**Designation: ~~D6618 – 16~~ D6618 – 23**

# Standard Test Method for Evaluation of Engine Oils in Diesel Four-Stroke Cycle Supercharged 1M-PC Single Cylinder Oil Test Engine[1]

This standard is issued under the fixed designation D6618; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## INTRODUCTION

This test method can be used by any properly equipped laboratory, without outside assistance. However, the ASTM Test Monitoring Center (TMC)[2] provides reference oils and an assessment of the test results obtained on those oils by the laboratory. By this means, the laboratory will know whether their use of the test method gives results statistically similar to those obtained by other laboratories. Furthermore, various agencies require that a laboratory utilize the TMC services in seeking qualification of oils against specifications. For example, the U.S. Army imposes such a requirement, in connection with several Army engine lubricating oil specifications.

Accordingly, this test method is written for use by laboratories that utilize the TMC services. Laboratories that choose not to use those services may simply ignore those portions of the test method that refer to the TMC.

This test method may be modified by means of Information Letters issued by the TMC. In addition, the TMC may issue supplementary memoranda related to the test method.



## 1. Scope*

1.1 This test method covers a four-stroke cycle diesel engine test procedure for evaluating engine oils for certain high-temperature performance characteristics, particularly ring sticking, ring and cylinder wear, and accumulation of piston deposits. Such oils include both single viscosity SAE grade and multiviscosity SAE grade oils used in diesel engines. It is commonly known as the 1M-PC test (PC for Pre-Chamber) and is used in several API oil categories, notably the CF and CF-2 and the military category described in MIL-PRF-2104 (see Note 1).

NOTE 1—Companion test methods used to evaluate other engine oil performance characteristics for API oil categories CF and CF-2 are discussed in SAE J304. The companion tests used by the military can be found in MIL-PRF-2104.

1.2 The values stated in SI units are to be regarded as standard.

1.2.1 *Exception*—The values in parentheses are provided for information only.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate ~~safety and health~~ safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.B0.02 on Heavy Duty Engine Oils. The test engine sequences were originally developed in 1956 by ASTM Committee D02. Subsequently, the procedures were published in an ASTM Special Technical Publication.

Current edition approved ~~April 1, 2016~~ July 1, 2023. Published ~~June 2016~~ July 2023. Originally approved in 2000. Last previous edition approved in ~~2014~~ 2016 as ~~D6618 – 14.~~ D6618 – 16. DOI: ~~10.1520/D6618-16.~~ 10.1520/D6618-23.

[2] ASTM Test Monitoring Center, ~~6555 Penn Avenue, Pittsburgh, PA 15206-4489.~~ 203 Armstrong Drive Freeport, PA 16229. The TMC issues Information Letters that supplement this test method. This edition incorporates revisions contained in all information letters through No. ~~15-1.~~ 23–1.

***A Summary of Changes section appears at the end of this standard**

1.4 This test method is arranged as follows:

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1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[3]

D86 Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure
D93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
D97 Test Method for Pour Point of Petroleum Products
D130 Test Method for Corrosiveness to Copper from Petroleum Products by Copper Strip Test
D235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)
D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
D482 Test Method for Ash from Petroleum Products
D524 Test Method for Ramsbottom Carbon Residue of Petroleum Products
D613 Test Method for Cetane Number of Diesel Fuel Oil
D664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration
D1319 Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption
D1796 Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure)
D2422 Classification of Industrial Fluid Lubricants by Viscosity System
D2425 Test Method for Hydrocarbon Types in Middle Distillates by Mass Spectrometry
D2500 Test Method for Cloud Point of Petroleum Products and Liquid Fuels
D2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry
D4052 Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants
D4294 Test Method for Sulfur in Petroleum and Petroleum Products by Energy Dispersive X-ray Fluorescence Spectrometry
D4485 Specification for Performance of Active API Service Category Engine Oils
D4863 Test Method for Determination of Lubricity of Two-Stroke-Cycle Gasoline Engine Lubricants (Withdrawn 2022)[4]
D5302 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Deposit Formation and Wear in a Spark-Ignition Internal Combustion Engine Fueled with Gasoline and Operated Under Low-Temperature, Light-Duty Conditions (Withdrawn 2003)[4]
D5844 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Rusting (Sequence IID) (Withdrawn 2003)[4]
D5862 Test Method for Evaluation of Engine Oils in Two-Stroke Cycle Turbo-Supercharged 6V92TA Diesel Engine (Withdrawn 2009)[4]
D6202 Test Method for Automotive Engine Oils on the Fuel Economy of Passenger Cars and Light-Duty Trucks in the Sequence VIA Spark Ignition Engine (Withdrawn 2009)[4]

2.2 *SAE Standard:*[5]

SAE J304 Engine Oil Tests

2.3 *Military Standard:*[6]

MIL-PRF-2104 Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service



[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] The last approved version of this historical standard is referenced on www.astm.org.

[5] Available from SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096, http://www.sae.org.

[6] Available from Standardization Documents Order Desk, Building 4, Section D, 700 Robbins Avenue, Philadelphia, PA 19111-5904, Attn: NPODS.

2.4 *Other ASTM Document:*
ASTM Deposit Rating Manual 20 (formerly CRC Manual 20)[7]

## 3. Terminology

3.1 *Definitions:*

3.1.1 *calibrate, v*—to determine the indication or output of a measuring device with respect to that of a standard. **D4175**

3.1.2 *candidate oil, n*—an oil that is intended to have the performance characteristics necessary to satisfy a specification and is tested against that specification. **D5844**

3.1.3 *clogging, n*—the restriction of a flow path due to the accumulation of material along the flow path boundaries. **D5844**

3.1.4 *engine oil, n*—a liquid that reduces friction or wear, or both, between the moving parts within an engine; removes heat, particularly from the underside of pistons; and serves as a combustion gas sealant for the piston rings. **D5862**

3.1.4.1 *Discussion*—
It may contain additives to enhance certain properties. Inhibition of engine rusting, deposit formation, valve train wear, oil oxidation, and foaming are examples.

3.1.5 *non-reference oil, n*—any oil other than a reference oil: such as a research formulation, commercial oil, or candidate oil. **D5844**

3.1.6 *purchaser, n—of an ASTM test*, a person or organization that pays for the conduct of an ASTM test method on a specified product. **D6202**



3.1.6.1 *Discussion*—
The preferred term is *purchaser*. Deprecated terms that have been used are *client*,*requester*,*sponsor*, and *customer*.



