Designation: D 5119 – 02

An American National Standard

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

This standard is issued under the fixed designation D 5119; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

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.

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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:

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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.

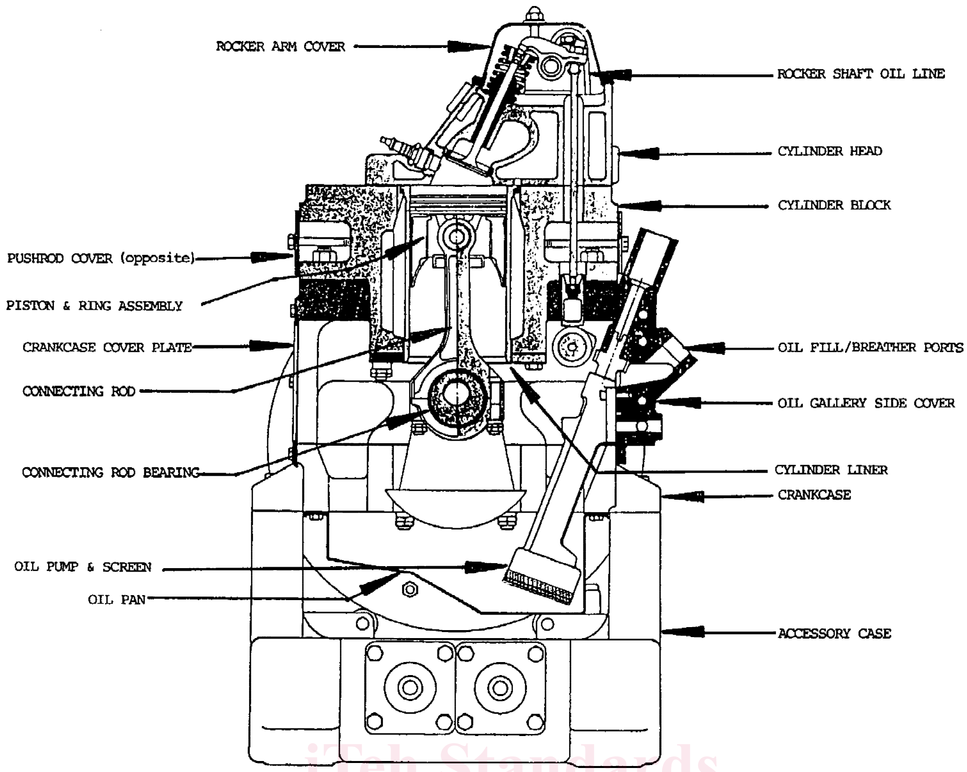


FIG. 1 Sectional View of L-38 Engine Power Section

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.

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

[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.

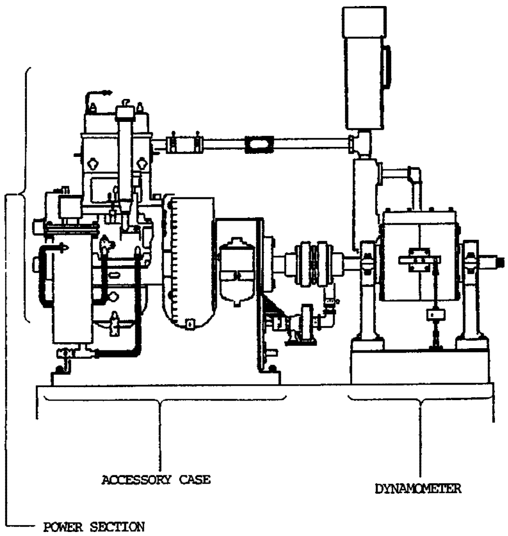


FIG. 2 Typical L-38 Test Stand

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.

