engines shall not be operated at or too close to any destructive critical speed because the resulting vibrations will cause serious engine damage. Critical speed ranges for each specific engine design shall be passed through as quickly as possible when changing engine speed. Detailed information concerning critical speed ranges is included in the applicable NAVSEA Technical Manual. Tachometers should be marked in red to show any critical speed ranges so the engine speed may be kept out of the critical ranges.

233-5.21.2 **TORSIONAL VIBRATIONS.** Every engine crankshaft has torsional vibrations which are caused by the firing pulses of the cylinders. A torsional vibration is a periodic motion twisting in alternately opposite directions of the crankshaft about its longitudinal centerline. Normally, the vibrations are damped out because vibration energy is consumed in twisting the shaft. Every particle of matter has one or more natural frequencies which will excite it. When the engine's power pulses excite a natural crankshaft frequency, it is called a resonant or critical vibration.

233-5.21.2.1 When applying an engine to a specific application, the manufacturer should determine mathematically that the combination of crankshaft, flywheel, and driven machinery will be free of critical vibrations or provide a means to control critical vibrations. The greatest crankshaft stresses created by critical vibrations alone are normally in the crankpin or crankshaft cheek area. Each manufacturer sets the limit on the permissible stresses due to critical vibration.

233-5.22 REDUCING OR ELIMINATING TORSIONAL VIBRATIONS

233-5.22.1 FLYWHEELS. All diesel engines deliver power as series of pushes on the crankshaft that causes a twisting motion of the crankshaft. The flywheel limits instantaneous fluctuations in crankshaft speed during sudden changes of load.

233-5.22.2 GENERAL. The flywheel is an energy storage device that uses the inertial effect (resistance of a weight to a change in motion) of a heavy disk (flywheel) to maintain the speed of the engine between the power pulses.

233-5.22.3 ATTACHING FLYWHEEL TO CRANKSHAFT. One of the three following methods is usually used:

- a. Split hub flywheel.
- b. Tapered shaft and hub.
- c. Flange connections.

233-5.22.3.1 The flywheel shall be tightly and securely fastened to the crankshaft and positioned and aligned so that the runout on the flywheel is within the manufacturer's specification. An out of alignment flywheel can create a severe imbalance in the rotation of the crankshaft and seriously damage major engine components.

233-5.22.4 FLYWHEEL MAINTENANCE. Consult the applicable NAVSEA Technical Manual and PMS for specific maintenance and repair.

233-5.22.5 COUNTERWEIGHTS. On some crankshafts counterweights balance the off-center weight of the individual crank and thereby balance the centrifugal forces created by the rotation of the crank. On some crankshafts part of the web of the crankthrow extends beyond the main journal to form or to support the counterweights. The counterweights use inertia the same way the flywheel does: to reduce the pulsating effect of the power pulses in the engine.

233-5.22.5.1 On some crankshafts the counterweight is integral with the crank webs. On others it is a separate piece secured to the webs with bolts or by welding. [Figure 233-5-2](#) shows typical modern counterweight assemblies. When counterweights are fitted to the crankshaft as separate assemblies, they shall be securely fastened. If counterweights are removed from the shaft for any reason they shall always be replaced in the same position, to maintain the dynamic balance of the shaft. Match marking the shaft web and the counterweight with punch marks before disassembly is recommended.

233-5.22.5.2 Counterweight assemblies shall be fastened to the crankshaft in accordance with the manufacturer's specification because, if improperly secured, they can loosen. As the counterweight rotates with the crankshaft,

a centrifugal force pulls the counterweights away from the cranks. Gravity, also, will tend to shift them back and forth as they move from one side of the shaft to the other. Because the centrifugal force reduces the contact pressure of the counterweight and the crankshaft web, if there is any freedom (clearance) at all the counterweight will move. Although the movement may be slight at first, the clearance will gradually increase as the counterweight continues to move (possibly causing pounding) until there is danger of breaking the hold down studs or unscrewing the nuts. If this happens, the counterweights can be thrown off, and the engine will be seriously damaged because of the weight and the severe imbalance of the crankshaft.

233-5.22.6 VIBRATION DAMPERS. Another alternative is a system to absorb the energy of vibration and, in this way, reduce the magnitude of crankshaft vibration and stresses. [Figure 233-5-3](#) shows a vibration damper which is attached to a free end of the crankshaft.

CAUTION

Do not use vibration damper as a leverage point for thrusting the crankshaft. Do not pry on the engine vibration dampener.

233-5.22.6.1 Viscous Type Vibration Damper. The vibration damper consists of a hollow housing that contains a free or floating flywheel. The small clearance between flywheel and housing is filled with a viscous silicone fluid. As the crankshaft vibrates and carries the housing with it, inertia tends to cause the flywheel to turn at a more constant speed. The resulting relative motion causes high shearing action in the silicone fluid and the energy is dissipated as heat. Thus, the flywheel is connected to the crankshaft through the fluid film and any instantaneous speed change is resisted by drag of flywheel inertia acting through the fluid film. The effect is to dampen all the crankshaft torsional vibrations. This type damper would reduce the stresses created throughout the complete speed range. The viscous type damper shall be replaced at engine overhaul, or when the dampener housing is dented or warped.

233-5.22.6.2 Gear Type Vibration Damper. The gear type vibration damper is often called a hydraulic damper, see [Figure 233-5-4](#). It consists of a spider gear with external teeth and an intermediate ring with internal teeth. As pressurized lube oil is supplied to the assembly, the spider gear drives the intermediate ring, which actually floats. Damping action is provided by strategically placed vent holes drilled in the system and designed to stabilize the intermediate ring as quickly as possible.

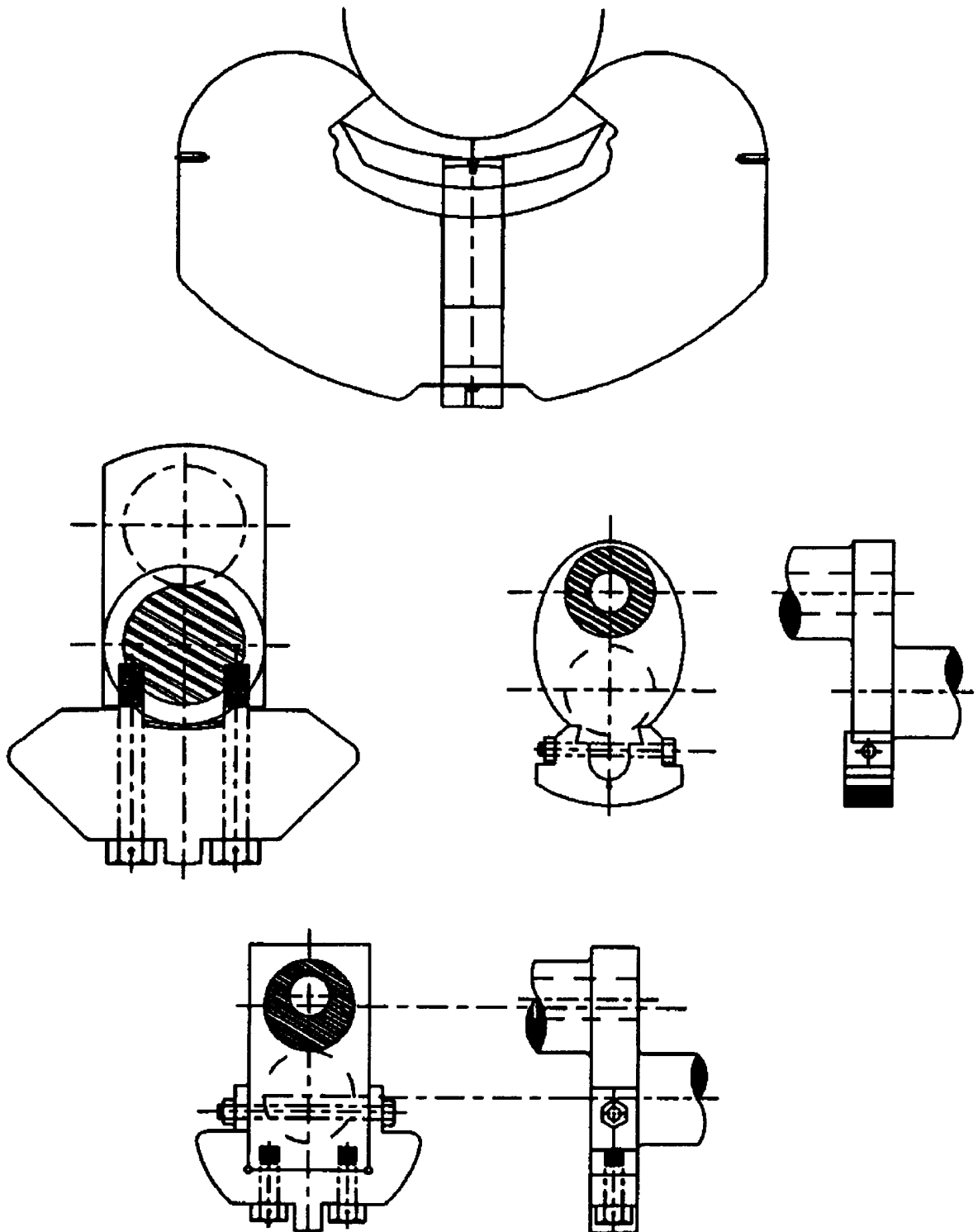


Figure 233-5-2. Typical Counterweight Assembly

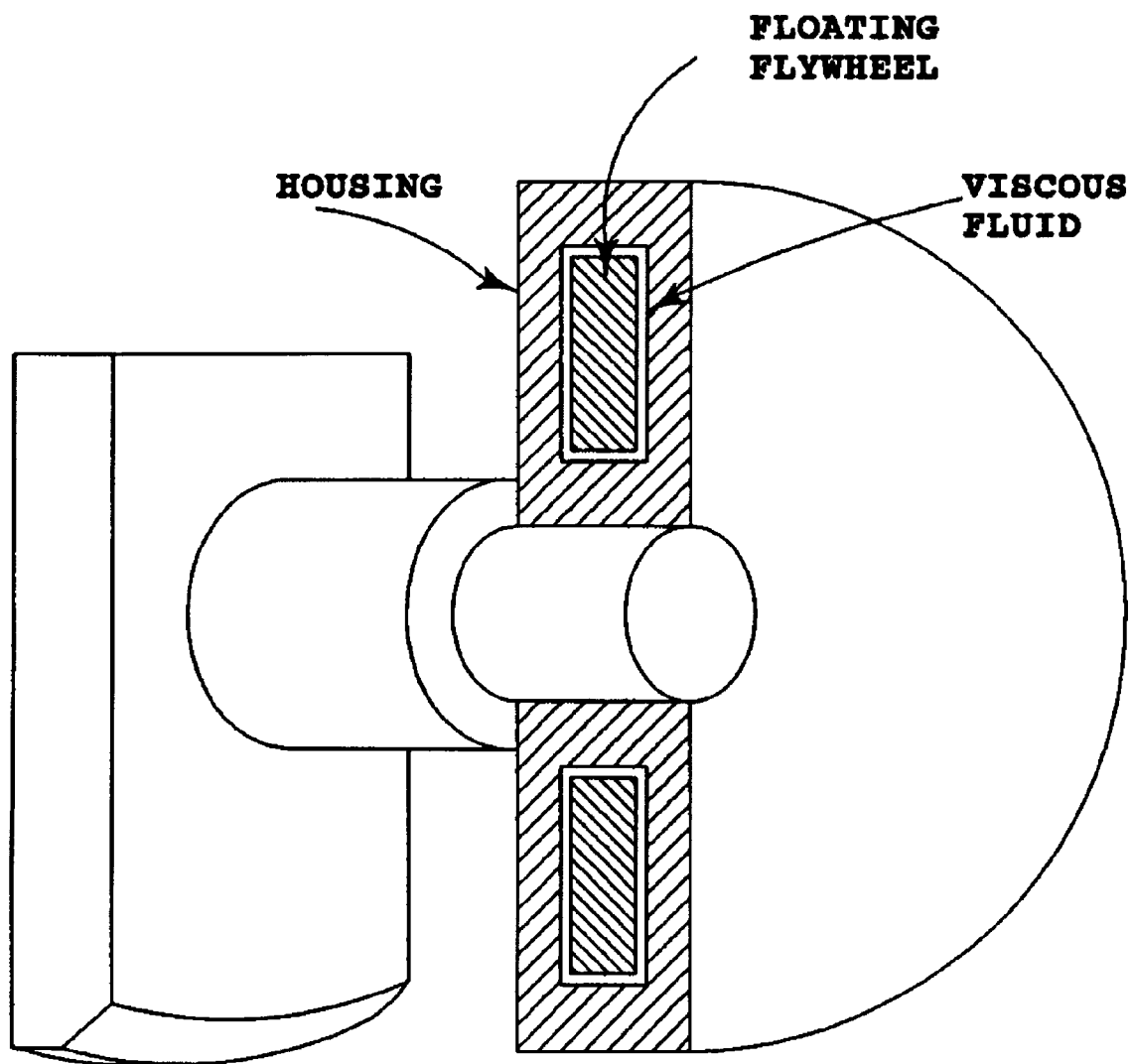


Figure 223-5-3. Vibration Damper on Free End of Crankshaft

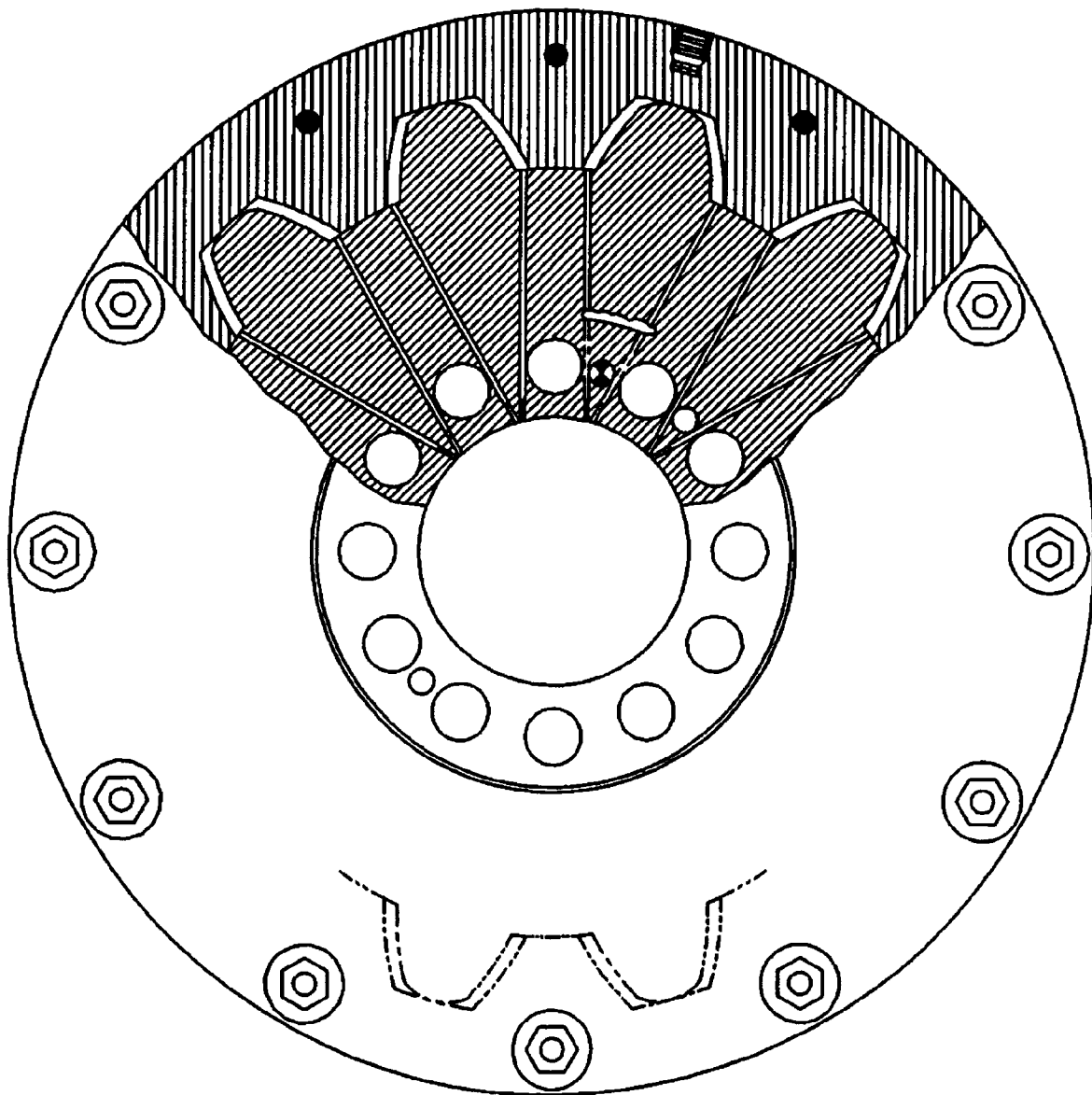


Figure 223-5-4. Gear Type or Hydraulic Type Vibration Damper

233-5.22.6.3 Pendulum Type. A pendulum damper consists of two or more symmetrically located, heavy steel segments or balances suspended so that they can swing in the plane of rotation, as does a pendulum. The weight of the segments and the length of the links are selected so that the natural frequency of the swing of the elements is equal to the frequency of the shaft system vibrations that should be damped out. During undisturbed rotations of the shaft, centrifugal force keeps the pendulum weights at the greatest distance from the axis of rotation. When the shaft starts to vibrate, the weights begin to swing, and they will be periodically drawn nearer the shaft axis. The work of bringing the pendulums closer to the axis against the resistance of centrifugal force is derived from the energy put into the shaft when it starts to vibrate. The work thus reduces this energy and dampens out, or at least considerably reduces, the angle of torsional vibration of the shaft. In actual construction the pendulums are suspended not on links, but on pins inserted through holes drilled in the sectors and in the housing. They are slightly larger than the pin diameter. Their action, however, is the same as that of the links. The Fairbanks Morse opposed piston engine uses damper weights mounted on pins to obtain the same effect.

233-5.22.6.4 Harmonic Balancer. Another type of torsional vibration damper, sometimes called a harmonic balancer, is located on an auxiliary flywheel on the front of a crankshaft driven by flexible leaf springs. The

vibrating energy in this case is dissipated by the friction of the leaves of the spring's inelastic couplings between the crankshaft and the main flywheel. The leaves serve to damp out some of the torsional vibration. This kind of damper usually operates in lubricating oil, which dampens the vibrations with its viscous friction and also carries away the heat generated. Similarly, hydraulic couplings or fluid drives also damp out and prevent the transmission of torsional vibration between the crankshaft and the driven load.

233-5.23 VIBRATION DAMPER MAINTENANCE

233-5.23.1 Consult the applicable NAVSEA Technical Manual and PMS for preventative and corrective maintenance.

233-5.23.2 An inoperative damper may produce rapid failure of bearings or gears connected to it. Long term, a fatigue failure of the crankshaft will occur. Engine driven pumps are usually on the free end of the engine and severe critical vibrations may damage them. Normally, viscous vibration dampers are changed at every engine overhaul period if the time period is not specified by the applicable NAVSEA Technical Manual, TRS or PMS.

233-5.23.3 When a vibrating engine is encountered, the alignment of the drive to driven unit immediately becomes suspect, and shall be checked before the vibration damper is condemned.

233-5.24 ENGINE ALIGNMENT

233-5.24.1 Correct alignment shall be maintained internally between the crankshaft main bearing bores, and their bearings. Correct alignment shall be maintained between the engine, generator, reduction gears, shaft coupling or any other driven equipment. Condition of alignment shall be checked at the original machinery installation; after engine overhaul; when engine blocks are lifted or separated from sub-base (foundation), repairs to foundations, collision, grounding and after each undocking or any condition that may effect the alignment of the engine or driven equipment.

233-5.24.2 To avoid duplication of efforts, whenever the engine is cast loose from the generator or shaft coupling, realignment shall be accomplished only after the ship is waterborne and with normal trim and load conditions. This procedure eliminates the possibility of aligning the machinery when the abnormal stresses of drydocking distort the hull and machinery foundation. Regardless of the machinery condition, alignment shall not be checked or realigned until a minimum of 48 hours after undocking.

NOTE

Specific procedures for alignment for each application see the applicable NAVSEA Technical Manual and original installation drawings.

233-5.24.3 The use of shims to correct minor deficiencies in diesel engine installation alignment is an accepted practice in both commercial and military service. The shims shall withstand loads imposed by the weight of the engine package and ships motions as well as mechanical vibration. Excessive deformation of shims can cause loss of bolt preloading. Only composition three shims, corrosion resistant steel, per MIL-S-22499 up to 0.050 inch thick are acceptable for use with marine diesel engines and their driven equipment. Most high shock installations use hand fitted steel chocks. Shims shall not be used in high shock installations to fit the steel chock to the foundation or the engine.

NOTE

For specific instructions for the use of shims in engine alignment see the applicable NAVSEA Technical Manual and the original installation drawings.

NOTE

Epoxy chocks (resin type) are not normally authorized for shipboard diesel engines. Check ship installation drawings to determine the approved type of mounting.

233-5.24.4 On large diesel engines, improper main bearing bore misalignment may be found using a crankshaft deflection gage or by indications of wear in the main bearings. Any indications of misalignment shall be verified by the use of a mandrel. Readings shall be taken on all of the main bearing bores and analyzed. Misalignment between drive and driven equipment is discovered through the use of a crankshaft deflection or strain gage at the drive end crankthrow. If out of specification, alignment is indicated in the main bearing bores, the problem may be corrected by pressing, welding and reboring or a combination of two or more repair methods. Refer to [paragraph 233-5.26.3](#) for additional information. Misalignment of drive and driven units is corrected by realignment.

233-5.24.5 The alignment of main bearing bores of small engines is usually checked with the crankshaft and bearing inserts removed from the engine, and the bearing caps torqued in place. The bearing bores can then be checked for alignment, using a mandrel. If serious misalignment is indicated, the most practical solution may be to replace the block.