3.1.7 *reference oil, n*—an oil of known performance characteristics, used as a basis for comparison **D5844**

3.1.7.1 *Discussion*—
Reference oils are used to calibrate testing facilities, to compare the performance of other oils, or to evaluate other materials (such as seals) that interact with oils.



3.1.8 *scuff, scuffing, n—in lubrication*, damage caused by instantaneous localized welding between surfaces in relative motion which does not result in immobilization of the parts. **D4863**

3.1.9 *wear, n*—the loss of material from, or relocation of material on, a surface. **D5302**

3.1.9.1 *Discussion*—
Wear generally occurs between two surfaces moving relative to each other and is the result of mechanical or chemical action or by a combination of mechanical and chemical actions.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *calibration test, n*—an engine test conducted on a reference oil under carefully prescribed conditions whose result is used to determine the suitability of the engine stand/laboratory to conduct such tests on non-reference oils.

3.2.1.1 *Discussion*—
In this test method, it can also refer to tests conducted on parts to ensure their suitability for use in reference or non-reference tests.

3.2.2 *test, n*—any test time accumulated in accordance with this test method.

## 4. Summary of Test Method

4.1 Prior to each test run, the power section of the engine (excluding piston assembly) is completely disassembled, solvent-cleaned, measured, and rebuilt in strict accordance with furnished specifications. A new piston, piston ring assembly, and cylinder liner are installed each test. The engine crankcase is solvent-cleaned, and worn or defective parts are replaced. The test

[7] For Stock #TMCMNL20, visit the ASTM website, www.astm.org, or contact ASTM International Customer Service at service@astm.org.

stand is equipped with appropriate accessories for controlling speed, fuel rate, and various engine operating conditions. A suitable system for supercharging the engine with humidified and heated air shall also be provided.

4.2 Test operation involves the control of the supercharged, single-cylinder diesel test engine for a total of 120 h at a fixed speed and fuel rate, using the test oil as a lubricant. A 1 h engine break-in precedes each test. At the conclusion of the test, the piston, rings, and cylinder liner are examined. Note the degree of cylinder liner and piston ring wear, the amount and nature of piston deposits present, and whether any rings are stuck.

## 5. Significance and Use

5.1 The test method is designed to relate to high-speed, supercharged diesel engine operation and, in particular, to the deposit control characteristics and antiwear properties of diesel crankcase lubricating oils.

5.2 The test method is useful for the evaluation of diesel engine oil quality and crankcase oil specification acceptance. This test method, along with others, defines the minimum performance level of the API categories CF and CF-2 (detailed information about passing limits for these categories is included in Specification D4485). It is also used in MIL-PRF-2104.

5.3 The results are significant only when *all details* of the procedure are followed. The basic engine used in this test method has a precombustion chamber (as compared to direct injection) and is most useful in predicting performance of engines similarly equipped. This factor should be considered when extrapolating test results. It has been found useful in predicting results with high sulfur fuels (that is, greater than 0.5 % by mass) and with certain preemission controlled engines. It has also been found useful when correlated with deposit control in two-stroke cycle diesel engines.

## 6. Apparatus



6.1 *Test Engine*—A single-cylinder Caterpillar diesel oil test engine having a 2.2 L (134.1 in.$^3$) displacement is required. Bore and stroke are 13.0 cm (5.125 in.) and 16.5 cm (6.5 in.) respectively. The engine arrangement is shown in Fig. A1.1. The supply of test engines and parts is discussed in 6.22. The engine is equipped with the accessories or equipment listed in 6.2 through 6.24.

6.2 *Air Pressure*—Use a supercharging blower or other device arranged to control air pressure.



6.3 *Air Intake System*—Use the 1Y38 surge chamber and the air heater mechanism (see Annex A1) or its equivalent.

6.4 *Humidity*—Use a system to control humidity to the specified test conditions.

6.5 *Cooling System*—Use a closed, pressurized, circulating cooling system having an engine-driven centrifugal water pump.

6.6 *Speed/Load Controls*—Use a dynamometer or suitable loading device to control engine speed and measure load.

6.7 *Starting*—Use a suitable starting arrangement capable of 420 N·m (310 lbf·ft) breakaway and 373 N·m (275 lbf·ft) sustained torque at approximately 200 r/min.

6.8 *Exhaust System*—Use an exhaust system using piping and an exhaust barrel as specified in Annex A1. A restriction valve down stream of the barrel maintains the exhaust gases at a given back pressure as specified in the test conditions.

6.9 *Data Acquisition*—Configure all stands to acquire data automatically for speed, fuel flow, intake air pressure, intake air temperature, coolant temperature, oil-to-bearing temperature, and oil-to-jet pressure (as a minimum) with closed loop control on speed, intake air temperature, coolant temperature, and oil-to-bearing temperature (as a minimum).

6.10 *Cylinder Head and Cylinder Assemblies*—Only cylinder head and cylinder assemblies that have previously passed a calibration test are acceptable for non-reference testing.

6.11 *Piston Cooling Nozzle:*

6.11.1 *Oil Jet Pressure Measurement*—The following is required to allow for measurement of the piston cooling nozzle pressure:

6.11.1.1 Replace the 3B9407 fitting with a ¼ in. tee fitting, and reconnect the 1Y6 oil line.

6.11.1.2 Modify the 1Y8199 oil pan to provide access for the pressure pickup.

6.11.1.3 Use oil pressure gauge 8M2743, or equivalent.

6.11.1.4 Only piston cooling jets that have been flow-checked by the specified industry standard are approved for use. See footnote 11 for supplier. Fig. A1.2 shows the suggested modification of the 1Y8199 oil pan and necessary hardware for the cooling nozzle pressure pickup. All test engines with serial numbers greater than 2511252 will be provided with the pressure pickup modification.

6.11.2 *Piston Cooling Jet Supplier*—To improve precision, Perkin Elmer Automotive Research and Southwest Research Institute (SWRI) have agreed to provide flow-checked 1M-PC P-tubes to the industry. Perkin Elmer Automotive Research will flow and serialize the units and determine if they are within specification and will maintain records, while SWRI will coordinate the redistribution. Send P-tubes to be inspected to Perkin Elmer Automotive Research.[8]

6.11.2.1 The P-tubes will be flowed, using EF-411 oil at 37.8 °C ± 0.6 °C (100 °F ± 1 °F) and 165.5 kPa ± 0.5 kPa (24 psi ± 0.5 psi) as measured at the location shown in Fig. A1.2. The acceptable flow range is 1.89 L/min to 2.27 L/min (0.50 gal/min to 0.60 gal/min).

