Standard Test Method for Evaluation of Automotive Engine Oils in the CRC L-38 Spark-Ignition Engine[1]

INTRODUCTION

The test method described in this standard can be used by any properly equipped laboratory without the assistance of anyone not associated with that laboratory. However, the ASTM Test Monitoring Center (TMC)[2] offers a very valuable service to a test laboratory; the Center provides reference oils and an assessment of the test results obtained on those oils by the laboratory (see Appendix X1). 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 lubricant 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 (see Annex A4).

1. Scope

1.1 This engine oil test method covers the evaluation of automotive engine oils (SAE[3] grades 5W 10W, 20, 30, 40, and 50, and multiviscosity grades) intended for use in either spark-ignition gasoline engines, or in diesel engines. The test procedure is conducted using a carbureted, spark-ignition Cooperative Lubrication Research (CLR) Oil Test Engine (referred to as the L-38 engine in this test method). An oil is evaluated for protection against engine and oil deterioration under high-temperature, heavy-duty service conditions. The test method can also be used to evaluate the viscosity stability of multiviscosity-graded oils.

1.2 The two measures of engine deterioration used in this test method are (1) weight loss of copper-lead bearings used in the test power section, and (2) varnish and sludge deposits on power section parts.

1.3 The two measures of oil deterioration used in this test method are (1) the change in the acid number of the oil, and (2) the change in the viscosity of the oil during the test period.

1.4 Correlation of test results with those obtained in automotive service has not been established. Furthermore, the results obtained in this test method are not necessarily indicative of results that will be obtained in a full-scale automotive spark-ignition or compression-ignition engine, or in an engine operated under conditions different from those of the test method. The test can be used to compare one oil with another.

NOTE 1—Companion test methods used to evaluate engine oil performance for specification requirements include the following current versions of single-cylinder and multicylinder engine tests:

ASTM STP 509A, Single Cylinder Engine Tests for Evaluating the Performance of Crankcase Lubricants[4]

Part I, Caterpillar 1G2 Test Method

Part II, Caterpillar 1H2 Test Method

ASTM STP 315H, Multicylinder Test Sequences for Evaluating Engine Oils[4]

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricantsand is the direct responsibility of Subcommittee D02.B0.01on Passenger Car Engine Oils.

Current edition approved June 10, 2002. Published September 2002. Originally published as D 5119–90. Last previous edition D 5119–99.

The procedure, originally developed by the Coordinating Research Council, was published as Federal Test Method 3405.2, Oxidation of Crankcase Lubricating Oils (CLR Engine), 1972. In 1980, it was published as *ASTM STP 509A*, Part IV Labeco L-38 Test Method.

[2] ASTM Test Monitoring Center, 6555 Penn Ave., Pittsburgh, PA 15206-4489. This edition includes all Information Letters through No. 31.

[3] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

[4] Available from ASTM International Headquarters.

Part 1, Sequence IID
Part 2, Sequence IIID
Part 3, Sequence V-D

ASTM Research Report RR:D02-1225 Sequence IIIE, Multicylinder Test Sequence for Evaluating Automotive Engine Oils[5]

ASTM D02 Proposal P212, Proposed Test Method for VE Test Procedure[4]

Also, see Engine Oil Tests—SAE J304 for details on these and other engine oil test methods.[6]

1.5 The values stated in inch-pound units are to be regarded as the standard; except for the case of bearing weight measurements, for which the unit is milligram; and except for viscosity measurements, for which the temperatures of measurement are expressed in °C (degrees Celsius). SI values are given in parentheses. In cases where materials, products, or equipment are available only in inch-pound units, SI units are omitted.

1.6 *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 practices and determine the applicability of regulatory limitations prior to use.*

1.7 This test method is arranged as follows:

2. Referenced Documents

2.1 *ASTM Standards:*

D 56 Test Method for Flash Point by Tag Closed Cup Tester[9]

D 86 Test Method for Distillation of Petroleum Products at Atmospheric Pressure[9]

D 156 Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method)[9]

D 235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvents)[10]

D 287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)[9]

D 323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)[9]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids [9]

D 664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration[9]

D 974 Test Method for Acid and Base Number by Color-Indicator Titration[9]

D 1093 Test Method for Acidity of Hydrocarbon Liquids and Their Distillation Residues[9]

D 1133 Test Method for Kauri-Butanol Value of Hydrocarbon Solvents[10]

D 1250 Guide for Petroleum Measurement Tables[9]

D 1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[11]

D 1353 Test Method for Nonvolatile Matter in Volatile Solvents for Use in Paint, Varnish, Lacquer, and Related Products[10]

D 2422 Classification of Industrial Fluid Lubricants by Viscosity System[9]

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1225.

[6] Order *SAE Handbook* Vol 3, from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001. This standard is not available separately.

[7] Soltrol 10 is a registered trademark of Phillips Petroleum Company. The sole source of supply of test fuel blend of Soltrol 10 and tetraethyllead known to the committee at this time is Phillips Petroleum Company, Special Products Service Center, Drawer "O," Borger, TX 79007.

[8] If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee [1], which you may attend.

[9] *Annual Book of ASTM Standards*, Vol 05.01.

[10] *Annual Book of ASTM Standards*, Vol 06.04.

[11] *Annual Book of ASTM Standards*, Vol 05.04.

D 2509 Test Method for Measurement of Load-Carrying Capacity of Lubricating Grease (Timken Method)[9]
D 2699 Test Method for Research Octane Number of Spark-Ignition Engine Fuel[12]
D 2700 Test Method for Motor Octane Number of Spark-Ignition Engine Fuel[12]
D 2782 Test Method for Measurement of Extreme-Pressure Properties of Lubricating Fluids (Timken Method)[13]
D 3120 Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry[13]
D 4175 Terminology Relating to Petroleum, Petroleum Products, and Lubricants[13]
D 4485 Specification for Performance of Engine Oils[13]
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[14]
E 270 Terminology Relating to Liquid Penetrant Inspection[15]

2.2 *Coordinating Research Council Motor Rating Method Manuals:*
No. 12, Sludge Rating Manual[16]
No. 14, Varnish Rating Manual[16]

2.3 *Military Specification:*
MIL-L-2104E, Lubricating Oil, Internal Combustion Engine, Tactical Service[17]

2.4 *SAE Standards:*
J183, Engine Oil Performance and Engine Service Classification (Other Than "Energy-Conserving")[6]
J304, Engine Oil Tests[6]

3. Terminology

3.1 *Definitions:*

3.1.1 *blind reference oil*, *n*—an oil supplied by an independent source for calibration purposes and designated by a code that gives no indication of the oil's performance characteristics to the laboratory running the test.

3.1.2 *blowby*, *n*—see Terminology D 4175.

3.1.3 *corrosion*, *n*—the chemical or electrochemical oxidation of the surface of metal, which can result in loss of material or accumulation of deposits (from Terminology E 270).

3.1.4 *noncompounded engine oil*, *n*—a lubricating oil having a viscosity within the range of viscosities of oils normally used in engines, and that may contain anti-foam agents or pour depressants, or both, but not other additives.

3.1.5 *oxidation, n, of engine oil*—the deterioration of the oil, which is observed as increased viscosity, sludge formation, varnish formation, or combination thereof, as a result of chemical and mechanical action.

3.1.6 *sludge, n, in an engine*—a deposit, principally composed of engine oil and fuel contaminants and oxidation products, that does not drain from engine parts but that can be removed by wiping with a soft cloth (see 3.1.7).

3.1.7 *varnish, n, in an engine*—a hard, dry, generally lustrous, oil-insoluble deposit, sometimes called lacquer, that cannot be removed by wiping with a soft cloth (see 3.1.6).

3.1.8 *wear*, *n*—the removal of metal from the test pieces by a mechanical or chemical action, or by a combination of mechanical and chemical actions (from Test Method D 2509 and Test Method D 2782).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *accessory case*, *n*—the mounting base containing the balancing mechanism, flywheel, and final driveshaft for the power section of the L-38 engine (see 6.1.1).

3.2.2 *build-up oil*, *n*—noncompounded ISO VG 46 (SAE 20) oil[18] used in lubricating the power section parts during assembly.

3.2.3 *calibrated L-38 power section/test stand combination*, *n*—one that has completed an operationally valid reference oil test within the previous six months, the results of which fall within industry severity and precision limits as published by the TMC.

3.2.4 *conditioning test run*, *n*—a full-length L-38 test using a TMC-designated reference oil in a new or newly rebuilt power section to prepare the cast iron parts before conducting routine standard tests with the power section.

3.2.5 *emergency shutdown*, *n*—the procedure for turning off the engine's ignition without using the prescribed engine cool-down period.

3.2.6 *full-length L-38 test*, *n*—a test of an engine oil conducted using a power section and a test stand, for a total time period of 44½ h, including an initial 4-h run-in, a ½-h flush, and four 10-h test intervals (steady-state operation).

3.2.7 *off-gas*, *n*—gas exiting the power section crankcase breather.

3.2.8 *off-test time*, *n*—any time that the engine is not operating at the prescribed test conditions (see Table 1).

3.2.9 *oil gallery side cover plate*, *n*—crankcase cover plate that contains the oil gallery and provision for mounting and driving the oil pump and ignition contact breaker assembly.

3.2.10 *operationally valid test*, *n*—an L-38 engine oil test that has been conducted in accordance with the conditions listed in this test method.

3.2.11 *power section*, *n*—the combination of the crankcase assembly, the cylinder block assembly, and the cylinder head assembly, all of which are attached to the accessory case (see Fig. 1).

3.2.12 *rebuilt power section*, *n*—an engine power section that has been disassembled, cleaned, and reassembled using a new crankcase, in accordance with the procedures in the assembly manual.[19]

3.2.13 *reconditioned power section*, *n*—an engine power section that has been disassembled, cleaned, and reassembled

---

[12] *Annual Book of ASTM Standards*, Vol 05.05.
[13] *Annual Book of ASTM Standards*, Vol 05.02.
[14] *Annual Book of ASTM Standards*, Vol 14.02.
[15] Discontinued; see *1991 Annual Book of ASTM Standards*, Vol 03.03. Replaced by E 1316.
[16] Available from Coordinating Research Council, Inc., 219 Perimeter Ctr. Pkwy., Atlanta, GA 30346.
[17] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098.
[18] Noncompounded oil ISO VG 46 (SAE 20) (see Classification D 2422) is available through the Mobil Oil Corp. (designated EF-411), P.O. Box 66940, AMF O'Hare, IL 60666, Attention: Illinois Order Board. Ask for P/N 47503-8.
[19] Refer to *Instructions for Assembly and Disassembly to CLR L-38 Test Engine*, available from Test Engineering, Inc., 12718 Cimarron Path, San Antonio, TX 78249.

TABLE 1 Test Operating Conditions

Item	Setting
Speed, r/min	3150 ± 25
Load bhp	Adjust load to provide proper fuel flow at specified air-fuel ratio.
Fuel flow, lb/h	4.75 ± 0.25 (2.15± 0.11 kg/h)
Air-fuel ratio	14.0 ± 0.5
Jacket outlet coolant Temperature, °F	200 ± 2 (93.5 ± 1°C)
Difference between jacket Inlet and jacket outlet Coolant temperatures, °F	10 ± 2 (5.6 ± 1°C)
Gallery oil temperature, °F	
SAE 10W	275 ± 2 (135 ± 1°C)
SAE 20, 30, 40, 50, and multiviscosity-graded oils	290 ± 2 (143.5± 1°C)
Spark advance, °BTDC	35 ± 1
Oil pressure, psi	40 ± 2 (276 ± 14 kPa)
Crankcase vacuum, in. H_2O	2 ± 0.5 (500 ± 120 Pa)
Exhaust back pressure, in. Hg	0 to 1 (0 to 3.4 kPa)
Crankcase off-gas, SCFH	30 ± 1
Blowby, SCFH	record

in accordance with the detailed procedures found in the assembly manual.[19] After completion of either a conditioning test run or a full-length L-38 engine oil test.

3.2.14 *reference oil test*, *n*—a standard L-38 engine oil test of a reference oil designated by the TMC, conducted to ensure that power section and test stand severity falls within industry limits.

3.2.15 *run-in and flush*, *n*—the initial 4½-h operation of a new, rebuilt, or reconditioned power section at the beginning of either a conditioning test run or a full-length test.

3.2.16 *scheduled downtime*, *n*—off-test time that is specifically allowed to include warm-up and cool-down periods as well as shutdown and intermediate bearing weight loss measurements.

3.2.17 *shutdown*, *n*—the procedure for turning off the engine's ignition following the prescribed engine cool-down period.

3.2.18 *standard test*, *n*—an operationally valid, full-length L-38 test conducted with a calibrated power section and test stand in accordance with the conditions listed in this test method.

3.2.19 *stripped viscosity*, *n*—the viscosity of the test oil after removal of volatile components and solids, in accordance with the procedure in military specification MIL-L-2104, paragraph 4.6.2.

3.2.20 *test oil*, *n*—an oil subjected to an L-38 engine oil test.

3.2.20.1 *Discussion*—It can be any oil selected by the laboratory conducting the test. It could be an experimental product or a commercially available oil. Often, it is an oil that is a candidate for approval against engine oil specifications (such as manufacturers' or military specifications,and so forth).

3.2.21 *test stand*, *n*—the engine accessory case connected to a dynamometer, both mounted to a suitable foundation (such as a bedplate) and equipped with suitable supplies of electricity, compressed air, and so forth, to provide a means for mounting and operating a power section in order to conduct an L-38 engine oil test.

3.2.22 *test start*, *n*—introduction of test oil into engine.

4. Summary of Test Method

4.1 Before every L-38 engine oil test, the power section of the CLR Oil Test Engine (see 6.1.1) is thoroughly cleaned, and power section parts are measured. A new piston, a complete set of new piston rings, a set of new copper-lead connecting rod test bearing inserts (from a batch approved by the ASTM D02.B0.02 L-38 Test Surveillance Panel), and other specified nonrated parts, as required, are installed.

4.2 The power section is installed on a test stand.

4.3 The engine is first operated for 4½ h in accordance with a run-in-and-flush schedule.

4.4 The engine is then operated for four 10-h intervals under specified conditions. At the end of each interval, the engine is shut down; and the test lubricant is drained from the power section, weighed, sampled, and (except at end of test) returned to the power section for continuation of the test.

4.5 The acid number of the four lubricant samples is determined, and the oil consumption for each of the four 10-h intervals is calculated. (To meet the shear stability requirements of military specification MIL-L-2104, the stripped viscosity of multiviscosity-graded oils is determined at the end of the first 10-h interval, in accordance with the procedure in paragraph 4.6.2 of that specification.)

4.6 At the completion of the test, the connecting rod bearing weight loss is determined; and the piston, tin-plated covers (see 6.2.8), and other internal power section parts are rated for sludge and varnish formation.

5. Significance and Use

5.1 This test method is used to evaluate automotive engine oils for protection of both gasoline and diesel engines against bearing weight loss and deposit formation.

5.2 The L-38 engine oil test method is also used to evaluate the deterioration of the oil in terms of changes in acid number and viscosity.

5.3 Correlation of test results with those obtained in automotive service has not been established.

5.4 The L-38 engine oil test is used in specifications and classifications of engine lubricating oils, such as the following:

5.4.1 Specification D 4485,

5.4.2 Military Specification MIL-L-2104, and

5.4.3 SAE Classification J 183.

6. Apparatus

6.1 *Test Engineering, Inc.*— The document *Instructions for Assembly and Disassembly of the CLR L-38 Test Engine*[19] provides detailed parts listings, modification instructions, assembly/disassembly instructions, maintenance procedures, and parts replacement requirements. The following is a descriptive listing of some of the test engine and associated parts.

6.1.1 *Test Engine*—Obtain the Cooperative Lubrication Research (CLR) Oil Test Engine from Test Engineering, Inc. (TEI)[20]. The test engine is known by various designations, such as the CLR engine, or the L-38 engine (as used in this test method). It is comprised of two principal units, the power

[20] Test Engineering, Inc., 12718 Cimarron Path, San Antonio, TX 78249.

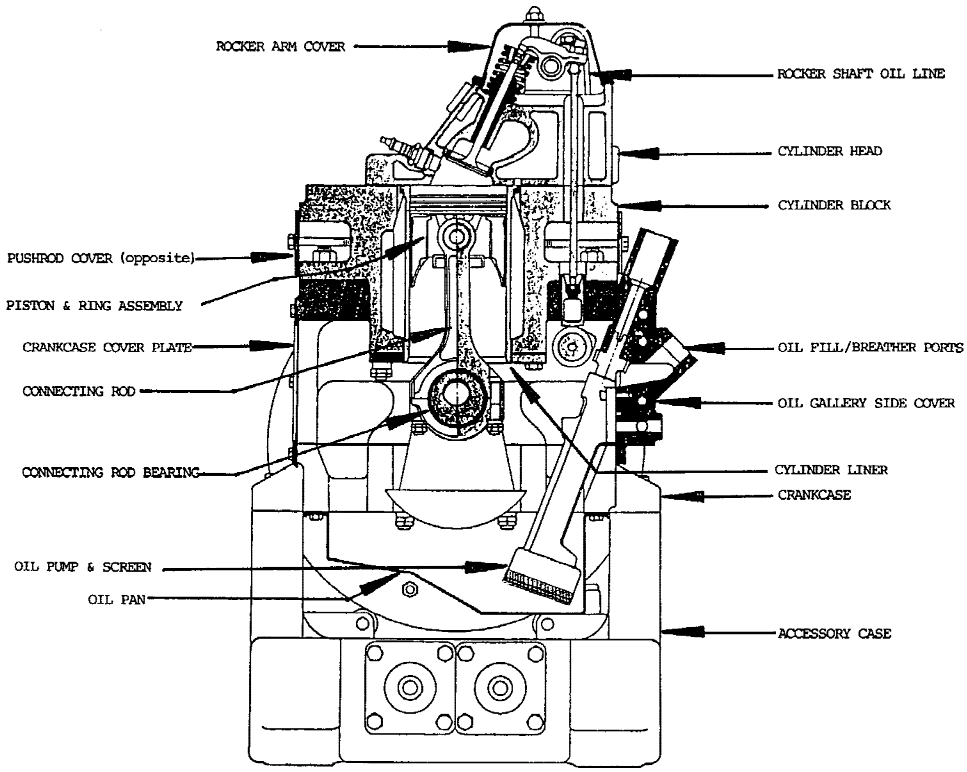


FIG. 1 Sectional View of L-38 Engine Power Section

section and the accessory case. See Fig. 1 for a sectional view of the power section. The power section is a single-cylinder, spark-ignition unit with 3.80-in. (96.5-mm) bore and 3.75-in. (95.2-mm) stroke, displacing 42.5 in.^{3}(0.696 L).

6.1.2 *Test Bearing*—A copper-lead connecting rod bearing, Part No. 100034-1, from a batch approved by the ASTM L-38 Test Surveillance Panel.

6.1.3 *Test Engine Crankshaft*—Obtain a crankshaft for the L-38 test engine, Labeco Part No. 100039-1, from Labeco. If desired, the crankshaft may be refinished in one of the following two manners:

6.1.3.1 The oil seal and main bearing journals may be refinished by welding material to the journals and regrinding the journals to the original specifications. The connecting rod journal shall not be refinished using this method.

6.1.3.2 The crankshaft may be refinished by chrome plating the oil seal, connecting rod bearing, and main bearing journals. When refinishing a crankshaft using this method, all journals listed shall be chrome plated.[8,21]

6.1.3.3 For tests conducted using a crankshaft refinished by either of the two methods listed above, a note shall be placed in the test report stating that a refinished crankshaft was used and also stating the method by which it was refinished.

6.1.4 *Miscellaneous Parts*—See Table 2.

6.2 *Fabricated or Specially Prepared Items*:

6.2.1 A typical L-38 engine test stand configuration is shown in Fig. 2.

[21] The sole source of supply of crankshaft refinishing by chrome plating known to the committee at this time is OH Technologies, Inc., P.O. Box 5039, Mentor, OH, 44061-5039.

TABLE 2 Miscellaneous Parts

Part Name	Labeco Part Number
Bearings:	
Babbitt main bearing	8252
Camshaft bearing	8231-A
Undersize main bearing	8252-US
Carburetor	9710
Crankcase vacuum control valve	9720
Distributor	100003-1
External oil heater	2430-B
Oil filter element	3105[A]
Oil filter housing	100023-1[A]
Oil filter housing bracket	9746[A]
Spark plug[B]	3129
Thrust Washers:	
Aluminum camshaft thrust washer	8405
Babbitt crankshaft thrust washer	8292
Water pump	12535-A

[A] Or equivalent. (A Fram HPK2 oil filter adapter and PH8A spin-on oil filter may be substituted.)

[B] Champion H-8-J or H-10 or equivalent is suitable.

6.2.2 *Crankcase Ventilation System*—Fig. 3 is a schematic of the required configuration of the crankcase ventilation measurement and control system.

6.2.2.1 Fabricate the air-tight rocker cover air and off-gas condensate trap/surge tank shown in Fig. 3, with provisions for draining and cleaning. The volume of the rocker cover air tanks shall be from 0.13 to 0.20 ft^3(1 to 1.5 gal) (3.79 to 5.68 L). The volume of the off-gas tank shall be from 1.34 to 1.60 ft^3(10 to 12 gal) (37.85 to 45.42 L). Fabricate both tanks from non-corrosive material. Locate the tanks as shown in Fig. 3.

6.2.2.2 *Rocker Cover Air Flow*—Measure the air flow into the rocker cover by using a Sierra Side Track model 830 flow

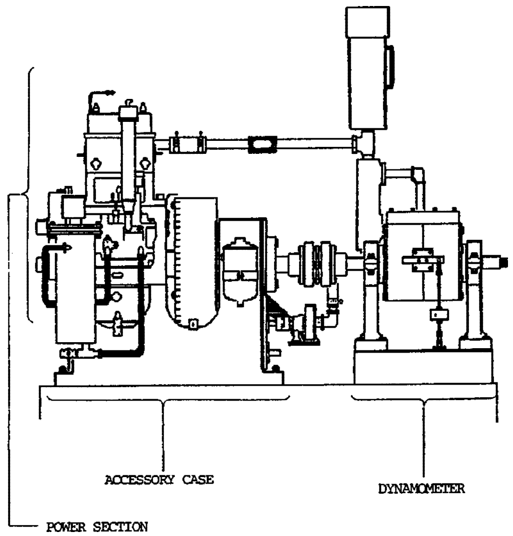


FIG. 2 Typical L-38 Test Stand

meter[8,22] capable of measuring 0 to 20 L/min. An optional Dwyer rotameter, Model No. RMC-101,[8,23] with a range from 0 to 50 standard ft^3/h (0 to 1420 L/h) may be used for ease of adjustments; however, take the actual measurements with the Sierra flow meter. All piping and tubing used to flow air into the rocker cover shall be nominal ⅜-in. I.D.

6.2.2.3 When a closed loop automated control system is employed, use a Badger Meter research control valve, Model No. 1002-GCN36-SVCSC-LN36,[8,24,25] to control the rocker cover air flow. When using a manual control system instead of the automated system, install a manually operated two-way control valve to control the air into the rocker cover.

6.2.2.4 Fig. 4 shows the details of the rocker cover inlet for the crankcase ventilation air. Braze one half of a ⅛-in. (3.2-mm) by ¼-in. (6.4-mm) brass tubing connector to the cover as shown. Use ¼-in. (6.4-mm) stainless steel tubing for the introduction of filtered shop air to the cover. Cut the end to be inserted into the cover at 60° to the vertical, and bend the exposed portion of the tubing as shown. Using a ferrule and nut, install the tubing in the connector with the beveled end facing the near corner of the rocker cover. Tighten the connector nut securely.

6.2.2.5 Construct the off-gas breather,[26] as shown in Fig. 5. Use American Standard Schedule 40, or equivalent nongalvanized pipe fittings. Apply sealant to the threads during assembly. Install the breather in the breather port of the oil gallery side cover (see Fig. 6) of the engine power section. Fig. 5 shows an alternative configuration.

6.2.2.6 *Crankcase Off-Gas Flow*—Measure the crankcase off-gas flow by using a Daniels Honed Orifice Flange Flow Section, Model H1905T-½ in.,[8,27] with orifice plate, F-150-⅛ in., and a Rosemount differential pressure transducer, Model No. 1151DP-3-S-22-D1B2.[8,28] Mount the flow section horizontally. The transducer may be set up as *square root extracting* to aid in interfacing with the readout. Locate temperature and pressure measurement devices at the inlet of the off-gas measurement apparatus as shown in Fig. 3.

6.2.2.7 When a closed loop automated control system is employed, use a Badger meter research control valve, Model No. 1002-TCN36-SVCSA-LN36[8,23,24] to control the crankcase vacuum. When using a manual control system instead of the automated control system, install a manually operated control valve to control the crankcase vacuum. Both systems are shown in Fig. 3.

6.2.2.8 Use a vacuum aspirator, Model No. JD-90M,[8,29] or a vacuum pump as a vacuum source.

6.2.3 *Oil Filter*—Install the oil filter as shown in Fig. 7. Use suitable hydraulic hose and fittings.[30]

6.2.4 *Oil Drain Valves*—Locate oil drain valves at points no higher than the bottom of the oil pan and the vertically mounted oil heater.

6.2.5 *Oil Heater*—Install the oil heater, as shown in Fig. 8. Use suitable hydraulic hose and fittings.[30]

6.2.6 *Power Section Cooling System*—Install a non-pressurized cooling system, as shown in Fig. 9, consisting of a heat exchanger, water pump, coolant throttling valve, sight glass, and tower. Use American Standard Schedule 40, or equivalent, ¾-in. nongalvanized pipe fittings; apply sealant to the threads during assembly.

6.2.6.1 Use a water-cooled heat exchanger.[8,31]

6.2.6.2 Mount the water pump, as shown in Fig. 9; connect it to the output drive shaft of the accessory section. Alternatively, an electric water pump[8,32], which does not require connection to the output drive shaft of the accessory case, may be used.

6.2.6.3 Install a ¾-in. gate-type coolant throttling valve on the output side of the coolant pump to maintain the specified temperature differential between the coolant flowing into, and that flowing out of, the power section jacket.

[22] The sole source of supply of Sierra Side Track Flow meters known to the committee at this time is Sierra Instruments Inc., 5 Harris Court, Bldg. L, Monterey, CA 93940.

[23] The sole source of supply of Dwyer instrumentation known to the committee at this time is Dwyer Instruments Inc., P.O. Box 60725, Houston, TX 77205.

[24] The letter prior to the last dash in the model number defines the trim size. Use the trim that gives the best system control.

[25] The sole source of Badger valves known to the committee at this time is Badger Meter Industrial Div., 6116 East 15th St., P.O. Box 581390, Tulsa, OK 74158-1390.

[26] Except for the stainless steel wool and screens, parts for the construction of the crankcase breather may be obtained from many commercial sources. The part numbers given identify the components available from McMaster Carr, Chicago, IL.