233-5.24.6 Alignment of the engine and driven equipment is checked, not realigned by a crankshaft deflection readings taken at the crankthrow nearest the coupling. Alignment of a generator set usually is accomplished by moving the generator about until it is properly aligned and installing new chocks and or shims between the generator and its base to maintain correct alignment. When main propulsion diesel engines and couplings are found to be misaligned, the coupling should first be correctly aligned with the drive shaft. The engine is then moved about until it is properly aligned with the coupling and the engine is secured in this position. Detailed alignment procedure and allowable limits recommended for any particular installation of any specific make and model engine usually can be obtained from the applicable NAVSEA Technical Manual and drawings applicable to that installation. When this information is not adequate, additional information can be obtained on a case basis from NAVSEA.

233-5.25 CRANKSHAFT DEFLECTION

233-5.25.1 The crankshaft of any large diesel engine is one of its most expensive parts, both to purchase and to install, however the effort and time required for its periodic inspection is minimal compared to the crankshaft's importance. An engine running at 500 RPM will rotate over 60 million times a year, and it is clear that every precaution shall be taken to protect the crankshaft from all unnecessary forces that might induce a fatigue failure. The crankshaft should transmit into rotary motion the forces developed in the cylinder and this is understood and allowed for in the original design. The manufacturer assumes the operator will maintain the shaft in a straight condition so the shaft is not subjected to additional bending loads which add to the normal shaft stresses. If the shaft does not lay in the main bearings, it will be subjected to flexing while turning. Various points on the shaft alternate between compressive and tensile stresses once each revolution. If these stresses are too high, the shaft will ultimately break just as a wire will break if bent severely back and forth many times.

233-5.25.2 [Figure 233-5-5](#) is a sketch of exaggerated crankthrow flexing through one-half revolution on an out-of-line crankshaft. The stresses produced by this bending are usually greatest in the crankweb along plane A-A. The most critical point is at B where stresses are magnified by the stress concentrating tendency of the inside corner. The crankpin fillet at B is alternately placed in tension and then in compression. Obviously, if the crankshaft centerline were straight the shaft could be rotated without flexing of crankwebs or developing bending stress at the fillet.

233-5.25.3 The universal method for checking crankshaft alignment is using the crankshaft deflection gage. The gage is a specially adapted dial indicator which fits between the crankwebs and directly reads the flexing motion of the webs as the crankshaft is slowly turned. The gage dial reads web spreading or closing in 1/1000 of an inch graduations. The dial face is graduated with numbers increasing on each side of zero with the numbers on the left side marked + (plus) and on the right side marked - (minus). If the pointer moves toward the plus side of zero, the webs are opening. Movement toward the minus side indicates that the webs are closing.

233-5.25.4 The magnitude of the indicator pointer swing depends on where the gage is located on the webs. The engine manufacturer may specify this as the dimension X shown in [Figure 233-5-6](#) or may provide center punch marks on the webs. The general industry standard is that the dimension X equals 1/2 the engine stroke. Locating the gage further out than the recommended X dimension results in higher indicated deflection values. It is of the utmost importance to locate the crankshaft deflection gage at the NAVSEA, PMS and manufacturer's recommended location.

WARNING

When the crankcase is opened for inspection or repairs, the starting system shall be de-energized and or deactivated and tagged out of service in accordance with the current shipboard and or shore tag out instructions.

233-5.25.5 Crankshaft deflection readings shall always be taken with the cylinder pressure indicator valves open and the engine prelubed, if prelube pump is available. The engine shall be completely assembled. This includes cylinder heads, pistons, connecting rods, and other parts. Without the strain of the weights of these parts and that of highly stressed bolts, the engine will not assume its natural shape, and accuracy of deflection readings will be affected. The barring device normally does not need to be disengaged when reading the deflection gage.

233-5.25.6 The crankshaft cannot be turned a full revolution with the connecting rod and crankshaft deflection gage in place. On some engines with the deflection strain gage in place, the crankthrow can not be brought to near bottom dead center because of interference with the connecting rod, crankpin and other parts.

233-5.25.7 If a crankshaft is not punched marked it shall be punched marked to take and record deflection readings. The punch marks shall be equal distance from the crankshaft (X dimension) to ensure the deflection strain gage is parallel to the crankshaft.

233-5.25.8 The center punch marks shall be small and made with a very sharp punch. A good tool for making this mark is the needle valve from a scrapped fuel injector.

NOTE

The accuracy of deflection readings may be reduced if the marks are too large or not made with a sharp punch.

233-5.25.9 When taking deflection readings the engine and the crankshaft deflection gage should be at the same ambient temperature. Readings are taken normally when engines are cold.

233-5.25.10 The crankpin should be near the bottom center. Ensure gage needle movement is smooth. Preload the crankshaft deflection gage 1/3 of its travel. Place the gage between the webs and adjust the gage to provide sufficient tension to hold the gage snugly in place. Twirl the gage, using the thumb and forefinger, and zero the gage. Repeat this procedure until the pointer remains on zero.

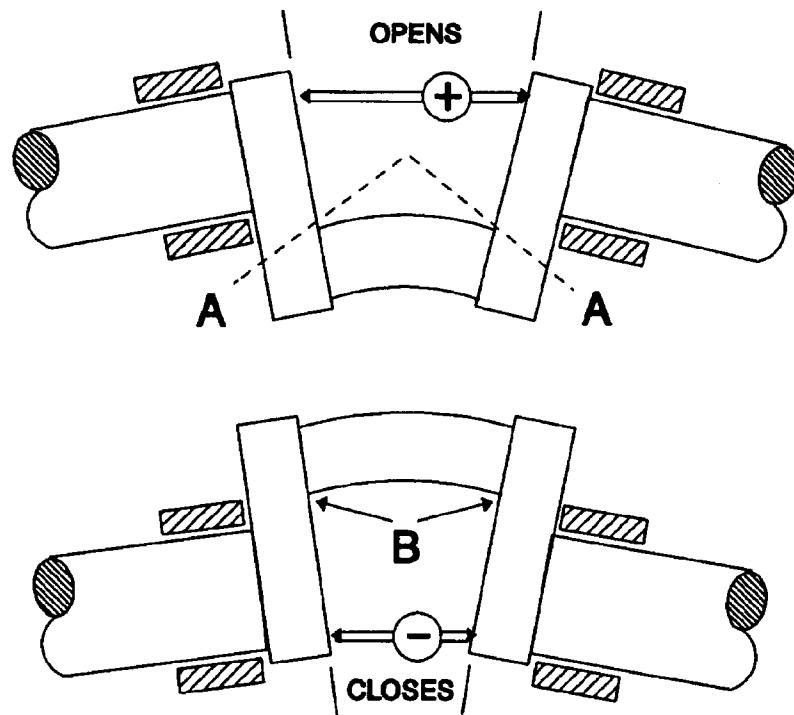


Figure 233-5-5. Out-of-Line Crankshaft Deflection

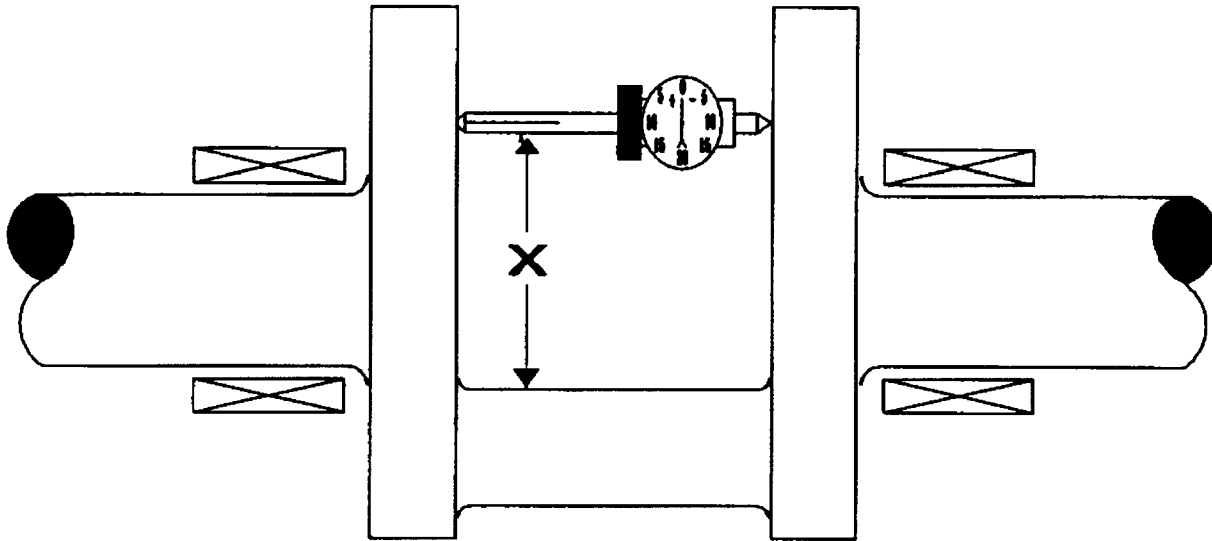


Figure 233-5-6. Mounting the Crankshaft Deflection Gage

233-5.25.11 When the crankshaft deflection gage maintains a constant zero reading, rotate in the reverse direction of normal engine rotation, stop before hitting the connecting rod. Bump in the normal direction of rotation and re-zero the crankshaft deflection gage. Slowly turn the crankshaft in the direction of rotation and stop when the crankshaft deflection gage is in position 2 as shown in [Figure 233-5-7](#). Record any changes in pointer deflection as a + (plus) or - (minus) reading. The magnitude of deflection is usually expressed in quarter-thousandths such as 1/4, 1/2, and 3/4 rather than the more cumbersome 0.00025, 0.00050, or 0.00075.

233-5.25.12 Repeat until readings at all five of the positions shown in [Figure 233-5-7](#) have been taken and recorded for each position. Reverse the direction of rotation back to position 1 as shown in [Figure 233-5-7](#). Bump in the direction of rotation to reconfirm zero. If the reading is not within 1/4 thousandths of zero, a complete set of readings shall be retaken. In each instance the 1 and 5 readings should be nearly the same; readings should be repeated if 1 and 5 vary by more than 1/2 thousandths. Usually the most important reading is at position 3 because it indicates the following:

- a. Bearing wear
- b. Condition of foundation
- c. Position of outboard bearing.

233-5.25.13 The drive end, the No. 3 position (bottom) shall show the sign of - (minus) negative, this is due to the weight of the flywheel and coupling. The exception to this is Alco model 251 diesel engines, it is zero in this position. A different method is used.

233-5.25.14 When a complete set of crankshaft deflection readings are taken and recorded, the relative shape of the crankshaft can be sketched as a function of the 3 position readings. [Figure 233-5-8](#) shows three hypothetical sets of deflections illustrating relative crankshaft shapes. The illustration shows the crankshaft in the up position or at top dead center where the 3 readings are taken.

233-5.25.15 For a crankshaft with all + (plus) deflection readings, the webs are open and the crankshaft is convex upwards; - (minus) deflections close the webs and the crankshaft is convex downward, and so forth. Sketching the shaft in this way helps to visualize the shape of the shaft and aids in determining cause of the deflection.

233-5.25.16 PMS and the applicable NAVSEA Technical Manual provide guidance and specifications for crankshaft deflection readings. If not available, this information should be obtained from NAVSEA.

233-5.25.17 A rule-of-thumb used for deflection is 0.0001 inch for each inch of engine stroke other than the last throw on the flywheel end. Actually, the amount of deflection the crankshaft will tolerate is dependent on the design and material used. A fairly limber shaft with large fillets may be able to sustain rather large deflections whereas a more rigid shaft with small fillets would have to be held within much closer tolerances. Study the results carefully because changes in deflection patterns may be caused by worn bearings, foundation deformation, loose foundation bolts and perhaps other reasons that should be investigated. By use of regular deflection tests and bearing inspections, there is no reason why the crankshaft will not last the life of the engine.

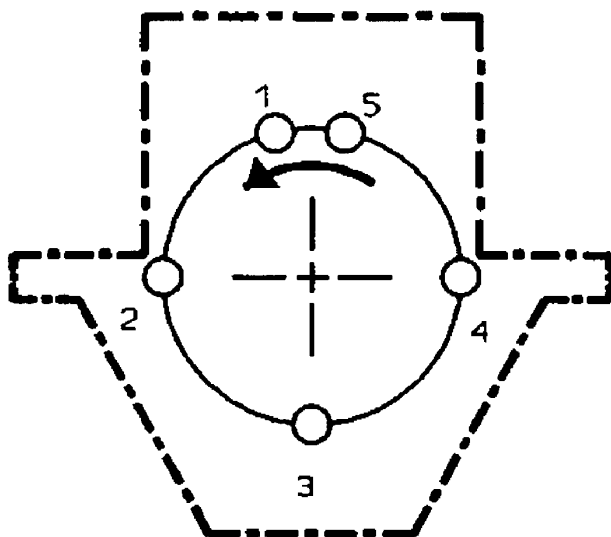
233-5.26 CRANKCASE, FOUNDATION AND FRAME REPAIR

233-5.26.1 Whenever large diesel engines, such as Fairbanks Morse Model 38D8-1/8, Alco, EMD or other large engines are stripped of parts for a general overhaul, the frames can be inspected by the magnetic particle method in the highly stressed area of the block. Highly stressed welds are defined as follows:

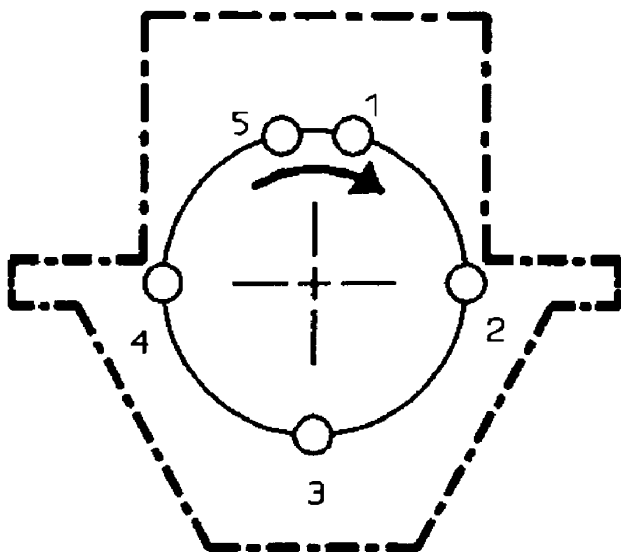
- a. Welds between bearing blocks (upper and lower) and the main vertical frames.
- b. Welds between decks and main frames.
- c. Welds of ribs and gussets in vertical drive housing and flywheel and frame.

NOTE

Never use magnetic particle Non Destructive Test (NDT) on Isotta Fraschini (IF) diesel engine blocks or other components.



COUNTERCLOCKWISE



CLOCKWISE

Figure 233-5-7. Angular Position for Taking Crankshaft Deflection

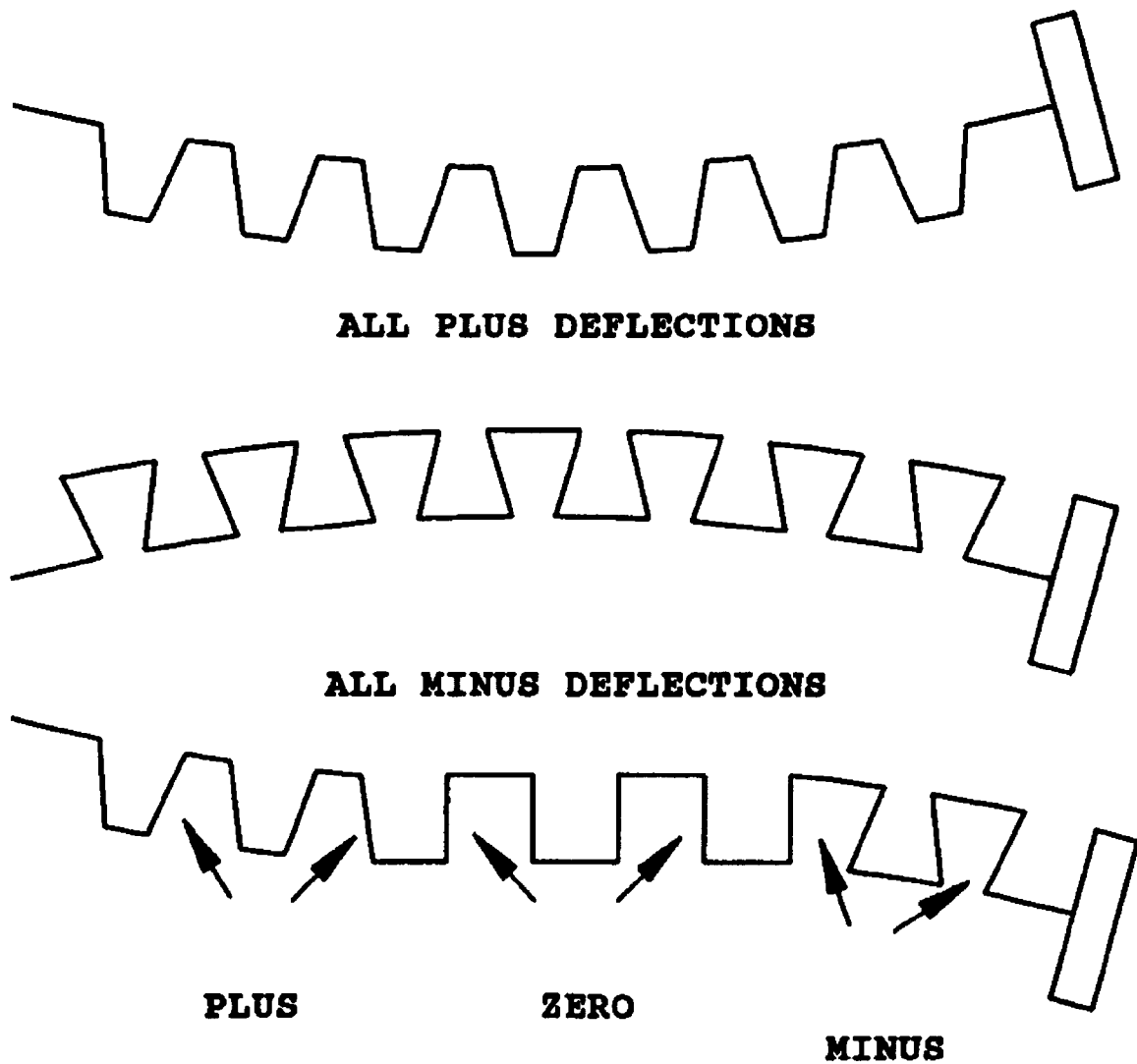


Figure 233-5-8. Sketches of a Relative Crankshaft Shape

233-5.26.2 The repair welding of any cracks or defects revealed shall be in accordance with MIL-STD-278 and the applicable instruction manual for the equipment.

233-5.26.3 For crankcase foundation repair instructions for all engines, including non-magnetic engines, see the applicable NAVSEA Technical Manual or contact NAVSEA.

233-5.27 WELDING ON ROTATING MEMBERS

233-5.27.1 Welding on moving or rotating equipment shall not be undertaken unless facilities to maintain and check alignment comply with the fabrication document requirements. If emergency conditions require work on such items where adequate facilities and equipment are not available, a record of details of the work that was

accomplished and the extent of noncompliance with the applicable fabrication document shall be made. This information shall be appropriately recorded as a departure from specification.

233-5.28 WELDING RESTRICTIONS AND CHROME PLATING OF CRANKSHAFTS

NOTE

Chrome plating of crankshaft journals is not authorized.

233-5.28.1 No welding shall be accomplished on any diesel engine without specific approval of NAVSEA. No welding shall be accomplished on any gears, such as main propulsion units, clutch and coupling assemblies, and similar components essential to the mission of the ship without approval of NAVSEA. No welding shall be accomplished on cast or nodular iron without an approved specific procedure for the material and application from NAVSEA.

233-5.28.2 When requesting approval for welding, the exact location, reason for the welding, description of the welding procedure to be used, and related information shall be forwarded to NAVSEA with the request.

233-5.28.3 Crankshaft and engine block weld repairs require formal acceptance and approval by NAVSEA . Welding and block repair requests shall be forwarded to NAVSEA.

233-5.29 DIESEL ENGINE MOUNTED PIPING MATERIALS

CAUTION

Do not use copper tubing or pipe for gage lines in fuel or lube oil systems.

233-5.29.1 Diesel engine mounted piping is defined as piping attached to the engine in the solid line portion of the jacketwater, seawater, fuel oil, and lubrication oil piping diagrams in the engine technical manual. All other diesel engine installation related piping is defined in the applicable NAVSEA Technical Manual, or is governed by the provisions of MIL-STD-777, **Schedule of Piping Valves, Fittings, and Associated Piping Components for Naval Surface Ships**. Flexible hoses shall conform to S6430-AE-TED-010, Technical Directive for Piping Devices, Flexible Assemblies. Flexible hose may be used in conjunction with hard piping as needed. Flexible hose offers ease of installation by field activities and can provide satisfactory service with annual inspections in accordance with PMS and S6430-AE-TED-010. Submarine applications refer to NAVSEA 0924-062-0010, Submarine Material Certification Requirements Manual for the Submarine Safety Program.

- a. Diesel engine fuel and lube oil system gage lines shall be in accordance with [paragraph 233-5.29.1](#) and [subparagraph 1](#).
 1. Corrosion resisting steel (CRES) conforming to MIL-P-1114 or ASTM A376 (Grade 304L or 316L) shall be used. CRES is nearly inert in contact with petroleum based fluids, has superior mechanical properties, and can provide good service for the life of the ship.

SECTION 6.

CORROSION PREVENTION

233-6.1 PROTECTION AGAINST CORROSION FOR ENGINES TEMPORARILY INACTIVE

233-6.1.1 Diesel engines in active service require jacketwater cooling system protection against corrosion, scale and cavitation. NSTM Chapter 220, Volume 3, Corrosion and Contamination Control for Diesel Engine Cooling Water Systems and Planned Maintenance System (PMS) provides detailed procedures for jacketwater cooling system protection. The fuel and the lube oil fluids in the systems provide the required protection against corrosion. Diesel engines onboard ships and submarines inactivated for 9 months or more require protection against corrosion. Engines inactive for less than 9 months also require protection against corrosion but to a lesser degree. The jacketwater chemistry and the fluids in the lube oil and fuel systems provide this protection.