6.11.2.2 To maintain impartiality in selecting P-tubes, only acceptable assemblies will be forwarded to SWRI as unmarked units. These units will be randomly selected for redistribution. In cases in which the only units available are from a single order, only those units will be returned. Assemblies that fall outside of the specifications will not be returned. Instead, Perkin Elmer Automotive Research will generate a nonconformance report with an additional copy to be sent to the laboratory that supplied the P-tube. The failed units will be returned to Caterpillar for credit. Perkin Elmer Automotive Research will indicate on the nonconformance report that the appropriate credit be issued to the originating laboratory. Additional piston cooling assemblies will need to be supplied by the requesting laboratory and submitted to Perkin Elmer Automotive Research.

6.11.2.3 Perkin Elmer Automotive Research will enclose a statement with each unit inspected, disclaiming any liability for subsequent performance of the part. No attempt will be made to ensure that the tubing is properly configured or that any other physical property makes it suitable for use. Units damaged during shipment will not be tested, unless specifically requested. Include a packing list and separate purchase orders to Perkin Elmer Automotive Research and SWRI[9] with each shipment. Please specify a name and address where the parts are to be returned.

6.12 *Engine Oil Level Gauge*—Lower the bayonet gauge housing 5 cm (2.0 in.) to provide for more accurate oil level readings. Parts required for this modification are shown in Fig. A1.3.

6.13 *Crankcase Pressure Control Valve*—Install a pressure control valve (1Y479) at the crankcase breather outlet to stabilize crankcase pressure. Installation is shown in Fig. A1.4.

6.14 *Oil Cooler Inlet ~~Temperature —~~Temperature*—Record the temperature of the oil cooler inlet by installing a thermocouple in the pipe-tapped hole provided on the rear side of the oil-cooler cover adjacent to the oil inlet port. Care should be taken to provide sufficient thermocouple insertion depth to provide a mid-stream oil temperature.

6.15 *Engine Oil System*—Use the *last chance* screen 1Y3549. Modify the oil pump as shown in Fig. A1.10. Add the external oil pump bypass line for safety and convenience factors to adjust oil pressure on engine break-in and warm-up.

6.16 *Cooling System*—Replace the 7.6 cm (3 in.) standard cooling tower with the 12.7 cm (5 in.) pressurized cooling tower as shown in Fig. A1.6. Modify the cooling system to accommodate the pressurized cooling tower, bypass flow control and flow meter as shown in Fig. A1.7 and Fig. A1.8. Use a Barco Venturi Meter #BR 12705-16-31.[10,11] Use brass or stainless steel pipe that has



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[8] Send P-tubes to be inspected to Perkin Elmer Automotive Research, 5404 Bandera Road, San Antonio, TX 78238.

[9] Southwest Research Institute, 6220 Culebra Road, P.O. Drawer 28510, San Antonio, TX 78228-0510.

[10] Available from J. P. Bushnell, 3436 Lindell Blvd., St. Louis, MO.

chamfered ends (45°) into and out of the venturi meter [15.2 cm (6 in.) minimum into and 5.1 cm (2 in.) minimum out]. Orient the high pressure tap (the first seen by the flow) horizontally.

6.17 *Fuel System*—Use a standardized engine fuel system to ensure that fuel-line pressure transients are held to acceptable values and to minimize cranking times. Use a Micro Motion flow meter[12,11] having a range no greater than 0 kg/h to 90.7 kg/h (0 lb/h to 200 lb/h) to measure fuel flow rate.

6.17.1 The line lengths, line sizes, and fuel system components are shown in Fig. A1.5. Use this system without modification, with the possible exception that the fuel shut-off solenoid[13,11] is eliminated if the line length from the engine-mounted filter to the injector pump is standardized at 107 cm ± 1 cm (42.25 in. ± 0.5 in.). Also, an external fuel pump may be used in place of the engine-mounted fuel pump. Control the fuel rate with either manual or automated fuel rack manipulation.

6.18 *Intake Air System*—Install a dry element oil and particle filter between the air supply source and each engine to be run. Use an air filter capable of 10 µm (or smaller) filtration. (Oil bath filters are not acceptable in this location.) Make air filter replacements as required to minimize pressure losses and with sufficient frequency to maintain the air heater barrel as free as possible form oil and dust particles. The 1Y38 surge chamber and air heater assembly required is shown in Annex A1.

6.18.1 Suitable equipment is required to maintain the specified moisture content, temperature, and pressure of the inlet air to the cylinder head. The accuracy of the humidification system is to be within ±0.648 g (±10 grains) of the humidity-measuring, chilled-mirror dew point hydrometer (see 9.6.2).

6.19 *Exhaust System*—Uniformity in exhaust system pressure patterns within a laboratory and from laboratory-to-laboratory is required to minimize a major test variable. The dimensions and distance of the exhaust piping from the exhaust elbow to the barrel, as well as the volume of the exhaust barrel, are specified in Figs. A1.30-A1.34. Note the exhaust barrel may be insulated or water cooled. The downstream distance of the restriction valve from the exhaust barrel is not specified.

6.19.1 Set the exhaust pressure at specified conditions as given in Table 1 by varying the restriction valve. Measure the pressure in the exhaust barrel as shown in Fig. A1.31. The location of the 1Y467 or equivalent exhaust thermocouple is shown in Fig. A1.30.

6.20 *Blowby Meter,* a displacement type gas meter or equivalent fitted with an oil separator and surge chamber. A fitting on the crankcase breather (see Fig. A1.4) permits attachment of the meter to the engine by using appropriate lengths of hose or pipe, or both, suitable to the laboratory's needs.



**TABLE 1 1M-PC Operating Conditions**$^{A,B}$

| | |
|---|---|
| Speed, r/min | 1800 ± 10 |
| Fuel flow, kg/h (lb/h) | 8.13 ± 0.07 (17.92 ± 0.15) |
| Temperature, water from cylinder head,° C (°F) | 87.8 ± 2.8 (190 ± 5) |
| Flow rate, engine coolant, L/min (gal/min) | 57.9 ± 3.8 (15.3 ± 1.0) |
| Temperature, oil to bearings, °C (°F) | 96.1 ± 2.8 (205± 5) |
| Temperature, inlet air to engine, °C (°F) | 123.9 ± 2.8 (255± 5) |
| Temperature, exhaust, °C (°F) | 573 ± 28 (1063 ± 50) |
| Pressure, fuel to injection pump, kPa (psi) | 137.9 ± 13.8 (20 ± 2) |
| Pressure, exhaust, kPa (in. Hg Abs.) | 106.7 ± 1.7 (31.5 ± 0.05) |
| Pressure, oil at jet cooling nozzle, kPa (psi)$^{C}$ | 165.5 ± 13.8 (24± 2) |
| Pressure, oil to bearings maximum, kPa (psi)$^{C}$ | 220.6 (32) |
| Pressure, air to engine, kPa (in. Hg Abs.) | 179.0 ± 1.0 (53 ± 0.3) |
| Vacuum, crankcase, kPa (in. $H_2O$) | 0.25 ± 0.12 (1.0± 0.5) |
| Humidity, air to engine, g/kg of dry air (grains/lb) | 17.8 ± 1.7 (125 ± 12) |
| Flow rate, engine air, approximate $m^3$/min ($ft^3$/min) at 15.6 °C (60 °F), 101.3 kPa Abs. (14.7 psi Abs.) | 0.2 (94) |