[27] The sole source of Daniels flow sections known to the committee at this time is Daniel Flow Products Inc., Flow Measurement Products Div., P.O. Box 19097, Houston, TX 77224.

[28] The sole source of Rosemount transducers known to the committee at this time is Rosemount Inc., 4001 Greenbriar, St. 150B, Stafford, TX 77477.

[29] The sole source of Vaccom aspirators known to the committee at this time is McKenzie Air Industries, 18523 IH 35 North, Shertz, TX 78108.

[30] Aeroquip ⅜-in. (10-mm) (inside diameter) hydraulic hose has been used successfully to plumb the oil filter and oil heater; select hose of a specification to cover temperatures and pressures encountered in L-38 engine oil testing.

[31] A heat exchanger of this type, suitable for this application, is available as American Heat Exchanger, Part Number 5-030-03014-011, from Compressor Engineering, 625 District Drive, Itasca, IL 60143.

[32] A water pump suitable for this application is available as TEEL-Part No. IP831, from any Grainger national branch location.

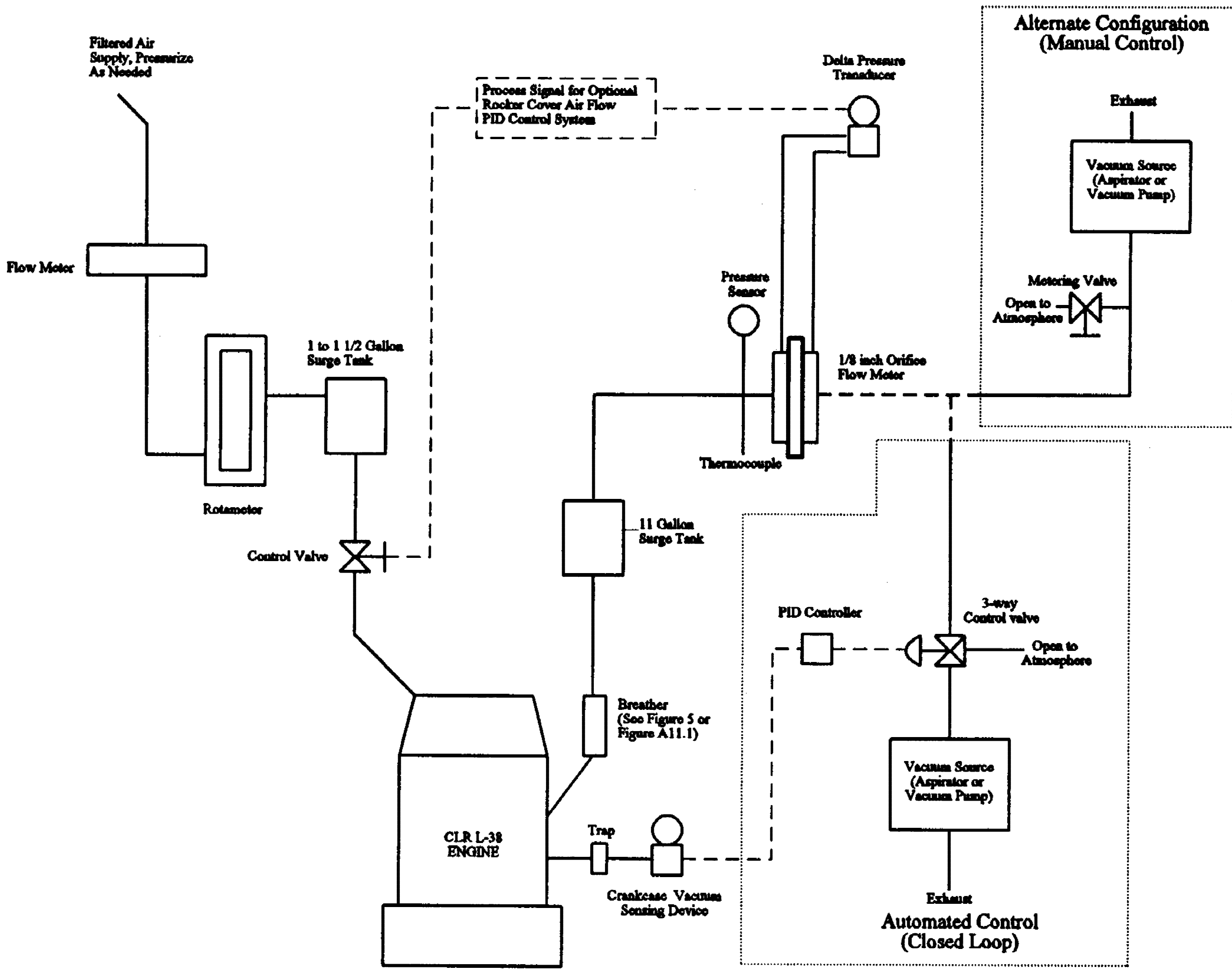


FIG. 3 Standard Crankcase Ventilation System for the L-38 Engine Power Section

6.2.6.4 Install a sight glass[8,33] (or plastic tube section) located downstream of the cylinder head to permit detection of air entrainment.

6.2.6.5 Fabricate the tower using non-galvanized metal. Make it approximately 3½ in. (90 mm) in diameter and 16-in. (410-mm) long. Fashion a loose-fitting cover for it. Install a level gage, positioned to give a mid-scale reading when the system is filled. The system must have a minimum capacity of 2 gal (7.5 L).

6.2.7 *Exhaust System*—Use either a water-quenched system or a dry system.

6.2.8 *Tin-Plated Power Section Parts*—The following power section parts are tin plated, as supplied by TEI: piston, rocker cover, push rod cover, crankcase cover, and oil pan.

6.2.9 *Ignition System*—A recommended electronic ignition system, as illustrated in Figs. A12.1-A12.10, can be used as an alternative to the breaker point ignition system. Other electronic ignition system configurations shall be reviewed and approved by the TMC and the L-38 Surveillance Panel, prior to use.

6.3 *Instruments and Controls*:

6.3.1 *Dynamometer*—Use a dynamometer and control system capable of maintaining the specified engine operating test conditions (see Section 11). Speed measurement accuracy of ±0.5 % of reading, and load measurement accuracy of ±2 % of reading, are required.

6.3.2 *Fuel Flowmeter or Fuel Weigh System*—Use a system with a range from 0 to 10 lb/h (0 to 4.5 kg/h), and having an accuracy of 1 % reading and 0.5 % repeatability.

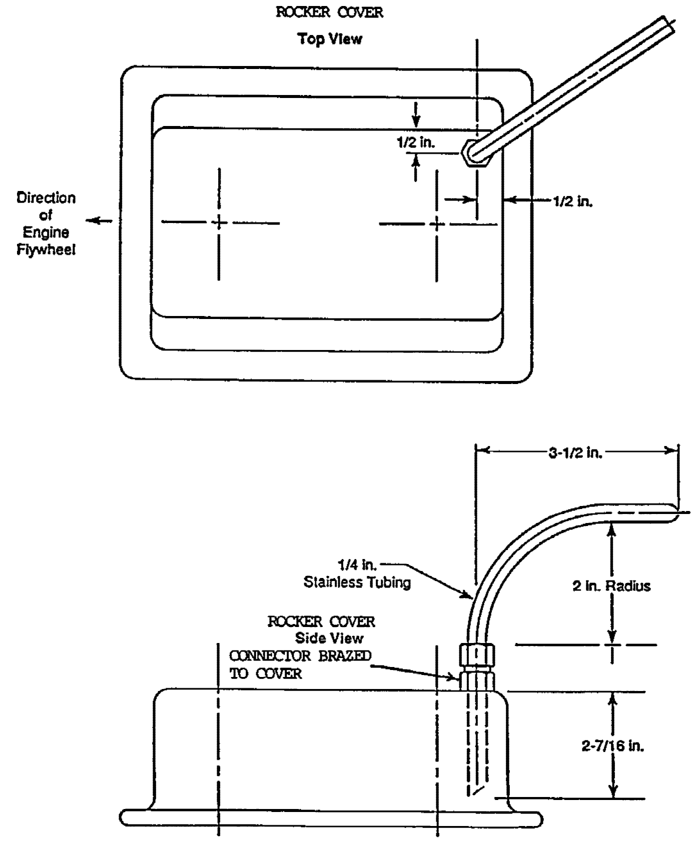
6.3.3 *Air-Fuel Ratio Measurement System*—Use a system with a calibration capability of the equivalent of ±0.5 air-fuel ratio number. The following are acceptable methods for determination of air-fuel ratio:

6.3.3.1 Electronic exhaust gas analyzer, which is calibrated using sample gases prior to each measurement. Use the chart in Annex A14 to determine the air-fuel ratio.

6.3.3.2 Individual air- and fuel-flow measurements.

6.3.4 *Pressure Measurement*:

[33] A sight glass of this type, suitable for this application, is available as Gitts—Part Number 3063-27, from Edward Fisher Co., 2118 S. Wabash, Chicago, IL 60616.



Metric Equivalents

in.	mm
¼	6.4
½	13
2	51
2$^7/_{16}$	62
3½	89

FIG. 4 Rocker Cover Air Inlet for Ventilation of the L-38 Engine Power Section Crankcase

6.3.4.1 *Crankcase Vacuum*—As shown in Fig. 3, connect a line trap[34] and an appropriate sensor, such as a manometer,[35] to the crankcase at the hole above and to the right of the oil heater inlet hose connection on the oil gallery side cover. See Fig. 6 for the location of the crankcase vacuum port. Measurement resolution of 0.2 in. H_2O (50 Pa) and 1 % accuracy in the specified range of 2 ± 0.5 in. H_2O (500 ± 120 Pa) are required.

6.3.4.2 *Exhaust Back Pressure*—Connect an appropriate sensor to the exhaust back-pressure tap at a point within 4 in. (100 mm) of the cylinder head exhaust flange. Sensor accuracy of ±10 % of reading and resolution of 0.1 in. Hg (340 Pa) are required.

6.3.4.3 *Intake Manifold Vacuum*—Measure the intake manifold vacuum at the elbow of the intake manifold by means of a sensor having an accuracy of 1 % and a resolution of 0.2 in. Hg (680 Pa).

6.3.4.4 *Oil Pressure*—Measure the oil pressure with an appropriate sensor having an accuracy of ±2 % and a resolution of 1 psi (7 kPa), connected to the point shown in Fig. 6.

6.3.4.5 *Crankcase Off-gas Inlet Pressure*—Measure the off-gas air pressure by using a Dwyer Magnehelic, Model No. 2320,[8,23] or a Sensotec pressure transducer, Model No. TJE-756-05.[8,36] Convert the measured value to in. Hg for use in off-gas measurement calculation (see 11.6.1). Locate the sensor at the inlet of the off-gas air flow apparatus, as shown in Fig. 3.

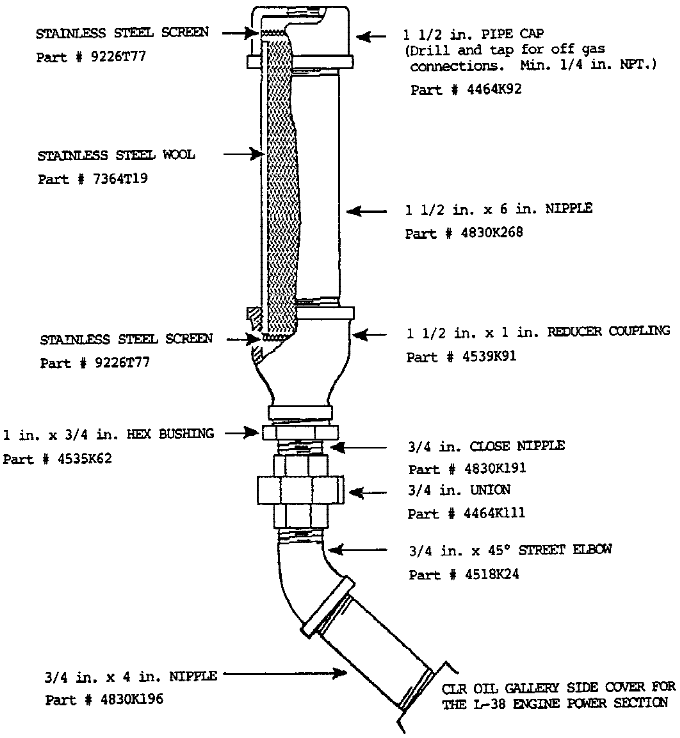
6.3.5 *Temperature Measurement*—Use only sensors that may be calibrated within 2°F (1°C). Thermocouples are specified in the following sections. If other thermocouples are used, they shall be of iron-constantan composition, or be shielded to prevent contact of any copper-containing metal with the test oil. Alternative sensors shall be reviewed by the TMC[2] and the L-38 Surveillance Panel prior to use.

6.3.5.1 *Jacket Coolant Temperatures*—Use thermocouples to measure the jacket coolant inlet and outlet temperatures.

[34] A line trap suitable for this application is available as Meriam Instrument Company—Model C2400, Type CG from Scott Fetzer Co., P.O. Box 5177-n, Cleveland, OH 44193.

[35] A manometer suitable for this application is available as Part Number 1221-16WM, from Dwyer Instruments, P.O. Box 3, Michigan City, MI 46360.

[36] The sole source of Sensotec transducers known to the committee at this time is Sensotec, Inc., 1200 Chesapeake Ave., Columbus, OH 43212.



NOTE 1—See footnote 19 for a source of the parts numbered as shown.

FIG. 5 L-38 Crankcase Breather Detail

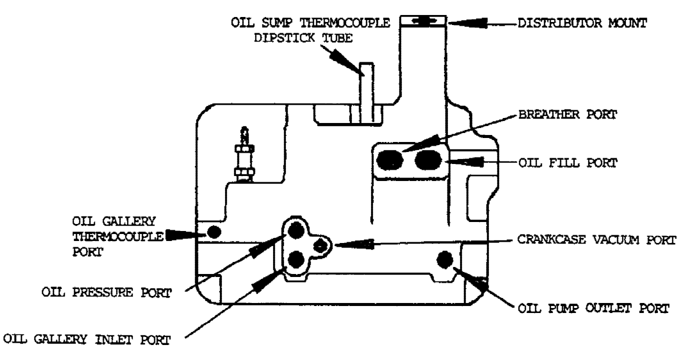


FIG. 6 Oil Gallery Side Cover for the L-38 Engine Power Section

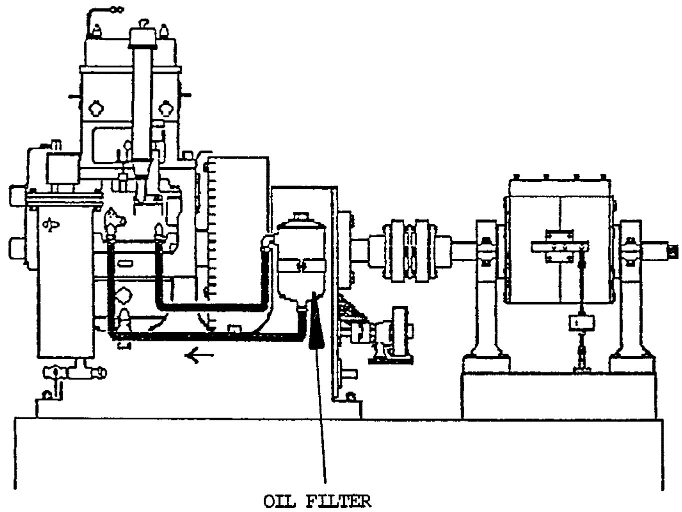


FIG. 7 Oil Filter Installation for the L-38 Engine Power Section (Refer to 11.1.1.)

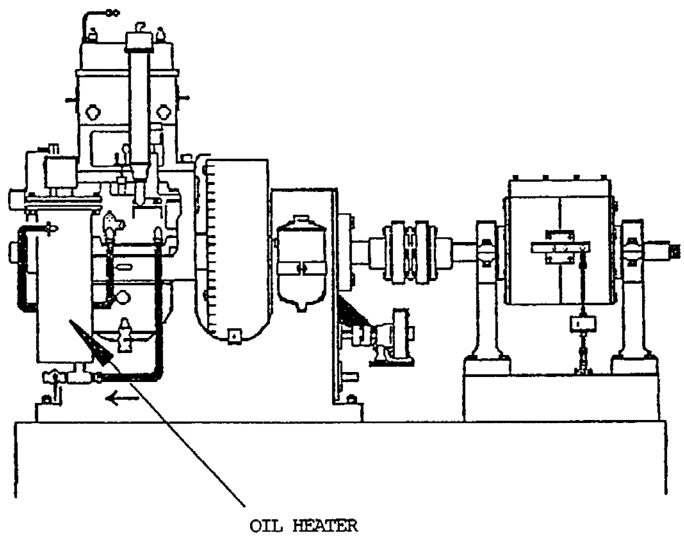


FIG. 8 Oil Heater Installation for the L-38 Engine Power Section (Refer to 11.1.5.)

These shall be located within 4 in. (100 mm) of the inlet and outlet bosses on the power section.

6.3.5.2 *Sump Oil Temperature*—Measure the sump oil temperature by replacing the dipstick with a thermocouple. See Fig. 6. Thermo-Electric[8,37] Thermocouple Style 502P and TEI Part Number 3113 have been found satisfactory. These thermocouples have a bayonet length of 15⅛in. (384 mm) from shoulder to tip, so that the tip of the thermocouple is in the same position as the end of the dipstick when it is installed in the power section.

6.3.5.3 *Oil Gallery Temperature*—Measure oil gallery temperature at the front main bearing passage (see Fig. 6). A Thermo-Electric[37] Thermocouple, either Style 5-A-0732P or Style 5A02P, or a TEI Part Number 3114, is recommended. The immersion length for these thermocouples is 1⅜in. (35 mm).

6.3.5.4 *Air Inlet Temperature*—Measure the air inlet temperature with an exposed thermocouple or thermometer located at the center of the air tube, 1½in. (38 mm) above the carburetor air horn.

6.3.5.5 *Off-gas Inlet Temperature*—Measure the off-gas temperature with a ⅛ in. J-type thermocouple. Position the thermocouple tip in the middle of the air stream and expose no more than 2 in. of the sheath to ambient air. Locate the thermocouple at the inlet of the off-gas flow measurement apparatus, as shown in Fig. 3.

6.4 *Procurement of Parts*—Obtain information concerning the CLR Oil Test Engine (see 6.1.1) and parts from TEI. Users of this test method shall comply with assembly manual[19] and the latest supplements (Information Letters and Memoranda) available from the TMC.[2]

[37] The sole source of the apparatus known to the committee at this time is Thermo-Electric Co., 109 N. 5th St., Saddle River, NJ 07662.

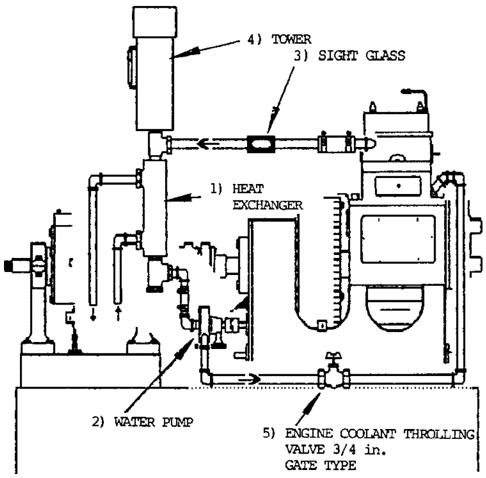


FIG. 9 Cooling System for L-38 Engine Power Section

7. Reagents and Materials

7.1 *Cleaning Materials*:

7.1.1 *Abrasive Paper*, 400-, 600-, 800-grit, wet or dry.

7.1.2 *Crocus Cloth*.

7.1.3 *Organic Solvent*—Penmul L460.[38] (**Warning**—Combustible. Health hazard.)

7.1.4 *Pentane (Solvent)*, 99 + %, high-performance liquid chromatography grade. (**Warning**—Flammable. Health hazard.)

7.1.5 *Steel Wool*, No. 0.

7.1.6 *Stoddard Solvent*, [39] Specification D 235, Type I (**Warning**—Combustible. Health hazard.).

7.1.7 *Tap Water*, heated to between 150°F to 180°F (66°C to 82°C).

7.2 *Expendable Power Section-Related Items*:

7.2.1 *Copper-Lead Test Bearings*.

7.2.2 *Sealing Compounds*—Only use approved sealing compounds, including pipe thread compound and gasket cement.[40] (**Warning**—A change of sealing compound for power section build-up may influence test severity. Conduct a calibration test following any such change.)

7.2.3 *TEI Gaskets, Seals, O-Rings*.

7.2.4 *Air and Oil Filter Elements* (Fram oil filter components may be used, as indicated in 6.1.3).

7.2.5 *Power Section Build-up Oil*—Noncompounded ISO VG 46 (SAE 20) oil.

7.2.6 *TEI Piston:*.

7.2.7 *Piston Ring Assembly*—Use a Dana/Perfect Circle piston ring assembly, Part Number 41274, in the L-38 test engine.[8,41]

7.3 *Power Section Coolant*—Use deionized or distilled water for the power section coolant, plus a suitable inhibitor such as 4 fl oz of Pencool 2000/gal (31 mL of Pencool 2000/L).[8,42] Such water purchased from a commercial source is suitable.

7.4 *Reference Oils*—Tests are conducted periodically on reference oils supplied by the TMC to document the test severity of a given power section and test stand, and the overall operation of the test. Approximately 2 gal (8 L) of reference oil is required for each reference test.

7.5 *Test Fuel*—The test fuel (**Warning**—Flammable. Health hazard.) is Soltrol 10[7] to which is added 2.95 to 3.05 mL tetraethyllead (TEL)/U.S. gal (0.779 to 0.806 mL/L) (**Warning**—TEL is extremely toxic. Do not attempt to procure or handle TEL.) The specification for Soltrol 10 is given in Annex A1.

8. Test Oil Sample Requirements (see 3.2.14)

8.1 *Selection*—The sample of test oil shall be representative of the lubricant formulation being evaluated and shall be uncontaminated.

8.2 *Inspection*—New oil sample baseline inspection requirements are described in 12.1.

8.3 *Quantity*—At least 13 lb (6 kg), approximately 7.25 qt (7 L), of fresh oil is required to complete the test. It is recommended that a test laboratory have 14 lb (6.5 kg), approximately 2 gal (8 L), of oil on hand when starting a test, to allow for inadvertent losses.

9. Preparation of Apparatus

9.1 *Test Stand Preparation*:

9.1.1 *Instrumentation Calibration*—Check the calibration of temperature sensors, flowmeters, pressure sensors, and dynamometer load indicator as required by the type of instrumentation being used. Details on calibration, of both power section and test stand, and of instrumentation, are given in Section 10.

9.1.2 *Preventive Maintenance*—Refer to and comply with the assembly manual[19] regarding details pertaining to care and maintenance of the accessory case.

9.2 *Conditioning Test Run on Power Section*—A new or newly rebuilt power section cannot be calibrated, nor is it suitable for test purposes, until a full-length, conditioning test run has been conducted on the power section. The conditioning test run is required to prepare the cast iron parts of such a power section, and the oil used for the run is a reference oil designated by the TMC. Upon completion of the conditioning run, the power section shall be reconditioned, as described in 9.4, before conducting a test. (A conditioning run on a

[38] Penmul L460 is a registered trademark of, and is available from Penetone Corp., 7400 Hudson Ave., Tenafly, NJ 07670.

[39] Stoddard Solvent, Specification D 235, Type I, is available from petroleum solvent suppliers.

[40] Sealing materials approved for use include Perfect Seal Sealant No. 4, (registered trademark of P.O.B. Inc), Permatex Ultra Blue 77B, Permatex 3H, Permatex High Tack 99 MA, (registered trademark of Loctite Corp.), Dow Corning High Vacuum Grease, Dow Corning RTV Gray 3154, (registered trademark of Dow Corning Corp.), and Vaseline Petroleum Jelly, (registered trademark of Chesebrough Ponds Inc.).

[41] The sole source of the Dana/Perfect Circle piston ring assembly known to the committee at this time is Dana Corp., Perfect Circle Div., 1883 E. Laketon Ave., Product Distribution Ctr., Muskegon, MI 49442–6123.

[42] The sole source of supply of Pencool 2000 known to the committee at this time is The Penray Cos., Inc., 1801 Estes Ave., Elk Grove, IL 60007.

reference oil will not qualify as a reference test. Testing can commence only after a conditioning run and a reconditioning.)

9.2.1 *Operational Settings and Clearances for Conditioning Test Run on New or Newly Rebuilt Power Sections*— Make the adjustments shown in Table 3.

9.3 *General Power Section Rebuild Instructions*—Assemble the power section in accordance with the detailed instructions found in the assembly manual.[19] Compliance with all provisions of the assembly manual is mandatory. The research report includes detailed instructions updated by information letters and memoranda issued by the TMC, which may modify the following procedures. Failure to follow the instructions provided in this document may cause incorrect test results.

9.3.1 Lubricate the power section parts with noncompounded ISO VG 46 (SAE 20) oil during assembly.

9.4 *Reconditioning of Power Section After Each Test*—Recondition a previously used power section before the start of a new test. Follow the cleaning and parts replacement procedures described in the following sections.

9.4.1 *New Parts*—Use the following new parts:

9.4.1.1 Piston and piston ring assembly.

9.4.1.2 Copper-lead connecting rod test bearing.

9.4.1.3 All gaskets, seals, and O-rings.

9.4.1.4 All parts that are excessively worn or that do not permit maintenance of the operating clearances specified in 9.4.4, 9.4.6.8, 9.4.6.9, 9.4.7, and 9.4.8.

9.4.1.5 *Crankcase, and Power Section*—If a new crankcase or power section is used, regard the power section as newly rebuilt rather than reconditioned. Comply with the conditioning procedures given in 9.2 when a new crankcase or power section is installed.

9.4.1.6 *Critical Parts*—The following parts are considered critical for conducting this test. The parts supplier will provide records stating source codes and additional information, such as batch code, lot number, and so forth. It will be the responsibility of the laboratory to maintain records documenting these parts by proper identification numbers and received date. Use the following parts in received date order: crankshafts, camshafts, connecting rod bearings, crankshaft main bearings, camshaft bearings, piston rings, connecting rods, pistons, and cylinder sleeves.

9.4.2 *Parts Cleaning Procedures*:

9.4.2.1 *Oil Pump, Oil Pressure Regulator, Distributor, and Crankcase Breather*—Remove the distributor and crankcase breather. Remove the oil pump and oil pressure regulator with the oil gallery side cover plate. Clean this cover plate thoroughly using organic solvent (**Warning**—Combustible; health hazard.) and a fiber brush or swab, then rinse the cover plate with tap water heated to between 150 to 180°F (65.5 to 82.0°C), and rinse it again with Stoddard Solvent (**Warning**—Combustible; health hazard.). Carefully spray the oil pump, oil pressure regulator, and distributor with Stoddard Solvent to remove deposits. Disassemble, inspect, and clean the crankcase breather with Stoddard Solvent.