233-6.2 ENGINES TEMPORARILY INACTIVATED

233-6.2.1 Engines temporarily inactivated for less than 9 months during ship repair or overhaul, shall be suitably protected against sand, dust, corrosion, weather, industrial environment and accidental damage by working personnel. Engine jacketwater coolant need not be drained, however cooling water inhibitor chemistry shall be maintained in accordance with NSTM Chapter 220, Volume 3 and PMS. The diesel engine should be pre-lubed and barred over every 30 days to maintain an oil film on internal components and assemblies.

233-6.2.2 Engines removed from a ship or small craft, shall be moved to an inside secured storage area ashore. Engine openings such as air intake and exhaust, or inlet connections to the ship air or fluid systems shall be covered by use of a gasket and a bolted blank flange. Openings may be covered and taped, when blank flanges are not practical. Exterior metal surfaces should be inspected for chipping or scrapes and the engine should be painted where necessary. A simple umbrella type covering such as a tarpaulin is adequate. The engine should be positioned in an area which affords protection against excessive airborne contaminants, wetting, pilfering, or damage by warehouse activity.

CAUTION

Engines containing demagnetized parts, such as Isotta Fraschini (IF) shall be stored in accordance with the applicable NAVSEA Technical Manual to preserve low magnetic signature.

233-6.3 PRESERVATION OF DIESEL ENGINES TEMPORARILY INACTIVATED ONBOARD U.S. NAVY COMMISSIONED SHIPS, SMALL CRAFT AND BOATS

NOTE

Ships in overhaul for 9 months or more must follow the procedure outlined in paragraph 233-6.3.3. Engines temporarily inactive for less than 9 months must follow the procedure outlined in paragraph 233-6.3.3, steps 25 through 32.

233-6.3.1 GENERAL. The following instructions are issued as general guidance to be amplified as the detailed design of the particular engine and application requires.

233.6.3.1.1 GENERAL PRECAUTIONS

- a. Ensure all tag-out procedures are in accordance with current shipboard instructions.
- b. De-energize/deactivate starting circuit/system and tag "Out of Service."
- c. Ensure generator circuit breaker is open; tag circuit breaker and circuit breaker control switches "Out of Service", if applicable.
- d. De-energize sump heater circuit and tag "Out of Service", if applicable.

233-6.3.2 MATERIALS REQUIRED

- a. MIL-L-21260 Grade 10
- b. MIL-L-21260 Grade 30
- c. MIL-L-21260 Grade 40
- d. Lint free rags
- e. Masking tape
- f. Heavy cardboard or plywood 1/4-inch
- g. Tags, waterproof
- h. Pump/heater unit to circulate the jacketwater system. Heating unit must be capable of maintaining a diesel jacketwater temperature of 105-110° F while circulating.

233-6.3.3 APPLICATION OF MIL-L-21260

CAUTION

Lint-free rags shall be used for cleaning lube oil and fuel oil system.

NOTE

Refer to NSTM Chapter 593, Pollution Control, for proper disposal instructions.

1. Thoroughly drain the lube oil system(s). Drain the engine, governor, generator bearing, marine gear, and any other ancillary (i.e. rocker arm) sump(s) if separate from engine oil system, as applicable. Drain the cooler and all low points of the system. Discard lube oil.
2. Remove the lube oil filters, clean the interior of filter housing and renew the elements.
3. Remove and clean the lube oil strainer and the interior of strainer housing, replace or clean the strainer element, as applicable.

CAUTION

When the engine sump is open, care shall be taken that no foreign material is allowed to enter the lube oil sump. Never leave an open engine unattended. Before the engine lube oil sump or any part of the engine is closed, a complete inspection shall be performed to ensure that no foreign material, rags, tools, etc, is left in the lube oil sump.

4. Clean and wipe the lube oil sump using lint free rags only.
5. Fill the lubricating oil system(s) to normal capacity for operation with MIL-L-21260 Grade 40.

NOTE

MIL-L-21260 Grade 30 may be used as an alternative with approval from NAVSEA.

NOTE

Maintain cleanliness and store the original preservation oil containers for reuse when off-loading preservation oil.

6. Isolate the engine fuel oil supply and return headers such that preservation oil can be circulated through the engine fuel oil system. Drain fuel oil from the engine.

CAUTION

Use only MIL-L-21260 Grade 10 in the fuel system.

7. Remove the fuel filters and the fuel strainer elements, clean the strainer and the interior of the filter and strainer housing. Reinstall the strainer and new filter element(s). Fill the housing(s) with MIL-L-21260 Grade 10 before reassembly.
8. Disconnect the fuel oil line at the supply pump or any other convenient place in the suction side of the fuel pump.
9. Install a temporary suction connection to take a suction from a 5 gallon (minimum size) container filled with MIL-L-21260 Grade 10 to the normal fuel supply header.
10. Disconnect the return line from the fuel supply header so that the return fuel discharges to a 5 gallon container or larger.
11. Prime fuel oil system. Prime/prelube the lube oil system. Vent filters and strainers, as applicable.

NOTE

Recheck the lube oil level(s) after priming/prelubing to ensure that the sump(s) is/are at the proper level(s).

CAUTION

Observe the lube oil pressure. If the lube oil pressure is not observed within 10-15 seconds secure the engine.

NOTE

Engine oil pressure may be higher or lower from normal when using MIL-L-21260 lube oil.

NOTE

The engine will smoke excessively due to the preservative oil in the fuel injection system.

12. Start the engine in accordance with normal operating procedures or **Engineering Operating Sequencing System (EOSS)**.
13. Let the engine idle for 5-6 minutes.

CAUTION

Do not let engine run out of preservative supplying the fuel system. Ensure that the fuel suction line stays submerged in the preservative.

14. Raise the engine speed to mid range of the normal operating speed.
15. Observe the fuel oil return line. Stop the engine in accordance with **EOSS** or approved operating procedure when a clear supply of the preservative is observed for 5 minutes at the fuel return line.
16. Reconnect the fuel supply and return lines for normal operation.

NOTE

It is not required to drain the lube oil and fuel oil systems of preservatives. The engine can be operated with MIL-L-21260 preservative oil for 2 hours at 90-100% load in an emergency situation. The fuel oil system should be aligned for normal operation and re-preserved upon completion of engine operations

17. If preservation oils are to be drained from engine, proceed to [step 18](#). If draining of the preservation oils is not required, proceed to [step 24](#).

NOTE

Preservative oil, if not dirty or contaminated may be reused to preserve other engines. Extreme care shall be used to keep the preservative compound clean. Use a 25-micron or better filter when removing preservation oil for reuse. Use original container and ensure it is clean.

18. Let the engine stand for 12 hours to allow all the preservation oil to drain down.

19. Thoroughly drain the lube oil system(s). Drain the engine, generator bearing, marine gear, and any other ancillary (i.e. rocker arm) sump(s) if separate from engine oil system, as applicable. Drain all the low points of the system and coolers.

CAUTION

Do not bar, jack, or roll engine over. Disruption of the protective film will occur.

20. Drain the lube oil filter and the strainer housing. Do not wipe interior of the housings. Filter elements need not be removed.
21. Drain the fuel filter and strainer housing. Do not wipe interior of housing. Filter elements need not be removed.
22. Do not drain the governor. Tag the governor stating that it is filled with MIL-L-21260 Grade 30 or 40.

NOTE

Governor shall be flushed and filled in accordance with PMS and the applicable NAVSEA Technical Manual before reactivating engine.

23. Tag the engine to indicate that the diesel engine has been treated with a corrosion preventative compound. The tag shall include the following information:
 - a. The date the engine was laid up.
 - b. The statement that the engine is not to be turned over because disruption of the protective film will occur.
 - c. The statement that the procedure as specified in [paragraph 233-6.5](#) shall be followed before placing the engine in service.
 - d. The statement that the lubrication, cooling, and the fuel systems shall be filled before operating.
 - e. Any special instructions for preservation or startup.

WARNING

Do not discharge treated cooling water into inland waters and harbors.

24. Install a temporary pump and heating unit to allow circulation of the diesel jacketwater system for testing and treatment, if applicable. Heating unit must be capable of maintaining a diesel jacketwater temperature of 105-110° F while circulating.
25. Ensure the jacketwater treatment is in accordance with NSTM Chapter 220, Volume 3 and PMS.
26. Clean oil and dirt from drive coupling, governor and fuel linkages, and other exposed unpainted machined surfaces.
27. Wipe or spray MIL-L-21260 Grade 40 on the drive coupling, governor and fuel linkage and all exposed unpainted machined surfaces.
28. Shut applicable diesel seawater isolation valves and tag: "Caution. DSW system in freshwater lay-up. Shut applicable vent and drain isolation valves prior to opening this valve."
 - a. Drain saltwater from diesel engine system.

CAUTION

Ensure fresh water source is equipped with back flow preventer to preclude cross contamination of potable water supply with seawater.

- b. Break saltwater connections as necessary to flush fresh water through saltwater system in reverse direction to normal flow.
 - c. Drain saltwater system when flushing is completed.
 - d. Makeup saltwater connections.
 - e. Attach plastic tubing to a connection at a high point of the system with a hose clamp; lead tubing up a minimum of 6 inches above high point of system then route to drain funnel or bilge.
 - f. Fill seawater system with fresh water. Vent all components to ensure full of fresh water.
 - g. Continue to fill seawater system with fresh water to bring water in tubing a minimum of 3 inches above system high point. Mark water level for inspection to detect leakage. Verify water level remains stable; add water as necessary.
 - h. Remove fresh water supply hose.
 - i. Place tag on water level inspection tubing noting date and name of individual placing system in fresh water lay-up. Tag to include statement "Initial freshwater lay-up"
29. Shut exhaust overboard valve or cover exhaust discharge opening.
30. Disconnect diesel engine intake air supply and exhaust piping, blank off with fire retardant plywood or other suitable material to prevent entrance of foreign material.
31. Tape and cover all other openings (i.e. air intake, crankcase breather, air box drains, and dipstick) to prevent entrance of dirt, foreign material and water. Install protective cover of fire retardant plywood to front of gage board.
32. Cover engine and outboard drive unit with fire resistant paper when unit requires direct protection from paint chipping, sandblast dust, and paint spray.

233-6.4 PRECAUTIONS DURING PRESERVATION

NOTE

Specific tags are needed for different locations, governor sump etc., where different preservatives have been used.

WARNING

When the compounds are used in confined spaces, adequate ventilation shall be provided; avoid open flames and sparks when spraying flammable liquids. All normal safety precautions for combustible material shall be applied.

233-6.4.1 GENERAL. Used preservative compounds may be added to and reused for the same purpose. Extreme care shall be exercised to keep the compounds clean. Use a 25-micron or better filter when removing preservation oil for reuse. Use original container and ensure it is clean.

1. Circulate and test the jacketwater system in accordance with NSTM Chapter 220, Volume 3 and PMS.
2. Circulate MIL-L-21260 preservative oil in engine every 6 months to maintain and reestablish the protective film. (Engines temporarily inactive for 9 months or more.)
3. Pre-lube and bar engine every 30 days to maintain oil film on internal components and assemblies if preservation oil has not been used. (Engines temporarily inactive for less than 9 months)
4. Inspect Water Level in Diesel Seawater System weekly.

NOTE

Diesel seawater system must be drained and returned to lay-up 2 weeks after original lay-up and monthly thereafter. Omit steps 4.b. (1) through 4.b. (6) if not applicable.

- a. Inspect tag on water level inspection tubing for date of lay-up or last drain and return to lay-up.
- b. Drain and return to lay-up as follows:
 - (1) Drain diesel seawater system.
 - (2) Attach plastic tubing to a connection at a high point of the system with a hose clamp; lead tubing up a minimum of 6 inches above high point of system then route to drain funnel or bilge, if not already accomplished.

CAUTION

Ensure fresh water source is equipped with back flow preventer to preclude cross contamination of potable water supply with seawater.

- (3) Fill seawater system with fresh water. Vent all components to ensure full of fresh water.
- (4) Continue to fill seawater system with fresh water to bring water in tubing a minimum of 3 inches above system high point. Mark water level for inspection to detect leakage. Verify water level remains stable; add water as necessary.
- (5) Remove fresh water supply hose.
- (6) Line-out, using single line, name and date on tag on water level inspection tubing; note current date and name of individual returning system to lay-up.

NOTE

Omit steps 4.c. through 4.d. when system is drained and returned to lay-up.

- c. Inspect water level in plastic tubing attached to a connection at a high point of the system; water level should be near original mark provided drain connections or sea valves are not leaking.
- d. If water is not visible in plastic tubing, refill system and inspect for leakage.

NOTE

Water level increase caused by atmospheric changes can be resolved by extending plastic tubing. Water level increase caused by leaking seawater valve(s) will continue to rise indicating need for corrective action.

- e. If water is running from plastic tubing, extend plastic tubing and remark water level; notify work center supervisor if water level continues to rise.

233-6.5 STARTING DIESEL ENGINES AFTER PRESERVATION WITH MIL-L-21260

1. Check the preservative tags for special instructions.
2. Remove fire resistant cover from engine and outboard drive unit, if applicable.
3. Remove tape or sealing material from engine openings (i.e. air intake, crankcase breather, air box drains, dipstick), if applicable. Remove protective cover from gage board, if installed.
4. Remove blank covers from the engine intake air supply and exhaust piping, if applicable, and inspect intake and exhaust systems to the best extent possible for foreign material.
5. Reconnect exhaust and intake piping to the engine, if applicable.
6. Remove water level indicating tubing from the seawater system.

WARNING

Do not discharge treated cooling water into inland waters and harbors.

7. Remove temporary diesel freshwater circulating pump and heating unit, if installed.
8. Check and verify that all other engine support systems are functioning properly and ready to support diesel engine operation.
9. Perform all applicable inactive equipment maintenance PMS related to start up or prolonged idleness.

NOTE

If engine was not treated with preservative oils/compounds, omit [steps 10.a.](#) and [10.b.](#)

10. Remove preservatives from engine.

NOTE

Preservative oil, if not dirty or contaminated may be reused to preserve other engines. Extreme care shall be used to keep the preservative compound clean. Use a 25-micron or better filter when removing preservation oil for reuse. Use original container and ensure it is clean.

- a. Thoroughly drain the lube oil system(s) of MIL-L-21260 preservative oil. Drain the engine, generator

bearing, marine gear, and any other ancillary (i.e. rocker arm) sump(s) if separate from engine oil system, as applicable. Drain all the low points of the system and coolers.

- b. Fill engine, generator bearing, marine gear, and any other ancillary (i.e. rocker arm) sump(s) if separate from engine oil system, as applicable, with the applicable new oil for the application, to normal operating level(s).

NOTE

Governor will have to be properly flushed after engine is operating in accordance with the applicable NAVSEA Technical Manual and PMS.

- c. Drain the engine governor and flush in accordance with PMS, if applicable. Fill with normal operating fluid.

CAUTION

When the sump is open, care shall be taken that no foreign material is allowed to enter. Never leave an open sump unattended. Before the sump or any part of the engine is closed, a complete inspection shall be performed to ensure that no foreign material, rags, tools, etc, is left in the sump.

- d. Remove inspection/access cover(s) to sump(s) and component(s), as required, to allow visual inspection of lube oil flow during priming/prelubing.
- e. Prime/prelube engine, generator bearing, marine gear, and any other ancillary (i.e. rocker arm) lube oil systems, if separate from the engine oil system. Inspect engine, generator bearing and any ancillary system oil flow indicators, and components, if applicable, to the best extent possible to ensure that lube oil is reaching all moving visible parts, i.e., main bearings, connecting rod bearings, rocker arm assembly, crankshaft, turbocharger, blower bearings, etc.
- f. Install inspection/access cover(s) to sump(s) and component(s).

NOTE

Recheck the lube oil level(s) after priming/prelubing to ensure that the sump(s) is/are at proper level(s).

CAUTION

Observe the lube oil pressure. If the lube oil pressure is not observed within 10-15 seconds, secure the engine.

NOTE

The engine will smoke excessively for a short period of time due to the preservative oil in the fuel injection system.

11. Start the engine in accordance with normal operating procedures or Engineering Operating Sequencing System (EOSS), observe pressures and temperatures. Operate engine for 2 hours with jacketwater temperature at or near 160° F.

NOTE

When preservative oils were used, lube oil viscosity may be out of specification, drain and replace 20% of the sump(s) lube oil capacity with the applicable new oil for the application and sample. Repeat once.

CAUTION

If lube oil viscosity is out of specification after the second lube oil drain and replace operation, secure diesel engine and determine cause of lube oil contamination.

12. Vent all system components to ensure fluid systems are free of air, as applicable.
13. Obtain an oil sample(s) every 15 minutes for the first hour of operation.
14. Obtain a jacketwater sample and test in accordance with NSTM Chapter 220, Volume 3 and PMS.
15. Observe all operating parameters for normal operation, if any abnormal conditions exists, the engine shall be stopped and the abnormality investigated to find and correct the cause.
16. If all conditions are normal, conduct performance test in accordance with current PMS requirements.
17. If the performance test results are satisfactory, return engine to normal service.
18. After completion of performance test, submit an oil sample for **Navy Oil Analysis Program (NOAP)** .

233-6.6 ENGINES TO BE STORED

233-6.6.1 An engine being placed into the Navy Supply System to be stored until issued as a replacement or government furnished equipment to ship builders requires extensive preservation and or packaging. This requirement includes new engines, overhauled engines, and used engines which are to be held for future overhaul or use, for periods exceeding 12 months shall follow the procedures outlined in [paragraphs 233-6.11 through 233-6.15](#).

233-6.7 NEW ENGINES

233-6.7.1 New engines should be received from the supplier completely preserved and packaged in accordance with MIL-E-23457 and MIL-E-24455. New engines need no maintenance except periodic inspection of desiccants.

233-6.8 OVERHAULED ENGINES

233-6.8.1 Overhauled engines which will not be operated for 12 months or more shall be preserved and packaged in accordance with Engines, Preparation for Shipment and Storage of, Type IV, MIL-E-0010062, as supplemented by Engines, Diesel, Propulsion and Auxiliary, Naval Shipboard, MIL-E-24455 and MIL-E-23457.

233-6.9 USED ENGINES

233-6.9.1 Used engines which are to be stored indefinitely awaiting overhaul, or engines installed in ships which are to be inactivated, require extensive corrosion preventative measures. The engines should be completely drained of all engine fluids and corrosion resistant compounds applied. All openings, such as air intake and exhaust headers and fluid system flanges, should be covered and taped. Engines destined for shed storage, shall be packaged in accordance with Method II of MIL-P-116, which calls for a floating waterproof bag with desiccant. If a replacement engine is received in a reusable container such as a plywood box, encased zipper type plastic bag, or hermetically sealed metal can, the replaced engine should be stored in these containers after preservations have been applied.

233-6.10 INITIAL RECEIPT INSPECTION

233-6.10.1 New or stocked engines furnished to contractors or repair facilities are usually opened for an initial receipt inspection. Unless the engine is to be installed immediately, careful opening and resealing procedures are necessary. The exterior box and engine container should be opened in accordance with instructions stenciled on the container or received from the shipping activity. After the inspection is completed, any disturbed preservative should be repaired, the container repaired as required, and resealed. The plywood box should be closed to prevent damage during storage. The inspection should be performed in a sheltered area. In no instances should the package remain open in a salt-spray or an industrial environment.

233-6.11 CORROSION PREVENTION COMPOUNDS

233-6.11.1 The specification for corrosion resistant compounds are covered by Compound, Corrosion Preventive, Solvent Cutback, Cold Application, MIL-C-16173, and Lubricating Oil, Internal Combustion Engine, Preservative, MIL-L-21260. The compound covered by MIL-C-16173 specifications are for fluid solutions at ordinary room temperatures. At temperatures approaching 1.7° C (35° F) or below, MIL-C-16173 compounds may become excessively viscous, and solid constituents tend to separate from the solution, resulting in stratification. This may be corrected by warming or agitating the compounds or both.

CAUTION

The flashpoint of MIL-C-16173 is approximately 37.7° C (100° F). It shall therefore be applied cold.

CAUTION

MIL-C-16173 corrosion preventive compound is injurious to rubber and electrical insulation such as varnishes, tapes, and fabrics, and should not be permitted to come into contact with them at any time.

233-6.11.2 MIL-C-16173 corrosion prevention is intended for use on metal surfaces as authorized in this section. It is not to be used on surfaces directly adjacent to electrical insulation.

CAUTION

All grades of MIL-C-16173 corrosion preventative and petroleum solvent cleaners are flammable materials. Continued exposure of personnel to the vapors given off by the compound may be a health hazard. Suitable precautions shall be taken to reduce the hazards.

233-6.11.3 The compounds covered by MIL-C-16173 are essentially a combination of two major elements: a solvent which evaporates, and a blend of semisolids that are left behind as a thin, tenacious protective film. These films are essentially nondrying, except for Grade 1, which does dry hard in about 4 hours; even Grades 2, 3 and 5 may eventually harden until it is extremely difficult to remove these compounds (particularly after long exposure periods) from small orifices or areas through which the removers cannot readily flow.

233-6.12 GRADES OF COMPOUNDS AND DESCRIPTION

233-6.12.1 MIL-C-16173 has five grades of corrosion preventive compounds. Selection for use of any of the compounds depends on the degree of weather protection to be afforded the stored engine. All grades readily wet a metallic surface and will, upon evaporation of the solvent, form a coating which is continuous, noncracking, nonvolatile when dried and, except for Grade 4 which is transparent, are easily discernible by their brown or black color. These compounds are sprayable above 4.4° C (40° F) and are sufficiently dry within 4 hours to permit handling without injury to the film or personnel involved. The five grades of compounds are as follows:

CAUTION

Do not use Grade 1 in lubrication or cooling systems.