$^{A}$ Count test time from the moment the conditions in this table are obtained (30 min maximum are allowed for stabilization).
$^{B}$ Only speed and fuel flow are controlled. Load is used as a verification of engine build and operation.
$^{C}$ Oil pressure operating specifications apply only to 15W-40 oils. Attempt to maintain these limits for all oils. When oils other than 15W-40 oils fall outside these limits, explain these deviations from the limits in the comments section of the test report.

[11] The sole source of supply of the apparatus known to the committee at this time is noted in the adjoining footnote. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.
[12] Available from Micro Motion, Inc., 7070 Winchester Circle, Boulder, CO 80301.
[13] Available from Asco, Florham Park, New Jersey 07932.

6.21 *Thermocouples*—Specified thermocouples (or equivalents) are required for obtaining temperatures at the following locations: air-to-engine (1Y468), exhaust temperature (1Y467), and water inlet, water outlet, oil-to-bearings (1Y466).

6.21.1 Install thermocouples 1Y468, 1Y467, and 1Y466 only at the temperature-sensing locations provided with the 1Y73 engine arrangement. Locate the immersion depth for water inlet, water outlet, and oil-to-bearing temperature sensors so that the tip of the sensor is midstream of the fluid measured. Immersion depth for the air and exhaust temperature sensors are measured as follows (variation from these dimensions is not permitted):

6.21.1.1 Air temperature sensor depth: 27 mm ± 2 mm ($1\frac{1}{16}$ in. ± $\frac{1}{16}$ in.)

6.21.1.2 Exhaust temperature sensor depth: 65 mm ± 2 mm ($2\frac{9}{16}$ in. ± $\frac{1}{16}$ in.)

6.22 *Parts:*

6.22.1 *Procurement of Parts*—Information concerning procurement of Caterpillar test engines and replacement parts and approval of equivalent parts substitutions allowed in this test method is obtained by contacting Caterpillar Inc.[14,11] Other parts and their sources referred to throughout the procedure are found in the footnotes. Use all Caterpillar parts on a first-in-first-out basis.

6.22.2 All parts for the 1Y73 engine and the 1Y73 Conversion Kit that are nonconforming by reason of faulty manufacture should be discussed with the Engine System Technology Department (ESTD) at Caterpillar Inc.[14,11]

6.22.2.1 The test labs should contact ESTD when they believe a part is nonconforming:

6.22.2.2 ESTD will determine if they want the part returned, or provide warranty without viewing the part.



6.22.2.3 If ESTD determines that the part is nonconforming without viewing the part, the test labs will be asked to return the part to their Caterpillar dealer. ESTD will contact the dealer with the information that the part is being returned and provide warranty for it.

6.22.2.4 If ESTD wants to view the part, they will issue a Return Goods Authorization Number (RGA) to the test lab and send the part and the form to Caterpillar Inc.[15,11]



6.22.2.5 If ESTD determines that the part is nonconforming, they will contact the dealer for the test lab and have the dealer provide warranty.

6.22.2.6 A sample of the RGA Claim Form is shown in Fig. 1. It should include return goods authorization number, part name, hours on the part, part number, quantity, purchase order number, date purchased, test lab that purchased the part, contact person's name, phone, fax, and address, dealer's name that sold the part, and measurements or photographs, or both, to document the nonconformance.

6.23 *Instrumentation,* capable of meeting (or exceeding) the calibration tolerances, measuring resolutions, and maximum *system* time constants shown in Tables 2-4.

6.24 *Crankcase Paint*—Inspect crankcases regularly to ensure proper paint coating. Coat crankcases as necessary, using either of two approved coatings.[16,11]

## 7. Reagents and Materials

7.1 *Fuel*—The specified test fuel is Haltermann Products 0.4 % Sulfur Diesel Test Fuel.[17,11] All fuel shall meet the fuel specifications as shown in Annex A3 and shall be referenced through the ASTM TMC. Approximately 1137 L (300 gal) are

[14] Caterpillar Inc., Engine System Technology Department, P.O. Box 610, Mossville, IL 61552.

[15] Caterpillar Inc., Tech Center TC-L, Wing 4, Room 405, 14009 Old Galena Rd., Mossville, IL 61552.

[16] Crankcase paint in one gallon cans as Yellow Primer Paint Cat Part #IE2083A, Primer #A123590, Serial #BIM0115877, B.A.S.F. Part #U27TD005 is available from B.A.S.F. Coating and Cocorant Division, P.O. Box 1297, Morganton, NC 28655; and as Glyptal 1201 Red Enamel, Brownell Outlet, 84 Executive Avenue, Edison, NJ 08817.

[17] Available from Howell Hydrocarbons and Chemicals, Inc., 1201 South Sheldon Road, P.O. Box 429, Channel View, TX 77530.

*RETURN GOODS AUTHORIZATION CLAIM FORM*

## RETURN GOODS AUTHORIZATION CLAIM FORM

Return Goods Authorization Number: ____________________.

Claim Date: _____________.

Contact: Caterpillar Inc
Engine System Tech Dev.
P.O. Box 610
Mossville, II 61552
Phone: 309-578-2131
Fax: 309-578-6457
Attn: R.A. Riviere

Part Number / Quantity: _____________________/_________.

Part Name / Hrs On Part: ____________________/_________.

Date Part Purchased: _____________.

Engine Serial Number: _____________________.

Test Lab

Name: ____________________________________________.

Address: __________________________________________.

Contact Person's Name: ______________________________.

Phone Number: ___________________________.

Fax Number: ____________________________.

Name of Dealer That Sold Part: ________________________________.