TABLE 3 Operational Settings and Clearances

Item	Adjustment
Spark plug gap	0.030 in. (0.76 mm)
Ignition breaker point gap	0.020 in. (0.51 mm)
Intake valve clearance (cold)	0.012 in. (0.30 mm)
Exhaust valve clearance (cold)	0.022 in. (0.55 mm)

9.4.2.2 *Power Section*—Dismantle the power section completely before each test and thoroughly clean the parts by soaking them in organic solvent for a minimum of 4 h. Remove remaining deposits on the crankshaft using fine or very fine 3M Scotch pads. After the minimal 4-h soak and cleaning period, rinse the parts in tap water heated to between 150 to 180°F (65.5 to 82.0°C) to remove all traces of organic solvent, and then rinse them with Stoddard Solvent. (**Warning**—Insufficient rinsing may allow organic solvent carryover to the test oil causing increased severity in copper-lead bearing weight loss.)

9.4.2.3 *Protection of Parts*—Immediately after cleaning, protect all parts against moisture and contamination by the use of a non-compounded ISO VG 46 (SAE 20) oil, vapor-proof plastic bag, or both. Give special attention to cleaning the following:

(1) Sludge trap and oil passages in crankshaft,

(2) Oil passage in cylinder block,

(3) Oil passages in crankcase,

(4) Oil passages in camshaft,

(5) Valve lifters,

(6) Timing gear oil jet,

(7) Tin-plated surfaces to be rated (Polish surfaces lightly with number 0 steel wool to achieve a fine dull shine.),

(8) Lubrication system for the rocker shaft assembly (oil line, rocker arms, rocker shaft, and rocker shaft supports),

(9) Valves and valve seats, and

(10) Cylinder head coolant water passages.

9.4.2.4 *Oil Heater*—Clean the oil heater case and inner cartridge with organic solvent to remove all residues, deposits, and foreign material. Use a wire brush or emery cloth as needed to completely remove residues and deposits, then rinse with hot tap water and spray the case and cartridge with Stoddard Solvent. Air dry.

9.4.2.5 *Copper-Lead Test Bearing*—Mark the bearing before using it in a test with the letters *T* (top) and *B* (bottom) on the backs of the bearing tangs, using a vibrating engraver. Make no other marks on the bearing until after the final weighing. Prior to initial weighing and prior to weighing at the end of a test, clean the bearing halves in accordance with the procedure given in Annex A11. (Fresh, clean Stoddard Solvent and pentane should be used for cleaning.) (**Warning**—Flammable. Health hazard.)

9.4.3 *Cylinder Liner Finish*—To minimize the effect of changes in oil consumption, a new cylinder liner with part number 100030-1 should be finished in accordance with the recommended honing procedure in Annex A8. The following procedure is recommended to refinish all other new or used cylinder liners before each test:

9.4.3.1 Wrap a half sheet of 400-grit wet or dry paper around a three-stone glaze breaker. Wet the paper with non-compounded ISO VG 46 (SAE 20) oil. Install the glaze breaker in the chuck of a low-speed (variable) electric drill motor having an operating speed of 40 r/min.

9.4.3.2 Work the glaze breaker and oil-wetted paper in 2-to-2½-in. (50-to-65-mm) strokes from the bottom to the top of the liner, producing a 60° crosshatch pattern. (At a drill speed of 40 r/min, working the glaze breaker back and forth along the vertical axis of the liner at a rate of two reciprocations per second will produce a crosshatch pattern of about 60°.)

9.4.3.3 Repeat this operation until the liner finish is from 13 to 15µ in. (0.33 to 0.38 µm) rms, as determined by using an appropriate measuring technique.

9.4.3.4 *Cleaning Procedure and Rust Prevention*—After the specified surface finish is achieved, spray the liner with Stoddard Solvent, and air dry it. Apply noncompounded ISO VG 46 (SAE 20) oil to the liner surface. Wipe the liner interior with a cloth or paper towel wetted with noncompounded ISO VG 46 (SAE 20) oil until the wiping material appears clean after wiping. Coat the liner with noncompounded ISO VG 46 (SAE 20) oil.

9.4.4 Determine the piston-to-sleeve clearance in accordance with the procedure given in Annex A6.

9.4.5 *Crankshaft Rear Seal Surface Conditioning*—Control of oil and air leakage at the crankshaft rear seal may be improved if the crankshaft rear seal surface is conditioned prior to each test in accordance with the recommendations of Laboratory Equipment Corporation (Labeco) Product Information Letter No. 10, issued February 9, 1967, and available from TEI.

9.4.6 *Crankshaft Journal Conditioning*:

9.4.6.1 Use crankshafts with all journals having out of-round measurements of 0.001 in. (0.025 mm) or less.

9.4.6.2 Since the test method is primarily designed to measure bearing weight loss, maintain the crankshaft rod bearing journal such that weight loss due to abnormal mechanical wear is minimized. Exercise care when handling the crankshaft to prevent nicking the journal surfaces. Should nicks be observed, lightly dress the journal with a dressing stone. Remove as little metal as possible. Observe bearing wear pattern for the test following this process to confirm that mechanical wear is at a practical minimum.

9.4.6.3 Polish the connecting rod bearing journal in accordance with the following guidelines: Mount the crankshaft on centers or position the main bearing journals in V-blocks. Prepare strips of polishing medium (only a wet/dry, silicon carbide, 400, 600, and 800 grit sand paper, standard crocus cloth, or Mylar 3µ tape is approved for use) ½-in. (13-mm) wide by 3 to 4-ft (0.9 to 1.2-m) long.[43] It is necessary to wet the strip of crocus cloth or sand paper with ISO VG 46 (SAE 20) oil or the Mylar tape with stoddard solvent. Wrap the strip 1½ times around the journal to provide a minimum of 360° contact between the cloth and journal. The Mylar tape will not slide over itself, so wrap it only 180°. Stroke the journal with the cloth or sand paper by alternately pulling on the two ends of the strip while maintaining a light tension on the strip, and while traversing across the journal. Do not dwell in the center of the journal. Rotate the crankshaft 90° beween each traverse. Repeat four times. If sand paper is used, complete the fourth and final polishing process using crocus cloth or Mylar tape.

9.4.6.4 Alternatively, rotate the crankshaft (with a metal turning lathe, for example) at about 120 r/min during the polishing process. Polishing for approximately 20 to 30 s, while traversing the cloth across the journal, has been found to be effective for this process. Do not dwell in the center of the journal. Absolutely no other polishing process is permitted.

9.4.6.5 Repeat the polishing procedure with dry crocus cloth or Mylar tape.

9.4.6.6 To confirm the trueness of the journal, visually check the journal with a straight edge 1.186-in. (30.12-mm) long; this length equals the width of the connecting rod bearing. Place a bright light source near the crankshaft on the side opposite your eyes. Hold the straight edge axially against the journal, and inspect for light leakage between the straight edge and the journal surface at 30° increments around the journal. If light leakage is observed, measure the journal diameters at the large- and small-diameter points, determine the axial distance between the two measurement points, and calculate the taper (using half of the diametral difference) of the journal between the points. Discard any crankshafts having a connecting rod journal taper larger than 0.0005 in/in. (0.0005 mm/mm). (Experience has shown that mechanical bearing wear with such crankshafts is unacceptably high.) The use of new technology, such as surface profile measuring equipment, is acceptable if approved by the TMC.

9.4.6.7 Do not resize the connecting rod journal.

9.4.6.8 Determine the connecting rod bearing clearance and journal taper in accordance with the procedure given in Annex A2 or an equivalent method approved through the ASTM Test Monitoring Center. Perform the connecting rod clearances measurements prior to the initial weighing of the bearing halves.

9.4.6.9 Determine the main bearing clearance in accordance with the procedure given in Annex A3.

9.4.6.10 After preparing the crankshaft in accordance with 9.4.6.1-9.4.6.9, clean it thoroughly. Either pressure spray it with Stoddard Solvent or brush it with Stoddard Solvent, and rinse it thoroughly.

9.4.7 *Camshaft Journal Conditioning*—The camshaft journal-to-bearing clearance shall be within the range from 0.0012 to 0.0052 in. (0.030 to 0.132 mm). [However, to maintain good oil pressure control when using low-viscosity oils, it may be necessary to reduce this clearance to between 0.0012 to 0.0032 in. (0.030 to 0.081 mm).] A suggested method for salvaging out-of-limit camshaft bearing journals or for decreasing the camshaft journal clearance is provided in Appendix X2.

9.4.8 *Power Section Valve Clearances*—Make the appropriate adjustments during power section reassembly to obtain the clearances shown in Table 4.

9.4.9 *Power Section Assembly Torque Specifications*—During power section assembly, use the torque specifications shown in Table 5.

9.4.10 *Connecting Rod Reconditioning*—When reconditioning connecting rods, the bore diameter shall be within the range from 2.2765 to 2.277 in. (57.8231 to 57.8358 mm).

[43] These materials can be obtained from many commercial sources.

TABLE 4 Valve Clearances

Item	Clearance
Inlet valve stem-to-tappet, cold	0.012 in. (0.30 mm)
Exhaust valve stem-to-tappet, cold	0.022 in. (0.55 mm)
Inlet valve stem-to-guide clearance	0.002–0.004 in. (0.05–0.10 mm)
Exhaust valve stem-to-guide clearance	0.003–0.005 in. (0.08–0.13 mm)

TABLE 5 Torque Specifications

Item	Torque
Connecting rod bearing cap	45 lbf · ft (61 N · m)
Main bearing guide bolts	35 lbf · ft (47 N · m)
Main bearing block	60 lbf · ft (81 N · m)
Cylinder hold-down	70 lbf · ft (95 N · m)
Drive plate	40 lbf · ft (54 N · m)
Cylinder barrel hold-down	50 lbf · ft (68 N · m)
Accessory oil gallery side cover plate cap	20 lbf · ft (27 N · m)
Crankcase cover plate cap	10 lbf · ft (14 N · m)

10. Calibration

NOTE 2—Annex A4 dictates specific procedures, which involve coordination with the TMC, to obtain calibration status of a test power section and a test stand. The information given in the following sections provides a summary of the calibration process required.

10.1 *Power Section and Test Stand Calibration*—Calibrate power sections in combination with test stands by running tests on reference oils (see 10.1.3 for frequency). The purpose is twofold: (1) to verify standardized engine operation, and (2) to document a laboratory's severity level for given combinations of power sections and test stands. (A test of a non-reference oil shall be conducted only on a given combination of power section, test stand, and bearing batch lot, which has been previously calibrated.) Conduct all non-reference oil and reference oil tests in the same manner.

10.1.1 *Reference Oils*—Obtain reference oils for calibration use from the TMC. Oils are available representing various levels of performance. See 14.1 for performance data.

10.1.2 *Test Numbering*—Calibration of power sections and test stands is closely related to test numbering; that is, the test number assigned to a test is a function of the calibration test recently conducted. Number each L-38 engine oil test by assigning it a test number that identifies the test stand number, the power section number, the number of tests conducted on the power section since the last successful reference oil test on that power section, and the total number of runs on the power section. For reruns of reference oil tests, the power section run number shall be followed by a letter *A* for the first rerun, *B* for the second rerun, and so forth. For example, test number 20–41–3–500 means test stand 20, power section 41, three tests on power section 41 since the last successful reference oil test on the power section (the reference oil test, itself, is designated by a zero), and the 500th test on power section 41. For reruns of unacceptable reference oil tests, the test number is incremented by a letter suffix on the final number of the test number. All other reruns are given a new sequential test number.

10.1.3 *Reference Oil Test Frequency*:

10.1.3.1 Using blind reference oils supplied by the TMC, calibrate each power section/test stand combination following each 15 test starts or upon the expiration of the six-month power section/test stand calibration time period, whichever occurs first. Calibrate a power section/test stand combination whenever a crankshaft or connecting rod is replaced or reconditioned. Count any test exceeding intervals of 40 h as more than one test start each time it exceeds 40 h. For example, 0 to 40 h equals one test start; 41 to 80 h equals two test starts; 81 to 120 h equals three test starts, and so forth.

10.1.3.2 Any test started within six months of the completion of the previous power section/test stand calibration is considered to be within the calibration time period.

10.1.3.3 When circumstances develop that are beyond a laboratory's control, such as fuel or parts shortages, calibration periods and the number of tests starts between calibrations may be adjusted. Adjustments to calibration periods and the number of test starts between calibrations shall be approved by the TMC and the L-38 Surveillance Panel before additional test starts are conducted. Make a note on the form shown in Fig. A15.6 in the final test report stating that the test was conducted on a power section/test stand in which calibration requirements were adjusted and also the reason for the adjustment.

10.1.3.4 Laboratories running nonstandard L-38 tests shall contact the TMC before resuming calibration L-38 testing with the test stand or power section, or both, involved. Depending upon the modifications to the power section or test stand (or both) and the time period of nonstandard testing, test stand checks or reference oil tests, or both, may be required before resumption of calibrated testing.

10.1.4 *Reference Oil Test Acceptance and Severity Monitoring*:

10.1.4.1 The TMC maintains records of reference oil test activity, analyzes severity trends, gives reports at ASTM meetings, and assists laboratories in the technical conduct of tests. (See Appendix X1 for a more detailed presentation of the TMC role.)

10.1.4.2 Submit all reference oil test reports to the TMC for review and acceptance. (See TMC document *Lubricant Test Monitoring System*[44] for reference oil test acceptance criteria.) The test data sheet for test reports on engine oils other than reference oils (see Fig. A15.3) shall include the test number and completion date of the power section reference oil test(s) used to calibrate the power section and test stand used for the test.

10.1.4.3 Failure of a reference oil test to meet Shewhart or EWMA control charts limits can be indicative of a false alarm, or a power section/test stand, laboratory or industry problem. When this occurs, the laboratory, in conjunction with the TMC, shall attempt to determine the problem source. Input from industry expertise (ASTM Technical Guidance Committee, The L-38 Surveillance Panel, Registration Systems, Inc., and so forth) may be solicited to help determine the cause and extent of the problem.

(*1*) In the event of a failed reference oil test, the calibration status of the power section or test stand, or both, shall first be reviewed before subsequent tests are conducted. If the TMC determines the problem is a false alarm, then there is no impact on non-reference tests running in the laboratory. If it is determined that the problem is related to the power section or

[44] Available from ASTM Test Monitoring Center.[2]

test stand, non-reference tests run during the problem period in that power section or test stand, or both, shall be reviewed for validity taking into account the related new information.

(*2*) If it is determined that the problem is related to the laboratory, all candidates tests run in the laboratory during the problem period shall be reviewed for validity, taking into account the related new information.

(*3*) If it is determined that the problem appears to be industry-wide, the ASTM L-38 Surveillance Panel shall be requested to develop a resolution.

10.2 *Instrumentation Calibration*—Calibrate the following instrumentation, immediately prior to each reference oil test, with the exception of a test stand where reference oil tests are conducted with multiple power sections: For a test stand using multiple power sections, the test stand instrument calibration may be extended by 14 days. For example, a reference oil test can be conducted in the same test stand with a second power section without calibrating the test stand instrumentation if the reference oil test is started within 14 days of the previous test stand instrument calibration. Unless otherwise specified in this test method, follow the instructions provided by the manufacturers of the instruments regarding the method of calibration. In calibrating each instrument, use certified reference standards having known values covering the range of measurements to be encountered in using this test method, and having tolerances less than those of the measurement tolerances specified in this test method. Retain the calibrations records for a minimum of 24 months.

10.2.1 Engine load measurement system,

10.2.2 Engine speed indicator,

10.2.3 Fuel flowmeter or weighing scale,

10.2.4 Temperature sensors and measurement system,

10.2.5 Electrical wattmeter,

10.2.6 Pressure gages,

10.2.7 Crankcase off-gas flowmeter,

10.2.8 Crankcase ventilation air flowmeter,

10.2.9 Air-fuel-ratio measurement system,

10.2.10 Weighing scales (oil measurement),

10.2.11 Torque wrenches (calibrate, as a minimum, every 6 months), and

10.2.12 Rocker cover air flowmeter.

11. Engine Operating Procedure

11.1 *Run-In and Flush*—At the beginning of each test, perform the following 4-h run-in and ½-h flush:

11.1.1 Install the full-flow oil filter in place of the oil heater (see Fig. 7). Use a new filter element for each test. (The oil filter is used only during the run-in portion of the procedure.)

11.1.2 Charge the power section with 5.4 lb (2.45 kg) of fresh test oil (see Section 8). Fill the oil filter first; put the remaining oil in the power section crankcase. Record this weighing and subsequent oil weighings on forms of the type shown in Fig. A5.1. Prior to starting the engine and any restarts during the 4-h run-in, perform the oil priming procedure in Annex A9.

11.1.3 Operate the power section for 4 h according to the schedule in Table 6. Maintain the oil gallery temperature no higher than 225°F (107.0°C), the oil gallery pressure at 40 ± 2 psig (280 ± 10 kPa), and the jacket outlet temperature no higher than 200°F (93.5°C). Record data hourly, using a form of the type shown in Fig. A5.1.

TABLE 6 Power Section Run-In Schedule

Speed, r/min (±25)	Load		Spark Advance, ° BTDC (±1)	Time, min (±2)	Total Time, h
	bhp (±0.2)	(w) (±150)			
1500	2.0	(1500)	25	60	1
2000	4.0	(3000)	25	60	2
2500	5.0	(3700)	35	60	3
3150	5.0	(3700)	35	60	4

11.1.4 Shut down the power section after four running hours (see 11.7). Immediately move the piston to top dead center (TDC) on the compression stroke, and drain the crankcase for 10 min. Vent the rocker cover to atmosphere during drain periods. Weigh the oil; record the weight.

11.1.5 After the 4-h run-in, remove the oil filter and install the oil heater (see Fig. 8). (The oil heater remains in the oil circuit for the flush and steady-state portions of the test procedure.)

11.1.6 Charge the power section with 3.15 lb (1.429 kg) of fresh test oil (see Section 8). Prior to starting the engine and any restarts during the ½-h flush, perform the oil priming procedure in Annex A9.

11.1.7 Flush the power section for ½ h under the following operating conditions: 3150 ± 25 r/min, 5.0 ± 0.2 bhp (3.73 ± 0.15 kW), 35 ± 1° before top dead center (BTDC) spark advance, 225°F (107.0°C) maximum oil gallery temperature, 200°F (93.5°C) maximum water jacket outlet temperature, and 40 ± 2 psig (280 ± 10 kPa) oil gallery pressure. Do not energize the oil heater during this period. Record operational data prior to shutdown using forms of the type shown in Fig. A5.1.

11.1.7.1 During this flush interval and the run-in interval (see 11.1.3) no more than 4 h of off-test time are allowed. No more than one emergency shutdown is allowed. No more than two total shutdowns are allowed.

11.1.7.2 During the shutdown between the 4–h run-in and ½-h flush, consider any time in excess of 85 min as off-test time counted against the 4 h limit listed in 11.1.7.1.

11.1.7.3 During the shutdown after the ½-h flush, consider any time in excess of 145 min as off-test time counted against the 2 h limit for the first interval listed in 11.7.

11.1.8 Shut down the power section; immediately move the piston to TDC on the compression stroke, and drain the crankcase and oil heater for 10 min. Weigh the oil; record the weight.

11.2 *Intermediate Bearing Weight Loss Checks*—If desired, weigh the copper-lead connecting rod bearings at the end of the run-in-and-flush period. Follow the cleaning instructions given in 9.4.2.5.

11.3 *Test Operating Conditions*—Throughout the remainder of the test (four 10-h intervals), operate the power section under the conditions shown in Table 1.

11.3.1 During the first 10-h interval, only one shutdown or one emergency shutdown is allowed and the total off-test time shall not exceed 2 h. During the four 10-h intervals, no more than 6 h of off-test time are allowed. During the second through the fourth 10-h intervals, no more than two emergency shutdowns are allowed and no more than four total shutdowns are allowed.

11.4 *Warm-up Schedule*—Charge the power section with 3.15 lb (1.429 kg) of fresh test oil (see Section 8). Perform the oil priming procedure in Annex A9. Start the engine. Follow the schedule in Table 7 at the beginning of the first 10-h test interval; when restarting the power section, after oil sampling and addition, after the first, second, and third intervals. After any unscheduled or emergency shut-downs, start the warm-up at the oil gallery temperature recorded when the engine is re-started and adjust the heater wattage or temperature set point to the next stage, in accordance with Table 7. For example, if the oil temperature is 255°F (123.9°C) when re-starting the engine, set the warm-up conditions at 1900 watts or 270°F (132.2°C) for 10 min as shown in Table 7. The warm-up shall proceed from this point and continue with the required steps in Table 7.

11.5 *Air-Fuel Ratio and Spark Advance*—During the first hour of each 10-h test interval, adjust and record the air-fuel ratio and spark advance. When determining the air-fuel ratio using the exhaust gas analysis measured by the calibrated electronic method (see 6.3.3.1), utilize Fig. A14.1 and correction procedure listed in Annex A14.

11.6 *Rocker Cover Air, Off-gas, and Blowby Measurement*:

11.6.1 To measure off-gas, adjust the vacuum control valve to maintain the crankcase vacuum at 2 ± 0.5 in. H_2O (500± 120 Pa). Observe the off-gas flow indication, record the reading in ft ^{3}/h, and then convert to standard conditions (29.92 in. Hg and 70°F) as follows:

$$SCFH = ACFH/[(29.92/(\text{baro metric pressure} + \text{gas pressure})) \times ((\text{gas temperature} + 460)/(460 + 70))] \quad (1)$$

where:

SCFH	=	standard ft^3/h,
ACFH	=	actual ft^3/h,
barometric pressure	=	barometer reading, in. Hg,
gas pressure	=	gage pressure at the inlet of the off-gas measuring device in in. Hg (if the system is under vacuum the value will be negative), and
gas temperature	=	temperature at the inlet of the measuring device, °F.

11.6.1.1 Adjust the rocker cover air control valve as needed to achieve 30 standard ft^3/h (SCFH) off-gas.

TABLE 7 Power Section Warm-up Schedule

Time, min	Total time, min^A	Heater Wattage^B	Temperature Set Point^B
15	15	1000	215°F (101.7°C)
10	25	1300	235°F (112.8°C)
10	35	1600	255°F (123.9°C)
10	45	1900	270°F (132.8°C)
15	60	2200, if needed	275 or 290°F (135.0 or 143.3°C)^C

^{A} Steady-state test time does not include warm-up time; rather, it begins only when the specified oil gallery temperature is reached.

^{B} Either heater wattage or temperature set point control may be used for warm-up operation.

^{C} As appropriate for test oil viscosity grade. See Table 7.

11.6.2 Observe and record the rocker cover air flow reading in SCFH after the off-gas flow has been adjusted to 30 SCFH.

11.6.3 Blowby is the difference between the standardized off-gas flow measured and the standardized rocker cover air flow measured.

11.7 *Shut-Down and Oil-Drain Procedure*—Follow the shut-down procedure given in the succeeding subsections for immediate shutdowns and at the end of each 10-h test interval. Any time in excess of 145 min, including cool-down and warm-up time, is considered off-test-time. If the off-test-time occurs following the run-in and flush intervals, the time counts against the 2-h maximum for the first interval. If it occurs following the first, second or third 10-h interval, the time counts against the 6-h maximum for the second through fourth intervals. In the event that an intermediate bearing weight loss measurement is performed, an additional 60 min downtime is allowed, provided that the weight loss is recorded and documented in the final test report.

11.7.1 At the end of each 10-h interval, turn off the oil heater and idle the power section at 1500 r/min for 10 min. (This action prevents overheating of the oil in the heater.) Allow the rocker cover fresh air input to remain on during the cool-down period, then turn it off. Turn off the ignition to stop the engine. It is also acceptable to disconnect the fuel supply and allow the engine to idle to a stop before turning off the ignition.

11.7.2 Move the piston to TDC on the compression stroke and wait 5 min before the next step. If the alternative forced-air-in version of the crankcase ventilation system is utilized, disconnect the system and vent the rocker cover to atmosphere during drain periods.

11.7.3 Drain the crankcase and oil heater for 10 min. Weigh the oil; record the weight of the drained oil.

11.8 *Oil Sampling and Oil Addition*— After each of the first three 10-h intervals, and after draining the crankcase and heater, as described in 11.7, take oil samples and make additions as directed in the following sections. Record the weights of all oil additions.

11.8.1 Retain the used oil in excess of 2.70 lb (1.225 kg) as a sample for analysis, as described in 12.1. To eliminate the possibility of deposit settling, take this sample within ½ h after draining the power section.

11.8.2 Add 0.45 lb (0.204 kg) of fresh test oil (see Section 8) and 2.70 lb (1.225 kg) of the used test oil to the crankcase. These weights are approximately equivalent to ½pt (0.24 L) of fresh test oil and 3 pt (1.42 L) of used test oil.

11.8.3 Follow the warm-up procedure specified in 11.4 when restarting the power section after the 10-, 20-, and 30-h oil samples are taken and the oil additions are made.

11.8.4 Use the data log sheet shown in Fig. A5.2 for recording all required operating conditions for each hour during the test.

11.9 *Oil Consumption Computation*—Compute the oil consumption in lb/h (kg/h) for each 10-h test interval. Average oil consumption for 40 h shall not exceed 0.037 lb/h (0.0168 kg/h). Average oil consumption for any 10-h test period shall not exceed 0.045 lb/h (0.0204 kg/h). Values in excess of these limits represent an oil test failure. That is, either the power section may be faulty or the test oil may be improperly formulated. Consider power section rebuilding and oil reformulation before proceeding.

11.10 *Periodic Measurements*:

11.10.1 Record, using the data log sheet shown in Fig. A5.2, the following data hourly:

11.10.1.1 Engine speed, r/min,

11.10.1.2 Engine load, bhp (kW),

11.10.1.3 Fuel flow, lb/h (kg/h),

11.10.1.4 Oil gallery temperature, °F (°C),

11.10.1.5 Oil sump temperature, °F (°C),

11.10.1.6 Oil heater input, W,

11.10.1.7 Jacket inlet coolant temperature, °F (°C),

11.10.1.8 Jacket outlet coolant temperature, °F (°C),

11.10.1.9 Oil pressure, psi (kPa),

11.10.1.10 Crankcase vacuum, in. H_2O (Pa),

11.10.1.11 Exhaust back pressure, in. Hg (kPa),

11.10.1.12 Intake air temperature, °F (°C),

11.10.1.13 Intake manifold vacuum, in. Hg (kPa),

11.10.1.14 Crankcase off-gas, SCFH, and

11.10.1.15 Rocker cover fresh air flow, SCFH.

11.10.2 Record the following data at least once every 10-h test interval:

11.10.2.1 Air-fuel ratio,

11.10.2.2 Spark advance, and

11.10.2.3 Blowby, SCFH.

11.11 *Operational Validity Criteria*—The test laboratory is responsible for determining and documenting the operational validity of every engine test. For a test to be operationally valid, the deviation percentage criteria defined in 11.11.1 shall be met. In addition, the test stand, test operation, and test buildup shall conform with the published procedure.