- a. Grade 1. An asphalt base compound intended for use on ferrous or nonferrous metal surfaces subjected to all weather conditions. It may also be applied to equipment stored under cover when required. The film dries hard to the touch in about 4 hours, and maximum protection is obtained about 2 days after application. Removal of the film upon activation is usually not required.

CAUTION

Do not use Grade 2 in water jackets.

- b. Grade 2. This amber colored compound is for use on ferrous and nonferrous metals when extended protection is required for interior or exterior surfaces of machinery and equipment not exposed to the weather. After the solvent evaporates, the resulting film remains soft for about 4 months. It may be recoated 12 hours after application. This compound mixes readily with lubricating oils, but very long periods of flushing may be required if the compound has aged over an extended period of time. Removal after short periods is usually readily accomplished with either petroleum solvents or vapor degreasing compounds.
- c. Grade 3. This compound is intended for use on ferrous and non-ferrous metals. It leaves a very thin nondrying film upon evaporation of the solvent; its ingredients have a greater affinity for metals than water has, thus giving water displacing characteristics to the film. For this reason Grade 3 is used in water contact areas such

as in the interiors of water jackets. A disadvantage of Grade 3 is that it will not be completely removed by the circulation of steam or hot water, particularly after it has aged for a long period of time. Additional coats may be applied about 6 hours after initial application, however, this provides no particular benefit.

- d. Grade 4. This is a transparent, tack free coating suitable for general purpose indoor or limited outdoor preservation. This coating will not mix with lubricating oil and shall not be employed on oil wetted surfaces. It is intended for use where a transparent film is desirable and where removal with Stoddard's solvent is important.
- e. Grade 5. This is much like Grade 3, and is used for the same purposes. The reason for using it is ease of removal upon activation. Low pressure steam or hot water are usually entirely effective. This property makes Grade 5 particularly valuable for magnesium or aluminum surfaces where boil out with an alkaline solution would be destructive to these metals.

233-6.12.2 The compounds covered by MIL-L-21260 are Grade 10, 30 and 40 nondrying lubricating oils with a corrosion inhibitor additive. These compounds are used in all systems for new procurement, long term storage engines. They are most effective when Method II packing (the sealed vapor bag) is used. These compounds also would be effective when the engine room is dehumidified. To prevent damage to fuel injection components during preservation and de-preservation, only Grade 10 of MIL-L-21260 should be used.

233-6.13 APPLICATION OF COMPOUNDS

233-6.13.1 APPLICATION. The compounds are applied by spraying, dipping, flushing or brushing, as appropriate. Spraying and dipping are the preferable methods, because these methods produce more uniform coatings, which are neater in appearance, and cracks and crevices are penetrated. Normally it is not necessary to disassemble the apparatus for application to interior surfaces, as this can be accomplished by flushing or by fogging (spraying) through access openings. A high-pressure spray, creating a fog, will satisfactorily coat the interior of gears, cylinders and blocks. For equipment with inaccessible interior surfaces, the fog or spray has a tendency to follow the normal vapor paths, and remote areas may not be coated with preservative. Take proper precautions to ensure the compressed air is dry and that water is not being mixed with the preservative. Dipping is best for small articles, such as repair parts, tools, bolts, and nuts. Flushing shall be used for the interior of lubricating systems to protect shaft journals.

233-6.13.2 APPLICATION PRECAUTIONS. While means of application may differ, depending upon physical characteristics of machinery or equipment concerned, individual procedures in each case shall be such as to bring the compound into intimate contact with the metal to be protected, so that a continuous film is formed. It is also important that all excess compound be drained. Failure in this respect may result in leaving pools of compound, which in time solidify and can cause damage when operation of machinery is resumed. While a single unbroken film will provide adequate protection, it is advisable to apply two coats, to ensure thorough coverage. It is important that application to weather exposed surfaces be made in good, dry weather, which shall include the drying time between coats. Inclement weather, within 12 hours of outside applications, will necessitate the reapplication of compound preceded by measures to ensure a clean dry surface. If an article preserved with the compound is touched by the bare hand, corrosion may occur unless the part is cleaned where touched and the compound is reapplied. Rotating machinery shall not be jacked or barred after preservation; to do so damages the preservation coating. If the machinery is operated or rotated, the compound shall be reapplied to wearing surfaces.

233-6.14 PRESERVATION OF DIESEL ENGINES BY MOTORING**CAUTION**

Ensure engine does not start while motoring.

233-6.14.1 The following instructions are a general guide to be amplified as the detailed design and application of the particular engine requires. Ensure that a sufficient quantity of the appropriate grade of compound is brought into intimate contact with the metal to be protected. The compound shall displace any remaining trace of dirt, water, or oil and leave a continuous protective film on the surfaces. The excess compound is drained off to prevent the formation of stagnant pools which may, with age, tend to solidify and complicate putting an engine back into service. When engines are preserved and stored in a dehumidified space, no external preservation need be applied. Definitions of the preservatives are as follows:

- a. MIL-L-21260, Grade 10, 30, or 40, for all fluid systems and internal surfaces of diesel engines.
- b. Appropriate grade of MIL-C-16173 for engine water, lubricating systems and external surfaces of all engines.

233-6.14.2 If motoring or operation on air is feasible, the procedural steps are as follows:

1. Thoroughly drain the engine of all water, lubricating oil, and fuel oil.
2. Remove the oil cartridge type filter elements and clean the interiors of all strainer and filter housings or containers.
3. Install new cartridge type filter elements.
4. Flush the engine seawater system with MIL-C-16173, Grade 3 or 5 preservative.
5. Drain the jacketwater system and fill with MIL-C-16173, Grade 3 or 5 preservative by connecting a supply line to the drain connections for the system. Cause the system to overflow from expansion tank vent to ensure that all surfaces are coated with the preservative. All ferrous parts, such as shafts, gear, flanges, or studs should be properly treated.
6. Fill the lubricating system to normal capacity with MIL-C-16173, Grade 2 preservative so the pump can take a full suction and, in wet sump type engines, a good splash effect from the crankthrows can be attained.
7. Disconnect the suction fuel line and circulate MIL-L-21260, Grade 10 through the injectors, booster pumps, filter, and fuel lines. Spray or brush preservative on internal surfaces of fuel tanks.
8. Relieve the cylinder compression by opening the indicator cocks if installed.
9. Drain the lubricating oil and cooling water from the cooler for the engine reverse and reduction gear systems.
10. Treat all filters and strainers in the reduction and reverse gear lubricating oil system, in the same manner as described in [paragraphs 233-6.15, 233-6.15.1 and 233-6.15.2](#), for the engine system.
11. Flush the reverse and reduction gear lube oil cooling system with preservative.
12. Fill the reverse and reduction gear lubrication system to normal capacity with preservative.

CAUTION

Ensure the engine does not start while motoring.

13. Motor the engine at a speed sufficient to circulate the compound through the engine systems. Several minutes should be adequate, but visual checks should be made to ensure that the compound is reaching all points. If an electrical starting motor is used for turning the engine, runs should be limited to 30 seconds each to prevent overheating the motor; at least 2 minutes should elapse between runs.
14. Remove the inspection and access covers and spray all gears, rockers, linkages, cams, and push rods with MIL-C-16173, Grade 2 preservative while the engine is being motored. Spray all surfaces, bearings, linkages, and working parts of dry type clutches and reverse mechanism. (No harm will be done if compound comes in contact with friction surfaces.)
15. Drain excess compound from all systems, paying particular attention to the low spots, pockets, and exposed piping in which the compound could collect. Save drained compounds for future use.
16. Reconnect all the lines for normal operation.
17. Replace all the inspection, handhole, and valve covers.
18. Seal all openings into the engine to prevent entrance of dirt or water.
19. Using MIL-C-16173, Grade 2 compound, spray or brush over all external unpainted areas. If the engine is to be exposed to the weather, Grade 1 compound should be used for this purpose. When engines are preserved and stored in a dehumidified space in a warehouse or aboard ship, no external preservative need be applied.
20. Tag the engine to indicate that the fluid systems have been treated with a rust preventive compound. The tag shall include the following information:
 - a. The date the engine was laid up.
 - b. The statement that the engine is not to be turned over until ready to be put into operation because disruption of protective film will occur.
 - c. The statement that the procedure as specified in [paragraphs 233-6.17](#) through [233-6.17.2](#) shall be followed before placing the engine in service.
 - d. The statement that the lubrication, cooling, and fuel systems shall be filled before operating.
 - e. Any special instructions for preservation or startup.

233-6.15 LAYING UP DIESEL ENGINES WHEN MOTORING IS NOT POSSIBLE

233-6.15.1 Where it is not practical to motor an engine over by air, starting motor, or motorized generator to treat it with thin film rust preservative compound, procedural steps for application areas are as follows:

1. Drain the fuel and water systems completely.
2. Fill jacketwater cooling system with preservative MIL-C-16173, Grade 3 or 5 by connecting a supply line to the drain connection for the system. Cause the system to overflow from expansion tank vent to ensure that all surfaces are coated. Drain compound from the system and close the drain connection.
3. Fill the seawater system with MIL-C-16173, Grade 3 or 5 preservative in the same manner as is done with

the jacketwater cooling system. If installed in a ship, ensure that the seawater inlet and overboard valves are locked closed and do not leak. All ferrous parts such as shafts, gears, flanges, or studs should be properly treated.

4. Drain the lubricating oil system. Remove the oil filter elements, clean the strainers, and wipe down the interiors of the strainers and filter housings. Install new filter elements.
5. Disconnect a pipe fitting in the lubricating oil piping system and connect the discharge side of a separately driven pump to the disconnected engine lubricating oil system fitting.
6. Use the separately driven pump to circulate the preservative MIL-C-16173, Grade 2 throughout the lubricating oil system of the engine while the engine is being jacked or barred over. The discharge pressure of the separately driven pump should approximate the operating pressure of the engine lubrication oil system. Where possible, access plates should be removed to determine that the compound reaches all points of the lubricating oil system.
7. The interior surfaces of the engine should be sprayed with preservative. This should include all internal parts such as the crankcase, connecting rods, crankshaft, and lower cylinder bores.
8. Remove the inspection and access covers and spray all gears, rockers, linkage, cams, and push rods with preservative while the engine is being jacked or barred over with the turning gear. Spray all surfaces, bearings, linkages, and working parts of dry type clutches and reverse mechanism. (No harm will be done if compound comes in contact with friction surfaces.)
9. Circulate MIL-L-21260, Grade 10 through injectors, fuel lines, booster pump, and filters. Drain all the excess compound from the fuel system.
10. Spray or brush preservative on the internal surfaces of fuel tanks and drain off any accumulation.
11. Disconnect the separately driven pump, installed in [step 5](#).
12. Remove excess preservative by draining compound from all the low points of the system.
13. Replace the access plates and covers using new gaskets.
14. Seal all openings into engine to prevent entrance of dirt or water.
15. Using MIL-C-16173, Grade 2 compound, spray or brush over all external unpainted areas. If the engine is to be exposed to the weather, Grade 1 compound should be used. When engines are preserved and stored in a dehumidified space in a warehouse or aboard ship, no external preservation need be applied.
16. Tag individual areas of the engine to indicate that the fluid systems have been treated with a rust preventive compound. The tag shall include the following information:
 - a. The date the engine was laid up.
 - b. The statement that the engine is not to be turned over until ready to be put into operation (because disruption of the protective film will occur).
 - c. The statement that the procedure as specified in [paragraphs 233-6.17](#) through [233-6.17.2](#) shall be followed before placing the engine in service.
 - d. The statement that the lubrication, cooling, and fuel systems shall be filled before operating.
 - e. Any special instructions for preservation or startup.

233-6.15.2 The compounds used have excellent flushing properties. When treating a dirty engine, remove any foreign matter which may collect on screens and strainers before considering the engine properly treated and ready for future service.

233-6.16 STARTING DIESEL ENGINES AFTER PRESERVATION WITH COMPOUNDS

WARNING

The total volume of the combustion space is small and an excess of compound may result in a hydraulic lock and cause serious damage when the engine is started. The engine shall be turned by hand through several revolutions prior to any start attempt with the pressure indicator valves open if installed.

233-6.16.1 Prior to operating an engine which has been out of service and treated with rust preventive compounds, the engine shall be hot lube oil flushed in accordance with [Section 8](#).

233-6.16.2 The procedure to be followed in removing rust preventative compound from the cooling system is:

WARNING

All chemicals and solutions shall be turned into the Public Works Officer or Public Works Center at any Naval Shipyard or other Naval Industrial Facility for proper disposal.

CAUTION

This procedure shall not be used in systems containing aluminum.

1. Fill the jacketwater cooling system with water meeting the requirements of [paragraph 233-10.8](#) and operate the engine for 5 minutes to ensure that no leaks are present in the cooling system.
2. Secure the engine and drain the cooling system.
3. Fill the cooling system with sodium metasilicate (NSN G6810-00-664-7062) and a 0.1 percent wetting agent (NSN G7930-00-282-9699) solution in water meeting the requirements of [paragraph 233-10.8](#). This solution may be made up by adding sodium metasilicate in a concentration of 16.7 pounds of sodium metasilicate and 0.83 pounds (approximately 1/2 pint) of wetting agent for each 100 gallons of solution required.
4. Start the engine and operate for 2 hours, keeping the solution temperature at 71.1° C (160° F).
5. Drain the cleaning solution from the cooling system.
6. Flush four times with water meeting the requirements of [paragraph 233-10.8](#) to remove all traces of cleaning solution. Disconnect several hose connections and examine waterside surfaces to ensure that they are clean.
7. If the engine is not clean, reassemble, fill with cleaning solution and repeat the cleaning and flushing operations.

NOTE

Run engine for 5 minutes during each flushing. The lubricating oil and the coolant should be checked for contamination after a few hours of operation, then drained and replaced, if necessary.

233-6.17 TREATMENT AFTER IMMERSION IN SEAWATER

233-6.17.1 Machinery and equipment which has become wet and is likely to become damaged due to corrosion can be saved if prompt corrective measures are taken. Wetting of the metal may be due to the equipment having fallen overboard, flooding of the space in which it is installed or stowed, contamination of a lubricating oil system with water because of failure of a heat exchanger or oil cooler on an engine, or any other cause from which a metal surface picks up sufficient water to initiate rapid corrosion.

233-6.17.2 MIL-C-16173 Grade 3 rust preventive compound is intended for displacing water and to inhibit further corrosion of machinery which has been submerged. Full advantage should be taken of the capacity of this compound to remove water from the surface of any wetted metal subject to corrosion.

233-6.18 IMMEDIATE REUSE FOLLOWING IMMERSION**NOTE**

In order to minimize engine damage from water contamination, it is critical to remove water and operate engine as soon as possible after contamination occurs. If it is suspected that water contamination occurred more than 24 hours prior to discovery, then a visual inspection of internal engine parts shall be conducted by a certified diesel engine inspector, if available.

233-6.18.1 If an engine, engine system or engine parts have good natural drainage, all that is necessary to remove the seawater is that they be dipped or thoroughly sprayed with MIL-C-16173, Grade 3 compound and allowed to drain. In a closed system such as the interior of an engine, the bulk of the water should first be removed by opening drains and pumping out all that can be reached. The crankcase should then be filled with the compound and the engine rotated, if possible. If a detached pump is at hand, the pump should be connected to help circulate the compound through the lubricating system to emulsify and blot up any water trapped in pockets. Cylinders should be treated through openings in the head by removing valves or injectors, whichever would be most expedient. The emulsion formed should then be pumped out and the salvage operations repeated until no water is detected in the compound removed from the engine. A second treatment is usually sufficient, even for complicated systems. Other parts of the engine, such as cam shafts, valve mechanisms, and gears should be similarly treated, using slushing, pumping, or spraying methods, whichever is best indicated.

233-6.18.2 Unless the equipment has been otherwise damaged or corroded prior to treatment, the equipment may be placed in service without additional disassembly, cleaning, or overhaul following the salvage operation. Operate the engine for 8 hours at 75-100 percent load to ensure elimination of all traces of water contamination. The residual film left on a mechanism is of a soft, waxy nature and will be absorbed without harmful effect in the normal lubricating process.

233-6.19 ENGINES AND PARTS FOR DELAYED REPAIR

233-6.19.1 Wetted equipment which is being prepared for delayed repair should be treated in accordance with [paragraph 233-6.15](#).

SECTION 7.

DIESEL FUEL OIL

233-7.1 FUEL SPECIFICATIONS

233-7.1.1 The only Navy diesel fuels authorized by NAVSEA for use in Navy shipboard main propulsion diesel engines, ships service diesel engine generators, emergency diesel engine generators, all small boats and service craft ashore and afloat are those conforming to MIL-F-16884, **Naval Distillate Fuel (North Atlantic Treaty Organization (NATO) Symbol F-76)** and commonly called **Diesel Fuel Marine (DFM)** and aircraft jet engine fuel meeting the requirements of **Grade JP-5 (NATO Symbol F-44)** of MIL-T-5624.

233-7.2 NAVAL DISTILLATE FUEL (DIESEL FUEL MARINE) (DFM)

233-7.2.1 Diesel fuels are of the light to medium distillation range with a high flash point of 60° C (140° F). Diesel Fuel Marine (DFM) is the primary fuel for Navy diesel engines and is recommended for use under normal conditions where readily available.

233-7.3 JET PROPULSION FUEL

233-7.3.1 Jet propulsion fuel (JP-5) is a kerosene type fuel with a high flash point 60° C (140° F). The use of JP-5 fuel instead of diesel fuel marine will usually increase fuel consumption by approximately 2 percent on a volume basis and exhaust temperatures will increase slightly.

NOTE

Diesel fuel marine (F-76) and Jet propulsion fuel (JP-5) may be combined in any proportion and used in diesel engines.

CAUTION

Jet propulsion fuel (MIL-T-8311) NATO Symbol F-34 (JP-8) shall not be used in Navy diesel engines due to the low flash point of 38° C (100° F).

233-7.4 ACCEPTABLE SUBSTITUTE FUELS

233-7.4.1 The NATO definition of an acceptable substitute fuel product is one that may be used in place of another product for extended periods of time without technical advice. The authorized acceptable substitute fuels for F-76, in order of preference, are JP-5 (NATO F-44), conforming to MIL-T-5624, NATO F-75, and Commercial Marine Gas Oil (MGO) (100-percent distillate, no residual) under a Defense Fuel Supply Center (DFSC) bunkers contract. MGO contracts for bunkers under naval regional contracting centers and Navy contracting departments are acceptable provided they comply with the NAVAL SEA SYSTEMS COMMAND purchase description and are 100 percent distillate containing no residuals. MGO is not considered an acceptable substitute for applications which involve long-term storage (6 weeks or greater), such as emergency diesel generators

on submarines, because MGO does not have a storage stability requirement as defined for F-76 in MIL-F-16884. Hence, the MGO taken onboard must be used immediately. For amplifying information refer to NSTM Chapter 541, Ship Fuel and Fuel Systems.

233-7.5 TEMPERATURE CONSIDERATION AND FUEL USE

233-7.5.1 Diesel fuel marine (MIL-F-16884) should be used whenever possible at temperatures above 0° C (32° F). At temperatures below 0° C (32° F) JP-5 (MIL-T-5624) is recommended. For amplifying information refer to **NSTM Chapter 541, Ship Fuel and Fuel Systems**.

233-7.6 FUEL CONTAMINATION

233-7.6.1 Fuels are generally delivered clean and free from impurities. The transfer and handling of fuel increases the danger of contamination with foreign material. The major contaminants are as follows:

- a. Water
- b. Rust
- c. Sediment
- d. Oil Soluble Soaps

233-7.6.2 Sediment and water in fuel causes accelerated engine wear, corrosion, erratic operation, gumming of injection equipment and power loss.

233-7.6.3 The presence of rust and sediment in diesel fuel can be detected by visual observation and testing. Water in diesel fuel can be detected by the cloudy appearance of the fuel oil or by the actual separation of the water from the oil during storage or testing.

233-7.6.4 Oil soluble soap contamination can be detected only by a laboratory ash analysis. The usual source of such contamination is the storage of diesel fuel in galvanized containers. Diesel fuel or JP-5 should not be stored in tanks or drums or allowed to pass through piping having galvanized surfaces that will come in contact with the fuel.

233-7.6.5 The tanks and fueling lines of the issuing activities and the tanks and lines of the receiving ships shall be checked as far as practical to ensure freedom from contaminants prior to fueling operations.

233-7.7 CENTRIFUGES, FILTERS AND COALESCERS

233-7.7.1 Freedom from contamination onboard ship can be obtained by the proper use of centrifuges, settling tanks, coalescers and filters in the engine fuel systems. Where installed, centrifuges and coalescers shall be used prior to the use of the fuel in an engine. Centrifuges and coalescers should be adjusted carefully and operated in accordance with the applicable NAVSEA Technical Manual, to ensure an efficient operation. The difference between the specific gravities of two different batches of fuel is often great enough to require a change in size of centrifuged discharge rings, ring dams and float assemblies from the use of DFM to JP-5 fuel. A centrifuge

shall be operated as a separator (with water seal) to remove water from the fuel being purified. Instructions regarding replacement of coalescer filter elements should be carefully followed.

233-7.8 SUPPLEMENTAL FUEL ADDITIVES

233-7.8.1 Supplemental additives are defined as products which are marketed as fuel conditioners, smoke suppressants, tune up compounds, top oils, break in oil, graphitizers and friction reducing compounds.

233-7.8.2 Diesel engines used in the U.S. Navy are designed and built in accordance with military specifications which require the finished product to perform satisfactorily using fuels which are manufactured to military specifications, MIL-F-16884 and MIL-T-5624. Diesel engines have been tested and approved using fuels conforming to these military specifications.

233-7.8.3 There is no real need for supplemental fuel additives. Their use may actually negate the effectiveness of the additive package manufactured into military specification fuels and cause damage to the diesel engine. In addition, the use of supplemental additives may mask a more serious engine problem.

233-7.8.4 After market supplemental fuel additive products shall not be used.

NOTE

Supplemental fuel additives do not include products which prevent or eliminate bacterial growth in diesel fuel and reduce the temperature at which fuel will flow (pour point depressants). Use these only as required.