INCLUDE DOCUMENTATION AND PHOTOS OF NONCONFORMING PART

**FIG. 1 Return Goods Authorization Claim Form**



required for each test. Include the fuel analysis for the last batch used for the test in the final report. The fuel supplier provides the analysis. If more than one batch is used, note this is in the comments section of the Unscheduled Downtime & Maintenance Summary form of the test report with the appropriate percentages of run time.

7.2 *Test Oil*—Approximately 30 L to 34 L (8 gal to 9 gal) of test oil are required for each test.

**TABLE 2 Calibration Tolerances**

| Parameter | Tolerance | |
|---|---|---|
| Speed, r/min | 2 | |
| Load | NA due to differences within industry. TMC to verify each lab during visits. | |
| Fuel flow | Absolute error ≤ 0.125 % | |
| Humidity | NA. Already specified. Checked during running conditions as outlined in the test procedure (see form attached) | |
| **Temperatures** | **°C** | **°F** |
| Coolant out | 0.25 | 0.5 |
| Coolant in | 0.25 | 0.5 |
| Oil to bearing | 0.5 | 1.0 |
| Intake air | 0.5 | 1.0 |
| Exhaust | 1.0 | 2.0 |
| **Pressures** | | |
| Oil to bearing, psig | 0.7 kPa | 0.1 |
| Oil to jet, psig | 0.7 kPa | 0.1 |
| Inlet air, in Hg | 0.3 kPa | 0.1 |
| Exhaust, in Hg | 0.3 kPa | 0.1 |
| Fuel at filter housing., psig | 0.7 kPa | 0.1 |
| Crankcase vacuum, in $H_2O$ | 0.02 kPa | 0.1 |

7.3 *Engine Coolant,* a mixture of 118 mL (4 fluid oz) Part Number 3P2044 coolant additive (Pencool 2000[18,11]) per 4 L (1 gal) of mineral-free water. Mineral-free water is defined as having a mineral content no higher than 34.2 ppm (2 grains/gal) total dissolved solids. A fresh coolant mixture is used for each new test.

7.4 *Cleaning Materials:*



7.4.1 *Solvent*—Use only mineral spirits meeting the requirements of Specification D235, Type II, Class C for Aromatic Content (0 % to 2 %) by vol, Flash Point (142 °F/61 °C, min) and Color (not darker than +25 on Saybolt Scale or 25 on Pt-Co Scale). (**Warning—**Combustible. Health hazard.) Obtain a Certificate of Analysis for each batch of solvent from the supplier.

7.4.2 *Dispersant Engine Cleaner*—Use Dispersant Engine Cleaner[19,11] (order by this name) in solution with mineral spirits where called for in the engine flush procedure.

7.4.3 *General Cleaning Agents*—Use sodium bi-sulfate ($Na_2SO_4$) and tri-sodium phosphate ($Na_3PO_4$) in solution with water in the cooling system flush procedure. (**Warning—**Eye and throat irritants; repeated exposure can cause dermatitis. Wear protective gloves, face mask, or chemical type goggles.)

## 8. Safety

8.1 The operating of engine tests can expose personnel and facilities to a number of safety hazards. It is recommended that only personnel who are thoroughly trained and experienced in engine testing should undertake the design, installation and operation of engine test stands. Each laboratory conducting engine tests should have its test installation inspected and approved by its safety department. Provide personnel working on the engines with the proper tools, be alert to common sense safety practices, and avoid contact with moving or hot engine parts. Guards should be installed around all external moving or hot parts. When engines are operating at high speeds, heavy duty guards are required and personnel should be cautioned against working alongside the engine and coupling shaft. Provide barrier protection for personnel. All fuel, oil lines, and electrical wiring should be properly routed, guarded, and kept in good order. Scraped knuckles, minor burns, and cuts are common if proper safety precautions are not taken. Safety masks or glasses should always be worn by personnel working on the engines, and no loose or flowing clothing should be worn near running engines.

8.2 Keep the external parts on the engine and the floor area around the engines clean and free of oil and fuel spills. In addition, keep working areas free of all tripping hazards. In case of injury, no matter how slight, first aid attention should be applied at once and the incident reported. Personnel should be alert for leaking fuel or exhaust gas. Leaking fuel represents a fire hazard, and exhaust gas fumes are noxious. Containers of oil or fuel cannot be permitted to accumulate in the testing area.

[18] Available directly from Nalco, 4639 Corona Drive, Suite 61, Corpus Christi, TX 78441.
[19] Available from The Lubrizol Corporation, 29400 Lakeland Blvd., Cleveland, OH 44092.

TABLE 3 Operational Specifications, Measurement Resolution, and Reporting Resolution

| | SI Specification | | | | US Customary System (USCS) Specification | | | |
|---|---|---|---|---|---|---|---|---|
| Parameter | Units | Spec | Minimum Measurement Regulation | Round Values to the Nearest | Units | Spec | Minimum Measurement Resolution | Round Values to the Nearest |
| Speed | r/min | 1800 ± 10 | 1 | Whole number | r/min | 1800 ± 10 | 1 | Whole number |
| Power | kW | 31.3 | | | bhp | 42 | | |
| BMEP | kPa | 951 | | | psig | 138 | | |
| Fuel rate | kJ/min | 6172 ± 53 | | | Btu/min | 5850 ± 50 | | |
| Fuel flow[A] | kg/h | 8.13 ± 0.07 | 0.01 | Hundredth | lb/h | 17.92 ± 0.15 | 0.01 | Hundredth |
| BSFC | kg/kWh | 0.260 | | | lb/bhp.h | 0.427 | | |
| Humidity | g/kg | 17.8 ± 1.7 | 0.1 | Tenth | grains/lb | 125 ± 12 | 1 | Whole number |
| Oil weight | g | N/A | 1 | Whole number | lb | N/A | 0.01 | Hundredth |
| **Temperatures** | | | | | | | | |
| Coolant out | °C | 87.8 ± 2.8 | 0.1 | Tenth | °F | 190 ± 5 | 0.1 | Tenth |
| Coolant in | °C | 82.8 | 0.1 | Tenth | °F | 181 | 0.1 | Tenth |
| Coolant Δ | °C | 5 ± 1.0 | 0.1 | Tenth | °F | 9 ± 2 | 0.1 | Tenth |
| Oil to bearing | °C | 96.1 ± 2.8 | 0.1 | Tenth | °F | 205 ± 5 | 0.1 | Tenth |
| Inlet air | °C | 123.9 ± 2.8 | 0.1 | Tenth | °F | 255 ± 5 | 0.1 | Tenth |
| Exhaust | °C | 573 ± 28 | 1 | Whole number | °F | 1063 ± 50 | 1 | Whole number |
| **Pressures** | | | | | | | | |
| Oil to bearing[B] | kPa | 220.6 Max | | | psig | 32 max | | |
| Oil to jet[B] | kPa | 165.5 ± 13.8 | 0.1 | Tenth | psig | 24 ± 2 | 0.1 | Tenth |
| Inlet air (ABS) | kPa | 179 ± 1 | 0.1 | Tenth | in. Hg | 53.0 ± 0.3 | 0.1 | Tenth |
| Exhaust (ABS) | kPa | 106.7 ± 1.7 | 0.1 | Tenth | in. Hg | 31.5 ± 0.5 | 0.1 | Tenth |
| Fuel at filter housing. | kPa | 137.9 ± 13.8 | 0.1 | Tenth | psig | 20 ± 2 | 0.1 | Tenth |
| Crankcase vac | kPa | 0.25 ± 0.12 | 0.01 | Hundredth | in. $H_2O$ | 1 ± 0.5 | 0.1 | Tenth |
| **Flows** | | | | | | | | |
| Coolant flow | L/min | 57.9 ± 3.8 | 0.1 | Tenth | gal/min | 15.3 ± 1.0 | 0.1 | Tenth |