11.11.1 *Deviation Percentage*—Calculate the deviation percentage using the equation:

$$DP = \sum_{i=1}^{i=n} \left[\frac{M_i}{0.5R} \times \frac{T_i}{D} \right] \times 100 \quad (2)$$

where:

DP = Deviation percentage,

M_i = Magnitude of test-parameter deviation from specification limit at occurrence i,

R = Test parameter specification range,

T_i = Length of time that test parameter was outside of specification range at occurrence i,

n = Number of times that a test parameter deviated from test specifications limits, and

D = Test or test-phase duration in same units as T_i.

NOTE 3—T_i is assumed to be no less than the recorded-data-acquisition frequency unless supplemental readings are documented.

11.11.1.1 Invalidate any tests exceeding the following deviation percentages:

Primary test parameter, 2.5 %
Secondary test parameter, 5.0 %

Primary Parameters

Fuel flow
Crankcase off gas
Oil gallery temperature
Coolant out temperature
Coolant delta temperature
Oil pressure

Secondary Parameters

Speed
AFR
Spark advance
Exhaust pressure
Crankcase vacuum

11.12 *Test Completion*—Define the end of test time as 25 min after the fortieth test hour.

12. Determination of Test Results

12.1 *Oil Sample Inspection*:

12.1.1 Determine the acid number and kinematic viscosity at 40°C and 100°C of the fresh oil (see Section 8) and the 10-, 20-, 30-, and 40-h used oil samples by Test Method D 974 or D 664, and Test Method D 445, respectively.

NOTE 4—To meet the requirements of Military Specification MIL-2104 for the viscosity stability of a multiviscosity-graded oil, measure the stripped viscosity of a 10-h sample of used oil. See the MIL-L-2104 Specification (paragraph 4.6.2) for the specified measurement method.

12.2 *Power Section Part Varnish Rating*—At the conclusion of the test, rate the following parts for varnish deposition:

12.2.1 Piston skirt,

12.2.2 Rocker arm cover,

12.2.3 Crankcase cover plate,

12.2.4 Cylinder wall below ring travel,

12.2.5 Oil pan, and

12.2.6 Push rod cover.

12.3 *Power Section Part Sludge Rating*— At the conclusion of the test, rate the following parts for sludge deposits:

12.3.1 Oil pan,

12.3.2 Push rod cover,

12.3.3 Oil screen,

12.3.4 Rocker arms,

12.3.5 Rocker arm cover, and

12.3.6 Crankcase cover plate.

12.4 *Test Bearing Weight Loss Determination*—Record, in milligrams, the weights of the top and bottom connecting rod test bearing halves within 4 h of conclusion of the test. If this determination is delayed longer than 4 h, the test is invalid. Clean each bearing half, as described in Annex A11, before weighing. Determine the weight loss of the bearing to the nearest 0.1 mg by subtracting from the initial weights recorded prior to power section run-in. Determine the corrected total bearing weight loss for H-24 bearings using the following equation:

$$\text{Corrected TBWL} = (\text{Actual TBWL} \times 1.56) + 8.22 \quad (3)$$

Record the corrected H-24 total bearing weight loss to the nearest 0.1 mg.

12.4.1 Ajdust the corrected H-24 total bearing weight loss determined in 12.4 in accordance with the procedure in Annex A7. Record the severity adjustments in Fig. A15.3.

13. Report

13.1 The forms that comprise the test report are presented in Annex A15 and shall be used without modification. The data dictionary is presented in Annex A16 and shall be used to describe the fields in the report pocket.

13.2 Use forms 1, 2, 4, 5, 6, 7, and 8 (see Figs. A15.1-A15.8) for initial transmission of reference oil tests to the TMC.

14. Precision and Bias

14.1 Test precision is established on the basis of reference oil test results (for operationally valid tests) monitored by the ASTM Test Monitoring Center. Contact the TMC[2] for current industry data.

14.1.1 Table 8 summarizes reference oil precision of the test as of January 20, 1998.

14.1.1.1 *Repeatability (r)*—The difference between successive results obtained by the same operator with the same engine under constant operating conditions on the same oil, would, in the long run, in the normal and correct conduct of the test method, exceed the values shown in Table 8 in only one case in twenty.

14.1.1.2 *Reproducibility (R)*—The difference between two single and independent results obtained by different operators working in different laboratories on the same oil would, in the long run, in the normal and correct conduct of the test method, exceed the values shown in Table 8 in only one case in twenty.

14.2 Bias is determined by applying an accepted statistical technique to reference oil test results, and when a significant bias is determined, a severity adjustment is permitted for non-reference oil test results (see Annex A7).

TABLE 8 L-38 Reference Oil Test Precision Data[A]

Oil	Total Bearing Weight Loss, mg				
	x	s_r	r	s_R	R
701-1	71.1	20.4	57.12	20.4	57.12
702	20.1	5.89	16.49	6.18	17.30
704	36.0	10.32	28.90	11.27	31.56
704-1	30.8	3.18	8.90	6.82	19.10

[A] Operationally valid tests reported through January 20, 1998.

Legend:
x = arithmetic mean,
s_r = repeatability standard deviation,
r = repeatability
s_R = reproducibility standard deviation, and
R = reproducibility.

15. Use of ASTM Rounding

15.1 Follow Practice E 29 guidelines for rounding of test results, operational parameters, and engine build-up measurements.

16. Keywords

16.1 bearing corrosion; bearing weight loss; CLR oil test engine; copper-lead bearings; deposits; engine oil; L-38 test; oil consumption; oxidation resistance; shear stability; sludge; varnish; viscosity loss

ANNEXES

(Mandatory Information)

A1. SPECIFICATION FOR SOLTROL 10

A1.1 Table A1.1 presents the specifications for Soltrol 10.

TABLE A1.1 Specification for Soltrol 10

Property[A]	Typical Value	Specification	Test Method
Distillation, °F at 760 mm Hg (101.3 kPa)			ASTM D 86
Initial boiling point	204	200 min	
Percent recovered			
5	205	202 min	
10	206		
50	208		
90	212		
95	215	219 max	
Dry Point	218	220 max	
API gravity at 60°F	70.6		ASTM D 287
Specific gravity, 60/60°F (with TEL: 3 mL/gal; 0.8 mL/L–0.7005)	0.698	0.697–0.710	ASTM D 1298
Density of liquid at 60°F, lb/gal	5.827 (0.6982 kg/L)		ASTM D 1250
Vapor pressure at 100°F, psia	2.2 (15.2 kPa)		ASTM D 323
Flash point, °F	+ 13		ASTM D 56
Composition, liquid volume %			gas chromatography
Heptane isomers	28		
Octanes	10		
2,2,4-Trimethylpentane	62		
Aromatic content (total), mass %	Nil (est.)		gas chromatography
Sulfur content, ppm	<1	10 max	ASTM D 3120
Nonvolatile matter, mg/100 mL	0.5	1 max	ASTM D 1353
Color, saybolt	+ 30	+ 30 min	ASTM D 156
Acidity of distillation residue	neutral		ASTM D 1093
Doctor test	negative		ASTM D 235
Kauri-butanol value	27.9		ASTM D 1133
Odor	pass	pass	panel
Research octane number (with TEL: 3 mL/gal; 0.8 mL/L–111)	96		ASTM D 2699
Motor octane number (with TEL: 3 mL/gal; 0.8 mL/L–109)	94		ASTM D 2700

[A] °C = (°F − 32)/1.8.

A2. MEASUREMENT OF CONNECTING ROD BEARING CLEARANCE AND JOURNAL TAPER

A2.1 Conduct the connecting rod bearing clearance measurements with the crankshaft, bearing sets, and measuring tools at room temperature.

A2.2 Use measuring tools having an accuracy of at least 0.0001 in. (0.003 mm).

A2.3 Thoroughly clean the connecting rod bore with Stoddard Solvent and air dry. Use caution not to affect the original surface. Clean the connecting rod bearing in accordance with A11.1 only. Install the cleaned rod bearing halves, which are to be used in the test, into the proper location (top and bottom as marked). Place the connecting rod into a holding device, clamping as close as possible to the large end of the connecting rod to prevent the rod from being twisted during the torquing procedure. Install lower bearing cap and apply 45 lbf·ft (61 N·m) torque to the bearing cap bolts. Immediately return connecting rod bearing to the original container filled with EF-411 after measurements are performed.

A2.4 Measure the connecting rod bearing vertical diameter at the two points A and B indicated in Fig. A2.1. Each of the points is located 0.25 in. (6.4 mm) from each bearing edge. Record the measurements in the appropriate spaces in a table such as the one in Annex A3.

A2.5 Mount the crankshaft on a workbench with the axis horizontal and with the connecting rod bearing journal verti-

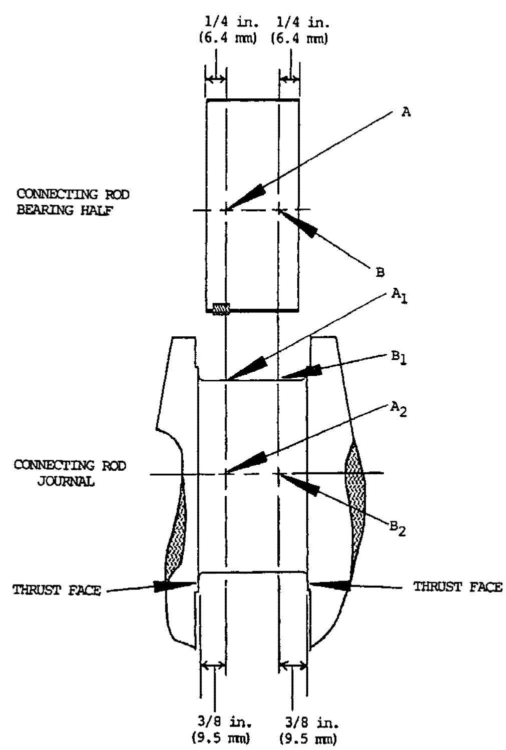


FIG. A2.1 Clearance Measuring Points for Connecting Rod Bearings

cally upward, simulating the top-dead-center position in the engine.

A2.6 Measure the diameter of the connecting rod bearing journal of the crankshaft at the points A_1, B_1, A_2, and B_2 indicated in Fig. A2.1. The measuring points are located 0.38 in. (9.5 mm) from each thrust face. Record the measurements in the appropriate spaces in a table such as Table A2.1.

TABLE A2.1 Connecting Rod Bearing Clearance[A]

A ________	B ________
A_1 ________	B_1 ________
A_2 ________	B_2 ________
$A - A_1$ = ________	$B - B_1$ = ________
$A - A_2$ = ________	$B - B_2$ = ________
min ________	max ________

[A] Diameters A_1 and B_1 are measured at points 90° from A_2 and B_2, respectively.

A2.7 Subtract the diameters to obtain the clearances, as directed in Table A2.1. From the four clearance values thereby determined, select the minimum and maximum values, and enter them in the spaces provided in the table.

A2.8 The minimum and maximum connecting rod bearing clearances determined in A2.7 shall be within the range from 0.0024 to 0.0030 in. (0.061 to 0.076 mm). If they fall outside of this range, select and measure a different crankshaft.

A2.9 Determine the taper of the connecting rod bearing journal by completing Table A2.2. The maximum quotient obtained in Table A2.2 is considered the journal taper. Discard any crankshafts having a connecting rod journal taper larger than 0.0005 in./in. (0.0005 mm/mm).

TABLE A2.2 Taper of Connecting Rod Bearing Journal[A]

Use measurements from Table A3.1.
($A_1 - B_1$ = ________)/1.372 in. (34.85 mm) = ________
($A_2 - B_2$ = ________)/1.372 in. (34.85 mm) = ________

[A] Bearing width = 1.186 in. (30.12 mm). Distance between the measuring points A_1 and B_1 (or A_2 and B_2) is 1.186 in. (30.12 mm) − 2 [¼ in. (6.4 mm)] = 1.186 in. (30.12 mm) − ½in. (12.7 mm) = 0.686 in. (17.4 mm). Taper = ($A_1 - B_1$) (or $A_2 - B_2$) divided by 2 divided by 0.686 in. (17.4 mm), or ($A_1 - B_1$) (or $A_2 - B_2$)/1.372 in. (34.85 mm). (Division by 2 is required to obtain the desired difference in shaft radius between the measuring points.)

A3. MEASUREMENT OF MAIN BEARING CLEARANCE

A3.1 Conduct the main bearing clearance measurements with the crankcase, crankshaft, bearing sets, and measuring tools at room temperature.

A3.2 Use measuring tools having an accuracy of at least 0.0001 in. (0.003 mm).

A3.3 Install two bearing sets in the crankcase, but do not install the crankshaft. Use either two standard main bearing halves, one standard main bearing half (Labeco Part No. 8252) and one undersize main bearing half (Labeco Part No. 8252-0.0012 U.S.), or two undersize bearing halves. For consistency, when using one standard and one undersize bearing half together, install the standard half in the bearing cap. Torque the bearing block bolts to 60 lbf·ft (81 N·m).

A3.4 Measure the front main bearing vertical diameter at the two points A and B indicated in Fig. A3.1. Each of the points is located in the middle of the respective nonrelieved bearing surface. Record the measurements in the appropriate spaces in a table such as Table A3.1.

TABLE A3.1 Crankshaft Main Bearing Clearance

Front Main Bearing[A]		Rear Main Bearing[A]	
A ______	B ______	A ______	B ______
A_1 ______	B_1 ______	A_1 ______	B_1 ______
A_2 ______	B_2 ______	A_2 ______	B_2 ______
$A - A_1$ = ______	$B - B_1$ = ______	$A - A_1$ = ______	$B - B_1$ = ______
$A - A_2$ = ______	$B - B_2$ = ______	$A - A_2$ = ______	$B - B_2$ = ______
min ______	max ______	min ______	max ______

[A] Diameters A_1 and B_1 are measured at points 90° from A_2 and B_2, respectively.

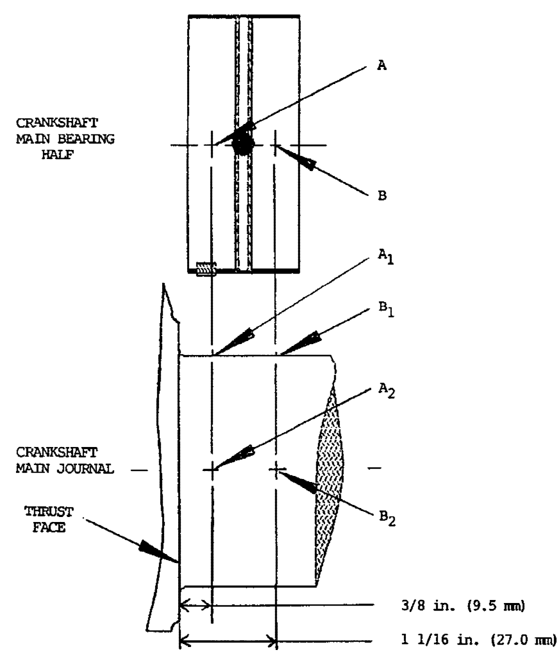


FIG. A3.1 Clearance Measuring Points for Crankshaft Main Bearings

A3.5 Mount the crankshaft on a workbench with the axis horizontal and with the connecting rod bearing journal vertically upward, simulating the TDC position in the engine.

A3.6 Measure the diameter of the front main journal of the crankshaft at the points A_1, B_1, A_2, and B_2 indicated in Fig. A3.1. Record the measurements in the appropriate spaces in a table such as Table A3.1.

A3.7 Measure the diameters of the rear main bearing and the rear main journal at the points described in A3.4 and A3.6. Record the measurements in Table A3.1.

A3.8 Subtract the diameters to obtain the clearances, as directed in Table A3.1. From the four clearance values, thereby determined for each main journal and bearing combination, select the minimum and maximum values, and enter them in the spaces provided in the table.

A3.9 The minimum and maximum main bearing clearances determined in A3.8 must be within the range from 0.0020 to 0.0030 in. (0.051 to 0.076 mm). If they fall outside of this range, either install different bearings, or a different crankshaft, and remeasure the clearances.

A4. THE ASTM TEST MONITORING CENTER CALIBRATION PROGRAM

A4.1 *Conducting a Reference Oil Test:*

A4.1.1 For those laboratories that choose to utilize the services of the TMC in maintaining calibration of power sections and test stands, full-scale calibration testing must be conducted at regular intervals. These full-scale tests are conducted using blind, coded reference oils supplied by the TMC. It is a laboratory's responsibility to maintain the calibration in accordance with the test procedure. It is also a laboratory's responsibility to keep the on-site blind reference oil inventory at or above the minimum level specified by the TMC test engineers.

A4.1.2 When laboratory personnel decide to run a reference calibration run, they must request a blind oil code from the cognizant TMC engineer. Upon completion of the reference oil test using the blind reference oil, the data must be sent in summary form (use TMC forms) to the TMC by telephone facsimile transmission, or by some other method acceptable to the TMC. The TMC will review the data and contact the laboratory engineer to report the laboratory's calibration status. All reference oil tests, whether aborted, invalidated, or successfully completed, must be reported to the TMC. Subsequent to sending the data in summary form to the TMC, the laboratory is required to submit to the TMC the written test report specified in the test procedure.

A4.2 *New Laboratories*—Laboratories wishing to become a part of the ASTM Test Monitoring System will be requested to generate both blind and nonblind tests to ensure that the laboratory is using the proper testing techniques. Information concerning fees, laboratory inspection, reagents, testing practices, appropriate committee membership, and rater training can be obtained by contacting the TMC Administrator.[2]

A4.3 *Introducing New L-38 Reference Oils*—The calibrating reference oils produce various copper-lead bearing weight loss and deposit characteristics. When new reference oils are selected, member laboratories will be requested to conduct their share of tests to enable the TMC to establish the proper industry average and test acceptance limits. The ASTM D02.B0.02 L-38 Surveillance Panel requires a minimum of four tests to be conducted prior to establishing the industry average and test acceptance targets for new reference oils. The TMC estimates that laboratories will be requested to run an average of one contributing test per year for each eight test power sections operated throughout the year.

A4.4 *TMC Information Letters:*

A4.4.1 Occasionally, it is necessary to change the procedure, and notify the test laboratories of the change, prior to consideration of the change by either Subcommittee D02.B on Automotive Lubricants or Committee D-2 on Petroleum Products and Lubricants. In such a case, the TMC will issue an Information Letter. Subsequently, prior to each semiannual Committee D02 meeting, the accumulated Information Letters are balloted by Subcommittee D02.B. The ballot is reviewed at the Subcommittee D02.B meeting, and the actions taken are considered at the following meeting of Committee D02. By this means, the Society due process procedures are applied to these Information Letters.

A4.4.2 Several methods and levels of review are conducted prior to issuing an Information Letter. In the case of an Information Letter concerning a part number change which does not affect test results, the TMC is authorized to issue such a letter. Long-term studies by the Surveillance Panel to improve the test procedure through improved operation and hardware control may result in a recommendation to issue an Information Letter. If obvious procedural items affecting test results need immediate attention, the test sponsor and the TMC will issue an Information Letter and present the background and data to the Surveillance Panel for approval prior to the semiannual Subcommittee D02.B meeting.

A4.4.3 Authority for the issuance of Information Letters was given by the Committee on Technical Committee Operations in 1984, as follows:

"COTCO recognizes that D-2 has a unique and complex situation. The use of Information Letters is approved providing each letter contains a disclaimer to the effect that such has not obtained ASTM consensus. These Information letters should be moved to such consensus as rapidly as possible."

A5. DATA LOG SHEETS

A5.1 Fig. A5.1 and Fig. A5.2 are examples of data log sheets.

Page Number ____________

"LABORATORY NAME"
L-38 TEST DATA LOG SHEET

RUN NUMBER ____________________
(Stand-Engine-Reference-Run)

ENGINE NUMBER ______________ CELL NUMBER ______________ OIL CODE ____________

		RUN-IN				FLUSH
	OBSERVER					
	DATE					
	TIME					
	TOTAL HOURS ON "RUN-IN" OR "FLUSH"	1	2	3	4	1/2
	TEST PARAMETER					
ENGINE	ENGINE SPEED (Specified, ± 25 r/min)	1500	2000	2500	3150	3150
	ENGINE SPEED (Actual, r/min)					
	ENGINE OUTPUT (Specified, ± 0.2 bhp) (Specified, ± 150 W)	2 (1490)	4 (2980)	5 (3730)	5 (3730)	
	ENGINE OUTPUT (Actual, bhp) (bhp = 745.6999 W)					
TEMPERATURES*	OIL GALLERY (225 °F MAX) (107.0 °C MAX)					
	**OIL SUMP (Record, °F)					
	**OIL HEATER INLET (Record, °F)	Oil Heater not in Oil Circuit.				
	**OIL HEATER OUTLET (Record, °F)					
	COOLANT OUTLET (200°F MAX) (93.5 °C MAX)					
	**COOLANT INLET (Record, °F)					
	**COOLANT DIFFERENTIAL (10 ± 2 °F) (5.6 ± 1 °F)					
	**CARBURETOR INTAKE AIR (Record, °F)					
	**EXHAUST (Record, °F)					
	* (°C = (°F-32)/1.8)					
PRESSURE	OIL GALLERY (40 ± 2 psig) (276 ± 14 kPa)					
	**CRANKCASE VACUUM (2.0 ± 0.5 in. H_2O) (500 ± 120 kPa)					
	**EXHAUST BACK PRESSURE (0 to 1 in. Hg) (0 to 3.4 kPa)					
	**INTAKE VACUUM (Record, in. Hg) (in. Hg = 3.37605 kPa)					
FLOWS	**FUEL (4.75 ± 0.25 lb/h @ 3150 r/min) (2.15 ± 0.11 kg/h @ 3150 r/min)					
	**CARBURETOR AIR (Record, lb/h) (lb/h = 0.4535924 kg/h)					
	**AIR FUEL RATIO (14.0 ± 0.5)					
	**CRANKCASE OFF-GAS (30 ± 1 ft^3/h) (850 ± 28 L/h)					
	**ROCKER AIR (Record, ft^3/h) (ft^3/h = 28.31685 L/h)					
	**BLOWBY (approx. 10 ± 2 ft^3/h) (approx. 280 ± 60 Lh/)					
MISC	IGNITION ADVANCE (Specified, ± 1° Before Top Dead Center, BTDC)	25	25	35	35	35
	IGNITION ADVANCE (Actual, BTDC)					
	OIL HEATER POWER (W)	Oil Heater not in Oil Circuit.				OFF

** Recommended but Not Required.

=== RUN-IN ===	=== RUN-IN ===	=== FLUSH ===	=== FLUSH ===	=== ZERO-HOUR ===
FRESH OIL ADD'N WEIGHT	OIL DRAIN WEIGHT	FRESH OIL ADD'N WEIGHT	OIL DRAIN WEIGHT	FRESH OIL ADD'N WEIGHT
OIL & CAN __________	OIL & CAN __________	OIL & CAN __________	OIL & CAN __________	OIL & CAN __________
- CAN __________	- CAN __________	- CAN __________	- CAN __________	- CAN __________
OIL 5.40 lb (2.45 kg)	OIL lb	OIL 3.15 (1.43 kg)	OIL lb	OIL 3.15 lb (1.43 kg)

FIG. A5.1 Run-In and Flush Data Log Sheet

Page Number __________

LABORATORY NAME
L-38 TEST DATA LOG SHEET

RUN NUMBER ____________________
(Stand-Engine-Reference-Run)

ENGINE NUMBER ______________ CELL NUMBER ____________ OIL CODE __________

	Column No. ----->	1	2	3	4	5	6	7	8	9	10
	OBSERVER										
	DATE										
	TIME										
	TOTAL HOURS ON STEADY-STATE TEST										
	TEST PARAMETER										
ENG	ENGINE SPEED (3150 ± 25 r/min)										
	ENGINE OUTPUT (Record, bhp) (bhp = 745.6999 W)										
TEMPERATURES	OIL GALLERY (XXX[1] ± 2 °F) (XXX[1] ± 1 °C)										
	OIL SUMP (Record, °F)										
	OIL HEATER INLET (Optional) (Record, °F)										
	OIL HEATER OUTLET (Optional) (Record, °F)										
	COOLANT OUTLET (200 ± 2°F) (93.5 ± 1°C)										
	COOLANT INLET (Record, °F)										
	COOLANT DIFFERENTIAL (10 ± 2 °F) (5.6 ± 1 °F)										
	CARBURETOR INTAKE AIR (Record, °F)										
PRESSURES	OIL GALLERY (40 ± 2 psig) (276 ± 14 kPa)										
	CRANKCASE VACUUM (2.0 ± 0.5 in. H_2O) (500 ± 120 Pa)										
	EXHAUST BACK PRESSURE (0 to 1 in. Hg) (0 to 3.4 kPa)										
	INTAKE VACUUM (Record, in. Hg) (in. Hg = 3.37685 kPa)										
FLOWS	FUEL (4.75 ± .25, lb/h) (2.15 ± 0.11 kg/h)										
	CARBURETOR AIR[2] (approx. 66.5 lb/h) (approx. 30.2 kg/h)										
	AIR FUEL RATIO[2] (14.0 ± 0.5)										
	CRANKCASE OFF-GAS (30 ± 1 SCFH)										
	ROCKER AIR (Record, SCFH)										
	BLOWBY (Record, SCFH)										
MISC	IGNITION ADVANCE[2] (35 ± 1° Before Top Dead Center, BTDC)										
	OIL HEATER POWER (Record, W)										

[1] 275°F (135.0°C) for SAE 10W; 290°F (143.5°C) for SAE 20, 30, 40, 50 and multiviscosity graded oils

[2] Required during hours: 1, 11, 21, 31

OIL DRAIN WEIGHT	USED OIL ADD'N WEIGHT	FRESH OIL ADD'N WEIGHT	OIL SAMPLE WEIGHT	OIL CONSUMPTION, lb/h,
at __________h	at __________h	at __________h	at __________h	at __________h
OIL & CAN __________	OIL & CAN __________	OIL & CAN __________	OIL & CAN __________	ADD minus DRAIN = __________
- CAN __________	- CAN __________	- CAN __________	- CAN __________	divided by 10 = __________
OIL __________lb	OIL __________lb	OIL __________lb	OIL __________lb	POUNDS per HOUR

NOTE: Oil Gallery Temperature - Refer to procedure, section 11.3, for vicosity-related temperatures.