NOTE

The Colt-Pielstick, model PC 2.5V, LSD-41 Class Main Propulsion Diesel Engine uses a special compound added to the fuel during run-in or break-in , this special compound is recommended and authorized. See the applicable NAVSEA Technical Manual.

233-7.9 SPRAY SHIELDS (FLANGE SHIELDS)

233-7.9.1 Spray shields shall be provided for flange joints (including simplex strainer flange covers and flanged valve bonnets in piping containing flammable fluids located above the floor plates. For further information refer to **NSTM Chapter 505, Piping Systems**, NAVSEA drawings 810-2117525, 803-2145518 and NAVSEA Technical Manual 0948-LP-102-2010, **Fuel and Lube Oil Strainer Safety Shield Design Guidance**.

233-7.10 PRECAUTIONS

233-7.10.1 The majority of engine casualties attributable to diesel fuel have been due to contaminants.

233-7.10.2 Precautions and regulations dealing with proper use, storage and handling of fuel shall be followed to ensure that engines obtain clean fuel of the proper grade and specification.

233-7.10.3 It is highly recommended to pressure test the fuel oil system and / or components , to the best extent possible, when they have been removed/replaced/repared prior to installation or engine operation to prevent lube oil contamination, fuel oil leaks, or fire hazards.

SECTION 8.

LUBRICATING OILS

233-8.1 INTRODUCTION

233-8.1.1 Lubricants are used primarily to reduce friction, dissipate heat, and prevent corrosion. Lubricants conduct friction generated heat away from bearings, gears and other motion parts, act as a seal to protect lubricated areas from contamination, and act as a carrier for materials such as rust preventatives, anti-friction agents, and other additives.

233-8.2 FRICTION REDUCTION

233-8.2.1 Whenever contacting surfaces of mechanical parts are in motion with respect to each other, a resisting force known as friction is created. Friction can be greatly decreased by using the correct lubricant for the specific application. Selection of a lubricant depends upon such factors as bearing and gear tooth pressure, operating temperatures, types of enclosures, and the nature and extent of contact between surfaces. Lubricants form a film between contacting surfaces, thereby separating the surfaces and reducing friction. Consequently, wear and seizing of parts are also reduced.

233-8.3 HEAT DISSIPATION

233-8.3.1 Friction generated heat shall be rapidly dissipated to prevent damage to equipment. Especially sensitive to damage are bearings, high speed gear trains, and other devices having relatively small surface areas in contact. Lubricant circulation systems are designed to dissipate friction generated heat.

233-8.3.2 Precautions shall be taken to avoid excessive heating caused by overfilling of the lube oil sump. An overfilled sump will result in the oil level contacting the crankshaft throws. The throws will agitate the lube oil causing aeration resulting in reduced lubrication and cooling. Excess lubricant can act as an insulating blanket around the moving parts, especially during high speed operation. Overfilling of the lube oil sump can also cause lubricants to overflow into, and damage, adjacent electrical equipment. The applicable NAVSEA Technical Manual and Planned Maintenance System (PMS) instructions specifying lubricants and lubrication procedures shall be followed to ensure optimum performance, reduce friction, and dissipate heat.

233-8.4 CORROSION PREVENTION

233-8.4.1 Preventing corrosion, particularly corrosion resulting from continuous exposure to a marine environment, is a major maintenance problem. The lubricant should accomplish the following:

- a. Remain on the surface to be protected under adverse conditions of pressure and temperature.
- b. Retard or prevent the formation of corrosion, particularly in the presence of moisture or seawater.

233-8.5 LUBRICATION SYSTEM REQUIREMENTS

233-8.5.1 Proper lubrication is vital to the operation of diesel engines. Neither the designed performance nor the designed overhaul intervals can be expected of machinery if proper lubrication practices are neglected. All rotating or sliding machinery surfaces in contact or close proximity shall receive a steady, sufficient supply of lubricant of suitable quality at the proper temperature. Contaminants such as dirt, moisture, corrosion products, and wear debris continually enter or are generated within the lubrication system, thus degrading the quality of the original lubricant. To ensure continued lubricant quality and quantity, the lubrication system shall provide for contaminant removal by filters, strainers, purification, heating or cooling, and replenishment or replacement of the lubricant.

233-8.6 GOVERNMENT SPECIFICATION LUBRICANT

233-8.6.1 GENERAL. Lubricants for shipboard machinery and equipment are described by specifications. These specifications establish the lubricant requirements and characteristics necessary to ensure satisfactory performance for the intended use.

233-8.6.2 MIL-L-2104 15W-40. MIL-L-2104, Grade MS/HDO 15W-40 is used in certain fleet engines installed on the MCM-1 class ships, MHC-51 class ships and SSN-774 class submarines.

233-8.6.3 MIL-L-9000 SERIES. MIL-L-9000 (MS 9250) oil can be used in the remaining fleet diesel engine without any special precautions. 9250 oil has a viscosity of 12.5 - 16.3 centistokes (CST) at 100° C (212° F).

233-8.6.4 MIL-L-2104 10W. MIL-L-2104 Grade MS/HDO 10W has a viscosity of 4.1 CST at 100° C (212° F) and is only used for hot lube oil flushing.

233-8.7 USE OF UNTESTED LUBRICANTS

233-8.7.1 NAVSEA does not approve the use of untested oils nor the purchase of oils not supplied under current contracts, except for emergency purchases in localities where military specification oils are unobtainable. Standard specification lubricants for shipboard machinery are listed in MIL-HDBK-267, **Guide for Selection of Lubricants and Hydraulic Fluids for Use in Shipboard Equipment**.

233-8.8 SUPPLEMENTAL LUBRICATING OIL ADDITIVES

233-8.8.1 Supplemental lube oil additives are defined as products which are marketed as fuel conditioners, smoke suppressants, tune up compounds, top oils, break in oil, graphitizers, and friction reducing compounds.

233-8.8.2 Diesel engines used in the U.S. Navy are designed and built in accordance with military specifications which require the finished product to perform satisfactorily using lubricating oils which are manufactured to military specifications, MIL-L-9000 and MIL-L-2104. Diesel engines have been tested and approved using lubricating oils conforming to these military specifications.

233-8.8.3 There is no real need for supplemental lube oil additives. Their use may actually negate the effectiveness of the additive package manufactured into military specification lubricating oils and cause damage to the diesel engine. In addition, the use of supplemental additives may mask a more serious engine problem.

233-8.8.4 After market lubricating oil supplemental additive products shall not be used.

NOTE

Supplemental lubricating oil additives do not include special lubricants recommended by the specific engine manufacturers for use during the assembly process, in lieu of clean oil.

233-8.9 PHYSICAL, CHEMICAL, AND PERFORMANCE CHARACTERISTICS

233-8.9.1 Lubricants may be categorized according to physical, chemical and performance characteristics. For complete information on lubricants see **NSTM Chapter 262, Lubricating Oils, Greases, Specialty Lubricants and Lubrication Systems**.

233-8.10 INTERNAL COMBUSTION ENGINE LUBRICANTS

233-8.10.1 Reciprocating internal combustion engine lubricants are commonly known as detergent or dispersive oils. These oils contain additives that keep combustion products such as soot, wear and oxidation products in suspension, thereby reducing the amount of contaminants deposited on engine parts. This property is particularly important in modern, high speed, turbocharged shipboard diesel engines. These engine oils also contain additives that reduce wear and inhibit rusting, foaming, and oxidation. Shipboard diesels operate satisfactorily on a single viscosity grade, MIL-L-9000 (MS 9250) or MIL-L-2104 (MS/HDO 15W-40). However, for engines that may be operating in an environment of 0° C (32° F) or below, MIL-L-2104 (MS/HDO 10) oil is recommended. For standardization reasons, engine oils are generally used in reduction gears associated with shipboard diesels. Although these engine oils are not formulated as gear oils, they perform well in such applications.

NOTE

Table 233-8-1 gives NSN's for ordering both MIL-L-9000 and MIL-L-2104 in various quantities.

Table 233-8-1. DIESEL ENGINE LUBRICATING OILS

USE ABOVE 0°C (32°F)		USE BELOW 0°C (32°F)	
MIL-L-9000 GRADE MS 9250		MIL-L-2104 GRADE 10W	
9150-00-181-8229	5 GAL CONTAINER	9150-00-186-6668	5 GAL CONTAINER
9150-00-181-8097	55 GAL DRUM	9150-00-191-2772	55 GAL DRUM
9150-00-181-8232	BULK		
MIL-L-2104 GRADE HDO 15W-40			
9150-01-152-4118	5 GAL CONTAINER		
9150-01-152-4119	55 GAL DRUM		

233-8.11 FORCED LUBRICATION SYSTEM

233-8.11.1 COMPONENTS OF A DIESEL ENGINE FORCED LUBRICATION SYSTEM

NOTE

Depending on engine and application, the following components may or may not be installed.

- a. Pumps. Oil is delivered to the various parts of the system by pumps. If the only available pump is driven by the unit it serves, priming pumps may or may not be provided to supply oil to the system until the unit is started.
- b. Sump Tanks. Oil is piped to the sump tanks after it passes through the various bearings and other parts of the system.
- c. Coolers. Oil passes through coolers on its way to the system in order to maintain the oil at the desired temperature.
- d. Settling Tank. Water and other impurities that have accumulated in the oil are allowed to settle, and used oil is stored in settling tanks.
- e. Stowage Tank. Clean makeup lube oil is stored in stowage tanks.
- f. Strainers and Filters. Strainers or filters remove foreign matter from the oil before it enters the engine lube oil system.
- g. Piping, Gages and Thermometers, and other Instruments. These devices are used to indicate system operating conditions. Lower than normal pressure may indicate pump failure or excessive leakage. Higher than normal pressure may indicate unsafe conditions such as clogged lines or filters. Clogging restricts oil flow to equipment being lubricated and can cause serious equipment damage.
- h. Centrifugal Purifiers. Water and other impurities are removed from the oil by centrifugal purifiers.
- i. Oil Heaters. The temperature of the oil is raised before it enters the centrifugal purifier to facilitate removal of water. Heaters are available for raising the temperature whenever ambient temperatures are extremely low, particularly before starting of main propulsion machinery. Heaters may be separate or combined, and may be part of a keep warm or prestart system.

233-8.12 DIESEL ENGINE LUBRICATION SYSTEM

233-8.12.1 In general, diesel engines installed on naval ships are provided with attached lubricating oil pumps driven by the engine. The lubricating oil pressure pump takes suction from the engine sump or sump tank and delivers the oil through a filter, strainer and cooler to the engine oil header. From the header, oil is distributed to all points requiring lubrication. Lubricating oil systems are classified as wet sump or dry sump systems, depending upon the method used to return oil to the sump. In the wet sump system, oil is returned directly to the attached sump by gravity flow after it lubricates the various engine parts. In the dry sump system, oil returns by gravity to an oil sump, it then drains by gravity to a separate sump, or an engine driven scavenging pump continuously pumps oil from this sump to a separate sump. The sump is therefore kept empty (dry).

233-8.12.2 Diesel engines are provided with a full flow lubricating oil filtering system. Duplex (parallel) units are used to allow elements to be replaced while the unit is in operation. Relief valves are provided to bypass the filters. These relief valves normally remain closed, except during high differential pressure conditions across the filter when the oil is cold (at start up) and when the filter is dirty or clogged. Diesel engine lubricating oil systems are usually provided with a priming pump so that oil can be circulated to engine parts requiring lubrication before engine start up.

233-8.13 SPRAY SHIELDS (FLANGE SHIELDS)

233-8.13.1 Spray shields shall be provided for flange joints (including simplex strainer flange covers and flanged valve bonnets in piping containing flammable fluids located above the floor plates. For further information refer to **NSTM Chapter 505, Piping Systems**, NAVSEA drawings 810-2117525, 803-2145518 and NAVSEA Technical Manual 0948-LP-102-2010, **Fuel and Lube Oil Strainer Safety Shield Design Guidance**.

233-8.14 CENTRIFUGAL PURIFIERS

233-8.14.1 Centrifugal purifiers are sometimes installed in diesel engine lubricating oil systems to remove water and impurities not trapped by the filter or strainer. If the diesel engine lubricating system has installed purifiers they shall be operated continuous while underway in accordance with [paragraphs 233-8.14.2](#) and [233-8.14.3](#).

233-8.14.2 If multiple engines share a common purifier, the 24 hour period of purifier operation shall be equally divided or shared among the operating diesel engines to re-circulate the engine sump oil. The diesel engines lube oil shall obtain the maximum benefit of the installed purifier.

233-8.14.3 If water is present in the lube oil system, purifiers shall be operated continuously until no water is discharged from the purifier.

233-8.14.4 NSTM Chapter 262, Lubrication oils, Greases, Specialty Lubrication, and Lubrication Systems, provides additional information on purifier operation and sampling requirements.

233-8.15 LUBRICATING OIL MAINTENANCE

233-8.15.1 MIL-L-9000 lubricating oil can be purified by normal shipboard methods. Water and larger size suspended particles can be removed in a properly operating shipboard purifier. Purifying for water is specified in **NSTM Chapter 262, Lubricating Oils, Greases, Specialty Lubricants, and Lubricating Systems**.

233-8.16 MIL-L-9000 USE IN DIRTY ENGINES

233-8.16.1 When new MIL-L-9000 oil is put into an engine which has been allowed to become very dirty, the detergent cleaner additive will loosen dirt deposits. These loose deposits will circulate with the oil and can collect elsewhere in the engine causing clogged oil holes and clogged oil pump suction screens. At best, the detergent cleaner in the new oil is used up rapidly, resulting in frequent strainer cleaning and a need for early oil and filter changes. Should this situation be encountered, give close attention to the filter and strainer differential pressure, and the engine lube oil pressure.

233-8.17 CHANGE IN COLOR OF OIL

233-8.17.1 Diesel engine lubricating oils usually turn dark in color after a few hours of use because of the suspension of finely divided fuel soot. The change in color in no way indicates a deterioration in the lubricating quality of the oil.

233-8.18 DRAIN PERIODS

233-8.18.1 The efficiency of an additive oil depends on the amount of compounding material it contains. This material is consumed in preventing ring sticking and the formation of sludge deposits. Optimum drain periods can best be determined by frequent oil analysis in accordance with PMS and by inspecting the condition of the engines. Exceeding any of the condemning limits in [Table 233-8-2](#) is cause for changing the oil.

Table 233-8-2. TESTS TO DETERMINE OIL CONDEMNING LIMITS

OIL TYPE/APPLICATION	TESTS PERFORMED	LIMITS ALLOWED
MIL-L-9000/Lube Oil	Viscosity @ 104° F (40° C)	90-200 Centistokes (cSt)
	Water Content (NOAP)	Pass/Fail
	Acidity Test (TBN)	≥ 8.0: Satisfactory 2.0 - 7.9: Marginal < 2.0: Reject
	Fuel Dilution	< 2.0%: Satisfactory 2.0 - < 3.5%: Marginal 3.5 - <5 %: Test lube oil every 10-15 hours of engine operation. ¹ ≥ 5 %Abnormal: Secure Engine
	Spectrographic Analysis Performed (NOAP)	Limits held by NOAP
MIL-L-2104 15W-40/Lube Oil	Viscosity @ 104° F (40° C)	69-144 Centistokes (cSt)
	Water Content (NOAP)	Pass/Fail
	Acidity Test (TBN)	≥ 3.5: Satisfactory 2.0 - 3.4: Marginal < 2.0: Reject
	Fuel Dilution	< 2.0 %: Satisfactory 2.0 - < 3.5 %: Marginal 3.5 - < 5.0 %: Test lube oil every 10-15 hours of engine operation. ¹ ≥ 5 %: Abnormal: Secure Engine
	Spectrographic Analysis Performed (NOAP)	Limits held by NOAP

¹ If % fuel dilution stabilizes, continue normal lube oil test periodicity. If fuel dilution continues to increase, determine source of problem and correct.

Table 233-8-3. DROP ROD TEST KIT

MIL 9000, (MS 9250), MIL-L-2104, SAE 40	
Tests Preformed	Use Limits
Viscosity	40 % increase from new oil or 35 % decrease (equivalent to 5 % fuel dilution) from new oil

Table 233-8-3. DROP ROD TEST KIT - Continued

MIL 9000, (MS 9250), MIL-L-2104, SAE 40	
Tests Performed	Use Limits
Acidity	Blue: Pass Yellow or Green: Fail

233-8.19 CONDEMNING LIMITS

233-8.19.1 Navy Oil Analysis Program (NOAP) laboratory facilities shall be used for required testing in accordance with PMS. MIL-L-9000, MIL-L-2104 15W-40 and SAE 40 oils should be subjected to the tests listed in [Tables 233-8-2](#) and [233-8-3](#). Exceeding any of the defined condemning limits and PMS requirements is cause for changing the oil. See NSTM Chapter 262, Lubricating Oils, Greases, Specialty Lubricants, and Lubricating Systems.

233-8.19.2 If no analytical data is available, the oil drain periods shall be according to the following:

- a. For large, low, and medium speed diesels (below 1,500 rpm) - after 750 hours of operation.
- b. For small high speed diesels (above 1,500 rpm) after 100 hours of operation or every 3 months, which ever comes first.

233-8.20 SHIPBOARD TESTING

NOTE

The Clear and Bright test is ineffective for diesel engine lubricating oils. Shipboard testing of diesel engine lubricating oils focuses on physical properties such as changes in viscosity and acidity.

233-8.20.1 Ships shall sample and test the physical properties (viscosity and acidity) of lubricating oil in main propulsion diesel engines, ships service diesel generators and emergency diesel generators. Lubricating oil shall be sampled daily and tested for viscosity when the diesel engine is operating, regardless of the number of hours operated during the day. Medium speed diesel engines having a rated speed below 1,500 rpm, the lubricating oil shall be sampled and tested for neutrality and acidity every 400 plus or minus 50 hours of diesel engine operation or quarterly. High speed diesel engines having a rated speed of 1,500 rpm or greater, lubricating oil shall be sampled and tested for neutrality and acidity every 100 plus or minus 10 hours of engine operation. Lubricating oil is tested in accordance with PMS and **NSTM Chapter 262, Lubricating Oils, Greases, Specialty Lubricants, and Lubricating Systems.**

NOTE

If engine is not operated, a lubricating oil sample for viscosity is not required.

NOTE

When conducting engineering casualty control drills, lube oil samples are not required prior to and after engineering casualty control drills.

233-8.21 POST-OVERHAUL OR REPAIR, LUBE OIL SYSTEM INTENSIVE CLEANING

233-8.21.1 GENERAL. In many instances lube oil contamination is a primary cause or contributing factor in diesel engine failure. Overhaul and repair standards often do not include effective lube oil system cleaning procedures, therefore, the potential for further engine failure remains due to particle contamination. During a casualty condition, such as bearing failure, metallic particles of the failed components are often dispersed throughout the lube oil system. This includes drilled oil passages, attached piping, and engine components. After complete overhaul or major repair of an engine, the lube oil system shall be thoroughly cleaned.

233-8.21.1.1 To accomplish thorough cleaning of the engine block, components, and attached piping, the following two methods are authorized:

- a. Method 1 - Soaking
- b. Method 2 - Flushing

233-8.21.2 SOAKING. Soaking is a process in which the stripped engine block is immersed in an alkaline solution, thoroughly cleaned, rinsed, and blown dry with compressed air. Soaking is the preferred method for small engine blocks.

WARNING

Never add water to alkaline powders; spattering or an explosive reaction will occur. Always add the powder to the water.

WARNING

Alkaline solutions of trisodium phosphate and especially sodium hydroxide are hazardous. Before preparation of the solution all of the following shall be secured or removed from the internal combustion engine shop: flammable liquids, acids, and organic halogen compounds (especially trichloroethylene). Skin or eye contact with either alkaline powder or solutions can cause severe burns and shall be avoided. Their ingestion can cause serious damage to the digestive system and shall be avoided. Eyewash fountains and safety showers shall be available for immediate use in all alkaline handling areas. Alkaline powder or solutions coming into contact with eyes shall be flushed with potable water for a minimum of 15 minutes immediately after exposure. Seek immediate medical attention. In the event of skin contact with the powder, carefully remove all visible particles with a clean soft

Warning - precedes

brush, then rinse affected area with cold water. In the event of skin contact alkaline solutions, rinse affected area with cold water immediately. In the event of ingestion of alkaline powder or solutions, immediately drink large amounts of milk or water followed by diluted vinegar or fruit juice. Vomiting may occur but do not induce it. Seek immediate medical attention, avoid breathing the solution spray, mist or alkaline powder. When handling these chemicals, the following protective equipment shall be worn: full face shield, rubber gloves, and apron. A dust respirator shall also be worn when handling alkaline powder.

CAUTION

All aluminum parts such as bearings, shall be removed from the engine block before soaking. Only iron or steel engine blocks may be cleaned by this method.

- a. For installation of alkaline soak solution in a diesel engine block soaking tank,

WARNING

Never use hot water. Hot water will cause a violent reaction.

1. Fill the soaking tank to the appropriate level with cold, fresh water.
 2. Reserve 1/2 pound of alkaline powder (either trisodium phosphate or sodium hydroxide) for each gallon of water in the soaking tank. When preparing solutions always add the powder slowly and in small amounts to the water to avoid violent boiling and spattering. Then add one fluid ounce of nonionic detergent (MIL-D-16791, Type 1) for each gallon of water.
 3. Air agitate the solution until well mixed.
- b. For degreasing of engine block in the soaking tank,
1. If feasible, heat the solution to between 71° to 82.2° C (160° C and 180° F) before use.
 2. Slowly immerse the engine block in the solution.
 3. Soaking time varies with the condition of the engine block. The minimum time is 1 hour.
 4. Upon completion of soaking, carefully and thoroughly rinse the block with warm water to remove all traces of alkaline solutions and blow dry.
- c. For disposal of alkaline soak solution when exhausted,
- 1 Slowly and carefully drain the alkaline solution into steel drums according to OPNAVINST 5090.1 and **NSTM Chapter 593, Pollution Control** .
 - 2 Drums containing alkaline wastes will be turned into the Public Works Officer or Public Works Center at any Naval Shipyard or other Navy Industrial Facility.