[A] Fuel flow spec is based on the high heating value of 19.590 Btu ⁄lb at an A.P.I. gravity of 35. Fuel spec is 33 to 35 A.P.I. gravity.
[B] Oil pressure operating specifications apply only to 15W-40 oils. Attempt to maintain these limits for all oils. When oils other than 15W-40 oils fall outside these limits, explain these deviations from the limits in the comments section of the test report.



TABLE 4 Maximum Allowable System Time Constants

| Measurements | |
|---|---|
| Speed | 3.0 s |
| Fuel Flow | 73.0 s |
| Temperatures | |
| Coolant Out | 3.0 s |
| Coolant In | 3.0 s |
| Oil to Bearings | 3.0 s |
| Intake air | 3.0 s |
| Exhaust | 3.0 s |
| Pressures | |
| Oil to Bearings | 3.0 s |
| Oil to Jet | 3.0 s |
| Intake Air | 3.0 s |
| Exhaust | 3.0 s |
| Fuel at Filter | 3.0 s |
| Crankcase Vac. | 3.0 s |

8.3 Equip the test installation with a fuel shut-off valve designed to automatically cut off the fuel supply to the engine when the engine is not running. A remote station for cutting off fuel from the test stand is recommended. Provide suitable interlocks so that engine is automatically shut down when any of the following events occur: engine or dynamometer loses field current, engine overspeeds, exhaust system fails, room ventilation fails, or the fire protection system is activated. Consider an excessive vibration pickup interlock if equipment is operated unattended. Provide fixed fire protection equipment, and make dry chemical fire extinguishers available at the test stands. (**Warning—**Many ASTM tests use chemicals to flush engines between tests. Some of these chemicals require that personnel wear face masks, dust breathers, and gloves because exothermic reactions are possible. Provide emergency showers and face rinse facilities when handling materials.)

## 9. Preparation of Apparatus

9.1 *Supplementary Service Information:*

9.1.1 *Caterpillar Service Manual*—Engine service information not found in this test method may be obtained by referring to the Caterpillar Single Cylinder Oil Test Engine Service Manual (Form No. SENR2074) and parts manual SEBP1299.[14,11]

9.1.2 *Pretest Maintenance Check List and Continuing Engine Inspection*—A recommended list of items that are checked or replaced at the intervals specified is shown in Table 5.

9.2 *General Engine Inspection:*

9.2.1 Perform a complete engine inspection every 10 000 test hours. This inspection is done to ensure that wearing surfaces, such as main bearings and journals, rod bearings and journals, camshaft bearings, and so forth, are within manufacturer's specifications. This inspection will terminate the current test stand calibration (if any). Recalibration is required any time the crank is removed for any purpose other than bearing replacement.

9.2.2 Maintain a complete record of all engine maintenance and measurements. Retain a description of inspection methods along with the maintenance records for review when requested.

9.3 *Intake Air System*—Prior to each stand calibration test, inspect the intake air barrel for rust and debris. This may be done through either of the pipe flanges, using a borescope or some other optical means. Remove any foreign material.

9.4 *Cooling System:*

9.4.1 Whenever visual inspection indicates the need, remove all mineral deposits and oil from the cooling system. Make the initial coolant charge at the start of the test with distilled or de-ionized water and a rust inhibitor (Penncol 2000) (see 7.3). The cooling system shall remain full during all shutdowns that do not require the cooling system to be drained.

9.4.2 Make any make-up coolant additions throughout the test with the same treated water solution. Monitor the cooling system visually at the glass or plastic tube in the 1Y504 water outlet line assembly. At any indication of vapor formation, the coolant will



**TABLE 5 Pretest Maintenance Check List[A] and Continuing Engine[B] Inspection**

| Item to be checked | Remarks | |
|---|---|---|
| Fuel injection pump adjusting screw (2F8337) | Inspect before each test. Replace as necessary. | |
| Fuel injection pump | Check pump plunger sector gear for tooth wear—general condition of pump (visual); replace pump as necessary. | |
| Fuel injection valve | Install new before each test. Inspect fuel injection line orifice (both ends) for correct diameter, 1.57 mm (0.062 in.) minimum. | |
| Fuel injection timing | 3.81 mm ± 0.127 mm (0.150 in. ± 0.005 in.) lift, BPC at 8° BTC. | |
| Injection pump inlet seal (2M4453) | Install new before each test. | |
| Filter-fuel system | Install when fuel pressure cannot be held within test limits. | |
| Cylinder head | New (calibration test only) or reconditioned head for each test. Measure and record valve head and stem projection. Measure prechamber orifice diameter (7.59 mm to 7.64 mm [0.299 in. to 0.301 in.]). | |
| Cylinder head gasket (1Y7960) | Install new before each test. | |
| Piston cooling jet | Inspect for plugging and proper positioning before each test; use aiming guide. Verify piston-to-cooling jet clearance. | |
| Water pump and fuel transfer pump belts | Inspect and adjust as necessary. (Measure deflection at point midway between pulleys - water and fuel.) | |
| | Belt deflection | Force |
| | 19.05 mm (0.75 in.) | 111 N (25 lb) |
| Fuel pressure | 138 kPa (20 psi) | |
| Water flow | 58.0 L ⁄min (15.3 gal ⁄min) | |
| Crankcase stud seal (1Y2310) | Inspect and replace as required. Install with taper down. | |
| Valve tappets | Zero lash + ½ turn hydraulic lash adjusters.[C] | |
| Piston pin | Clearance in rod pin bushing—0.051 mm (0.002 in.) maximum | |
| Fuel pump rack and rack control rod, gov. button, lever, and sliding sleeve | Check rack for tooth wear—rack control rod for worn ball and socket joints and loose nuts and washers. Gov. button and lever for wear and free movement, sliding sleeve for free movement, bearing condition, and gov. wt. contact and wear. | |
| Valve rotators | Inspect for proper operation at start of test and end of test. | |
| Leaks | Repair immediately upon detection, particularly fuel, oil, air, exhaust, and coolant. | |