FIG. A5.2 Test Data Log Sheet

A6. MEASUREMENT OF PISTON-TO-SLEEVE CLEARANCE

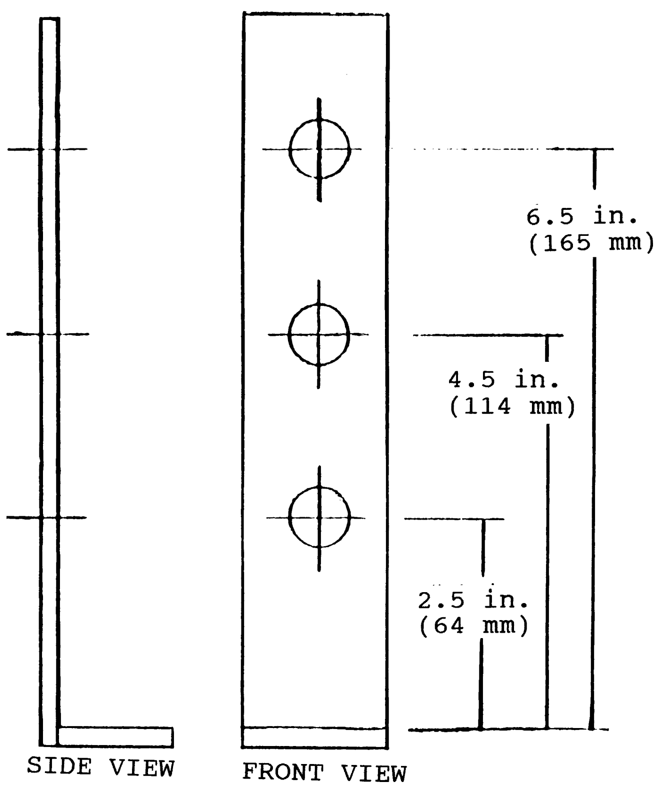
A6.1 Conduct the piston-to-sleeve clearance measurements with the sleeve, barrel assembly, cylinder head, piston, and measuring tools at room temperature.

A6.2 Use measuring tools having an accuracy of at least 0.0001 in. (0.003 mm).

A6.3 Install the sleeve into the barrel assembly and torque the cylinder head into place.

A6.4 Measure the sleeve diameter in the transverse (between the valves) direction at the top, middle, and bottom of the sleeve using a bore gage and the bore measurement ladder (see Fig. A6.1). Record the measurements in the appropriate spaces in a table such as Table A6.1. Repeat the preceding for the longitudinal (across the valves) direction.

A6.5 Heat the piston so that the piston pin can be installed wtihout using any force. Do not exceed 150°F (65.5°C) piston temperature. Allow the piston to return to room temperature before measuring. Measure the piston skirt at the middle and bottom of the skirt as indicated in Fig. A6.2. Record the measurements in the appropriate spaces in a table such as Table A6.1.



NOTE 1—Overall dimensions are not critical.

NOTE 2—Make the ladder of brass or aluminum to prevent liner scratching.

NOTE 3—Holes should be sized as dictated by the bore measurement device which will be used.

FIG. A6.1 L-38 Bore Measurement Ladder

TABLE A6.1 Piston-to-Sleeve Clearance

	Sleeve Diameters, in. (mm)			Taper	
	TOP	MIDDLE	BOTTOM	in.	(mm)
Transverse	a	b	c	g	
Longitudinal	d	e	f	h	
Out-of-Round	i	j	k		

g = (Largest of a, b or c)—(smallest of a, b, or c)
h = (Largest of d, e or f)—(smallest of d, e, or f)
i = (Largest of a or d)—(smallest of a or d)
j = (Largest of b or e)—(smallest of b or e)
k = (Largest of c or f)—(smallest of c or f)

Piston Skirt Diameters	
Middle	m
Bottom	n
Taper	p
Average	q

p = (Largest of m or n)—(smallest of m or n)
q = (m + n)/2
Piston-to-Sleeve Clearance ((b + c)/2) − q)

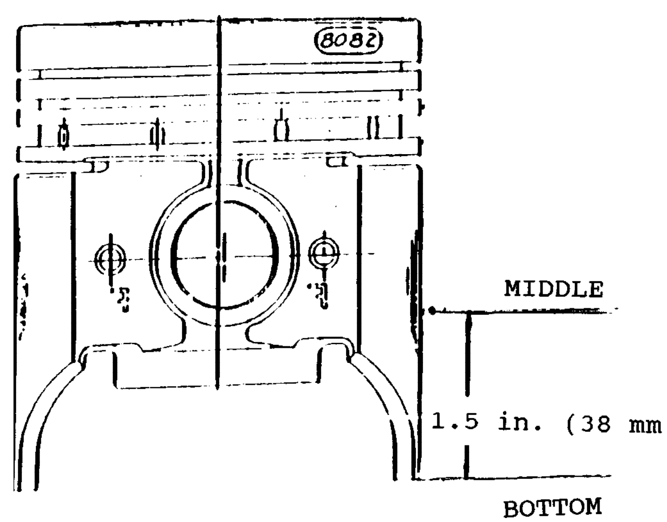


FIG. A6.2 Measuring Points for L-38 Piston

A6.6 Calculate the sleeve bore diameter to be used for the piston-to-sleeve clearance using the middle and bottom transverse measurements according to Table A6.1.

A6.7 Calculate the sleeve taper according to Table A6.1.

A6.8 Calculate the sleeve out-of-round according to Table A6.1.

A6.9 Calculate the piston diameter to be used for the piston-to-sleeve clearance using the middle and bottom measurements in accordance with Table A6.1.

A6.10 Calculate the piston taper in accordance with Table A6.1.

A6.11 Calculate the piston-to-sleeve clearance in accordance with Table A6.1.

A6.12 The piston-to-sleeve clearance as determined in Table A6.1 shall be within the range from 0.0012 to 0.0025 in. (0.030 to 0.063 mm). If the clearance falls outside of this range, replace the liner, the piston, or both depending on their relative size.

A7. CONTROL CHART TECHNIQUE FOR A LABORATORY'S SEVERITY ADJUSTMENT (SA)

A7.1 Include all operationally valid calibration tests in a laboratory control chart.

A7.2 Integrate the calibration tests into a control chart in the order of test completion date/time.

A7.3 A minimum of two calibration tests are required to initialize a control chart.

A7.3.1 Subtract the target mean value for each reference oil from the 40-h test result with each oil. Divide the differences obtained by the target standard deviations for the oils. (Target mean and standard deviation values are periodically published by the TMC.) Multiply the first delta/s value by 0.16 and the second delta/s by 0.2. Add the results of these two products. This is the initial exponentially weighted moving average (EWMA). The 0.16 weighting is equivalent to calculating an EWMA after each of the first two tests using 0.8 weighting in each calculation {(that is, $0.8((0 \times 0.8) + (0.2 \times \text{delta/s}_1)) = (0.16 \times \text{delta/s}_1)$ which would then be added to $(0.2 \times \text{delta/s}_2)$}.

A7.4 As subsequent tests are added, multiply the previous EWMA by 0.8 and the test being added by 0.2. The sum of these two products is the EWMA until another calibration test is conducted.

A7.5 Apply an SA to each subsequent non-reference result when the absolute value of an EWMA is greater than 0.600. Calculate this adjustment after first rounding the EWMA to three places after the decimal. Convert the resulting EWMA to appropriate units since the EWMA is unitless; multiply the EWMA by 9.0 for total bearing weight loss. This multiplier is an estimated reproducibility standard deviation of an oil near the pass/fail limit, and is subject to update by way of TMC memoranda. Multiply the converted EWMA values by -1, round this product to one place after the decimal, and add the calculated SA value to each non-reference result until another calibration test updates the EWMA.

A7.5.1 When applying an SA to bearing weight loss, if the resulting value is less than 0.0, it shall be recorded as 0.0.

A8. RECOMMENDED NEW LINER HONING PROCEDURE

A8.1 Remove new liner from box and clean protective coating from the liner.

A8.2 Install fret ring and liner into cylinder barrel. Install head gasket and stress plate, torque to specified setting. Fig. A8.1 shows a recommended stress plate.

A8.3 Set cylinder barrel fixture and cylinder barrel into Sunnen CK-10 or CV-616 honing machine and secure. Fig. A8.2 shows a recommended cylinder barrel fixture. The appropriate honing machine setups and honing stone selections are in Table A8.1.

A8.4 Coarse hone liner to within 0.001 in. (0.025 mm) of determined finish diameter. During coarse honing, it is recommended to rotate and clean stones after every 30 strokes and to measure liner between stone rotations for correct taper.

A8.5 After reaching the desired coarse honed liner diameter, allow liner to cool to room temperature and coarse hone to within 0.0005 in. (0.013 mm) of the desired diameter before beginning the finish honing.

A8.6 Complete honing with finishing stone to desired liner diameter and surface finish. The approximate number of strokes will depend on the finishing stone selected.

A8.7 Final liner measurements shall be made in the actual cylinder barrel of the power section to be used.

A8.8 This procedure is to be used only for initial new liner honing. For used liners, follow the procedure in 9.4.3 of the L-38 Procedure, Test Method D 5119.

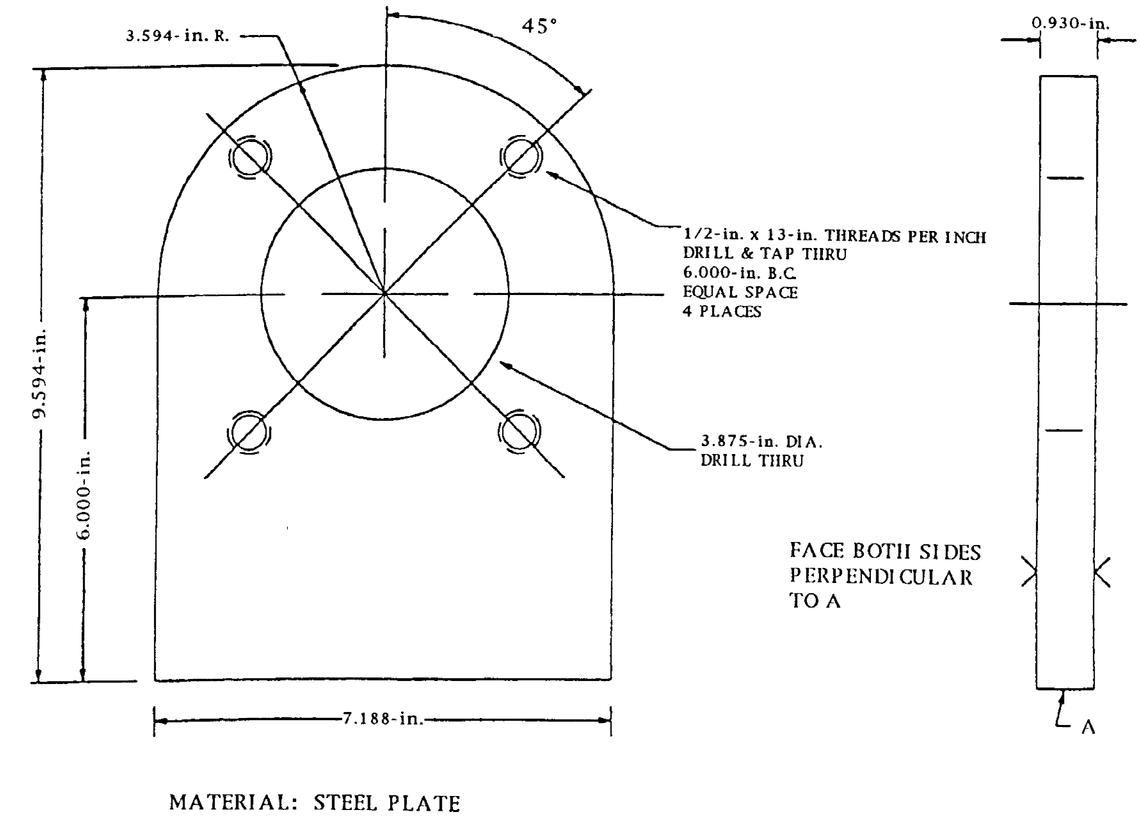


FIG. A8.1 Stress Plate

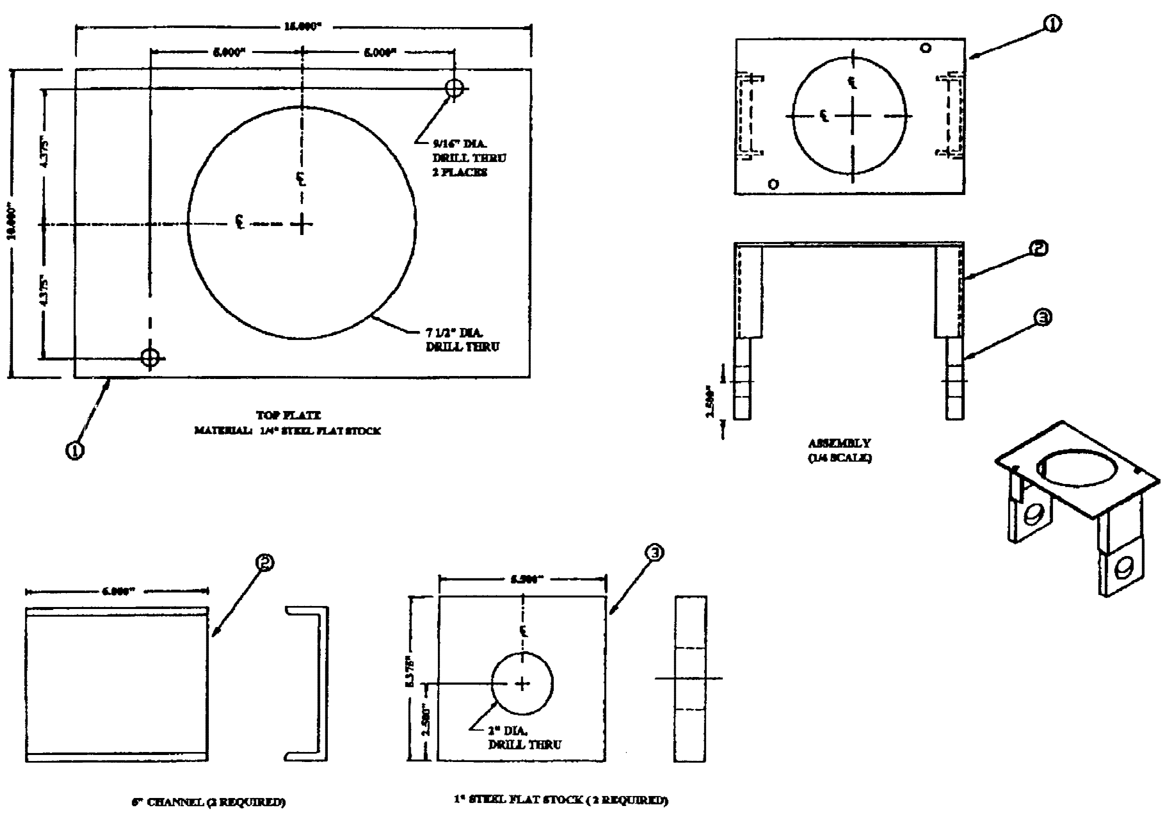


FIG. A8.2 Cylinder Barrel Fixture

TABLE A8.1 Honing Machine Setups and Honing Stone Selection

Honing Machine Setup		
Parameter	Honing Machine Model No.	
	CK-10	CV-616
Honing oil flow, gpm	2	2
Spindle speed, r/min	155	170
Stroke rate, spm	46	57
Stroke length, in.	7 to 7.25	7 to 7.25
Over-stroke, in.	0.375	0.375
Honing Stones		
Desired Hone	Honing Stone Selection	No. of Strokes (approximate)
Coarse hone	EHU 525	—
Finished hone	JHU 625	10
Finished hone	JHU 820	4

A9. L-38 OIL PRIMING PROCEDURE

A9.1 Prior to engine starts, confirm that the crankcase has been filled with test oil to the required level.

A9.2 Disconnect the fuel supply.

A9.3 Remove the spark plug.

A9.4 Motor the engine, using the starter, until the oil pressure gage shows a pressure increase.

A9.5 Cease motoring and reinstall the spark plug.

A9.6 Start the engine.

A10. ALTERNATIVE CRANKCASE BREATHER CONFIGURATIONS

A10.1 See Fig. A10.1 for L-38 crankcase breather detail.

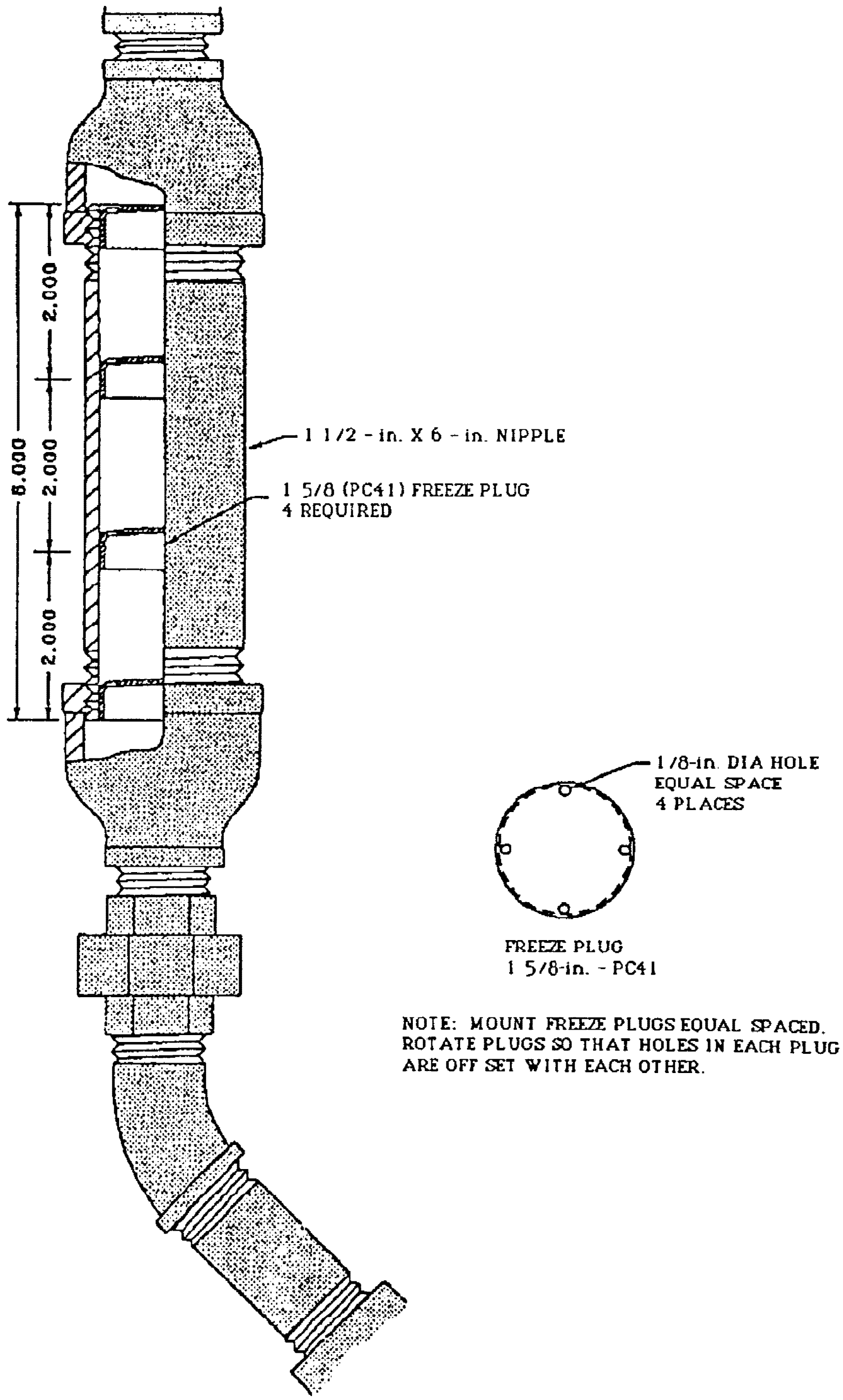


FIG. A10.1 L-38 Crankcase Breather Detail

A11. CONNECTING ROD BEARING CLEANING PROCEDURE

A11.1 Soak bearings halves in a container of Stoddard Solvent for a minimum of 5 min to remove all traces of oil from both the front and back of the bearing. During the soak period, move the bearing halves back and forth in solvent using protective tongs. Exercise care when handling the bearings to prevent nicking or scratching the bearing surface. (Always use latex gloves and protective tongs when handling bearings.)

A11.2 Dip the bearing halves in pentane (**Warning**—Flammable. Health hazard.).

A11.3 Place bearing halves into vacuum desiccator for a maximum of 5 min.

A11.4 Remove bearing halves from the vacuum desiccator and inspect for any traces of residue. Repeat steps A11.1-A11.3

if any residue is evident.

A11.5 Weigh and record, to the nearest tenth of a milligram, the initial weight of the whole test bearing and the separate weights of the top and bottom halves.

A11.6 Coat the bearing halves with EF-411.

A11.7 Store the bearing halves in a vacuum desiccator until ready for installation into engine. The test break-in shall be started within 8 h of removal of the bearing halves from the vacuum desiccator. If the 8 h limit is exceeded, clean, weigh, and install a new set of bearings.

A12. L-38 ELECTRONIC IGNITION CONVERSION PROCEDURE

A12.1 The following parts are needed for the Ford distributor assembly modification:

A12.1.1 Ford distributor assembly,[45] part number D7EE-12127DA.
A12.1.2 Ford wiring harness,[45] part number D7JL-12A200A.
A12.1.3 Ford module,[45] part number D9VZ-12A199A.
A12.1.4 Ford stator assembly,[45] part number D5TZ-12A112A.
A12.1.5 Ford ignition coil,[45] part number D5AZ-12029-A.
A12.1.6 GM flat washer,[46] part number 1984361.
A12.1.7 Nylon flat washer,[8,47] part number 98160-0.62.
A12.1.8 Fabricated distributor shaft.[8,48]
A12.1.9 Fabricated hold down assembly.[8,48]

A12.2 Disassemble the Ford distributor assembly, part number D7EE-12127DA. Save all parts as most will be needed for the modification.

A12.3 Remove the vacuum advance mounting assembly from the Ford distributor housing as shown in Fig. A12.1.

A12.4 Modify the lower section of the Ford distributor housing as shown in Fig. A12.2.

A12.5 Remove three of the four existing poles from the armature of the Ford distributor assembly as shown in Fig. A12.3. Reference the grooves for the roll pin to remove the correct poles.

A12.6 Remove the fibre seat from the lower plate assembly of the Ford distributor and enlarge the hole to 3⁄16 in. (4.76 mm), as shown in Fig. A12.4.

A12.7 Remove the vacuum advance bracket from the upper stator assembly plate of the Ford distributor shown in Fig. A12.5.

A12.8 Center and mount the upper stator assembly plate onto the lower plate. Drill a 3⁄16-in. (4.76-mm) hole through the upper plate aligning the hole with 3⁄16-in. (4.76-mm) hole in the lower plate as shown in Fig. A12.5.

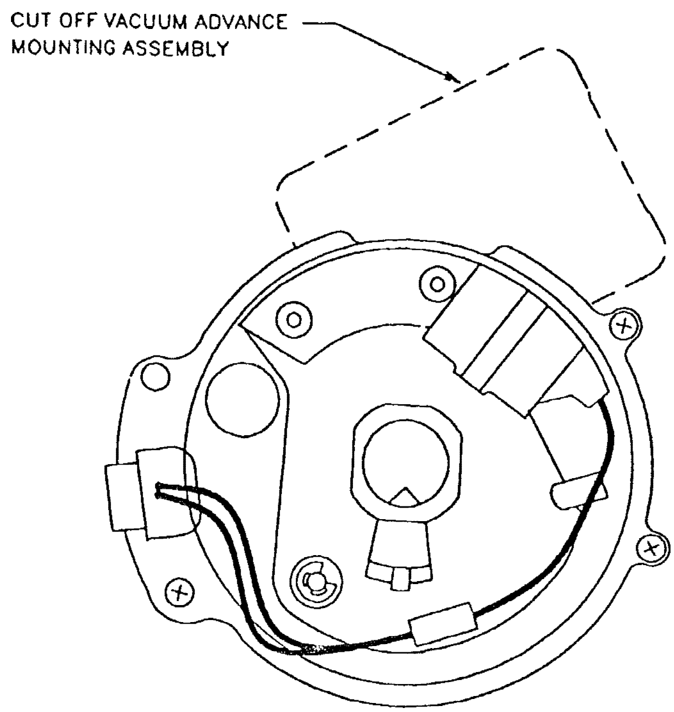


FIG. A12.1 Modified Ford Distributor Housing

A12.9 Attach the upper and lower plates using a 3⁄16-in. (4.76-mm) rivet as shown in Fig. A12.5. Use a spacer of approximately 0.085-in. (2.16-mm) between the two plates.

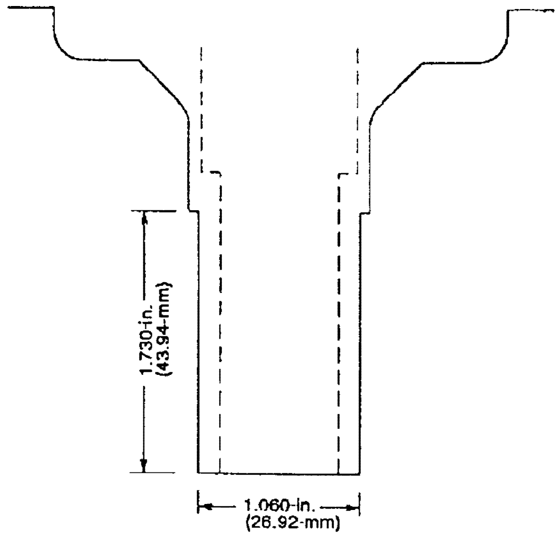
A12.10 Cut the drive gear from the upper collar of the Ford distributor assembly. Fig. A12.6 shows the dimensions of the collar after the drive gear has been removed.

A12.11 Fabricate the distributor shaft as shown in Fig. A12.7. The shaft may also be purchased from Texas Tool Makers, Incorporated.[8,48]

A12.12 Fabricate the hold down assembly as shown in Fig. A12.8 and Fig. A12.9. The hold down assembly may also be purchased from Texas Tool Makers, Incorporated.[8,48]

A12.13 Assemble the modified distributor as shown in Fig. A12.10.

[45] Apparatus is available from any Ford dealership.
[46] Apparatus is available from any General Motors dealership.
[47] The sole source of the apparatus known to the committee at this time is Accurate Screw Machine Co., 19 Baltimore St., Nutley, NJ 07110.
[48] The sole source of the apparatus known to the committee at this time is Texas Tool Makers, Inc., San Antonio, TX 78216.