233-8.21.3 FLUSHING. Engine lube oil flushing is a process that requires forcing clean, hot lube oil through engine internal and external lube oil passages using pumps, heaters, and filtering mediums. This NSTM, Chapter 233, Diesel Engines is the definitive document for lube oil flushing of diesel engines.

233-8.21.4 QUALIFICATION. Diesel Engines and their lube oil systems which cannot be soaked in accordance with [paragraph 233-8.21.2](#) shall be intensively cleaned by flushing. Navy engines which require hot oil flushing are provided in [paragraph 233-8.21.6](#).

a. Flushing of these engines is required after the following:

- 1 Complete overhaul.
- 2 Partial overhaul. Engines rebuilt by OEM's, commercial engine repair facilities and naval repair facilities shall be flushed by the overhauling activity prior to delivery.
- 3 New or stored engine where the internal lube oil system has been preserved with MIL-C-16173.

b. Flushing of these engines and their lube oil systems is required after

- 1 Casualties, in which particles from failed components have been circulated in the lube oil system and found in the lube oil filters and strainers and contamination is visible in the lube oil.
- 2 Fresh (jacketwater) or salt water contamination of lube oil system. Refer to [paragraph 233-8.21.17](#).

233-8.21.5 EXEMPTIONS. New engines preserved with MIL-L-21260 shall not be lube oil flushed, however, the external lube oil systems shall be flushed.

233-8.21.5.1 Engines requiring repair that have not sustained a casualty but require removal of internal components do not have to be flushed provided that precautions are taken to prevent internal lube oil wetted surfaces from becoming contaminated with foreign or air born debris. A certified diesel engine inspector shall make the final determination of the flushing requirement prior to completion of the repair.

233-8.21.6 ENGINES THAT REQUIRE HOT OIL FLUSHING. The following engines and their lube oil systems qualified by [paragraph 233-8.21.4](#) require hot oil flushing:

- a. All models of Fairbanks Morse
- b. All models of EMD and GM
- c. All Models of Colt-Pielstick (See Note on MIL-L-2104 and the use of two Navy standard flushing pumps in parallel)
- d. Caterpillar models 3500 and 3600 series
- e. Ruston Paxman
- f. DDA (C) Stewart Stevenson model 149
- g. All models of Alco

NOTE

All engines regardless of make or model, if they have an external lube oil system, the external lube oil system shall be hot oil flushed. See [Figures 233-8-1 and 233-8-2](#).

233-8.21.7 PROCEDURE. In general, the flushing procedure is comprised of two operations that use various pumps, filters and heaters rigged according to engine configuration.

- a. External piping system.
- b. External piping and internal lube oil systems.

233-8.21.8 EXTERNAL FLUSHING PROCEDURE FIRST OPERATION. External flushing is the initial flushing operation. The engine external lube oil system is isolated from the engine and flushed separately. This is necessary to avoid foreign particles being carried into engine internal lube oil passages, where clogging might occur. External flushing pertains only to the external lube oil piping systems including filters, strainers, and lube oil sumps.

233-8.21.9 INTERNAL AND EXTERNAL FLUSHING PROCEDURE - FINAL FLUSH. The second or final flushing operation flushes the external and internal lube oil systems together to a specified cleanliness.

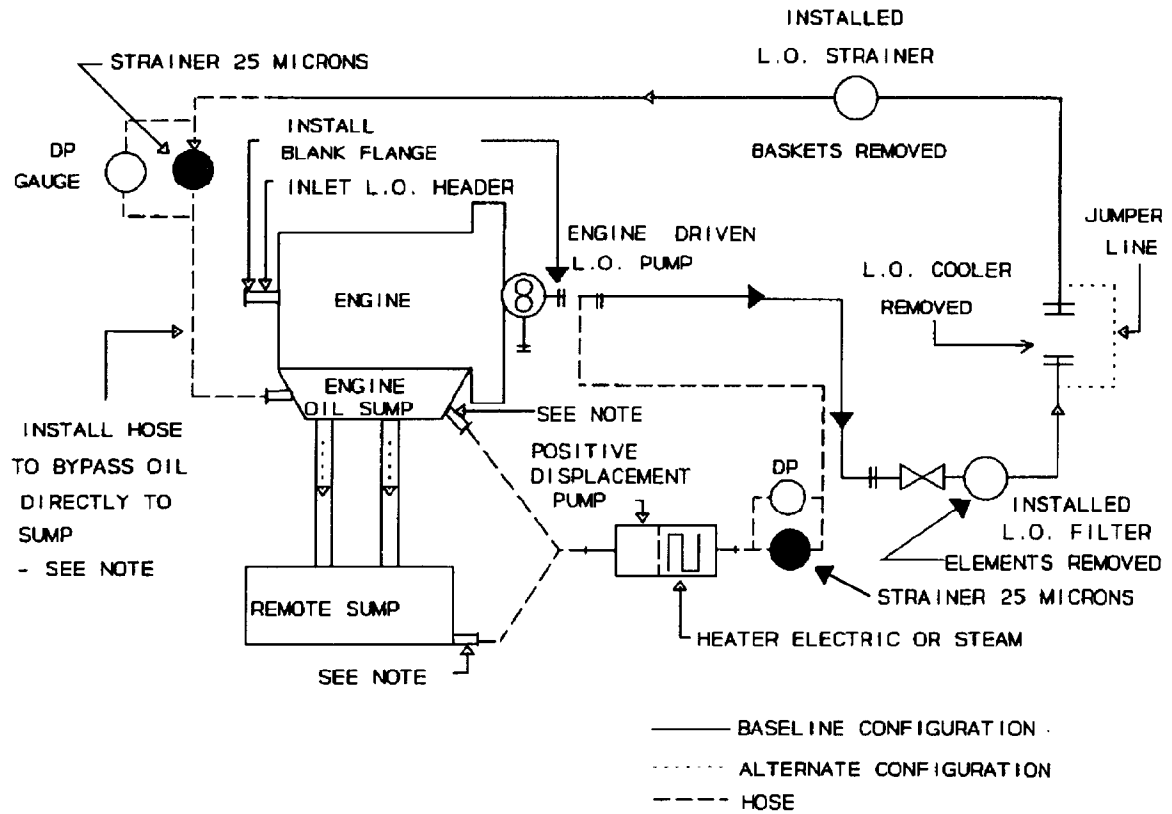
233-8.21.10 FLUSHING MEDIUM. MIL-L-2104 Grade MS-HDO 10W shall be used for hot lube oil flushing.

NOTE

MIL-L-9000 may be used for flushing when MIL-L-2104 is unavailable or in an emergency. However, if MIL-L-9000 lube oil is used, the flushing pump shall meet or exceed the flow rate of the attached lube oil pump and 79.5° to 87.7°C (175° to 190°F) oil temperature must be maintained.

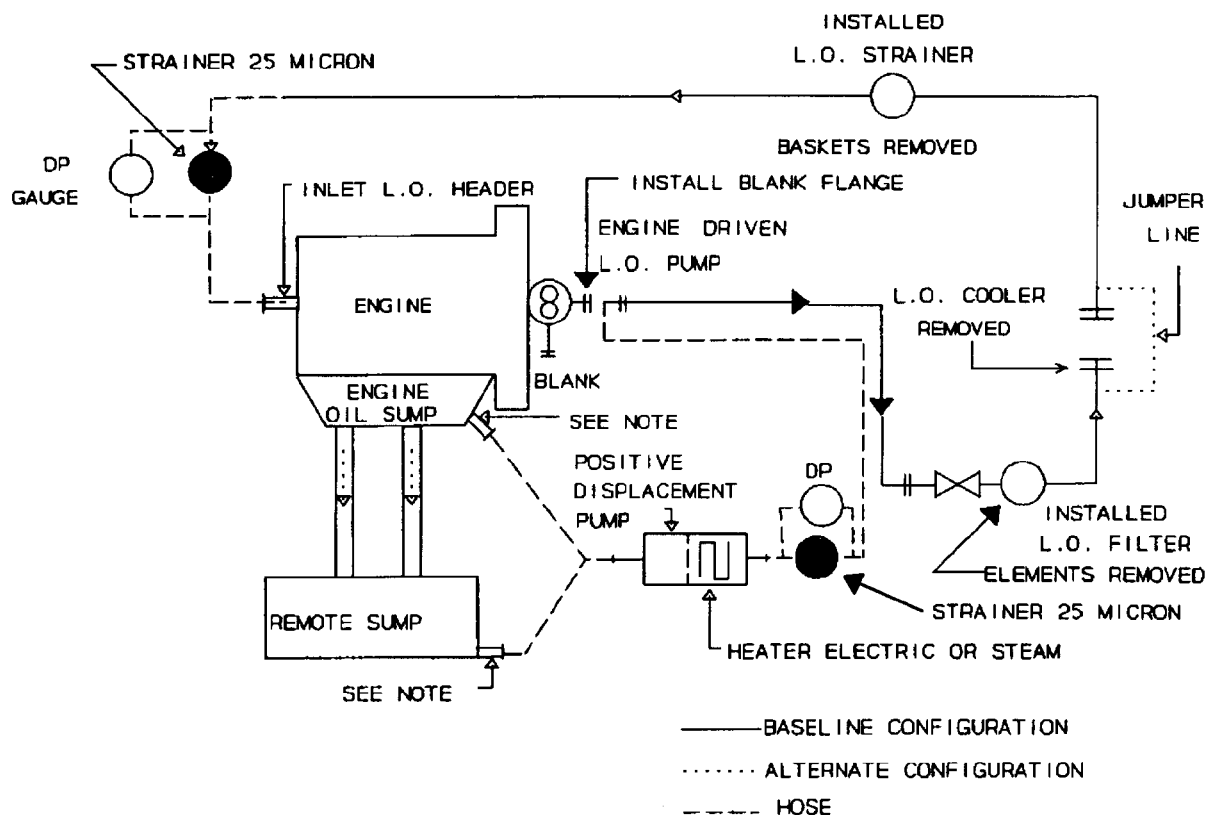
NOTE

Upon completion of lube oil flushing, the flushing oil may be returned to clean containers and can be used for the next hot lube oil flush provided cleanliness of lube oil can be maintained.



NOTE: Connections shown on engine sump (or remote sump) may or may not actually exist. If not, do not modify sump. Make use of other existing connections or inspection and or hand hole covers to take suction and return lube oil to sump.

Figure 233-8-1. Typical Flushing Diagram of the External Lube Oil System



NOTE: Connections shown on engine sump (or remote sump) may or may not actually exist. If not, do not modify sump. Make use of other existing connections or inspection and or hand hole covers to take suction and return lube oil to sump.

Figure 233-8-2. Typical Flushing Diagram of the Internal and External Lube Oil System

233-8.21.11 FLUSHING EQUIPMENT. Equipment required for hot lube oil flushing is as follows:

CAUTION

All flushing equipment, including the flushing pump, shall be rated for a minimum flow of 260 GPM when using MIL-L-2104. Ensure that flow is not restricted by use of fittings smaller than existing piping system. Maximum flushing pressure shall not exceed 110 percent of attached lube oil pump relief valve setting.

NOTE

The Navy standard diesel engine flushing system is supported by Allowance Parts List (APL) 417950001.

NOTE

When using MIL-I-2104, the standard Navy flushing rig (260 GPM) can be used for all engines with an attached lube oil pump flow rate of 450 GPM or less. All engines with an attached lube oil pump flow rate greater than 450 GPM shall use two Navy standard flushing system pumps in parallel (260 GPM + 260 GPM = 520 GPM).

NOTE

Sandpiper or diaphragm type pumps may be used if they meet the requirements of flow. When using diaphragm type pumps, flow meters shall be used to assure minimum flow requirements.

- a. Heating device electric or steam capable of maintaining oil at 71° to 87.7° C (160° to 190° F).
- b. Two duplex or simplex basket type strainer assemblies fitted with magnets and 25 micron muslin filter bags with differential pressure indicators and capable of handling flow rate of pump used for flushing.

NOTE

One of the basket type strainers is installed before return oil to the sump and the other is installed after the flushing pump discharge. See [Figures 233-8-1 and 233-8-2](#).

- c. Hose assembly (engine sump to pump), as required, MIL-H-24135. (suction application).
- d. Hose assembly (pump discharge to engine), as required, MIL-H-24135.
- e. Muslin bag filter - (sized to suit strainer basket), as required, FED SPEC CCC-C-432, Type 7, Class 1, NSN 8305-01-391-9081.
- f. Commercial Polyester full flow filter bags (sized to suit strainer basket) are an acceptable filtering medium. Full flow filter bags shall be 25 microns particle retention rating.
- g. Heavy duty plastic or canvas, as required.
- h. Lint-free rags, as required.
- i. Miscellaneous components; hose MIL-H-24135 (cut to suit), hose clamps, pipe nipples, fittings, valves, etc. As required per engine configuration.

NOTE

Nylon is not an acceptable substitute for MIL SPEC muslin or polyester full flow filter bags.

233-8.21.12 FLUSHING PREREQUISITES. External, flush prerequisite (See [Figure 233-8-1](#)) is as follows:

NOTE

Ensure that flushing arrangement is set up as a series flow circuit. That is, each component in line consecutively with the next. Parallel flow paths shall be avoided because this divides the flow and makes flushing less effective. Where parallel flow paths cannot be eliminated they shall be blanked off in turn to ensure a complete flush.

- a. The lube oil cooler shall be removed for independent cleaning. Install a jumper line in place of the cooler.

NOTE

The lube oil cooler is designed for a low velocity flow and as a result lube oil system contamination will collect in the cooler.

- b. Strainer baskets shall be removed from system strainer.
- c. Filter elements shall be removed from system housing.
- d. Remove and jumper system relief valves. Ensure filter and strainer bypass valves are properly set prior to reinstallation.
- e. All dead end run or blanked off piping shall be cleaned by hand.
- f. Engine sump shall be drained and wiped clean with lint free rags. Internal lube oil pump suction piping shall be cleaned by hand from the suction bell mouth or strainer to the pump inlet.
- g. Lube oil inlets to engine shall be blanked.

233-8.21.13 EXTERNAL FLUSHING PROCEDURE.

CAUTION

During the start of a flush, a severely contaminated system can instantly clog and rupture a filter, strainer or muslin bag. The start of a flush on a severely contaminated system should include bumping the pump (short intervals of 5-10 seconds of operation) several times, followed immediately by inspection, cleaning and replacement of the filter, strainer or muslin bag. Observe the differential pressure gage and clean filter, strainer, muslin or polyester bags as required.

1. Heat clean MIL-L-2104 oil, equaling 60 to 70 percent of sump capacity, to a temperature of 71° to 87.7° C (160° to 190° F), and circulate throughout the external lube oil circuit.
2. Circulate hot oil through Mil Spec muslin bags or filters rated at 25 microns for a period of not less than 12 hours. (Flushing cannot be estimated by time but is conditional on the level of system contamination).
3. During the flush the external piping system shall be manually shocked or vibrated using soft mallets or

mechanical vibrators to dislodge contaminants within the piping. During the flush, ensure that the entire system is shocked or vibrated, starting at the flushing pump connection to the external piping system and working in the direction of flow, to the strainer/filter connection before the oil sump.

4. During the flush, clean the filters or change the muslin bags a minimum of every two hours so that a pressure differential of no more than 5 psig higher than the differential of a clean filter or muslin bag can be maintained.
5. The flush shall be continued until a differential pressure increase of less than 2 psig higher than the differential pressure of a clean filter or muslin bag can be maintained for a period of 2 hours and a visual inspection of the muslin bag and strainer magnets indicates that the sum total of solid and solid based contaminants at the end of that two hour period does not exceed a volume larger than one 25 cent piece. Upon completion of the external flush, change the muslin bags and modify the system for final flushing.

NOTE

Solid and solid-based contaminants are those that cannot be crushed between the thumbnail and the finger.

233-8.21.14 FINAL FLUSHING PROCEDURE

CAUTION

If the engine being flushed drives a generator set and the engine lube oil provides lubrication to the generator bearings, for example Fairbanks Morse, either blank off or bypass the generator oil lines to the sump to avoid flooding the generator windings with oil. Bypassing the generator oil lines to the sump is preferred to ensure thorough flushing of the generator oil lines. The generator drain pumps that are engine driven will not remove oil pumped to the generator bearings while flushing and will cause flooding of the generator if the generator oil lines are not bypassed or blanked off.

233-8.21.14.1 Internal and external flushing is the final flush operation. The engine block, internal oil passages and external piping are flushed together to a specified cleanliness.

233-8.21.14.2 Final flushing procedure prerequisites (see [Figure 233-8-2](#)).

- a. Blank off pedestal bearing oil feed lines.
- b. Blank off turbocharger or blower lube oil feed lines.
- c. Remove lube oil main bearing jumper lines.
- d. Remove end plugs or caps on main lube oil header.

NOTE

On Fairbanks Morse engines remove both upper and lower crankshaft main bearing lube oil jumper lines and end plugs on lower main lube oil header. After the first two hours of flush, reinstall the end plug on the lower lube oil header

and reinstall the lower bearing lube oil jumper lines. Remove the end plug on the upper main lube oil header and flush for additional two hours. After the second two hour flush, reinstall end plug on the upper main lube oil header and reinstall upper main bearing lube oil jumper lines.

NOTE

On Alco engines model 251-8 cylinders, remove and blank oil supply lines to balance shaft.

233-8.21.14.3 For Internal and External Flushing procedures.

1. Heat a quantity of clean MIL-L-2104 oil, equaling 60 to 70 percent of sump capacity, to a temperature of 71° to 87.7° C (160° to 190° F) and circulate throughout the external and internal lube oil circuit.

NOTE

Ensure lube oil is reaching all internal oil passages by doing a visual inspection; e.g., rocker arms, camshafts and gear trains.

CAUTION

Use extreme care to maintain cleanliness while the engine system is being flushed. Openings into the engine shall be closed or covered with heavy duty plastic or canvas.

2. Filter circulating oil using Mil Spec Muslin bags or filters rated at 25 microns.
3. Change muslin bags a minimum of every 2 hours to maintain a differential pressure increase of no more than 5 psig over the differential pressure of a clean filter or muslin bag.
4. After 2 hours replace main bearing jumper lines and replace end plugs on main internal lube oil header.
5. Continue flush for a minimum of 12 hours and during this period manually rotate the engine crankshaft through 90 degrees travel at 20 minute intervals.
6. After this 12 hour period the flush shall be continued, without engine rotation until a differential pressure increase of less than 2 psig higher than the differential of a clean filter or muslin bag can be maintained for a period of 2 hours and a visual inspection of the filters or muslin bag and strainer magnets indicates that the sum total of contaminants (solid, solid based, and nonsolid) at the end of that two hour period does not exceed a volume larger than a ten cent piece. The filters or muslin bags and strainer magnets shall contain no more than five solid or solid-based contaminants, no one larger than 1/64 inch in any dimension. The filters or muslin bags shall contain no non-solid contaminant larger than 1/16 inch in any dimension except for hairlike particles which can be up to 1/8 inch long.

NOTE

Solid and solid-based contaminants are those that cannot be crushed between the thumbnail and the finger.

233-8.21.14.4 The keep warm, prelube system on ships with MACHALT-184 installed shall be flushed separately. Remove and clean the heater. Disconnect the return line to engine and using the keep warm pump, flush through a separate filter bag to determine system cleanliness according to above criteria. Reconnect system when final flush is complete.

233-8.21.15 POST-FLUSH CLEAN UP. Upon completion of engine flushing the following procedures apply:

1. Drain flushing oil from sump, piping, filter and strainer housings, place flushing oil in clean containers.

NOTE

Every effort shall be made to remove MIL-L-2104 from the lube oil system. This will ensure a satisfactory NOAP report for viscosity, which will eliminate the need to change oil after a few hours of engine operation.

NOTE

Careful use of clean low pressure air (100 psi or less) may be used to blow flushing lube oil back to the engine sump through the filter and strainer housings.

NOTE

Upon completion of lube oil flushing, the flushing oil may be returned to clean containers and can be used for the next hot lube oil flush provided cleanliness of lube oil can be maintained.

2. De-energize, secure and remove all flushing equipment.
3. Restore lube oil system to original configuration in preparation for engine run. Remove jumper line and reinstall lube oil cooler.
4. Remove blank flanges from generator bearings, turbocharger(s) and blower. Reinstall Alco engine balance shaft oil supply lines.
5. Clean and inspect lube oil sump using lint free rags. Clean and inspect internal lube oil pump suction piping from the suction bell mouth or strainer to the pump inlet.
6. Clean lube oil filter housing and install new lube oil filters.
7. Clean and inspect system lube oil strainer and housing. Install system strainer baskets. Install muslin bags in system strainer baskets if configuration permits.

233-8.21.16 ENGINE RUN AFTER COMPLETION OF FLUSHING

CAUTION

Thorough inspection of the engine through the air boxes and engine blowers (where applicable) is necessary to avoid the damage of hydraulic lock.

CAUTION

Ensure all temporary modifications to lube oil piping, resulting from flush operation have been reconfigured to the original installation. Ensure lock-wire on all main bearing jumper lines and lube oil gallery end plugs has been reinstalled.

CAUTION

Ensure blank flanges to generator bearings, turbocharger(s) blowers and main bearings (if installed) are removed.

CAUTION

Ensure the lube oil cooler and relief valves jumper lines are removed (if installed). Reinstall lube oil cooler, relief valves and associated piping (if removed). Ensure strainer and filter bypass valves are properly set.

1. Fill the engine sump or remote sump, if applicable, with new oil, as specified for application, to the required level for engine operation.
2. If the lube oil flush was accomplished after an overhaul or major repair, operate the engine in accordance with the standard run-in schedule for an overhauled engine (refer to [paragraphs 233-3.4 through 233-3.8.1.6](#)).
3. Before starting the engine, see Preparation for Starting After Overhaul or Long Idle Periods ([paragraphs 233-3.3 and 233-3.3.1](#)).

CAUTION

Lube oil shall be sampled and tested for viscosity after 15 minutes of engine operation.