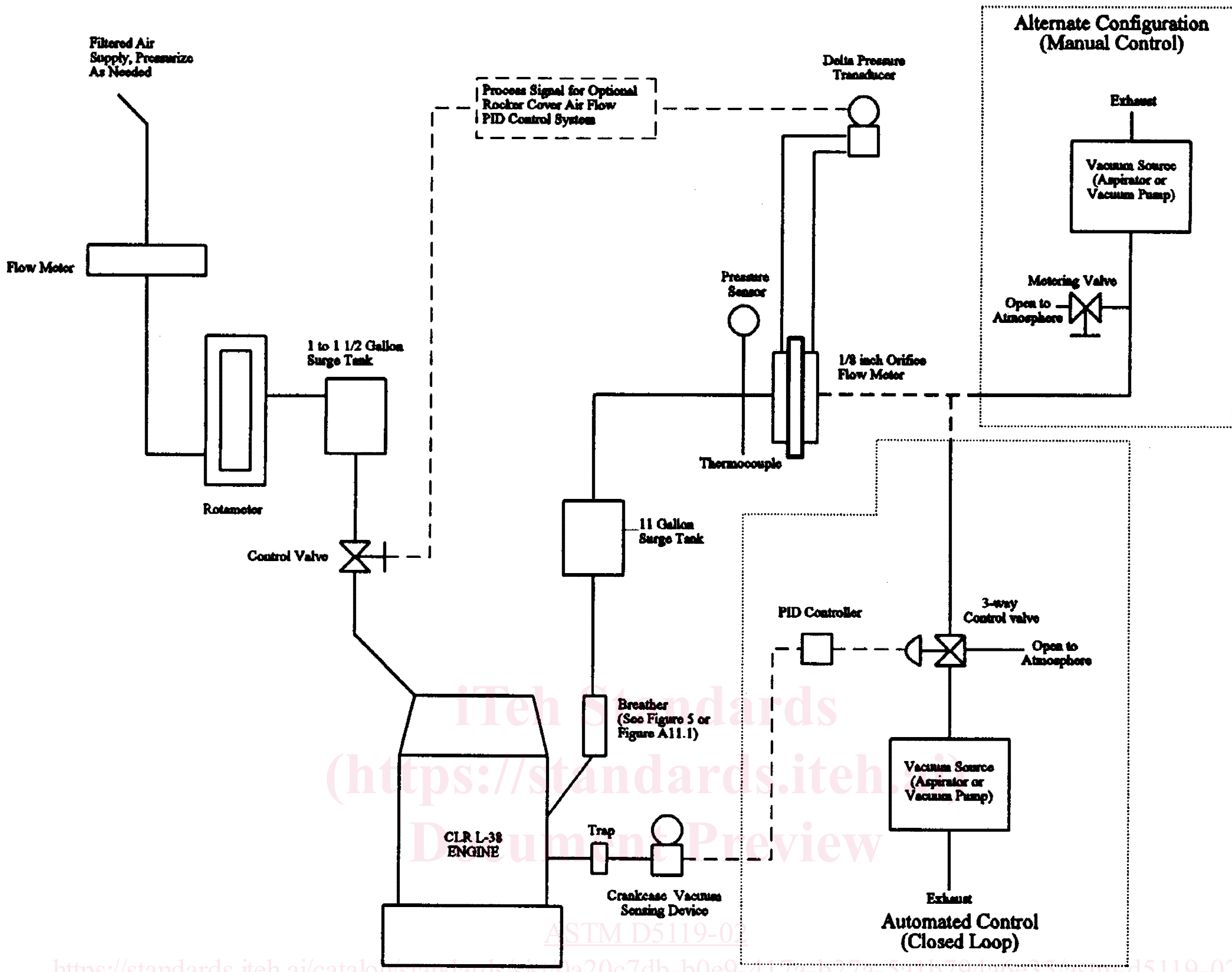


FIG. 3 Standard Crankcase Ventilation System for the L-38 Engine Power Section

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.