[A] This check list is made to cover the maintenance to be performed before and during each test. Included are those parts, in addition to the piston rings and liner, to be installed new at the beginning of each test. Replace all gaskets that are disturbed during such disassembly and assembly that takes place between tests or at intermediate inspections. Carefully inspect seals before their reuse.
[B] ENGINE: 1Y73 130 mm (5.125 in.) bore, 165 mm (6.5 in.) stroke.
[C] Leakdown time 8 s to 45 s for 3.175 mm (0.125 in.) plunger travel under a 22.68 kg (50 lb) load and filled with kerosene having a viscosity of 35 sus at 21.1 °C (70 °F).

have a clouded appearance. Should this occur during a test, shutdown the engine and check for air leakage on the suction side of the water pump or combustion gas leakage in the cylinder head. No air is permitted in the system.

9.5 *Engine Cooling System Cleaning*—Clean the cooling system when visual inspection shows the presence of oil or grease, mineral deposits, or rust. Heads may be cleaned when either on or off the engine. Use the following procedure:

9.5.1 Operate the engine long enough to reach oil and water operating temperatures; drain the cooling system.

9.5.2 Fill the cooling system with a solution of 450 g (1 lb) commercial sodium bisulfate ($Na_2SO_4$) to 19 L (5 gal) of water; then run the engine at operating temperature for ½ h.

9.5.3 Drain and flush the engine with fresh water, and drain the water from the system.

9.5.4 Fill the cooling system with a solution of 450 g (1 lb) of tri-sodium phosphate ($Na_3PO_4$) to 38 L (10 gal) of water; operate the engine for 5 min to ensure complete mixing of the $Na_3PO_4$ solution with any material left from the previous flush.

9.5.5 Drain the engine, flush with clear water, and drain after flushing.

9.5.6 Disassemble the engine, and prepare for the next test.

NOTE 2—If the purpose of the system cleaning is to descale only, 9.5.4 and 9.5.5 can be omitted.

9.6 *Instrumentation Calibration Requirements:*



9.6.1 *General Requirements:*

9.6.1.1 Calibrate all facility read-out instrumentation used for the test immediately prior to commencing a test stand calibration. Instrumentation calibrations prior to subsequent stand calibration tests (that is, those that follow a failed or invalid first attempt) are at the discretion of the test laboratory. Make these calibrations part of the laboratory record (refer to Tables 2-4 for specifications).



9.6.1.2 Calibrate on a yearly basis all temperature, pressure, flow, and speed measurement standards with instruments traceable to a national bureau of standards (for example, the National Bureau of Standards and Technology or its successor agency for labs operating in the United States). Maintain records of all calibrations for a minimum of two years.

9.6.2 *Specific Humidity Requirements:*

9.6.2.1 Calibrate the primary laboratory humidity measurement system during the first 24 h of each individual stand calibration test using a chilled-mirror dew point hygrometer with an accuracy of at least ±0.55 °C at 24 °C (±1 °F at 75 °F) dew point. The calibration consists of a series of *paired* comparison measurements between the primary system and the chilled-mirror dew point hygrometer. The comparison period lasts from 20 min to 2 h with measurements taken at 1 min to 6 min intervals, for a total of 20 paired measurements. The measurement interval should be appropriate for the time constant of the humidity measuring instruments.

9.6.2.2 The location of the hygrometer tap is shown in Fig. A1.28. The sample line may require insulation to prevent dropping below dew point temperature and shall not be hygroscopic. The flow rate shall be verified to be within the equipment manufacturer's specification.

9.6.2.3 All measurements taken with the dew point hygrometer are at atmospheric pressure and corrected to standard conditions (101.12 kPa [29.92 in. Hg]) using the perfect gas law or Table X1.1 to Table X1.9 in Appendix X1. Compute the difference between each pair of measurements and use to form a mean and standard deviation. The absolute value of the mean difference shall not exceed 0.648 g (10 grains), and the standard deviation shall be less than or equal to 0.324 g (5 grains). Both of these requirements shall be met for the primary humidity measurement system to be considered calibrated. If either of these requirements cannot be met, the laboratory should investigate the cause, make repairs, and recalibrate. Maintain the calibration data for two years.

9.6.2.4 *Recommended Practice*—Install drain taps at the low points of the combustion air system and keep open during shut-down and warm-up.

9.6.3 *Specific Coolant Flow Requirements:*

9.6.3.1 As a calibration standard, each test lab is required to maintain at least one Barco venturi flow meter configured as shown in Fig. A1.8 and described in 6.16. On a yearly basis, calibrate this Barco (with its inlet and outlet piping) with an instrument traceable to a national bureau of standards (for example, the National Bureau of Standards and Technology or its successor agency for labs operating in the United States). The inlet and outlet piping shall remain with this Barco assembly.

9.6.3.2 During the break-in prior to each calibration test, place this calibrated Barco assembly in the standard mounting position. Adjust the coolant flow bypass valve until the readout equipment being used registers the differential pressure that corresponds to 57.9 L/min (15.3 gal/min) for this calibrated Barco assembly.

9.6.3.3 After break-in, replace the calibrated Barco assembly with the stand's running Barco assembly. *Do not re-adjust the coolant flow bypass valve*. Maintain whatever differential pressure is registered with the stand Barco at this point throughout the duration of the test. Test all non-reference oils with this stand Barco assembly run at this differential pressure. If desired, adjust any readout equipment to make this differential pressure correspond to 57.9 L/min (15.3 gal/min).

9.7 *Engine Crankcase Cleaning*—Flush the engine prior to each new test. The objective is to remove all deposits from all surfaces of all engine cavities prior to each test. In some instances, extra cleaning may be required. A finger-wiping check may be made on less accessible engine surfaces from time-to-time to determine if the engine is clean.