4. Run engine at no load at idle speed for 15 minutes. After this 15 minutes of no load operation sample and test lube oil for viscosity in accordance with NOAP requirements.
5. Continue to run engine at no load and increase engine speed from idle to full speed over a 15 minute period.

CAUTION

Monitor the differential pressure across the strainer and filter during engine operation. Ensure the differential pressure does not exceed bypass valve set point. If the strainer or filter require repeated cleaning to maintain proper differential pressure, the entire flushing procedure shall be repeated.

NOTE

Although an engine run-in procedure is conducted to wear in and seat new parts, the wear occurring during a properly conducted run-in should not be sufficient to release visible particles.

6. Continue to run the engine at no load full speed for an additional 15 minutes. Stop the engine.
7. Open, inspect and clean the strainer. If the strainer has solid contaminants larger than 1/64 inch or volume of solid contaminants is larger than a dime, repeat the final flush procedures until an acceptable criteria is obtained.
8. If engine is being run-in, stop the engine after first two hours and open, inspect and clean the strainer. If the strainer has solid contaminants as noted above, repeat the final flush procedure. If the strainer is clean continue with engine run-in. Stop and inspect the strainer to the above criteria every two hours until run-in is complete.
9. If engine is not being run-in, operate engine at minimum of 60 percent load at rated speed for two hours. After two hours stop the engine and inspect the strainer for solid contaminants to the above criteria. Repeat this step until an acceptable criteria is obtained.
10. Operate engine at 80 percent load at rated speed for 1 hour. Stop and inspect strainer to above criteria. Repeat until acceptable criteria is obtained.
11. Operate engine at 100 percent load at rated speed for 1 hour. Stop and inspect strainer to above criteria. Repeat until acceptable criteria is obtained. When the strainer meets the cleanliness criteria stated above after run-in or 100 percent load the flush is complete.

233-8.21.17 WATER CONTAMINATION FLUSH. Lube oil systems that have been contaminated with water that cannot be removed by purification shall be flushed as follows immediately or soon as possible after water contamination occurs:

NOTE

The following procedure is to be used only under the following conditions:

- a. **Cracked or broken liners or cylinder heads.**
- b. **Failed jacketwater gaskets or seals.**
- c. **Failed lube oil cooler.**
- d. **Failed lube oil steam heaters for purifiers or sumps.**
- e. **Water contamination from washing and cleaning of the engine.**
- f. **False start on submarine diesel engines where the outboard exhaust valve failed to shut and allowed salt water to enter the engine. Ensure no other engine damage has occurred.**
- g. **If engine or engine space has been flooded refer to NSTM Chapter 233, Diesel Engines, [Section 6](#).**

NOTE

In order to minimize engine damage from water contamination it is critical to remove water and operate engine as soon as possible after contamination occurs. If it is suspected that water contamination occurred more than 24 hours prior to discovery, then a visual inspection of internal engine parts shall be conducted.

1. The system shall be completely drained. Dispose of oil in accordance with NSTM Chapter 593, Pollution Control and OPNAVINST 5090.1.
2. The valve gear and exposed internal engine components shall be cleaned with lint free rags.
3. The sump shall be completely drained and cleaned with lint free rags. Ensure that all frame members and pockets that could trap water are wiped out.
4. Strainer and filter housing shall be cleaned with lint free rags. Clean strainer and reinstall, renew filters.
5. The cooler should be drained separately if possible.
6. The system shall be filled to 100 percent capacity with new oil as specified for application.

CAUTION

During the prelube operation for the additional 2-3 minutes, ensure pedestal bearing does not flood and overflow to the generator.

7. Immediately prior to starting the engine, prelube until oil is observed at the main and rod bearings. Continue to prelube for an additional 2-3 minutes.
8. Start engine in accordance with EOSS or normal operating procedures. Run engine at idle for 5 minutes. Take a lube oil sample while operating. Visually inspect lube oil sample for the presence of water. Diesel engine lubricating oil has an affinity for water. Oil will turn to a coffee cream or khaki color if oil is heavily contaminated with water. If color of lube oil changes, repeat [steps 1](#) through [8](#). Continue to sample lube oil every 5 minutes until 30 minutes has elapsed without a color change to the lube oil.
9. Gradually load engine to a minimum of 80 percent and run for a period of 2 hours. Ensure oil temperature is above 71° C (160° F). Sample oil for color change every 15 minutes. If oil turns to a coffee cream or khaki color, oil is contaminated. Repeat [steps 1](#) through [9](#).
10. Continue to flush and run engine until oil sample remains dark green or black color. Submit oil sample to NOAP for water content.

SECTION 9.

FILTERS AND STRAINERS

233-9.1 FUNCTION AND DESCRIPTION

233-9.1.1 Filters and strainers are installed on diesel engines for the following reasons:

- a. Filters and strainers remove abrasive and foreign materials from the lubricating oil to decrease wear and reduce deterioration of the lubricating oil.
- b. Filters and strainers remove foreign substances from the fuel oil to decrease wear of the fuel pumps and injection valves and deter clogging of the nozzles.
- c. Filters are used to clean intake air before it enters the engine. Air filters may be of the disposable type or the type that require periodic cleaning.

233-9.1.2 According to Navy diesel terminology, all metal-edge devices and wire mesh devices are termed strainers, while all disposable, fibrous depth and surface-type element devices are called filters.

WARNING

Safety and fire hazard precautions presented in NSTM Chapter 505, Piping Systems and Planned Maintenance System (PMS) shall be carefully adhered to when cleaning fuel oil or lube oil filters and strainers.

233-9.2 FUEL OIL STRAINERS

233-9.2.1 Fuel oil strainers are made in both simplex and duplex types. A strainer consists of a metal-edge element surrounded by a case which serves as a sump to collect foreign material and water which are caught by the strainer. Some strainers have devices for manually rotating the strainer elements against a metallic scrapers to remove material caught by the strainer. Strainers also are normally provided with vents for venting air from the fuel or lube oil system.

233-9.2.2 Fuel oil strainers shall not contain pressure relief valves because such valves would permit dirty fuel to bypass the strainer element and damage the fuel injection equipment.

233-9.2.3 A duplex fuel (MIL-S-17849) strainer is a two strainer elements built into one assembly which has a manual valve for directing the flow of fuel or lube oil through either one of the elements or both. Each element of the strainer shall be capable of passing the full flow of the system.

233-9.3 MAINTENANCE OF FUEL OIL STRAINERS

233-9.3.1 Some metal edge strainers may be cleaned by rotating the knife edge past a cleaner blade causing the sludge and foreign matter on the surfaces to drop into the sump. Whenever possible metal edge strainer cleaning should be done while fuel is not passing through the strainer.

CAUTION

A wire brush shall never be used in cleaning strainer elements.

233-9.3.2 Other strainers are designed so the engine strainer element shall be removed and washed. Care shall be exercised in the cleaning of all strainers to prevent damage to the elements. Strainers should be washed in fuel oil or some other approved solvent, using a soft cloth or brush.

233-9.3.3 The sumps of fuel oil strainers should be checked periodically and drained at a frequency, based on experience for that particular installation, to remove any collection of water or sludge. Maintenance is done in accordance with the applicable NAVSEA Technical Manual and PMS.

233-9.4 LUBRICATING OIL STRAINERS

WARNING

Do not gag the lube oil filter or strainer bypass relief valve to prevent their operation, severe engine damage will occur.

233-9.4.1 Lubricating oil strainers can be of the simplex and duplex types. Lubricating oil strainers are similar in construction to fuel oil strainers but usually are of larger mesh and will permit the passage of larger sized particles.

233-9.4.2 All lubricating oil strainers shall contain a built-in, spring loaded, pressure relief valve of a size sufficient to bypass all the oil around the strainer, so an uninterrupted flow of lubricating oil will be maintained to the engine at all times.

233-9.4.3 Where duplex strainers are supplied in lubricating oil systems, the element being bypassed can be removed and cleaned while the engine is running without disturbing the flow of oil to the engine.

233-9.4.4 The same precautions exercised in cleaning fuel oil strainers shall also be taken in cleaning lubricating oil strainers.

233-9.5 LUBRICATING OIL FILTERS

233-9.5.1 FULL FLOW FILTERS. Lubricating oil filter elements shall be procured in accordance with FED SPEC F-F-351. The Navy uses a standard full flow filter for Fairbanks Morse, Colt Pielstick, Alco, EMD, Stewart Stevens 149 and Caterpillar Model 3600. The FSN is 2940-00-580-6282.

NOTE

Sock type oil filters shall not be used in Navy diesel engines. Sock type filter is defined as a filter element that has an outer covering of cloth only.

233-9.5.1.1 The full flow element is designed for high flow rates, permitting entire lube oil pump discharge delivery to pass through the filter elements. A relief valve is installed with this system to protect the engine. During normal operation the relief valve will remain closed. The relief valve will bypass the entire oil flow when the pressure across the filter increases to a predetermined set point. This will occur when filters are clogged or when oil is cold. A differential pressure gage installed around the relief valve will assist the operator to determine when elements require changing. When the pressure drop across the differential pressure gage reaches a predetermined value, the dirt collecting capacity of the element has reached a point where their continued use results in no appreciable filtration of the lubricating oil.

233-9.5.2 BYPASS FILTER SYSTEM. The bypass filter system is designed to filter a portion of the lubricating oil being delivered to the engine. An orifice plate is installed either in the filter or in the line to the filter to control the amount of oil removed from the system by taking only 10 to 15 percent from the pressure line, filtering it, and returning the filtered oil to the sump. The remainder of the oil, the unfiltered portion, is delivered to the engine.

233-9.6 FUEL OIL FILTERS.

233-9.6.1 Fuel oil filter elements shall be procured in accordance with MIL-F-20627.

233-9.6.2 Fuel oil filters approved for Navy use consist of replaceable throwaway filter elements mounted in a suitable casing. Fuel oil filters contain no bypass or relief valve and shall be of a size adequate to take the full flow of the fuel oil pumps.

233-9.6.3 Fuel oil filter elements are designed for an operation life of 500 hours. The varying quality and cleanliness of the fuel used may necessitate changing elements at more frequent intervals. When a gage is installed across a fuel oil filter, the element should be changed when the pressure drop reaches the value specified in the applicable NAVSEA Technical Manual and PMS.

233-9.7 FILTER REPLACEMENT

233-9.7.1 For specific instructions concerning replacement of filter elements, sizes to be used, and installation instructions, reference should be made to the applicable NAVSEA Technical Manual and PMS. Lubricating oil filter elements shall be changed at the same time lubricating oil is changed.

SECTION 10.

COOLING WATER SYSTEMS

233-10.1 ENGINE COOLANT

233-10.1.1 Engine coolant accepts heat from the hot areas of an engine and rejects heat at a heat exchanger. The coolant thus provides a medium for transferring heat from the engine to the heat exchanger. Without engine coolant, engine components would rapidly overheat and fail due to the large amounts of heat produced by combustion.

233-10.2 EFFECTS OF UNTREATED COOLANT

233-10.2.1 Scale, corrosion and cavitation corrosion will occur in engine cooling systems if untreated coolant is used. These conditions reduce the transfer of heat from the effected surfaces. In order to minimize these problems, high quality water treated with corrosion inhibitors is used in engine cooling systems. The following types of corrosion inhibitor treatments are currently authorized for use by the Navy in engine cooling systems: MIL-A-53009 inhibitor, Nalcool 2000/3000, inhibited antifreeze (A-A-52624 Type I), soluble oil (MIL-I-24453), Nalfleet 9111, Paxcool, Catcool, Glysacor G93 and Glysantin G05. Refer to [Table 233-10-1](#) for a listing of inhibitor treatments for each ship class.

233-10.3 WATER

233-10.3.1 Water is used as coolant because it is readily available and because of its large heat capacity (i.e., the quantity of heat it can absorb). Depending on its source, water quality can vary widely. For example, seawater contains large amounts of dissolved salts. Shore waters contain significantly lower levels of dissolved salts than seawater, although shore waters vary in composition from location to location. Shore waters include municipal water (tap, city, potable, fresh or dock) as well as water originating from rivers, lakes or wells.

233-10.4 WATER IMPURITIES

233-10.4.1 Certain constituents of the dissolved salts in both shore waters and seawater can be troublesome.

233-10.5 HARDNESS

233-10.5.1 Hardness (dissolved calcium and magnesium) can lead to scale formation. Scale consists of compounds of calcium and magnesium which form deposits on hot metal surfaces. Scale acts as an insulator, thereby reducing the transfer of heat from hot metal surfaces in the engine to the coolant. This can cause overheating.

233-10.6 CHLORIDE AND SULFATE

233-10.6.1 Chloride and sulfate tend to break down the protective layers formed on metal surfaces by corrosion inhibitor treatment chemicals and make the layers more difficult to reform. Thus, chloride and sulfate can lead to corrosion problems.

233-10.7 IMPURITIES IN SHORE WATERS AND SEAWATER

233-10.7.1 Unprocessed shore waters contain varying amounts of dissolved calcium and magnesium (hardness), chloride and sulfate. Water purification processes such as distillation, demineralization or reverse osmosis remove most hardness, chloride and sulfate from water. Seawater contains significantly greater amounts of these constituents. Since most diesel engine cooling systems employ seawater cooled heat exchangers, heat exchanger leaks can allow seawater to contaminate the engine coolant. Seawater contamination is detected by testing the engine coolant for chloride.

233-10.8 WATER REQUIREMENTS

233-10.8.1 An important part of a coolant treatment program is using water containing minimal amounts of hardness, chloride and sulfate for filling or topping off cooling systems. Water used for final flushing, fresh filling or topping off cooling systems or for mixing treatment chemicals for addition to cooling system shall be as follows in order of precedence:

- a. Shipboard boiler feedwater or condensate meeting the requirements of **NSTM Chapter 220, Volume 3, Corrosion and Contamination Control for Diesel Engine Cooling Water Systems**.
- b. Shore source water meeting the requirements of **NSTM Chapter 220, Volume 3** for shore source feedwater.
- c. Water produced by shore-based or shipboard distilling plants, demineralizers or reverse osmosis units. (Prior to use, the water shall be tested for chloride. The maximum acceptable limit is 60 ppm Cl-).
- d. Potable water (brominated or chlorinated) produced by shipboard distilling plants. (Prior to use, the water shall be tested for chloride. The maximum acceptable limit is 60 ppm Cl-).

NOTE

Only in emergency situations when the above waters are not available can clean fresh water (shore source potable water) be used.

NOTE

Water used for cleaning and flushing cooling systems may be clean fresh water provided that a final flush is performed with water meeting the above requirements.

233-10.9 INITIATING COOLANT TREATMENT

233-10.9.1 Before initiating coolant treatment, the cooling system of the engine shall be inspected. If oil is present, clean the system in accordance with the procedure in **NSTM Chapter 220, Volume 3, Corrosion and Contamination Control for Diesel Engine Cooling Water Systems**. If corrosion or scale deposits are noted, clean the system using the procedure in **NSTM Chapter 220, Volume 3**. The system shall be thoroughly flushed with water meeting the requirements of **NSTM Chapter 220, Volume 3** after any cleaning to ensure complete removal of all cleaning chemicals.

WARNING

Water treated with any corrosion inhibitor cannot be used as a source of emergency drinking water. Cooling system expansion tanks shall have signs affixed which state "Poison. Not to be used for emergency drinking water".

233-10.10 FRESH FILL AND TREATMENT OF COOLING SYSTEMS

WARNING

Wear proper protective equipment when handling inhibitor chemicals.

233-10.10.1 Refer to [Table 233-10-1](#) for a listing of inhibitor treatments for each ship class. The capacity of the cooling system, in gallons of water, shall be determined in order to calculate the correct dosage of chemicals. Add water meeting the requirements of **NSTM Chapter 220, Volume 3** to the system. (If the system is to be hydrostatically tested, do not fill the system until just before the hydro. Delay chemical treatment until completion of a satisfactory hydro.) The chemical solution may usually be added to the system at the jacketwater expansion tank or the chemical injection tank. Top off the system, then recirculate for at least 10 minutes after operating temperature has been reached. Obtain a sample after the system has been recirculated.

NOTE

The cooling system shall be recirculated as soon as possible following the addition of chemicals in order to mix them thoroughly. Do not sample a cooling system until it has been recirculated so that a representative sample will be obtained.

Table 233-10-1. INHIBITOR TREATMENTS AUTHORIZED FOR DIFFERENT SHIP CLASSES

Treatment	Ships
Mil-A-53009 Inhibitor ^{1 2}	ASR Class, ATS-1 Class, LSD-41 Class, LST 1182 Class, YTB Class, YTM Class, MTS Class, Submarines except SSN 774 Class. All diesel engines and generators on ships not listed below
Nalcool 2000/3000 ³	AOE Class, ARS Class, FFG-7 Class, SSN 774 Class submarines, LPD-4 Class, LCC Class, AGF Class, PB Mk III, PB Mk IV, PBR Mk II
Inhibited Antifreeze, A-A-52624 Type I ⁴	All small craft and all small boats not listed elsewhere in this table.
Soluble Oil, Mil-I-24453 ⁵	MSO Class, MCM 1, 2
Nalfleet 9111 ⁶	MCM 3-14, MHC Class
Paxcool and Catcool ⁷	PC-1 class
Glysacor G93 and Glysantin G05	PB MK V

¹ Ships authorized to use Mil-A-53009 shall use Inhibited Antifreeze when freezing protection is required. See NSTM Chapter 220, Volume 3, paragraph 220-43.6 and Section 45.

² Not authorized for SSN-774 Class Submarines.

³ Nalcool 3000 is equivalent to Nalcool 2000. Ships authorized to use Nalcool 2000 shall use Nalcool 2000 plus Antifreeze when freezing protection is required. See NSTM Chapter 220, Volume 3, paragraph 220-44.6.

⁴ A-A-52624 Type I replaces Mil-A-46153, which was cancelled.

⁵ Ships authorized to use soluble oil shall use Inhibited Antifreeze when freezing protection is required. See NSTM Chapter 220, Volume 3, paragraph 220-46.6 and Section 45.

⁶ Ships using Nalfleet 9-111 do not use Antifreeze.

⁷ Paxcool is used in PC-1 class Paxman engines. Catcool is used in PC-1 Caterpillar generators.

233-10.11 SAMPLING

233-10.11.1 Samples of engine coolant are obtained and tested to ensure that the coolant contains the correct level of inhibitor chemicals and to detect any seawater contamination of the cooling system.

233-10.12 SAMPLING FREQUENCY

233-10.12.1 **NSTM Chapter 220, Volume 3** covers the specific inhibitor treatments giving details concerning sampling frequency requirements. Regardless of inhibitor treatment, samples shall be obtained after fresh fill and treatment, following the addition of water or inhibitors and monthly. Whenever treatment chemicals or makeup water have been added, the cooling system shall be recirculated for at least 10 minutes after reaching operating temperature prior to obtaining a sample. When routine samples are taken, prior recirculation of the cooling system is not required. Sampling is in accordance with **NSTM Chapter 220, Volume 3**.

SECTION 11.

SPARE PARTS AND ALLOWANCE LISTS

233-11.1 GENERAL

233-11.1.1 The availability of spare parts, in the proper ratio and of the proper types, is mandatory for the successful continued operation of diesel engines. Improvising for precision parts or substituting unapproved and nonstandard components may imperil the entire engine and should be resorted to only in extreme necessity.

233-11.2 REPAIR PARTS

233-11.2.1 Repair parts are of prime importance to material readiness of a ship. Ready availability of these items significantly determines capability of a ship to maintain continuous operations over an extended period of time. Lack of a needed part could seriously affect the military efficiency of a ship. A complete stock of onboard repair parts is a vital asset in day-to-day ship operations.

233-11.2.2 Repair part refers to any item, including a spare module (which is itself a repairable item) and consumable type material. In addition, the item shall also have an equipment application and shall appear on an Allowance Parts List (APL), NAVSEA drawing or in the applicable NAVSEA Technical Manual. Examples of repair parts are bearings, cam shaft sections, and pump impellers. The Coordinated Shipboard Allowance List (COSAL) (Section A, Parts III) lists repair parts and equipment related consumables normally stocked by the supply department.

233-11.2.3 Shipboard allowance for repair parts is developed in accordance with specific logistic support doctrine set forth by the Chief of Naval Operations (CNO). Calculation of the allowance is a mathematical model based on failure rates, population, and Planned Maintenance System (PMS) requirements.

233-11.3 ALLOWANCE LISTS

233-11.3.1 INTRODUCTION. The Commander, Naval Sea Systems Command (NAVSEA) directs, coordinates and participates in preparation and verification of the accuracy and completeness of allowance lists for ships and shipboard systems.

233-11.3.2 PURPOSE. A ship's allowance list is designed to provide the ship with self support capability over an extended period of operation. It specifies the kind and quantity of equipment and supporting materials a ship in commission is required to carry onboard. (Ships ordinarily are required to carry a full allowance of such material.) The allowance list provides both technical and supply management data. It is used to prepare custody, stock, and locator records, to determine maintenance philosophy for equipment, to identify technical repair parts, and to determine sources of supply.

233-11.3.3 COORDINATED SHIPBOARD ALLOWANCE LIST (COSAL). The Coordinated Shipboard Allowance List (COSAL) is an authoritative document which lists the following:

- a. Equipment and components installed onboard ship to perform its operational mission.
- b. Repair parts and special tools required for operation, overhaul, and repair of equipment and components.

c. Operating space items (OSI's) and consumables necessary for safety, care, and upkeep of the ship.

233-11.3.3.1 The COSAL is both a technical and supply document. It is a technical document in that equipment, component and part nomenclatures, operating characteristics, technical manuals, and so on, are described in APL's or Allowance Equipage Lists (AEL's). It is a supply document, in that the COSAL provides a list of items required to achieve maximum, self supporting capability for an extended period of time. It is a bridge between a part number in a technical manual and the repair part carried by supply.

233-11.4 RESPONSIBILITIES

233-11.4.1 SUPPLY OFFICERS. On most ships, allowance of both repair parts and consumables is located in storerooms under the cognizance of the Supply Officer. The Supply Officer is responsible for ordering, receiving, storing, and issuing the ship's allowance of these items. In addition, the Supply Officer maintains complete, accurate, and up-to-date records of all transactions, including location records.