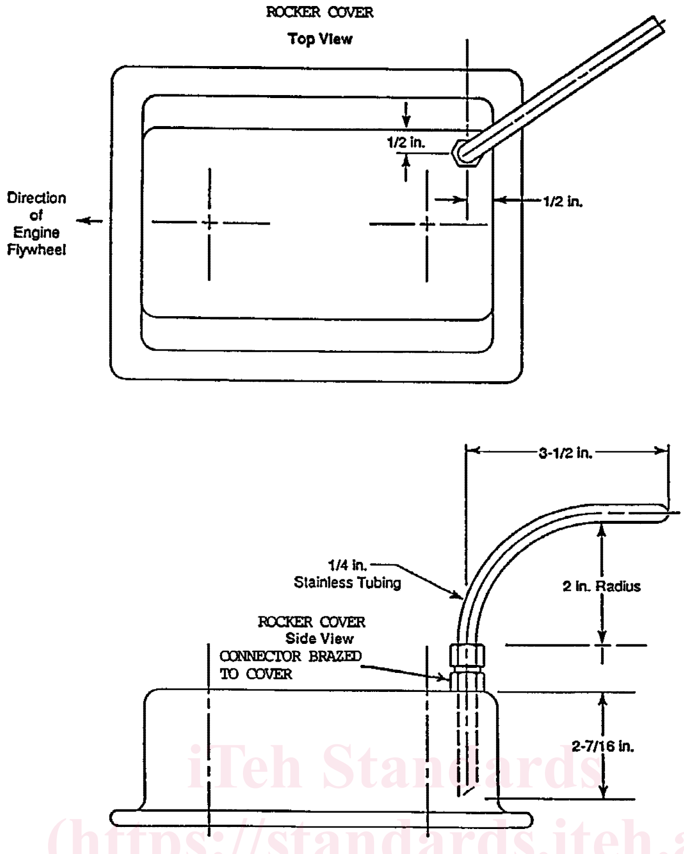
6.3.3 *Air-Fuel Ratio Measurement System*—Use a system with a calibration capability of the equivalent of ±0.5 air-fuel ratio number. The following are acceptable methods for determination of air-fuel ratio:

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
1/4	6.4
1/2	13
2	51
2 7/16	62
3 1/2	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.

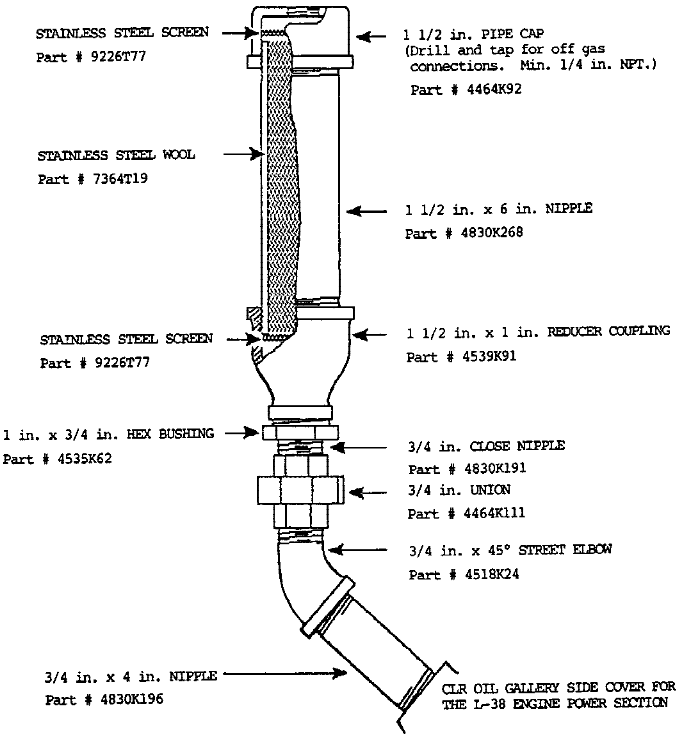
6.3.5 *Temperature Measurement*—Use only sensors that may be calibrated within 2°F (1°C). Thermocouples are specified in the following sections. If other thermocouples are used, they shall be of iron-constantan composition, or be shielded to prevent contact of any copper-containing metal with the test 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