9.8 *Additional Oil Filter*—Install a full-flow paper element oil filter in the flushing pump unit to remove engine wear particles during engine flush. Such particles have been known to cause piston scuffing during subsequent testing.[20,11]



9.9 *Flushing Procedure Components*—Conduct the engine flushing procedure with the components shown in Fig. A1.12 through Fig. A1.19 (the design for mobilizing the flushing pump arrangement, Fig. A1.13, is optional). Fig. A1.17 (Views A and B) illustrates the use of the flushing components.

9.10 *Flushing Procedures*—Use the following flushing procedure:



9.10.1 Rotate the crankshaft until the top end of the connecting rod is below the cylinder block bore in the top of the crankcase. Install the poly(methyl methacrylate) (PMMA) or clear plastic cover (Fig. A1.12 on the top surface of the crankcase, as shown in Fig. A1.17 (View A).

9.10.2 *For First Stage Flushing with Mineral Spirits:*[21,11]

9.10.2.1 Install a clean 1Y5700 element in both the engine and flushing pump oil filter housings.

9.10.2.2 Connect the flushing pump (Fig. A1.13) outlet hose to the engine oil cooler drain location.

9.10.2.3 Remove breather assembly 1Y2592 (top portion of side cover assembly) and clean separately by soaking in mineral spirits. Air-dry.

9.10.2.4 Insert the 1Y5 rocker shaft oil line in the center opening of the clear plastic cover (see Fig. A1.12).

9.10.2.5 Place the flushing pump inlet line in a clean supply tank (sample location illustrated in Fig. A1.13) containing 7.6 L (2 gal) of mineral spirits. Open the crankcase drain, start the flushing pump, and run this flush material through the engine into a drain pan one time. *Do not recirculate*.

9.10.2.6 Close the crankcase drain and connect the flushing pump inlet line to the crankcase drain.

[20] TEI CLR engine oil filter housing #2418 and filter element #3105 have been found satisfactory for this use. Available from Test Engineering, Inc., 12758 Cimarron Path, Suite 102, San Antonio, TX 78429.

[21] Available from UNOCAL Chemicals Division, 7010 Mykawa Street, Houston, TX 77033.

9.10.3 *For Second Stage Flushing and Recirculating with Cleaning Mixture*—Mix 1.9 L (½ gal) of dispersant engine cleaner (see Footnote 19) with 5.7 L (1 ½ gal) of mineral spirits to obtain 7.6 L (2 gal) of flushing solution. Add this mixture to the crankcase.

9.10.3.1 Connect the flushing pump outlet line to the engine oil cooler drain location. Open the crankcase drain valve, start the flushing pump, and circulate the flushing solution through the engine for approximately 15 min. Turn off the pump. (Do not drain the flushing solution from the crankcase.)

9.10.3.2 Close the oil cooler drain valve, disconnect the flushing pump outlet hose from the oil cooler drain location, and connect to the crankcase sprayer (Fig. A1.14).

9.10.3.3 Remove the 1Y5 oil line from the cover hole, insert the crankcase sprayer through the opening in the PMMA cover. Start the flushing pump, and spray the interior of the crankcase by slowly moving the sprayer around and into all accessible areas of the crankcase (see Fig. A1.17, View A) for approximately 10 min. Turn off the pump. (Do not drain the flushing solution from the crankcase).

9.10.3.4 Remove the ½ in. pipe plug from the modified 1Y1990 governor housing cover (see Fig. A1.15). Insert the crankcase sprayer (Fig. A1.14) through the opening in the governor housing cover, start the pump, and spray the interior of the governor housing for approximately 10 min. Turn off the pump. (Do not drain the flushing solution from the crankcase.)

9.10.3.5 Remove the oil filler spout assembly from the front of the crankcase, and install the front cover sprayer (see Fig. A1.16) as shown in Fig. A1.17.

9.10.3.6 Connect the flushing pump outlet to a 64 mm × 13 cm (½ in. × 5 in.) pipe on the front cover sprayer (see Fig. A1.16). Start the flushing pump, and spray the interior of the front cover for approximately 10 min. Drain the crankcase, governor, oil filter, and oil cooler; and discard the flushing solution.

9.10.4 *Using Mineral Spirits*—Repeat 9.10.2.4 through 9.10.2.6 until the mineral spirits discharge is clean. (Three to four flushes with mineral spirits are usually sufficient to remove all traces of the flushing solution from the engine.) Drain the mineral spirits from the crankcase, governor housing, oil filter, and oil cooler.

9.10.5 *Test Oil Flushing*—When engine is to be used immediately:

9.10.5.1 Prepare for the flush with the test oil by blocking off the 1Y5 oil line to the rocker arm shaft and installing the 6.4 mm (¼ in.) fitting (see Fig. A1.18) on the open end of the line. Close all drain openings.

9.10.5.2 Using the flushing pump, add 4.7 L (5 qt) of test oil to the engine crankcase through the engine oil cooler.

9.10.5.3 Connect the flushing pump outlet to the engine oil cooler drain location. Start the flushing pump, and force any mineral spirits in the system out the crankcase drain. After the mineral spirits have been forced out of the system, connect the inlet line of the flushing pump to the crankcase drain. Install the dummy piston (reference service manual SENR2074[14,11]) and the assembled cylinder liner and block assembly or the alignment fixture specified in Fig. A1.19. Re-install the oil filler spout and pipe plug in the modified governor housing cover (see Fig. A1.15).

9.10.5.4 Open the crankcase drain and start the flushing pump. Set and maintain the oil pressure at 207 kPa (30 psi). With the starter or dynamometer, turn the engine over for 1 min. Turn off the pump, and drain all oil from the engine crankcase, governor housing, oil filter, and oil cooler. Discard the oil drained.

9.10.5.5 Charge the engine again with 4.7 L (5 qt) of test oil, and repeat the procedure described in 9.10.2. During this flush, check the alignment of the piston cooling nozzle and adjust, if necessary. Before any such adjustment, make sure that the oil-stream condition has stabilized, that is, a steady stream of oil impinges the piston indicating that the oil pressure has attained a constant value. After draining the oil, install a clean element in the engine oil filter housing. Reinstall crankcase breather assembly 1Y2592.

9.10.6 *Test Oil Flushing*—When the test oil is not available and the engine test start will be delayed: follow the steps up to 9.10.5.2. However, in 9.10.5.2, use buildup oil[22,11] in place of test oil. When a test oil is scheduled for the engine, perform the following steps:

[22] Non-compounded oil ISO VG (SAE 20) (see Classification D2422) is available from lubricant marketers. One supplier is Mobile Corporation. The Mobile product is designated EF-411 and is available from Mobile Corporation, Illinois Order Board, P.O. Box 66940, AMF O'Hare, IL 60666. Ask for P/N 47503-8.