MODIFY TO SPECIFICATION SHOWN

FIG. A12.2 Modified Ford Distributor Housing

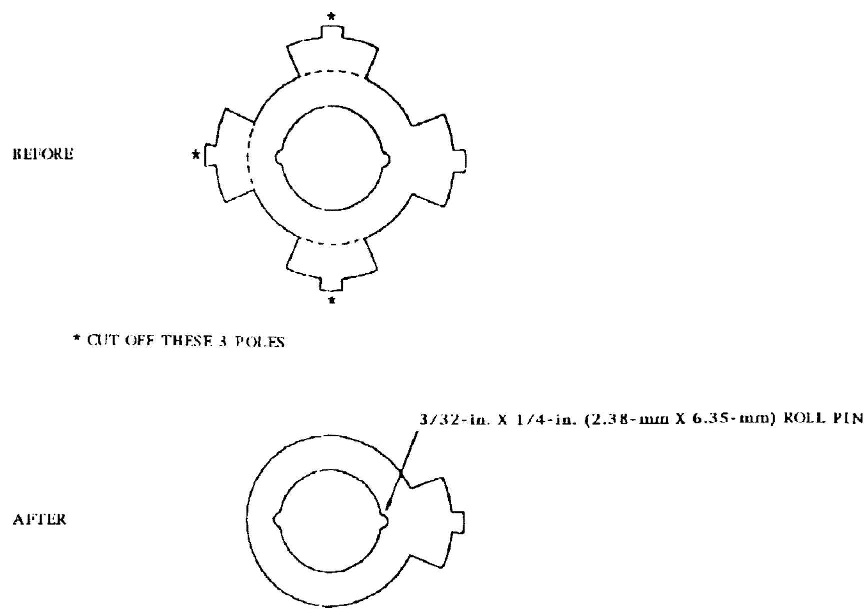


FIG. A12.3 Modified Ford Distributor—Armature

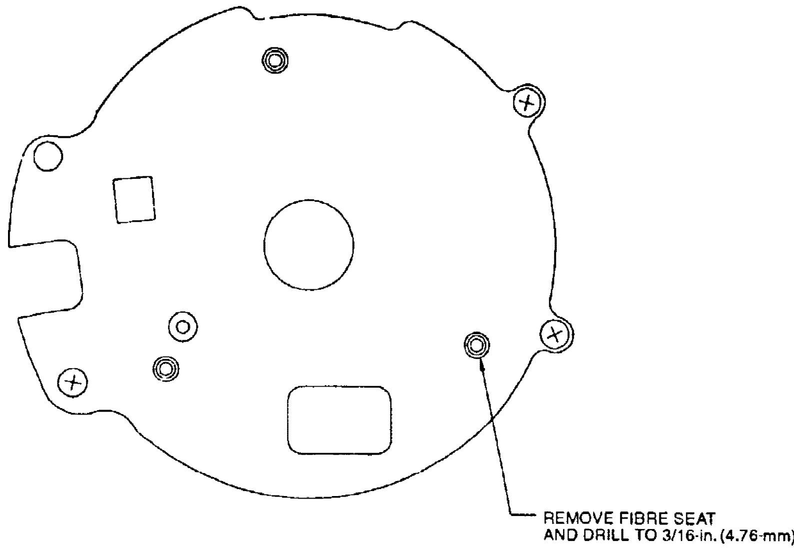


FIG. A12.4 Modified Ford Distributor—Lower Plate Assembly

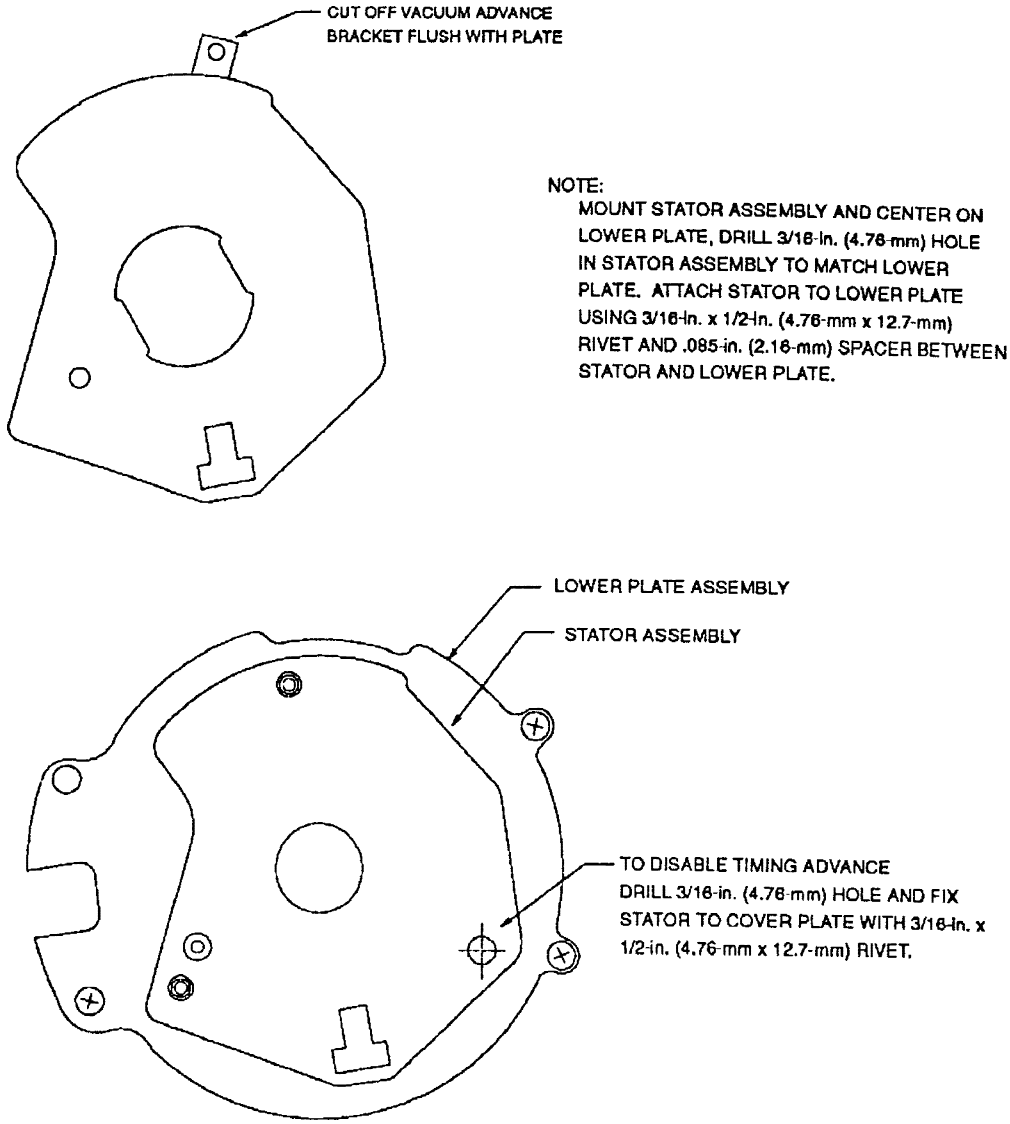


FIG. A12.5 Modified Ford Distributor—Stator Assembly

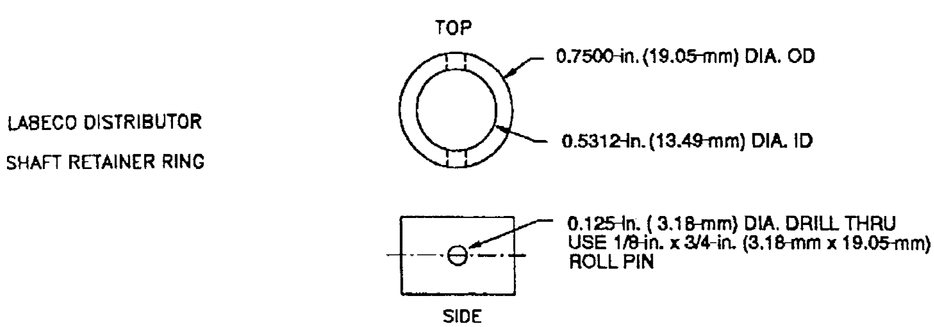


FIG. A12.6 Modified Ford Distributor—Upper Collar

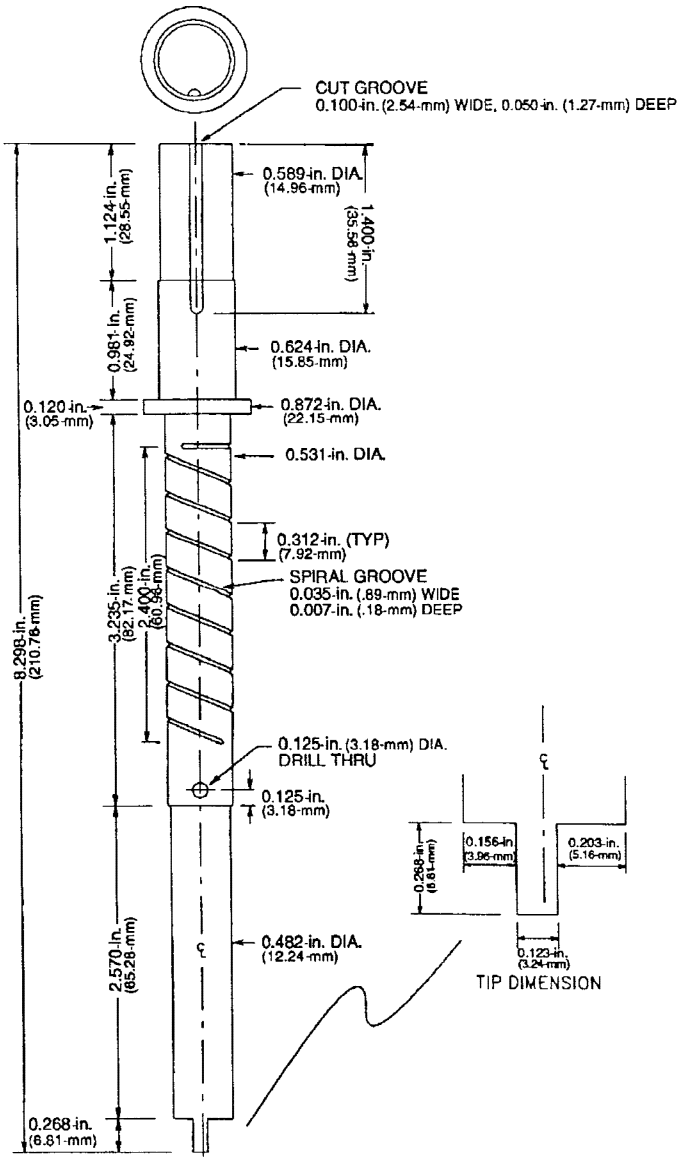
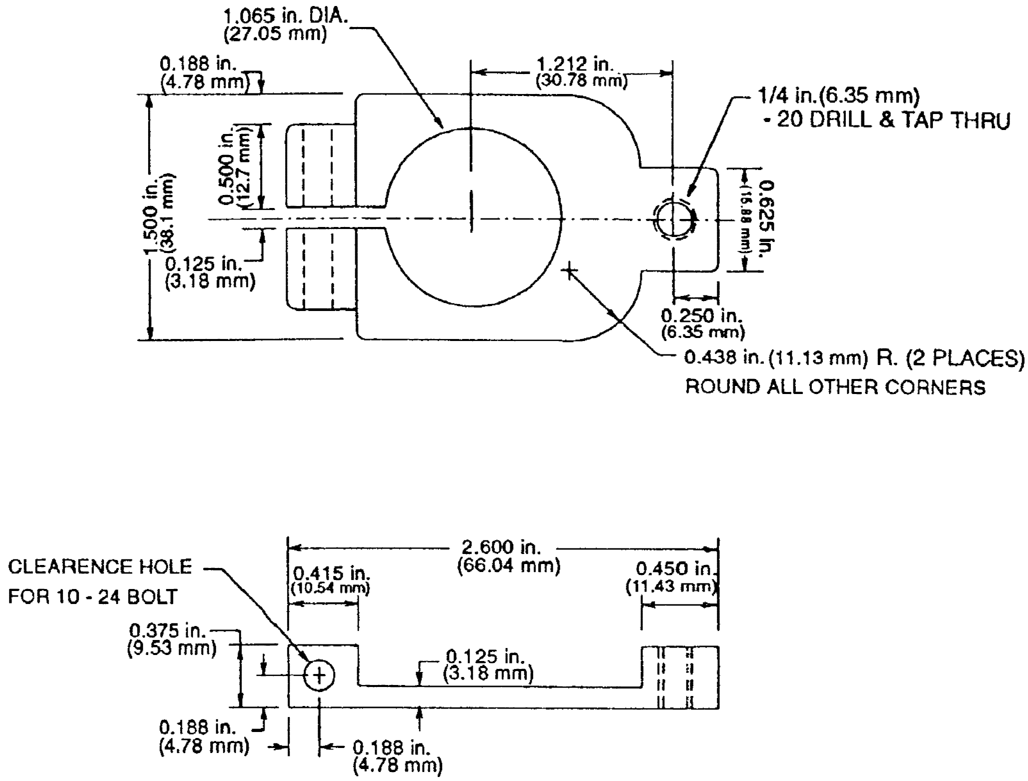
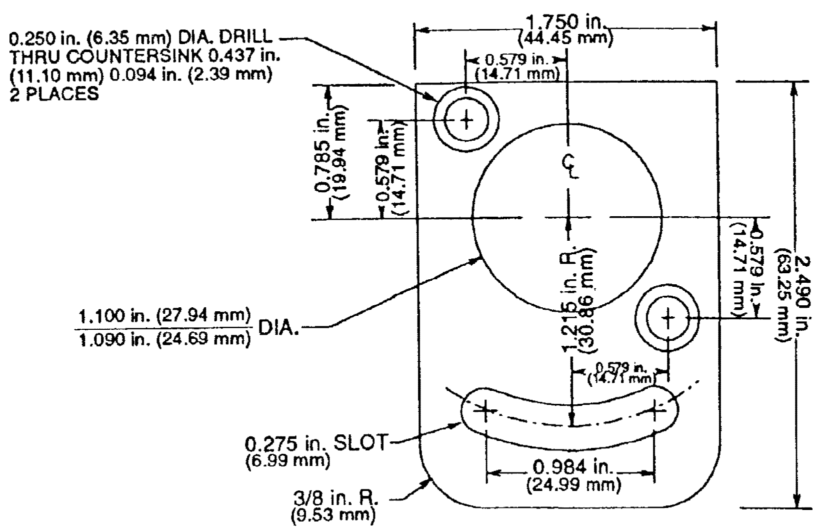


FIG. A12.7 Fabricated Distributor Shaft



MATERIAL: ⅜-in. 1 ½-in. × 2 ⅝-in. (9.53-mm, 38.1-mm × 66.68-mm) PLATE

FIG. A12.8 Fabricated Hold Down Clamp



MATERIAL: ⅛-in. (3.18-mm) PLATE

FIG. A12.9 Fabricated Hold Down Clamp

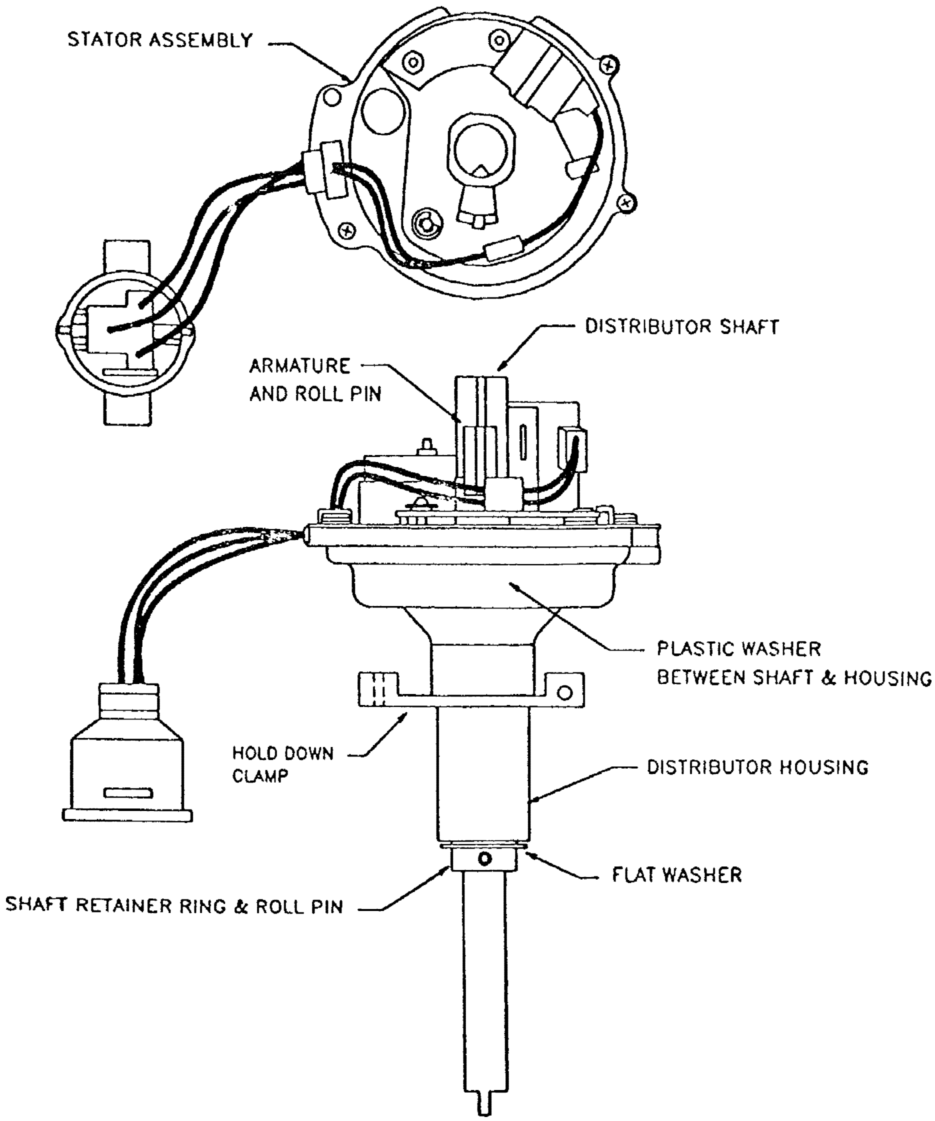


FIG. A12.10 Modified Ford Distributor Assembly

A13. SYSTEM RESPONSE PROCEDURE

A13.1 Temperatures

A13.1.1 Remove the thermocouples from the engine locations as specified in 6.3.5. Allow the thermocouples to stabilize at ambient conditions, then insert them into a bucket of ice water. Record the time it takes the thermocouple to reach 63 % of its final value.

A13.2 Pressures and Vacuums

A13.2.1 First perform a leak-down on the measurement system to ensure there are no air leaks by following the test in A13.2.1.1 and A13.2.1.2,

A13.2.1.1 Disconnect the sensor lines at the engine locations as specified in 6.3.4. Connect an air line to the sensor line and pressurize the line slightly above the specified range required (test specification). Isolate the air pressure in the sensor line and remove the source from the sensor line. If the system leaks down, repair the leak before proceeding.

A13.2.1.2 After completion of the leak down step, determine the system response. Connect an air line to the sensor line and pressurize the system to the specified mean range. Let the system stabilize, then quickly release pressure, record the time to reach 63 % of its final value.

A13.2.1.3 For vacuums, follow the procedure in A13.2.1.1 and A13.2.1.2, replacing air pressure with vacuum.

A13.3 Fuel Flow

A13.3.1 *Flow Meters*—Establish a steady flow at the normal test specified mean range, let system stabilize. Shut off the flow and record the time required to reach 63 % of the final value.

A13.3.2 *Fuel Weight Scale*—Follow the normal procedure for measuring fuel usage. This value will represent the total time it takes to measure the fuel flow (from the time the engine begins to run from the beaker until the scale trips).

A13.4 Speed

A13.4.1 Using a frequency counter, inject a frequency so that the system readout stabilizes at the test specified mean value. Use a frequency device to determine the engine speed. Disconnect the frequency device, measure and record the time required to reach 63 % of the final value.

A13.5 Load and Oil Weight Scale

A13.5.1 Place a weight on a measurement device and let reading stabilize. Quickly remove the weight, measure, and record the time required to reach 63 % of the final value. Weights used should represent the normal readout value.

A13.5.2 For manual measurements, a stopwatch with 0.1 s increments is required.

A14. AIR-FUEL RATIO MEASUREMENT

A14.1 Correct carbon monoxide (CO) or carbon dioxide (CO_2) measurements to an oxygen-free basis, using the formulas below, prior to determining air-fuel ratio. Use corrected CO or CO_2 value and Fig. A14.1 to determine air-fuel ratio.

$$\frac{\text{Observed Percent CO} \times 100}{100 - 5\ (\text{Observed }\%\ O_2)} = \text{Corrected CO} \qquad (A14.1)$$

$$\frac{\text{Observed Percent } CO_2 \times 100}{100 - 5\ (\text{Observed }\%\ O_2)} = \text{Corrected } CO_2 \qquad (A14.2)$$

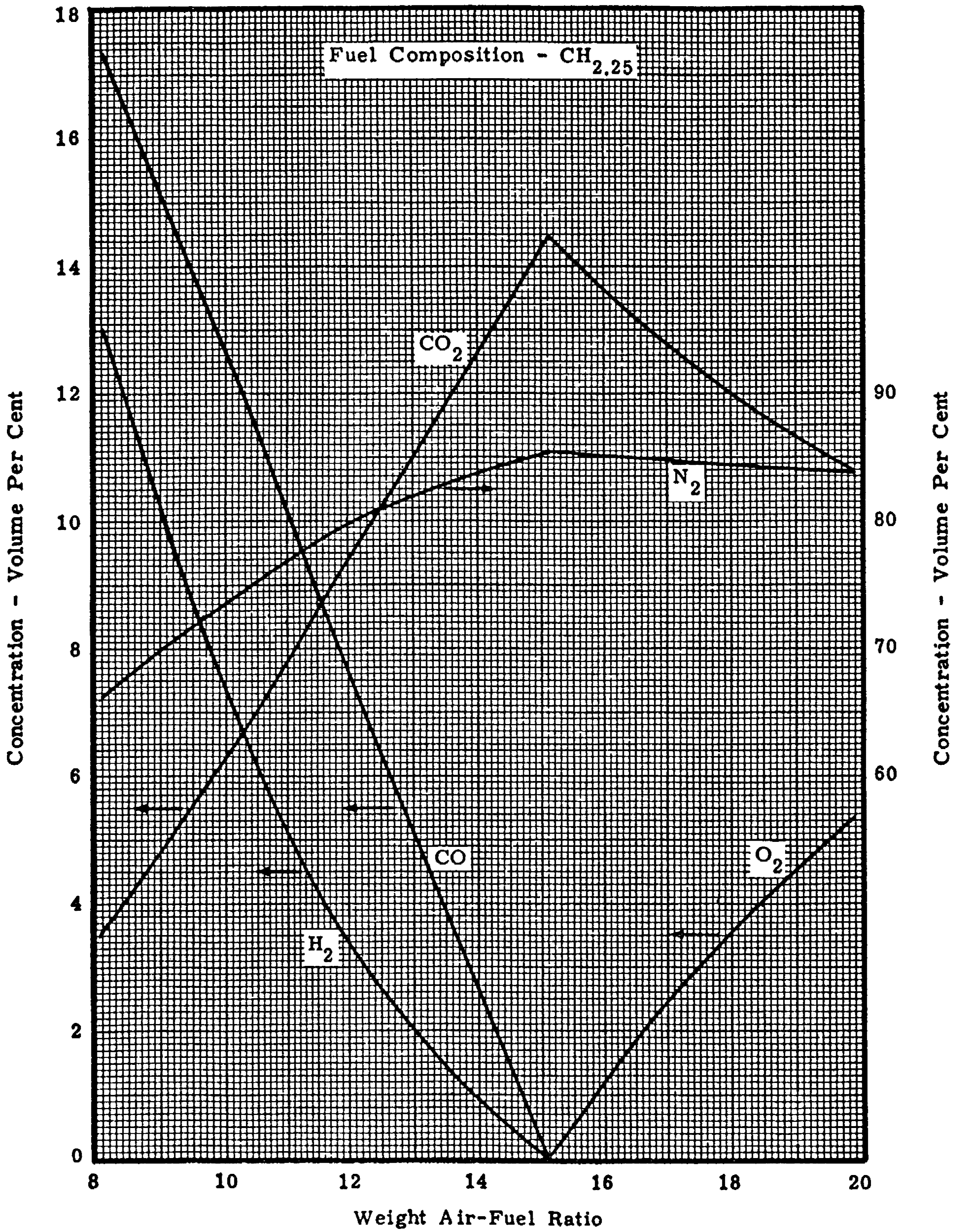


FIG. A14.1 Weight Air-Fuel Ratio Determination

A15. L-38 ENGINE EVALUATION REPORT FORMS

A15.1 Figs. A15.1-A15.9 are examples of report forms used for the L-38 engine evaluation of engine oils.