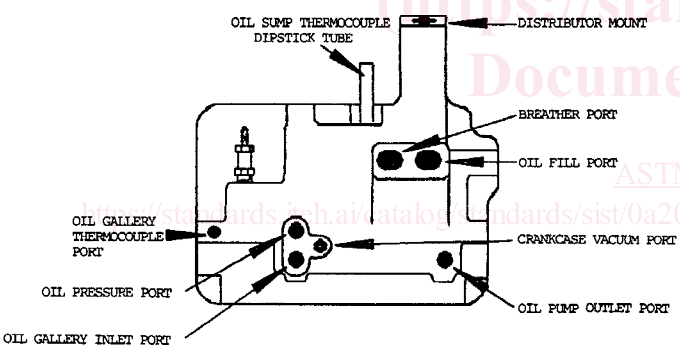


FIG. 6 Oil Gallery Side Cover for the L-38 Engine Power Section

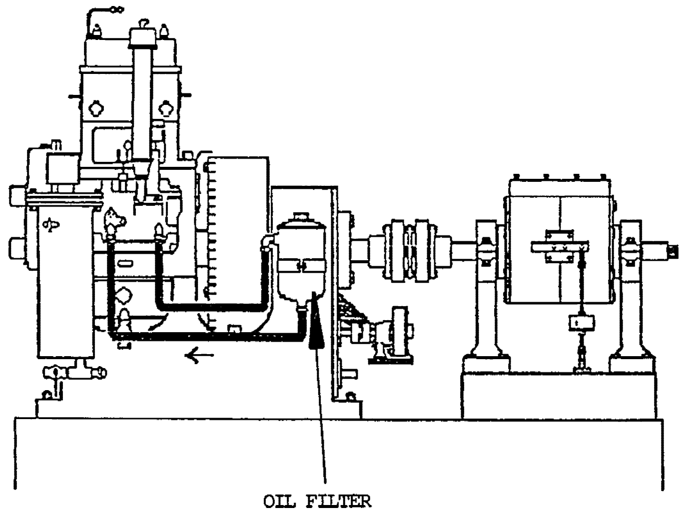


FIG. 7 Oil Filter Installation for the L-38 Engine Power Section (Refer to 11.1.1.)

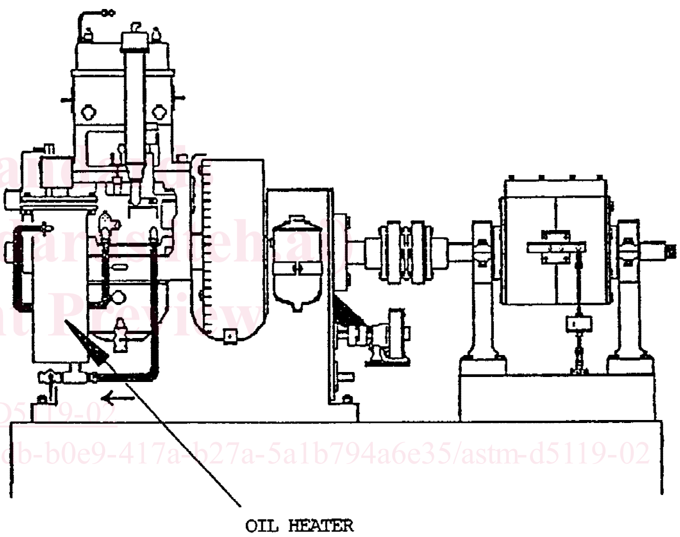


FIG. 8 Oil Heater Installation for the L-38 Engine Power Section (Refer to 11.1.5.)

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.

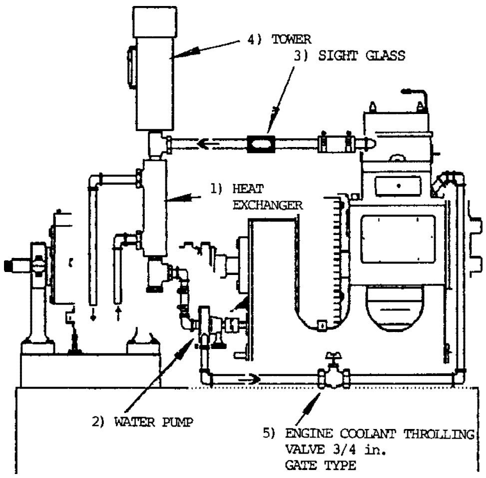


FIG. 9 Cooling System for L-38 Engine Power Section

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