233-11.4.1.1 All consumables which cannot be stored in supply department spaces will be procured for direct turnover (DTO) to the department which will use them. Certain repair parts, such as bulkhead mounted spares, may require storage in spaces under control of other department heads. The Supply Officer, however, will continue to exercise inventory control over such material.

233-11.4.2 TECHNICIANS. To accomplish equipment maintenance or repair, technicians shall have the right tools and necessary repair parts. By knowing what is required in terms of material, the technician becomes a vital link in the requisitioning and issuing process. As part of the job planning, the technician shall furnish necessary job related information so smooth material flow can be initiated in support of equipment repair.

233-11.5 TURN IN REPAIRABLE ITEMS

233-11.5.1 Mandatory Turn in Repairable Items (MTR) are those repair parts which, based on unit cost, annual demand, difficulty of repair, or other economic considerations, have been designated for special inventory control. MTR items are identified in NAVSUP Publication 4107, **Master Repairable Item List (MRIL)** .

SECTION 12.

INSPECTIONS, RECORDS, AND REPORTS

233-12.1 BOARD OF INSPECTION AND SURVEY REQUIREMENTS

233-12.1.1 Article 0321, U.S. Navy Regulations, requires that the President, Board of Inspection and Survey (INSURV), conduct acceptance trials and inspections of all ships, service craft and boats before acceptance for naval service. Such trials and inspections are required for all new construction ships, service craft and boats. Refer to **NSTM Chapter 090, Inspections, Tests, Records and Reports** for further information.

233-12.1.2 MATERIAL INSPECTIONS OF ACTIVE AND INACTIVE SHIPS AND SERVICE CRAFT Material inspections are required by Title 10 U.S. Code 7304 and Article 0321, U.S. Navy Regulations. Refer to NSTM Chapter 090 for further information.

233-12.2 DIESEL ENGINE INSPECTORS AND DIESEL INSPECTION REPORTS

233-12.2.1 The OPNAV Diesel Inspector Certification program provides fleet support by certifying personnel fully capable of a systematic and effective evaluation inspection of diesel engines.

233-12.2.2 Certified diesel engine inspectors are personnel with in-depth knowledge of diesel engine operation and maintenance experience. OPNAVINST 9220.3 Propulsion and Auxiliary Plant Inspection and Inspector Certification Program provides guidance for the DEI program.

233-12.2.3 Certified Diesel Engine Inspectors (DEI) can troubleshoot, investigate engine casualties and provide repair recommendations. The DEI can also provide shipboard diesel engine training on preventive maintenance, corrective maintenance and performance test evaluation.

233-12.2.4 Requirements for scheduling diesel engine inspections by a certified diesel engine inspector are given in OPNAVINST 9220.3, Planned Maintenance System (PMS), and TYCOM instructions.

233-12.2.5 All diesel inspections are conducted in accordance with OPNAVINST 9220.3, and the NAVSEA Handbook S9233-CJ-HBK-010, **U.S. Navy Diesel Engine Inspector Handbook, Part 1, Inspection Procedures**, and TYCOM instructions.

233-12.2.6 Diesel Inspection reports shall be maintained onboard for ten years or until a major diesel engine overhaul. Diesel Inspection reports provide valuable information for troubleshooting, past engine performance and recurring maintenance problems.

233-12.3 SHIPS' MAINTENANCE AND MATERIAL MANAGEMENT (3-M) SYSTEM

233-12.3.1 The **Ship's Maintenance and Material Management (3-M) Manual** has been promulgated (OPNAVINST 4790.4) to assist Navy Commanders and Managers to attain and maintain readiness in the fleet. The main objective of the Navy's record system is to improve record keeping through standardization, automation, speed, and efficiency. Included in the 3-M system are the PMS, which delineates preventive maintenance requirements (see [Figure 233-12-1](#)), and the Maintenance Data System (MDS) which provides the means for

recording and reporting maintenance data by use of automatic data processing equipment. Although additional records and reports are required, the 3-M system is the main vehicle for recording and reporting equipment maintenance data.

233-12.3.2 The MDS provides documents on which maintenance personnel record, at the source, information concerning corrective or deferred maintenance action tests and alterations. The basic procedures and criteria for reporting are described in the 3-M Manual (OPNAVINST 4790.4) as supplemented by Type Commander directives.

233-12.3.3 In addition to the coded information reported through MDS, the material history also will contain any narrative remarks included on OPNAV Form 4790/2K. For example, clearances and tolerances or other readings would be reported in this section. With this narrative remark capability, the machinery history reports can be comprehensive, and the requirements are usually determined by the Department Head. This does not include routine readings and measurements if such readings and measurements are normal and are not taken in conjunction with a casualty or equipment malfunction.

DISTRIBUTION STATEMENT D:

Distribution authorized to DOD components and DOD contractors only; Critical Technology; February 2004. Other requests for this document shall be referred to Naval Sea Systems Command (SEA 04RM). Destroy by any method that will prevent disclosure of contents or reconstruction of the document.

Date: February 2004 MIP 2331 Periodicity: 24M-1

Series:

Location:

Ship System: Propulsion Units 230
System: Propulsion Internal Combustion Engines 233
SubSystem: Propulsion Diesel Engines, Main 2331
Equipment: Propulsion Diesel Engine

Rates	Man- Hours	Rates	Man- Hours	Rates	Man- Hours
ENG OFF		NEC 4314			
Total Man- Hours:		Elapsed Time:			

MAINTENANCE REQUIREMENT DESCRIPTION

1. Schedule/Accomplish Diesel Inspection.

SAFETY PRECAUTIONS

1. Forces afloat comply with NAVOSH Program Manual for Forces Afloat, OPNAVINST 5100.19 series.

TOOLS, PARTS, MATERIALS, TEST EQUIPMENT**MISCELLANEOUS**

1. [01365] Technical manuals/drawings/forms (OPNAVINST 9220.3; Propulsion and Auxiliary Plant Inspection and Inspector Training and Certification Program. (Non-Nuclear)
2. [01365] Technical manuals/drawings/forms (NAVSEA S9233-CJ-HBK-010; Diesel Inspectors Handbook, Part 1 Inspection Procedures) (See NOTE 2)

NOTE: Numbers in brackets can be referenced to Standard PMS Materials Identification Guide (SPMIG) for identification.

PROCEDURE

NOTE 1 : Diesel inspection(s) shall not exceed 24 months.

NOTE 2 : NAVSEA Handbook, NAVSEA S9233-CJ-HBK-010 is held by Diesel Inspectors.

1. Schedule/Accomplish Diesel Inspection.

- a. Engineering Officer schedule diesel engine inspection by a certified Diesel Inspector (NEC 4314) in accordance with OPNAVINST 9220.3 and TYCOM instructions. Diesel inspection(s) should be scheduled in the early phase of inter-Deployment Training Cycle (IDTC). OPNAVINST 9220.3 does not provide waivers or extensions for diesel inspections beyond 24 months. in ear
- b. Certified Diesel Inspector, inspect diesel engine in accordance with OPNAVINST 9233.1, NAVSEA S9233-CJ-HBK-010, and TYCOM instructions. Diesel Inspection(s) that are not complete within 45 days shall be closed and reported as incomplete.
- c. Diesel Engine Inspector, ensure all diesel engine inspection discrepancies are entered into the Diesel Engine Inspection Report Generator (DEIRG) system. Provide ship with computer disk after completion of diesel inspection. Report results of inspection in accordance with TYCOM instructions.

Figure 233-12-1. Sample Diesel Inspection Maintenance Requirement Card

233-12.4 OPERATING RECORDS

233-12.4.1 Data recorded on operating records ensure frequent observation of the machinery by the watch standers and provide a basis for performance analysis. Such records should be examined daily by the Division Officer and the Engineering Officer, as appropriate.

233-12.5 DIESEL ENGINE PERFORMANCE TEST

233-12.5.1 The optimum performance and reliability of marine diesel engines is essential to the readiness of a large number of Navy ships. The high temperature, numerous moving parts, and rigid technical specifications which characterize the marine diesel require that these engines are properly operated and maintained. The PMS performance test provides the operator with operating parameters that should be used to more effectively monitor engine operation and determine corrective maintenance and overhaul requirements. Greater engine operating efficiency and longer periods between overhauls and major maintenance are potential benefits of data from the PMS performance test.

233-12.5.2 Baseline Data collected after overhaul by the PMS performance test shall be retained as part of diesel engine maintenance history. The baseline data provides operating data to effectively monitor engine performance and provides a valuable source of operating parameters for troubleshooting. Baseline data should also be used to help identify trends or changes in diesel engine performance.

233-12.5.3 The PMS performance test provides complete instructions for the collection of engine operating data and analysis of the collected information.

SECTION 13.

SAFETY PRECAUTIONS

233-13.1 GENERAL INSTRUCTIONS

233-13.1.1 In addition to the specific safety precautions prescribed in the applicable NAVSEA Technical Manual and the Planned Maintenance System (PMS), maintenance and operating personnel shall continuously exercise good judgment and employ common sense to prevent damage to machinery and injury to personnel.

233-13.1.2 Damage to diesel engines may be prevented by proper operation of the engines in accordance with **Engineering Operating Sequencing System (EOSS)** or **Engineering Operating Procedures (EOP)**, the applicable NAVSEA Technical Manual, PMS, **Diesel Engine Inspection Program**, and the **Navy Oil Analysis Program (NOAP)**. A thorough knowledge and familiarity of all aspects of diesel engine operations and maintenance will enhance diesel operational safety and readiness.

233-13.1.3 Damage to the ship may be prevented by eliminating conditions which constitute fire or explosion hazards. Proper operation of the diesel engine will assure that no loss of power will be encountered at inopportune times, and that the engines will be ready for service in any emergency.

233-13.1.4 Injury to personnel may be prevented by a thorough knowledge of duties and responsibilities and proper maintenance. Safety precautions around moving or rotating parts shall be strictly adhered to by all personnel involved in operation and maintenance. Adequate guards shall be installed at exposed danger points of rotating shafts and couplings. Training programs shall be conducted to eliminate carelessness and thoughtlessness and teach safety awareness.

233-13.2 CRANKCASE EXPLOSIONS

233-13.2.1 **DEFINITION OF CRANKCASE EXPLOSIONS.** Three elements are needed for a crankcase explosion; fuel, oxygen and high heat. While the engine is operating, fuel and oxygen are present at all times in the crankcase in a combustible vapor form. The heat generated during normal operation is not of sufficient temperature to ignite this combustible vapor. The high heat necessary to ignite combustible crankcase vapors can originate at any moving part in the enclosed crankcase or any external part with a direct path to the crankcase, i.e., oil drain piping. Parts that have been known to generate the heat necessary to cause an explosion are as follows, but not limited to, rod and main bearings; pistons; piston pins; cylinders liners; gears; roller and ball bearings.

233-13.2.1.1 Localized heating of the combustible vapor by a "hot spot" on a failing or failed part always precedes ignition. Once combustion or ignition has occurred, the flame propagates throughout the crankcase. The speed of the flame depends on the distribution and volume of the combustible vapor in the crankcase. The development of the explosive pressure is due to the fact that the flame travels with a vibratory or wave motion leading to increased flame velocity thereby increasing the pressure in the crankcase. Without pressure development there would only be a fire.

233-13.2.1.2 Normally the pressure developed by a crankcase explosion in an enclosed crankcase is evenly distributed. However, detonation may occur due to the formation of an intense shock wave. Detonation produces a hammer blow effect which can destroy any portion of the engine frame or structure not strong enough to withstand the blow. If the engine is not strong enough to contain the explosion or if a means is not provided to relieve

the pressure, a second explosion can be expected. The second explosion is a result of fresh air rushing back into the crankcase to equalize the pressure differential, this air combines with the combustible vapor remaining from the previous explosion. Usually a fire results from the second explosion causing the most damage.

233-13.2.1.3 There is a mistaken belief that crankcase explosions occur without prior warning and that nothing can be done to prevent these explosions. Usually it takes time to heat a malfunctioning part to a degree required to start a crankcase explosion. The one exception to this may be a cracked or a blown piston.

233-13.2.1.4 Signs of an impending crankcase explosion may be white smoke coming from around crankcase covers, doors and other openings, and excessive engine vibration and noise. Engine operators shall watch for changes in temperature, pressures, and especially changes in crankcase vacuum and or pressure readings. On engines designed to run with a crankcase vacuum, the gaskets and seals on crankcase covers and all other access openings shall be checked in accordance with PMS and the applicable NAVSEA Technical Manual. This shall be done to keep fresh air leakage into the crankcase at a minimum. These air leaks are a source of combustion air.

NOTE

It should be remembered that while there is no absolute method to predict a crankcase explosion, proper engine operation and approved maintenance procedures will reduce and in most cases eliminate the possibility of a crankcase explosion.

233-13.2.1.5 The following warning statement shall be attached to all diesel engines, main propulsion, emergency generators, ship service generators, small boats and crafts. The statement shall be displayed on both sides of the engine in a conspicuous location.

WARNING

Do not remove engine crankcase covers or any access covers until at least 30 minutes have elapsed after shutdown when it is known or suspected that there has been a crankcase explosion, fire or an overheated part in the crankcase.

NOTE

On small boats and craft the warning statement may be attached to the engine access covers in a conspicuous location.

233-13.3 CRANKCASE RELIEF VALVES

233-13.3.1 Crankcase relief valves shall be checked periodically in accordance with PMS and the applicable NAVSEA Technical Manual to ensure that they are in proper working order. The purpose of these valves is to release burnt gases resulting from a crankcase explosion. This maintains the pressure in the crankcase within a safe range for the strength of the crankcase. The relief valves are designed to shut immediately after releasing the

pressure to prevent re-entry of fresh air into the crankcase. This prevents a second explosion. These valves shall operate freely and reseat perfectly so that a minimum of fresh air is allowed to be drawn into the crankcase.

233-13.4 UNINTENTIONAL ROTATION OF AN ENGINE

233-13.4.1 Precautions against unintentional starting or rotation of an engine shall be strictly adhered to before commencing overhaul or repair operations. The starting system shall be secured in at least two places and in accordance with shipboard and or shore tag out procedures. Only when the engine is completely secured shall maintenance personnel be allowed to work in the engine crankcase or otherwise come in contact with movable parts. If an engine is provided with a remote control station, positive steps shall be taken to see that the remote controls are made inoperative and tagged out of service.

233-13.4.2 If a propulsion engine is to be worked on while underway, steps shall be taken to positively secure the engine from turning so it cannot be rotated by its connected propeller shafting or through clutch windage. The following are suggested methods of accomplishing this:

1. Engage jacking gear.
2. Use timbers or heavy wooden blocks in crankcase to prevent crankshaft rotation.

233-13.5 CYLINDER RELIEF VALVES

233-13.5.1 If the relief valve on any cylinder opens the engine shall be stopped immediately and the cause of the trouble determined and remedied.

233-13.5.2 Relief valves shall never be locked closed except in case of an emergency.

233-13.6 OVERHEATED ENGINE

233-13.6.1 Under no circumstances shall a large amount of cold water be allowed suddenly to enter a hot engine. The rapid cooling may crack the cylinder liner and head or seize the piston(s).

233-13.6.2 Remove the load from engine and let idle, temperature should stabilize or start to cool, within 3-5 minutes. If engine does not start to cool or stabilize within 3-5 minutes or temperature rises, stop engine.

233-13.6.3 When the volume of circulating water cannot be increased and the temperatures are too high, stop the engine.

233-13.6.4 If engine was shutdown on high jacketwater temperature, if conditions permit, bar engine over to prevent engine seizure.

233-13.6.5 In freezing weather, all spaces containing fresh water and subject to freezing shall be carefully drained unless an antifreeze solution is added. In many cases, multiple drains shall be opened to drain the water from all low points.

233-13.7 INTAKE AIR

233-13.7.1 Intake air shall be kept as clean as possible; accordingly, all ducts and passages shall be kept clean. Air inlet filters shall be cleaned in accordance with PMS.

233-13.8 CLEANLINESS

233-13.8.1 Engines shall be kept clean at all times and the accumulation of oil in the bilges or other pockets shall be prevented.

233-13.8.2 Care shall be taken that water in the bilges cannot reach electrical machinery or wiring, both with an even keel and when rolling and pitching.

233-13.8.3 Cleanliness is one of the most important basic essentials in operation and maintenance of diesel engines. Clean fuel, clean air, clean coolants, clean lubricants, and clean combustion shall be maintained.

233-13.8.4 Do not use burlap or other materials containing lint for wrapping journals, wiping bearing surfaces or cleaning lube oil sumps.

233-13.8.5 Do not paint internal engine surfaces that are oil wetted during normal engine operation.

233-13.9 SUBMARINE ENGINES

233-13.9.1 Engines on submarines shall not be started until steps have been taken to ascertain that there is no water in the cylinders.

233-13.10 OVERSPEED TRIPS AND OVERSPEED GOVERNORS

233-13.10.1 Overspeed trip and governor mechanisms shall be tested once each quarter and after each major engine overhaul to verify that the complete mechanism is in proper working order. When making this test, a tachometer shall be used to check the speed at which the overspeed mechanism operates. This mechanism shall operate at the speed specified in PMS or the applicable NAVSEA Technical Manual.

NOTE

Two independent speed measuring devices are required when testing speed limiting governors and overspeed trips. A portable single range, single scale, hand held tachometer is the preferred primary measurement device. Backup speed verification can be accomplished by the unit installed tachometer.

233-13.10.2 If any irregularity is observed, the complete mechanism shall be checked and the condition corrected.

233-13.11 PREVENTION OF FIRES IN MACHINERY SPACES

233-13.11.1 The uncooled portions of exhaust connections, piping, expansion joints, turbochargers, support brackets, or any other part of diesel engines where surface temperatures exceed 125° F during any service condition, shall be insulated wherever practical and necessary to protect personnel. Temperatures which exceed 400° F during any service condition and are not insulated to protect personnel and are subject to fuel or lube oil leaks or sprays shall be shielded. Metal lagging shall be installed wherever necessary to protect insulation from physical damage and where insulation can become oil or water soaked. These precautions will prevent fires. For additional information, refer to **NSTM Chapter 555, Volumes 1, 2, and 3.**

233-13.11.2 Wherever possible, lubricating and fuel oil lines shall be located so any pipe or fitting leaks will not drip or spray on hot engine surfaces or into air intakes. Any fuel oil or lube oil system component which cannot be so located shall be shielded as necessary to minimize the fire hazard.

233-13.12 DIESEL ENGINE CASUALTY CONTROL PROCEDURES

CAUTION

CO₂ from portable fire extinguisher bottles or Halon will have little or no effect on securing the diesel, due to the large volume of air consumed by the diesel as compared to the small volume of CO₂ in the fire extinguisher bottles, or the small volume of Halon in the atmosphere. Refer to [paragraph 233-13.14](#).

233-13.12.1 Most Navy ships have Engineering Operational Casualty Control (EOCC) Procedures for diesel engines. Ships that do not have (EOCC) have locally prepared and approved Engineering Casualty Control Procedures (ECCP) for diesel engines.

233-13.12.2 EOCC and ECCP shall provide technically correct and logically required procedures for responding to and controlling common diesel engine casualties. When properly followed these procedures result in placing the diesel engine in a safe and stable condition while the cause of the casualty is being determined.

233-13.12.3 In an emergency situation, recommended procedures to stop the engine should the diesel fail to stop by normal means are as follows:

1. Secure the fuel supply to the diesel.
2. Secure the diesel intake air supply as follows:
 - a. Shut the air intake flapper(s).
 - b. Install intake covers.
 - c. Cover blower intake.

233-13.13 DIESEL ENGINE LUBE AND FUEL OIL LEAKAGE GUIDANCE

233-13.13.1 Diesel engines will not be free of lube oil leakage. Slight weeping of lube oil at gaskets and seals is acceptable.

233-13.13.2 Fuel oil systems for diesel engines should be leak free, with the exception of acceptable traces of fuel that are used for lubrication on fuel injection pump racks, fuel strainer and fuel filter shifting levers. These trace amounts are normal and are needed for proper lubrication of the fuel racks, strainer and fuel filter shifting levers. These trace amounts do not indicate an unsafe condition, as long as they do not develop into unacceptable weepage. Unacceptable weepage is defined as any fuel oil leak that develops into a noticeable accumulation either on or below the effected equipment or fitting. Due to the dangers involved with flammable liquid leaks, any unacceptable weepage that develops in a fuel oil system shall be corrected immediately.

233-13.13.3 Diesel engine high-pressure fuel lines (fuel piping between the fuel oil pump discharge and fuel oil nozzles) are not permitted to have any fuel oil leakage or weepage.

233-13.13.4 Diesel engine fuel oil drain lines should also be leak-free. If drain lines exhibit unacceptable weepage, corrective maintenance/repairs must be performed immediately. SAFETY IS THE NUMBER ONE CONCERN.

233-13.14 DISCHARGE OF HALON IN DIESEL ENGINE SPACE

WARNING

Halon becomes extremely toxic when ingested and burned within the diesel engine. Avoid breathing or coming in contact with the yellow-orange exhaust smoke. This exhaust contains by products consisting of hydrogen fluoride, hydrogen bromide and possibly bromine which result from the decomposition of Halon at the elevated temperatures within the cylinders.

NOTE

If an engine has been run while pulling combustion air from an engine room or other space that has had a Halon discharge, the engine lube oil acidity will increase. The engine lube oil shall be checked for viscosity and acidity immediately after exposure to a Halon discharge. If oil is not replaced, retest for viscosity and acidity 50 hours after Halon discharge. Engine lube oil shall be replaced if NOAP or PMS condemning limits are exceeded.

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 forwarded to:

COMMANDER,

CODE 310 TMDER, BLDG 1388

NAVSURFWARCENDIV NSDSA

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:

<http://nsdsa.phdnswc.navy.mil/tmder/tmder.asp?lvl=1>

All feedback comments shall be thoroughly investigated and originators will be advised of action resulting therefrom..

TMDER / MAILER