VERSION ***19990621***

CONDUCTED FOR
TSTSPON1

TSTSPON2

LABVALID	V = VALID	
	I = INVALID	

Test Number			
Test Stand: *STAND*	Power Section	# of Runs on Power Section Since Last Ref.	Total Runs on Power Section
	ENGINE	*RENRUNSR/ENRUNSR*	*RTOTENRN/TOTENRUN*
Date Completed: *DTCOMP/RDTCOMP*		Completion Time: *REOTTIME/EOTTIME*	
Oil Code:[A] *CMIR/OILCODE*			
Formulation/Stand Code: *FORM*			
Alternate Codes:	*ALTCODE1*	*ALTCODE2*	*ALTCODE3*

In my opinion this test ***OPVALID*** **been conducted in a valid manner in accordance with Test Method D5119 and the appropriate amendments through the information letter system. The remarks included in this report describe the anomalies associated with this test.**

[A] CMIR or Non-Reference Oil Code

SUBMITTED BY:

SUBLAB
Testing Laboratory

SUBSIGIM
Signature

SUBNAME
Typed Name

SUBTITLE
Title

FIG. A15.1 Operational Validity Statement — Reference or Non-Reference Oil

Laboratory:	*LAB*	TMC Oil Code:	*IND*
Lab Oil Code:	*LABOCODE*	Oil Code:	*CMIR*
Test Stand No.:	*STAND*	Date Started:	*RDTSTRT*
Power Section No.:	*ENGINE*	Date Completed:	*RDTCOMP*
No. Runs Since Ref.:	*RENRUNSR*	Completion Time:	*REOTTIME*
Runs on Power Section:	*RTOTENRN*	Test Bearing Part No.:	*BEARNUM*
Fuel Type:	*FUELTYPE*	Bearing Batch No.:	*BEARBAT*
Fuel Lot:	*FUELLOT*	Bearing Lot No.:	*BEARLOT*
Test Length:	*RTESTLEN*	Bearing Storage Oil Lead:	*BEARLEAD*
Viscosity Grade:	*RSAEVISC*		

Bearing Weight Loss, mg	
	40 Hours
Top	*RBWTH040*
Bottom	*RBWBH040*
Total	*RTBWH040*
Adjusted H-24 Total	*RCBWH040*

TARGET	STD. DEV.
TARBWL	*SBWL*

Power Section Deposit Inspection
Rating

Varnish Deposits		Sludge Deposits	
Piston Skirt	*PISKVRT*	Rocker Arms	*RASRT*
Rocker Arm Cover	*RACVRT*	Rocker Arm Cover	*RACSRT*
Push Rod Cover	*PRCVRT*	Push Rod Cover	*PRCSRT*
Cylinder Wall, BRT^	*CYLWLVRT*	Oil Screen	*OILSRT*
Oil Pan	*OILPNVRT*	Oil Pan	*OILPNSRT*
Crankcase Cover Plate	*CCCPVRT*	Crankcase Cover Plate	*CCCPSRT*
Total Varnish	*TEV*	Total Sludge	*TES*

^ BRT-Below ring travel

FIG. A15.2 Bearing Wear and Deposit Ratings — Reference Oil

Test Purchaser 1: *TSTSPON1*
Test Purchaser 2: *TSTSPON2*
Test Sponsor Oil Code: *OILCODE*

Testing Lab: *LAB*
Viscosity Grade: *SAEVISC*
Test Stand No.: *STAND*
Power Section No.: *ENGINE*
No. Runs Since Ref.: *ENRUNSR*
Runs on Power Section: *TOTENRUN*
Test Fuel Type: *FUELTYPE*
Test Fuel Lot: *FUELLOT*
Test Length: *TESTLEN*

Test Oil Temp.(275 or 290° F): *OILTEMP*
Lab Internal Oil Code: *LABOCODE*
Date Started: *DTSTRT*
Date Completed: *DTCOMP*
Completion Time: *EOTTIME*
Test Bearing Part No.: *BEARNUM*
Bearing Batch No.: *BEARBAT*
Bearing Lot No.: *BEARLOT*

Formulation/Stand: *FORM*

Bearing Weight Loss, mg	
	TST_H040 Hours
Top	*BWLTH040*
Bottom	*BWLBH040*
Total	*TBWLH040*
Corrected H-24 Total	*CBWLH040*
Severity Adjustment	*BWL_SA*
Adjusted Total	*FBWLH040*

Test Stand/Power Section Reference History

Stand No. *STAND* Power Section No. *ENGINE* Runs on Power Section *RTOTENRN*
Bearing Batch No. *BEARBAT* Bearing Lot No. *BEARLOT*

Industry Ref. Oil Code	Completion Test Date	Completion Time(hour)	Total Brg weight loss, mg	Corrected H-24 Total	Oil Code
IND	*RDTCOMP*	*REOTTIME*	*RTBWH040*	*RCBWH040*	*CMIR*

Power Section Deposit Inspection Rating

Varnish Deposits		Sludge Deposits	
Piston Skirt	*PISKVRT*	Rocker Arms	*RASRT*
Rocker Arm Cover	*RACVRT*	Rocker Arm Cover	*RACSRT*
Push Rod Cover	*PRCVRT*	Push Rod Cover	*PRCSRT*
Cylinder Wall, BRT[A]	*CYLWLVRT*	Oil Screen	*OILSRT*
Oil Pan	*OILPNVRT*	Oil Pan	*OILPNSRT*
Crankcase Cover Plate	*CCCPVRT*	Crankcase Cover Plate	*CCCPSRT*
Total Varnish	*TEV*	Total Sludge	*TES*

[A] BRT-Below ring travel

FIG. A15.3 Bearing Wear and Deposit Ratings — Non-reference Oil

Laboratory *LAB* Oil Code: *CMIR/OILCODE*
Date Completed: *DTCOMP/RDTCOMP*
Test No.: *STAND* / *ENGINE* / *RENRUNSR/ENRUNSR* / *RTOTENRN/TOTENRUN*
Formulation/Stand *FORM*

	Minimum	Maximum	Average	Specification
Speed, r/min	*IRPM*	*XRPM*	*ARPM*	(3150 ± 25)
Air/Fuel Ratio	*IAFR*	*XAFR*	*AAFR*	(14.0 ± 0.5:1)
Fuel Flow, lb/h	*IFFLO*	*XFFLO*	*AFFLO*	(4.75 ± 0.25)(2.25 ± 0.11 kg/h)
Output, bhp	*IPWR*	*XPWR*	*APWR*	(Record)(bhp = 745.6999 W)
Oil Heater Input, W	*IOHTRIN*	*XOHTRIN*	*AOHTRIN*	(Record)
Crankcase Off-Gas, Std. ft^3/h	*ICCOG*	*XCCOG*	*ACCOG*	(30 ± 1)(850 ± 28 L/h)

Temperatures, °F{°C = (°F-32)/1.8}

Sump Oil	*ISUMPT*	*XSUMPT*	*ASUMPT*	(Record)
Gallery Oil [A]	*IGALT*	*XGALT*	*AGALT*	(290 or 275 ± 2)(143.5 or 135.0 ± 1° C)
Coolant-In	*ICOLIN*	*XCOLIN*	*ACOLIN*	(Record)
Coolant-Out	*ICOLOUT*	*XCOLOUT*	*ACOLOUT*	(200 ± 2)(93.5 ± 1° C)
Delta T Coolant	*ICOLDT*	*XCOLDT*	*ACOLDT*	(10 ± 2)(5.6 ± 1° C)
Intake Air	*IINAIRT*	*XINAIRT*	*AINAIRT*	(Record)

Pressures (in. Hg = 3.37685 kPa)

Oil, psig	*IOILPRS*	*XOILPRS*	*AOILPRS*	(40 ± 2)(276 ± 14 kPa)
Intake Man.Vac., in. Hg	*IIMNVAC1*	*XIMNVAC1*	*AIMNVAC1*	(Record)
Exhaust, in. Hg.	*IEXPR*	*XEXPR*	*AEXPR*	(0 to 1)(0 to 3.4 kPa)
Crankcase Vac., in. H_2O	*ICCV*	*XCCV*	*ACCV*	(2.0 ± 0.5)(500 ± 120 kPa)
Spark Advance, °BTDC	*ISPKTIM*	*XSPKTIM*	*ASPKTIM*	(35 ± 1)
Blowby, Std. ft^3/h	*IBLOBY*	*XBLOBY*	*ABLOBY*	(Record)

Oil Consumption, lb/h (lb/h = 0.4535924 kg/h)

0-10 h	*OILCHNEW*	(Record)
10-20 h	*OILCH010*	(Record)
20-30 h	*OILCH020*	(Record)
30-40 h	*OILCH030*	(Record)
0-40 h	*OILCHAVG*	(Record)
Maximum Oil Consumption	*OILCHMAX*	(Record)

[A] (See Table 6 for Viscosity-Related Temperature.)

FIG. A15.4 Operational Summary — Reference or Non-reference Oil

Laboratory *LAB* Oil Code: *CMIR/OILCODE*
Date Completed: *DTCOMP/RDTCOMP*
Test No.: *STAND* / *ENGINE* / *RENRUNSR/ENRUNSR* / *RTOTENRN/TOTENRUN*
Formulation/Stand *FORM*

Power Section Measurements, inches [A]

	Minimum	Maximum	Average	Specification
Valve Stem Clearance in Guide				
Inlet	*IVSCIN*	*XVSCIN*	*AVSCIN*	(0.002-0.004 in.)
Exhaust	*IVSCEX*	*XVSCEX*	*AVSCEX*	(0.003-0.005 in.)
Connecting Rod Bearing Clearance	*ICRODCL*	*XCRODCL*	*ACRODCL*	(0.0024-0.003 in.)
Main Bearing Clearance				
Front	*IMBCF*	*XMBCF*	*AMBCF*	(0.002-0.003 in.)
Rear	*IMBCR*	*XMBCR*	*AMBCR*	(0.002-0.003 in.)
Connecting Rod Journal Out-of-Round		*XCRODOR*		(0.001 in. max)

Runs on Liner *LINRUN* (Liner may be used as long as the piston to liner clearance is in the specified range)
Piston to Liner Clearance *PISLINCL* (0.0012 to 0.0025 in.)

Oil Analysis

Hours	New Oil	10	20	30	40
Acid Number	*ACIDHNEW*	*ACIDH010*	*ACIDH020*	*ACIDH030*	*ACIDH040*
Viscosity[B] cSt @40°C	*VIS_HNEW*	*VIS_H010*	*VIS_H020*	*VIS_H030*	*VIS_H040*
Viscosity[B] cSt @100°C	*VIS1HNEW*	*VIS1H010*	*VIS1H020*	*VIS1H030*	*VIS1H040*

Stripped Viscosity,[B] cSt @100°C(for multiviscosity-graded oils only: see MIL-L-2104) *SVIS100*

	10	20	30	40
%Viscosity[B] increase,cSt @40°C	*PVISH010*	*PVISH020*	*PVISH030*	*PVISH040*
%Viscosity[B] increase,cSt @100°C	*PVS1H010*	*PVS1H020*	*PVS1H030*	*PVS1H040*

CRITICAL PARTS LISTING	I.D. Code	Received Date
Crankshaft	*CRANKID*	*CRANKRD*
Camshaft	*CAMSN*	*CAMRD*
Rod Bearings		*RBEARRD*
Main Bearings	*MBEARID*	*MBEARRD*
Camshaft Bearings	*CAMBRID*	*CAMBRRD*
Connecting Rod	*CRODID*	*CRODRD*
Piston	*PISTSN*	*PISTONRD*
Cylinder Liner	*CLINID*	*CLINRD*

[A] 1 in. = 25.4 mm.
[B] {°C = (°F-32)/1.8}

FIG. A15.5 Parts Measurement, Oil Analysis, and Critical Parts Listing — Reference or Non-reference Oil

Laboratory: *LAB* Oil Code: *CMIR/OILCODE*
Date Completed: *DTCOMP/RDTCOMP*
Test No.: *STAND* / *ENGINE* / *RENRUNSR/ENRUNSR* / *RTOTENRN/TOTENRUN*
Formulation/Stand: *FORM*

Number of Downtime Occurrences			*DWNOCR*
Test Hours	Date	Downtime	Reasons
DOWNH001	*DDATH001*	*DTIMH001*	*DREAH001*
		TOTLDOWN	Total Downtime

Other Comments	
Number of Comment Lines	*TOTCOM*
OCOMH001	

FIG. A15.6 Downtime Occurrences and Other Comments — Reference or Non-reference Oil

Laboratory: *LAB* Oil Code: *CMIR/OILCODE*

Date Completed: *DTCOMP/RDTCOMP*

Test No.: *STAND* / *ENGINE* / *RENRUNSR/ENRUNSR* / *RTOTENRN/TOTENRUN*

Formulation/Stand *FORM*

Number of Operational Outliers Occurrences *OUTOCR*					
Test Hours	**Parameter**	**Parameter Range**	**Reading**	**Time Out**	**Deviation**
OUT_H001	*OUTPH001*	*OPARH001*	*OREDH001*	*OTIMH001*	*ODP_H001*

FIG. A15.7 Operational Outliers Occurrences — Reference or Non-Reference Oil

Laboratory *LAB*	Oil Code: *CMIR/OILCODE*
Date Completed: *DTCOMP/RDTCOMP*	
Test No.: *STAND* / *ENGINE* / *RENRUNSR/ENRUNSR* / *RTOTENRN/TOTENRUN*	
Formulation/Stand *FORM*	

Primary Parameter	Maximum Permitted Deviation Percentage	Calculated Total Deviation Percentage
Engine Oil Gallery Temperature, °F	2.5%	*GALTDP*
Engine Coolant Outlet Temperature, °F	2.5%	*COLOUTDP*
Engine Coolant Delta Temperature, °F	2.5%	*COLDTDP*
Fuel Flow, lb/h	2.5%	*FFLODP*
Crankcase Off Gas, std. ft^3/h	2.5%	*CCOGDP*
Oil Pressure, psi	2.5%	*OILPDP*
Secondary Parameters		
Engine Speed, r/min	5%	*RPMDP*
AFR	5%	*AFRDP*
Spark Advance, BTDC	5%	*SPRKADP*
Exhaust, in. Hg	5%	*EXPRDP*
Crankcase Vacuum, in. H_2O	5%	*CCVACDP*

FIG. A15.8 Deviations of Operational Parameters — Reference or Non-reference Oil

Laboratory *LAB* Oil Code: *CMIR/OILCODE*
Date Completed: *DTCOMP/RDTCOMP*
Test No.: *STAND / ENGINE / RENRUNSR/ENRUNSR / RTOTENRN/TOTENRUN*
Formulation/Stand *FORM*

PARAMETER (1)	SENSING DEVICE (2)	CALIBRATION FREQUENCY (3)	RECORD DEVICE (4)	OBSERVATION FREQUENCY (5)	RECORD FREQUENCY (6)	LOG FREQUENCY (7)	SYSTEM RESPONSE (8)
OPERATION CONDITIONS							
TEMPERATURES							
OIL IN (°F)	OILISENS	OILICALF	OILRECD	OILIOBSF	OILRECF	OILILOGF	OILISYSR
COOLANT OUT (°F)	COTSENS	COTCALF	COTRECD	COTOBSF	COTRECF	COTLOGF	COTSYSR
COOLANT DELTA (°F)	COLDSENS	COLDCALF	COLDRECD	COLDOBSF	COLDRECF	COLDLOGF	COLDSYSR
OTHER							
FUEL FLOW (lb/h)	FFLOSENS	FFLOCALF	FFLORECD	FFLOOBSF	FFLORECF	FFLOLOGF	FFLOSYSR
ENGINE SPEED (r/min)	RPMSENS	RPMCALF	RPMRECD	RPMOBSF	RPMRECF	RPMLOGF	RPMSYSR
AFR	AFRSENS	AFRCALF	AFRRECD	AFROBSF	AFRRECF	AFRLOGF	AFRSYSR
EXHAUST PRESSURE (in. Hg)	EXPRSENS	EXPRCALF	EXPRRECD	EXPROBSF	EXPRRECF	EXPRLOGF	EXPRSYSR
CRANKCASE OFF GAS (std. ft³/hr)	CCOGSENS	CCOGCALF	CCOGRECD	CCOGOBSF	CCOGRECF	CCOGLOGF	CCOGSYSR
OIL (PSI)	OPSISENS	OPSICALF	OPSIRECD	OPSIOBSF	OPSIRECF	OPSILOGF	OPSISYSR
CRANKCASE VAC. (in H2O)	CCVSENS	CCVCALF	CCVRECD	CCVOBSF	CCVRECF	CCVLOGF	CCVSYSR

LEGEND:
(1) OPERATING PARAMETER
(2) THE TYPE OF DEVICE USED TO MEASURE TEMPERATURE, PRESSURE OR FLOW
(3) FREQUENCY AT WHICH THE MEASUREMENT SYSTEM IS CALIBRATED
(4) THE TYPE OF DEVICE WHERE DATA IS RECORDED
LG - HANDLOG SHEET
DL - AUTOMATIC DATA LOGGER
SC - STRIP CHART RECORDER
C/M - COMPUTER, USING MANUAL DATA ENTRY
C/D - COMPUTER, USING DIRECT I/O ENTRY
(5) DATA ARE OBSERVED BUT ONLY RECORDED IF OFF SPEC
(6) DATA ARE RECORDED BUT ARE NOT RETAINED AT EOT
(7) DATA ARE LOGGED AS PERMANENT RECORD, NOTE SPECIFY IF:
SS - SNAPSHOT TAKEN AT SPECIFIED FREQUENCY
AG/X AVERAGE OF X DATA POINTS AT SPECIFIED FREQUENCY
(8) TIME FOR THE OUTPUT TO REACH 63.2% OF FINAL VALUE FOR STEP CHANGE AT INPUT
(9) SEE ANNEX A14 FOR PROCEDURE TO DETERMINE SYSTEM RESPONSE OF THE CHARACTERSITICS OF THE ACQUISITION SYSTEM.

FIG. A15.9 Data Acquisition Details — Reference or Non-Reference Oil

A16. DATA DICTIONARY

A16.1 See Fig. A16.1 for data dictionary and Fig. A16.6 for repeating field specifications.

21-jun-1999

Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
10	1	L38	VERSION	8	0	C	YYYYMMDD	L38 VERSION 19990621
20	1	L38	TSTSPON1	40	0	C		CONDUCTED FOR, FIRST LINE
30	1	L38	TSTSPON2	40	0	C		CONDUCTED FOR, SECOND LINE
40	1	L38	LABVALID	1	0	C	V, I OR N	TEST LAB VALIDATION (V, I OR N)
50	1	L38	STAND	5	0	C		STAND
60	1	L38	ENGINE	6	0	C		POWER SECTION
70	1	L38	ENRUNSR	3	0	C		NO. OF POWER SECTION RUNS SINCE REF.
80	1	L38	RENRUNSR	3	0	C		REFERENCE NO. OF POWER SECTION RUNS SINCE REF.
90	1	L38	TOTENRUN	5	0	C		RUNS ON POWER SECTION
100	1	L38	RTOTENRN	5	0	C		REFERENCE RUNS ON POWER SECTION
110	1	L38	RDTCOMP	8	0	C	YYYYMMDD	REFERENCE COMPLETED DATE (YYYYMMDD)
120	1	L38	DTCOMP	8	0	C	YYYYMMDD	DATE COMPLETED (YYYYMMDD)
130	1	L38	REOTTIME	5	0	C	HH:MM	REFERENCE END OF TEST TIME (HH:MM)
140	1	L38	EOTTIME	5	0	C	HH:MM	TIME COMPLETED (HH:MM)
150	1	L38	OILCODE	38	0	C		NON-REFERENCE OIL CODE
160	1	L38	CMIR	6	0	C		CMIR
170	1	L38	FORM	38	0	C		FORMULATION/STAND CODE
180	1	L38	ALTCODE1	10	0	C		ALTERNATE OIL CODE 1
190	1	L38	ALTCODE2	10	0	C		ALTERNATE OIL CODE 2
200	1	L38	ALTCODE3	10	0	C		ALTERNATE OIL CODE 3
210	1	L38	OPVALID	8	0	C		OPERATIONAL VALIDITY -- HAS/HAS NOT
220	1	L38	SUBLAB	40	0	C		TESTING LABORATORY NAME
230	1	L38	SUBSIGIM	70	0	C		TESTING LABORATORY VALIDATORS SIGNATURE
240	1	L38	SUBNAME	40	0	C		TESTING LABORATORY VALIDATORS NAME
250	1	L38	SUBTITLE	40	0	C		TESTING LABORATORY VALIDATORS TITLE
260	2	L38	LAB	2	0	C		LAB CODE
270	2	L38	IND	6	0	C		TMC OIL CODE
280	2	L38	LABOCODE	12	0	C		LABORATORY INTERNAL OIL CODE
290	2	L38	RDTSTRT	8	0	C	YYYYMMDD	REFERENCE STARTING DATE (YYYYMMDD)
300	2	L38	BEARNUM	8	0	C	nnnnnn-n	TEST BEARING PART NO. (nnnnnn-n)
310	2	L38	FUELTYPE	16	0	C		FUEL TYPE
320	2	L38	BEARBAT	5	0	C	nn-nn	BEARING BATCH NO. (nn-nn)
330	2	L38	FUELLOT	8	0	C	nccnnnnn	TEST FUEL LOT (nccnnnnn)
340	2	L38	BEARLOT	2	0	C	nn	BEARING LOT NO. (nn)
350	2	L38	RTESTLEN	3	0	Z	HHH	REFERENCE TEST LENGTH (HHH)
360	2	L38	BEARLEAD	3	0	N	PPM	BEARING STORAGE OIL LEAD: (PPM)
370	2	L38	RSAEVISC	7	0	C		REFERENCE SAE VISCOSITY GRADE
380	2	L38	RBWTHxxx	6	1	N	MG	REFERENCE TOP HALF BEARING WEIGHT LOSS (MG)
390	2	L38	RBWBHxxx	6	1	N	MG	REFERENCE BOTTOM HALF BEARING WEIGHT LOSS (MG)
400	2	L38	RTBWHxxx	6	1	N	MG	REFERENCE TOTAL BEARING WEIGHT LOSS (MG)
410	2	L38	RCBWHxxx	6	1	N	MG	REFERENCE CORRECTED TOTAL BEARING WEIGHT LOSS (MG)
420	2	L38	TARBWL	5	1	N		TARGET BWL
430	2	L38	SBWL	4	1	N		BWL STD DEV
440	2	L38	PISKVRT	5	2	N	MERITS	PISTON SKIRT VARNISH DEPOSITS,(MERITS)
450	2	L38	RASRT	5	2	N	MERITS	ROCKER ARMS SLUDGE DEPOSITS,(MERITS)
460	2	L38	RACVRT	5	2	N	MERITS	ROCKER ARM COVER VARNISH DEPOSITS,(MERITS)
470	2	L38	RACSRT	5	2	N	MERITS	ROCKER ARM COVER SLUDGE DEPOSITS,(MERITS)
480	2	L38	PRCVRT	5	2	N	MERITS	PUSH ROD COVER VARNISH DEPOSITS,(MERITS)
490	2	L38	PRCSRT	5	2	N	MERITS	PUSH ROD COVER SLUDGE DEPOSITS,(MERITS)
500	2	L38	CYLWLVRT	5	2	N	MERITS	CYLINDER WALL, BRTA VARNISH DEPOSITS,(MERITS)
510	2	L38	OILSRT	5	2	N	MERITS	OIL SCREEN SLUDGE DEPOSITS,(MERITS)
520	2	L38	OILPNVRT	5	2	N	MERITS	OIL PAN VARNISH DEPOSITS,(MERITS)
530	2	L38	OILPNSRT	5	2	N	MERITS	OIL PAN SLUDGE DEPOSITS,(MERITS)

FIG. A16.1 Data Dictionary

21-jun-1999 Report: ASTM Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
540	2	L38	CCCPVRT	5	2	N	MERITS	CRANKCASE COVER PLATE VARNISH DEPOSITS,(MERITS)
550	2	L38	CCCPSRT	5	2	N	MERITS	CRANKCASE COVER PLATE SLUDGE DEPOSITS,(MERITS)
560	2	L38	TEV	5	2	N	MERITS	TOTAL ENGINE VARNISH DEPOSITS,(MERITS)
570	2	L38	TES	5	2	N	MERITS	TOTAL ENGINE SLUDGE DEPOSITS,(MERITS)
580	3	L38	SAEVISC	7	0	C		SAE VISCOSITY GRADE
590	3	L38	OILTEMP	8	0	C		OIL TEMPERATURE
600	3	L38	DTSTRT	8	0	C	YYYYMMDD	START DATE (YYYYMMDD)
610	3	L38	TESTLEN	3	0	Z	HHH	NON-REFERENCE TEST LENGTH (HHH)
620	3	L38	TST_Hxxx	3	0	C	HHH	TEST HOURS(HHH)
630	3	L38	BWLTHxxx	6	1	N	MG	BEARING WEIGHT LOSS TOP HALF (MG)
640	3	L38	BWLBHxxx	6	1	N	MG	BEARING WEIGHT LOSS BOTTOM HALF (MG)
650	3	L38	TBWLHxxx	6	1	N	MG	BEARING WEIGHT LOSS TOTAL (MG)
660	3	L38	CBWLHxxx	6	1	N	MG	CORRECTED TOTAL BEARING WEIGHT LOSS (MG)
670	3	L38	BWL_SA	6	1	N	MG	BEARING WEIGHT LOSS SEVERITY ADJUSTMENT (MG)
680	3	L38	FBWLHxxx	6	1	N	MG	FINAL TOTAL BEARING WEIGHT LOSS (MG)
690	4	L38	IRPM	6	1	N	R/MIN	MIN ENGINE SPEED (R/MIN)
700	4	L38	XRPM	6	1	N	R/MIN	MAX ENGINE SPEED (R/MIN)
710	4	L38	ARPM	6	1	N	R/MIN	AVERAGE ENGINE SPEED (R/MIN)
720	4	L38	IAFR	6	1	N		MIN AIR TO FUEL RATIO
730	4	L38	XAFR	6	1	N		MAX AIR TO FUEL RATIO
740	4	L38	AAFR	6	1	N		AVG AIR TO FUEL RATIO
750	4	L38	IFFLO	5	2	N	lb/h	MIN FUEL FLOW (lb/h)
760	4	L38	XFFLO	5	2	N	lb/h	MAX FUEL FLOW (lb/h)
770	4	L38	AFFLO	5	2	N	lb/h	AVG FUEL FLOW (lb/h)
780	4	L38	IPWR	4	1	N	BHP	MIN LOAD (BHP)
790	4	L38	XPWR	4	1	N	BHP	MAX LOAD (BHP)
800	4	L38	APWR	4	1	N	BHP	AVG LOAD (BHP)
810	4	L38	IOHTRIN	7	1	N	W	MINIMUM OIL HEATER INPUT, (W)
820	4	L38	XOHTRIN	7	1	N	W	MAXIMUM OIL HEATER INPUT, (W)
830	4	L38	AOHTRIN	7	1	N	W	AVERAGE OIL HEATER INPUT, (W)
840	4	L38	ICCOG	5	1	N	STD FT3/H	MINIMUM CRANKCASE OFF-GAS, (STD FT3/H)
850	4	L38	XCCOG	5	1	N	STD FT3/H	MAXIMUM CRANKCASE OFF-GAS, (STD FT3/H)
860	4	L38	ACCOG	5	1	N	STD FT3/H	AVERAGE CRANKCASE OFF-GAS, (STD FT3/H)
870	4	L38	ISUMPT	6	1	N	°F	MIN OIL SUMP TEMPERATURE (°F)
880	4	L38	XSUMPT	6	1	N	°F	MAX OIL SUMP TEMPERATURE (°F)
890	4	L38	ASUMPT	6	1	N	°F	AVG OIL SUMP TEMPERATURE (°F)
900	4	L38	IGALT	6	1	N	°F	MINIMUM GALLERY OIL TEMPERATURE (°F)
910	4	L38	XGALT	6	1	N	°F	MAXIMUM GALLERY OIL TEMPERATURE (°F)
920	4	L38	AGALT	6	1	N	°F	AVERAGE GALLERY OIL TEMPERATURE (°F)
930	4	L38	ICOLIN	6	1	N	°F	MIN ENGINE COOLANT IN TEMPERATURE (°F)
940	4	L38	XCOLIN	6	1	N	°F	MAX ENGINE COOLANT IN TEMPERATURE (°F)
950	4	L38	ACOLIN	6	1	N	°F	AVG ENGINE COOLANT IN TEMPERATURE (°F)
960	4	L38	ICOLOUT	6	1	N	°F	MIN ENGINE COOLANT OUT TEMPERATURE (°F)
970	4	L38	XCOLOUT	6	1	N	°F	MAX ENGINE COOLANT OUT TEMPERATURE (°F)
980	4	L38	ACOLOUT	6	1	N	°F	AVG ENGINE COOLANT OUT TEMPERATURE (°F)
990	4	L38	ICOLDT	5	1	N	°F	MIN COOLANT DELTA (°F)
1000	4	L38	XCOLDT	5	1	N	°F	MAX COOLANT DELTA (°F)
1010	4	L38	ACOLDT	5	1	N	°F	AVG COOLANT DELTA (°F)
1020	4	L38	IINAIRT	6	1	N	°F	MIN INTAKE AIR TEMPERATURE (°F)
1030	4	L38	XINAIRT	6	1	N	°F	MAX INTAKE AIR TEMPERATURE (°F)
1040	4	L38	AINAIRT	6	1	N	°F	AVG INTAKE AIR TEMPERATURE (°F)
1050	4	L38	IOILPRS	6	1	N	PSIG	MIN OIL GALLERY PRESSURE (PSIG)
1060	4	L38	XOILPRS	6	1	N	PSIG	MAX OIL GALLERY PRESSURE (PSIG)
1070	4	L38	AOILPRS	6	1	N	PSIG	AVG OIL GALLERY PRESSURE (PSIG)

FIG. A16.1 Data Dictionary *(continued)*

21-jun-1999 Report: ASTM Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
1080	4	L38	IIMNVAC1	4	1	N	in. Hg gage	MIN INTAKE MANIFOLD VACUUM STAGE I (in. Hg gage)
1090	4	L38	XIMNVAC1	4	1	N	in. Hg gage	MAX INTAKE MANIFOLD VACUUM STAGE I (in. Hg gage)
1100	4	L38	AIMNVAC1	4	1	N	in. Hg gage	AVG INTAKE MANIFOLD VACUUM STAGE I (in. Hg gage)
1110	4	L38	IEXPR	4	1	N	in. Hg gage	MIN EXHAUST PRESSURE (in. Hg gage)
1120	4	L38	XEXPR	4	1	N	in. Hg gage	MAX EXHAUST PRESSURE (in. Hg gage)
1130	4	L38	AEXPR	4	1	N	in. Hg gage	AVG EXHAUST PRESSURE (in. Hg gage)
1140	4	L38	ICCV	5	1	N	in. H2O Gage	MIN CRANKCASE VACUUM PRESSURE (in. H2O Gage)
1150	4	L38	XCCV	5	1	N	in. H2O Gage	MAX CRANKCASE VACUUM PRESSURE (in. H2O Gage)
1160	4	L38	ACCV	5	1	N	in. H2O Gage	AVG CRANKCASE VACUUM PRESSURE (in. H2O Gage)
1170	4	L38	ISPKTIM	3	0	N	°	MIN SPARK ADVANCE BTDC (°)
1180	4	L38	XSPKTIM	3	0	N	°	MAX SPARK ADVANCE BTDC (°)
1190	4	L38	ASPKTIM	3	0	N	°	AVG SPARK ADVANCE BTDC (°)
1200	4	L38	IBLOBY	5	1	N	STD FT3/H	MIN BLOWBY (STD FT3/H)
1210	4	L38	XBLOBY	5	1	N	STD FT3/H	MAX BLOWBY (STD FT3/H)
1220	4	L38	ABLOBY	5	1	N	STD FT3/H	AVG BLOWBY (STD FT3/H)
1230	4	L38	OILCHxxx	6	3	N	lb/h	OIL CONSUMPTION (lb/h)
1240	5	L38	IVSCIN	7	4	N	IN	MINIMUM INLET VALVE STEM CLEARANCE IN GUIDE(IN)
1250	5	L38	XVSCIN	7	4	N	IN	MAXIMUM INLET VALVE STEM CLEARANCE IN GUIDE (IN)
1260	5	L38	AVSCIN	7	4	N	IN	AVERAGE INLET VALVE STEM CLEARANCE IN GUIDE (IN)
1270	5	L38	IVSCEX	7	4	N	IN	MINIMUM EXHAUST VALVE STEM CLEARANCE IN GUIDE (IN)
1280	5	L38	XVSCEX	7	4	N	IN	MAXIMUM EXHAUST VALVE STEM CLEARANCE IN GUIDE (IN)
1290	5	L38	AVSCEX	7	4	N	IN	AVERAGE EXHAUST VALVE STEM CLEARANCE IN GUIDE (IN)
1300	5	L38	ICRODCL	7	4	N	IN	MINIMUM CONNECTING ROD VALVE STEM CLEARANCE IN GUIDE (IN)
1310	5	L38	XCRODCL	7	4	N	IN	MAXIMUM CONNECTING ROD VALVE STEM CLEARANCE IN GUIDE (IN)
1320	5	L38	ACRODCL	7	4	N	IN	AVERAGE CONNECTING ROD VALVE STEM CLEARANCE IN GUIDE (IN)
1330	5	L38	IMBCF	7	4	N	IN	MINIMUM FRONT MAIN BEARING CLEARANCE (IN)
1340	5	L38	XMBCF	7	4	N	IN	MAXIMUM FRONT MAIN BEARING CLEARANCE (IN)
1350	5	L38	AMBCF	7	4	N	IN	AVERAGE FRONT MAIN BEARING CLEARANCE (IN)
1360	5	L38	IMBCR	7	4	N	IN	MINIMUM REAR MAIN BEARING CLEARANCE (IN)
1370	5	L38	XMBCR	7	4	N	IN	MAXIMUM REAR MAIN BEARING CLEARANCE (IN)
1380	5	L38	AMBCR	7	4	N	IN	AVERAGE REAR MAIN BEARING CLEARANCE (IN)
1390	5	L38	XCRODOR	7	4	N	IN	MAX. CON. ROD JRNL. OUTOFROUND (IN)
1400	5	L38	LINRUN	3	0	N		RUNS ON LINER
1410	5	L38	PISLINCL	7	4	N	IN	PISTON TO LINER CLEARANCE (IN)
1420	5	L38	ACIDHxxx	6	2	N		ACID NUMBER ASTM-D445
1430	5	L38	VIS_Hxxx	7	2	N	CST	VISCOSITY AT 40 °C AT XXX HOURS (CST)
1440	5	L38	VIS1Hxxx	7	2	N	CST	VISCOSITY AT 100 °C AT XXX HOURS (CST)
1450	5	L38	SVIS100	6	2	A	CST	STRIPPED VISCOSITY, BCST @ 100 °C ,[N/A] (CST)
1460	5	L38	PVISHxxx	6	2	N	CST	% VISCOSITY INCREASE @ 40 °C , @ XXX HOURS (CST)
1470	5	L38	PVS1Hxxx	6	2	N	CST	% VISCOSITY INCREASE @ 100 °C , @ XXX HOURS (CST)
1480	5	L38	CRANKID	10	0	C	c-yyyymmdd	CRANKSHAFT ID CODE (c-yyyymmdd)
1490	5	L38	CRANKRD	8	0	C	YYYYMMDD	CRANKSHAFT RECEIVED DATE (YYYYMMDD)
1500	5	L38	CAMSN	10	0	C	nnnnnnnnnn	CAMSHAFT ID CODE S/N (nnnnnnnnnn)
1510	5	L38	CAMRD	8	0	C	YYYYMMDD	CAMSHAFT RECEIVED DATE (YYYYMMDD)
1520	5	L38	RBEARRD	8	0	C	YYYYMMDD	ROD BEARINGS RECEIVED DATE (YYYYMMDD)
1530	5	L38	MBEARID	10	0	C	nn-nn	MAIN BEARING ID CODE (nn-nn)
1540	5	L38	MBEARRD	8	0	C	YYYYMMDD	MAIN BEARINGS RECEIVED DATE (YYYYMMDD)
1550	5	L38	CAMBRID	10	0	C		CAMSHAFT BEARING ID CODE
1560	5	L38	CAMBRRD	8	0	C	YYYYMMDD	CAMSHAFT BEARINGS RECEIVED DATE (YYYYMMDD)
1570	5	L38	CRODID	10	0	C	nnnn	CONNECTING ROD ID CODE (nnnn)
1580	5	L38	CRODRD	8	0	C	YYYYMMDD	CONNECTING ROD RECEIVED DATE (YYYYMMDD)
1590	5	L38	PISTSN	10	0	C	nn-nn	PISTON SERIAL NUMBER (nn-nn)
1600	5	L38	PISTONRD	8	0	C	YYYYMMDD	PISTON RECEIVED DATE (YYYYMMDD)
1610	5	L38	CLINID	10	0	C	nn-nn	CYLINDER LINER ID CODE (nn-nn)

FIG. A16.1 Data Dictionary *(continued)*

21-jun-1999 Report: ASTM Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
1620	5	L38	CLINRD	8	0	C	YYYYMMDD	CYLINDER LINER RECEIVED DATE (YYYYMMDD)
1630	6	L38	DWNOCR	2	0	Z		NUMBER OF DOWNTIME OCCURRENCES
1640	6	L38	DOWNHxxx	6	0	C	HHH:MM	DOWNTIME TEST HOURS XXX (HHH:MM)
1650	6	L38	DDATHxxx	8	0	C	YYYYMMDD	DOWNTIME DATE XXX (YYYYMMDD)
1660	6	L38	DTIMHxxx	6	0	C	HHH:MM	DOWNTIME TIME XXX (HHH:MM)
1670	6	L38	DREAHxxx	60	0	C		DOWNTIME REMARKS/REASONS XXX
1680	6	L38	TOTLDOWN	6	0	C	HHH:MM	DOWNTIME TIME TOTAL (HHH:MM)
1690	6	L38	TOTCOM	2	0	Z		TOTAL LINES OF COMMENTS & OUTLIERS
1700	6	L38	OCOMHxxx	70	0	C		OTHER DOWNTIME COMMENT XXX
1710	7	L38	OUTOCR	3	0	N		NUMBER OF OPERATIONAL OUTLIERS OCCURRENCES
1720	7	L38	OUT_Hxxx	5	0	C	HH:MM	OUTLIERS HOURS (HH:MM)
1730	7	L38	OUTPHxxx	15	0	C		OUTLIERS PARAMETER
1740	7	L38	OPARHxxx	15	0	C		OUTLIERS PARAMETER RANGE
1750	7	L38	OREDHxxx	8	0	C		OUTLIERS READING
1760	7	L38	OTIMHxxx	5	0	C	HH:MM	OUTLIERS TIME OUT (HH:MM)
1770	7	L38	ODP_Hxxx	6	1	Z	%	OUTLIERS DEVIATION (%)
1780	8	L38	GALTDP	6	1	Z	%	ENGINE OIL GALLERY TEMPERATURE TOTAL CAL DEV(%)
1790	8	L38	COLOUTDP	6	1	Z	%	ENGINE COOLANT OUTLET TEMP CAL DEV (%)
1800	8	L38	COLDTDP	6	1	Z	%	ENGINE COOLANT DELTA TEMPERATURE TOTAL CAL DEV (%)
1810	8	L38	FFLODP	6	1	Z	%	ENGINE FUEL FLOW TOTAL CAL DEV(%)
1820	8	L38	CCOGDP	6	1	Z	%	ENGINE CRANKCASE OFF GAS TOTAL CAL DEV (%)
1830	8	L38	OILPDP	6	1	Z	%	OIL PRESSURE TOTAL CAL DEV(%)
1840	8	L38	RPMDP	6	1	Z	%	ENGINE SPEED TOTAL CAL DEV (%)
1850	8	L38	AFRDP	6	1	Z	%	AIR TO FUEL RATIO TOTAL CAL DEV(%)
1860	8	L38	SPRKADP	6	1	Z	%	SPARK ADVANCE TOTAL CAL DEV(%)
1870	8	L38	EXPRDP	6	1	Z	%	EXHAUST TOTAL CAL DEV(%)
1880	8	L38	CCVACDP	6	1	Z	%	CRANKCASE VACUUM TOTAL CAL DEV(%)
1890	9	L38	OILISENS	14	0	C		OIL INLET SENSING DEVICE
1900	9	L38	OILICALF	14	0	C		OIL INLET CALIBRATION FREQUENCY
1910	9	L38	OILIRECD	3	0	C		OIL INLET RECORD DEVICE
1920	9	L38	OILIOBSF	12	0	C		OIL INLET OBSERVATION FREQUENCY
1930	9	L38	OILIRECF	12	0	C		OIL INLET RECORD FREQUENCY
1940	9	L38	OILILOGF	12	0	C		OIL INLET LOG FREQUENCY
1950	9	L38	OILISYSR	8	0	C		OIL INLET SYSTEM RESPONSE
1960	9	L38	COTSENS	14	0	C		COOLANT OUT TEMPERATURE SENSING DEVICE
1970	9	L38	COTCALF	14	0	C		COOLANT OUT TEMPERATURE CALIBRATION FREQUENCY
1980	9	L38	COTRECD	3	0	C		COOLANT OUT TEMPERTURE RECORD DEVICE
1990	9	L38	COTOBSF	12	0	C		COOLANT OUT TEMPERATURE OBSERVATION FREQUENCY
2000	9	L38	COTRECF	12	0	C		COOLANT OUT TEMPERATURE RECORD FREQUENCY
2010	9	L38	COTLOGF	12	0	C		COOLANT OUT TEMPERATURE LOG FREQUENCY
2020	9	L38	COTSYSR	8	0	C		COOLANT OUT TEMPERATURE SYSTEM RESPONSE
2030	9	L38	COLDSENS	14	0	C		COOLANT DELTA TEMPERATURE SENSING DEVICE
2040	9	L38	COLDCALF	14	0	C		COOLANT DELTA TEMPERATURE CALIBRATION FREQUENCY
2050	9	L38	COLDRECD	3	0	C		COOLANT DELTA TEMPERTURE RECORD DEVICE
2060	9	L38	COLDOBSF	12	0	C		COOLANT DELTA TEMPERATURE OBSERVATION FREQUENCY
2070	9	L38	COLDRECF	12	0	C		COOLANT DELTA TEMPERATURE RECORD FREQUENCY
2080	9	L38	COLDLOGF	12	0	C		COOLANT DELTA TEMPERATURE LOG FREQUENCY
2090	9	L38	COLDSYSR	8	0	C		COOLANT DELTA TEMPERATURE SYSTEM RESPONSE
2100	9	L38	FFLOSENS	14	0	C		FUEL FLOW SENSING DEVICE
2110	9	L38	FFLOCALF	14	0	C		FUEL FLOW CALIBRATION FREQUENCY
2120	9	L38	FFLORECD	3	0	C		FUEL FLOW RECORD DEVICE
2130	9	L38	FFLOOBSF	12	0	C		FUEL FLOW OBSERVATION FREQUENCY
2140	9	L38	FFLORECF	12	0	C		FUEL FLOW RECORD FREQUENCY
2150	9	L38	FFLOLOGF	12	0	C		FUEL FLOW LOG FREQUENCY

FIG. A16.1 Data Dictionary *(continued)*

21-jun-1999 Report: ASTM Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
2160	9	L38	FFLOSYSR	8	0	C		FUEL FLOW SYSTEM RESPONSE
2170	9	L38	RPMSENS	14	0	C		ENGINE SPEED SENSING DEVICE
2180	9	L38	RPMCALF	14	0	C		ENGINE SPEED CALIBRATION FREQUENCY
2190	9	L38	RPMRECD	3	0	C		ENGINE SPEED RECORD DEVICE
2200	9	L38	RPMOBSF	12	0	C		ENGINE SPEED OBSERVATION FREQUENCY
2210	9	L38	RPMRECF	12	0	C		ENGINE SPEED RECORD FREQUENCY
2220	9	L38	RPMLOGF	12	0	C		ENGINE SPEED LOG FREQUENCY
2230	9	L38	RPMSYSR	8	0	C		ENGINE SPEED SYSTEM RESPONSE
2240	9	L38	AFRSENS	14	0	C		AFR MEASUREMENT SENSING DEVICE
2250	9	L38	AFRCALF	14	0	C		AFR MEASUREMENT CALIBRATION FREQUENCY
2260	9	L38	AFRRECD	3	0	C		AFR MEASUREMENT RECORD DEVICE
2270	9	L38	AFROBSF	12	0	C		AFR MEASUREMENT OBSERVATION FREQUENCY
2280	9	L38	AFRRECF	12	0	C		AFR MEASUREMENT RECORD FREQUENCY
2290	9	L38	AFRLOGF	12	0	C		AFR MEASUREMENT LOG FREQUENCY
2300	9	L38	AFRSYSR	8	0	C		AFR MEASUREMENT SYSTEM RESPONSE
2310	9	L38	EXPRSENS	14	0	C		EXHAUST PRESSURE SENSING DEVICE
2320	9	L38	EXPRCALF	14	0	C		EXHAUST PRESSURE CALIBRATION FREQUENCY
2330	9	L38	EXPRRECD	3	0	C		EXHAUST PRESSURE RECORD DEVICE
2340	9	L38	EXPROBSF	12	0	C		EXHAUST PRESSURE OBSERVATION FREQUENCY
2350	9	L38	EXPRRECF	12	0	C		EXHAUST PRESSURE RECORD FREQUENCY
2360	9	L38	EXPRLOGF	12	0	C		EXHAUST PRESSURE LOG FREQUENCY
2370	9	L38	EXPRSYSR	8	0	C		EXHAUST PRESSURE SYSTEM RESPONSE
2380	9	L38	CCOGSENS	14	0	C		CRANKCASE OFF GAS SENSING DEVICE
2390	9	L38	CCOGCALF	14	0	C		CRANKCASE OFF GAS CALIBRATION FREQUENCY
2400	9	L38	CCOGRECD	3	0	C		CRANKCASE OFF GAS RECORD DEVICE
2410	9	L38	CCOGOBSF	12	0	C		CRANKCASE OFF GAS OBSERVATION FREQUENCY
2420	9	L38	CCOGRECF	12	0	C		CRANKCASE OFF GAS RECORD FREQUENCY
2430	9	L38	CCOGLOGF	12	0	C		CRANKCASE OFF GAS LOG FREQUENCY
2440	9	L38	CCOGSYSR	8	0	C		CRANKCASE OFF GAS SYSTEM RESPONSE
2450	9	L38	OPSISENS	14	0	C		OIL PSI SENSING DEVICE
2460	9	L38	OPSICALF	14	0	C		OIL PSI CALIBRATION FREQUENCY
2470	9	L38	OPSIRECD	3	0	C		OIL PSI RECORD DEVICE
2480	9	L38	OPSIOBSF	12	0	C		OIL PSI OBSERVATION FREQUENCY
2490	9	L38	OPSIRECF	12	0	C		OIL PSI RECORD FREQUENCY
2500	9	L38	OPSILOGF	12	0	C		OIL PSI LOG FREQUENCY
2510	9	L38	OPSISYSR	8	0	C		OIL PSI SYSTEM RESPONSE
2520	9	L38	CCVSENS	14	0	C		CRANKCASE VAC. SENSING DEVICE
2530	9	L38	CCVCALF	14	0	C		CRANKCASE VAC. CALIBRATION FREQUENCY
2540	9	L38	CCVRECD	3	0	C		CRANKCASE VAC. RECORD DEVICE
2550	9	L38	CCVOBSF	12	0	C		CRANKCASE VAC. OBSERVATION FREQUENCY
2560	9	L38	CCVRECF	12	0	C		CRANKCASE VAC. RECORD FREQUENCY
2570	9	L38	CCVLOGF	12	0	C		CRANKCASE VAC. LOG FREQUENCY
2580	9	L38	CCVSYSR	8	0	C		CRANKCASE VAC. SYSTEM RESPONSE

FIG. A16.1 Data Dictionary *(continued)*

```
###########################################################################
#                                                                         #
#           D a t a   D i c t i o n a r y   R e p e a t i n g            #
#               F i e l d   S p e c i f i c a t i o n s                   #
#                                                                         #
###########################################################################
# The following contains specifications and field groupings for fields in the
# Data Dictionary that are REPEATING Fields.  These fields can be identified
# in the Data Dictionary by the Hxxx or Rxxx in the last four positions of the
# field name.
#
# Repeating fields are used to specify repeating measurements.
#
# The format for a repeating field name is 4 descriptive characters followed
# by the letter H or R followed by 3 characters for the actual interval
# the measurement was taken. The field will always be a total of 8 characters.
#
# Example ABCDHxxx.
#
# The following is the format of this specification:
#
# Column 1 - 8:   Repeating Field Name
# Column 10 - 17: The Parent Field Name of the Group
# Column 19 - 80: Comments about the Repeating Field Group.
#
# The lines following the Repeating Field Name Record will contain the required
# measurements for the particular field.  Multiple 80 characters lines
# can be specified.  A blank line marks the end of each specification.
#
# The Field Name in Column 10-17 designates the the Group in which the field
# belongs.  The First field name in a group is the Parent of the grouping
# and can be used to determine how fields should be grouped.
# The changing of the Parent Field marks the end of a repeating group
# specification.
#
# Example:
#
# VIS_Hxxx, DVISHxxx and PVISHxxx expanded for transmission (8 and 16 hours):
#
#          VIS_H008
#          DVISH008
#          PVISH008
#          VIS_H016
#          DVISH016
#          PVISH016
#
# Note:  During electronic transmission, repeating field groups must be kept
#        together within the specified group but the order within the group
#        does not have to be maintained.
#
###########################################################################
#                Start of Field Grouping Specifications                   #
###########################################################################
#
L38 VERSION 19990621
RBWTHxxx RBWTHxxx   REFERENCE TOP HALF BEARING WEIGHT LOSS (MG)
040

RBWBHxxx RBWTHxxx   REFERENCE BOTTOM HALF BEARING WEIGHT LOSS (MG)
040
```

FIG. A16.6 Repeating Field Specifications

```
RTBWHxxx RBWTHxxx   REFERENCE TOTAL BEARING WEIGHT LOSS (MG)
040

RCBWHxxx RBWTHxxx   REFERENCE CORRECTED TOTAL BEARING WEIGHT LOSS (MG)
040

TST_Hxxx TST_Hxxx   TEST HOURS(HHH)
040

BWLTHxxx BWLTHxxx   BEARING WEIGHT LOSS TOP HALF (MG)
040

BWLBHxxx BWLTHxxx   BEARING WEIGHT LOSS BOTTOM HALF (MG)
040

TBWLHxxx BWLTHxxx   BEARING WEIGHT LOSS TOTAL (MG)
040

CBWLHxxx BWLTHxxx   CORRECTED TOTAL BEARING WEIGHT LOSS (MG)
040

FBWLHxxx BWLTHxxx   FINAL TOTAL BEARING WEIGHT LOSS (MG)
040

OILCHxxx OILCHxxx   OIL CONSUMPTION (lb/h)
NEW MAX 030 010 020 AVG

ACIDHxxx ACIDHxxx   ACID NUMBER ASTM-D445
030 NEW 010 020 040

VIS_Hxxx VIS_Hxxx   VISCOSITY AT 40 DEG C AT XXX HOURS (CST)
030 NEW 010 020 040

VIS1Hxxx VIS1Hxxx   VISCOSITY AT 100 DEG C AT XXX HOURS (CST)
030 NEW 010 020 040

PVISHxxx PVISHxxx   % VISCOSITY INCREASE @ 40 DEG C, @ XXX HOURS (CST)
030 010 020 040

PVS1Hxxx PVS1Hxxx   % VISCOSITY INCREASE @ 100 DEG C, @ XXX HOURS (CST)
030 010 020 040

DOWNHxxx DOWNHxxx   DOWNTIME TEST HOURS XXX (HHH:MM)

DDATHxxx DOWNHxxx   DOWNTIME DATE XXX (YYYYMMDD)

DTIMHxxx DOWNHxxx   DOWNTIME TIME XXX (HHH:MM)

DREAHxxx DOWNHxxx   DOWNTIME REMARKS/REASONS XXX

OCOMHxxx OCOMHxxx   OTHER DOWNTIME COMMENT XXX

OUT_Hxxx OUT_Hxxx   OUTLIERS HOURS (HH:MM)
```

FIG. A16.6 Repeating Field Specifications *(continued)*

```
OUTPHxxx OUT_Hxxx   OUTLIERS PARAMETER

OPARHxxx OUT_Hxxx   OUTLIERS PARAMETER RANGE

OREDHxxx OUT_Hxxx   OUTLIERS READING

OTIMHxxx OUT_Hxxx   OUTLIERS TIME OUT (HH:MM)

ODP_Hxxx OUT_Hxxx   OUTLIERS DEVIATION (%)
```

FIG. A16.6 Repeating Field Specifications *(continued)*

A17. STRIPPED VISCOSITY MEASUREMENT PROCEDURE

A17.1 Determine the stripped viscosity of the test oil (multiviscosity oils only) by using the following method:

A17.1.1 Weigh 25 g of the test oil sample taken at 10 h into a 50 mL three-necked round bottom flask equipped with a thermometer, gas inlet tube, stirrer, and distillation side arm.

A17.1.2 Heat the sample at 120 ± 5 °C in a vacuum of 100 mm Hg with a nitrogen sparge for 1 h. Do not consider warm-up time to meet the specified temperature as part of the 1 h time period.

A17.1.3 Filter the stripped sample through a 0.5 µm filter pad.

A17.1.4 Determine the kinematic viscosity, measured at 100 °C, of the filtered sample using Test Method D 445.

APPENDIXES

(Nonmandatory Information)

X1. ROLE OF THE ASTM TEST MONITORING CENTER AND THE CALIBRATION PROGRAM

X1.1 The TMC is a nonprofit organization located in Pittsburgh, Pennsylvania and is staffed to administer engineering studies; conduct engineering laboratory visits; conduct statistical analysis of reference data; store, blend, and ship reference oils; and provide the associated administrative functions to maintain the referencing calibration program for various lubricant tests as directed by Subcommittee D02.B and the Test Monitoring Board. The TMC maintains close communication with the test sponsors, the test developers, the surveillance panels, and the testing laboratories.

X1.2 The TMC operates in accordance with the ASTM Charter, the ASTM Bylaws, the Regulations Governing ASTM Technical Committees, the Bylaws Governing ASTM Committee D02, and the Rules and Regulations governing the ASTM Test Monitoring System. The management of the system is vested in the Test Monitoring Board elected by Subcomittee D02.B.

X1.3 The TMC operating income is obtained from fees for each reference oil test conducted and each reference oil issued. Fee schedules are reviewed and established by Subcommittee D02.B.

X2. SUGGESTED METHOD FOR SALVAGING CAMSHAFT BEARING JOURNALS

X2.1 The following method is suggested for salvaging out-of-limit camshaft journals, or for decreasing the camshaft journal clearance.

X2.1.1 Build up material on the journals by flamespraying. The following material has proven successful:

Met-Caloy Number 2[49] (mass %)
0.32 % carbon
0.50 % silicon
0.50 % magnesium
0.02 % phosphorus
0.02 % sulfur
13.5 % chrome
Balance—iron

X2.1.2 Apply a layer of Met-Caloy Number 2, 0.010 in. (0.25 mm) maximum thickness, directly to the worn surface. Grind the journal to the desired size.

X2.1.3 If a buildup of more than 0.010-in. (0.25-mm) thickness is required, first grind the surface undersize and apply a spray of bond material to within 0.002-in. (0.05-mm) undersize of the final diameter. Cover the remaining surface with Met-Caloy Number 2 and grind to the desired size.

[49] The sole source of Met-Caloy Number 2 known to the committee at this time is Metco, Inc., 1101 Prospect Ave., Westbury, NY 11590.