



## Standard Test Method for Evaluation of Automotive Engine Oils in the Sequence VIII Spark-Ignition Engine (CLR Oil Test Engine)<sup>1</sup>

This standard is issued under the fixed designation D 6709; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### INTRODUCTION

This test method can be used by any properly equipped laboratory without outside assistance. However, the ASTM Test Monitoring Center (TMC)<sup>2</sup> offers a very valuable service to the 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 American Petroleum Institute (API) imposes such a requirement, in connection with several engine lubricating oil specifications.

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

This test method may be modified by means of Information Letters issued by the TMC. In addition, the TMC may issue supplementary memoranda related to the test method (see Annex A3).

### 1. Scope

1.1 This test method is used to evaluate automotive engine oils (SAE grades 5W, 10W, 20, 30, 40, and 50, and multiviscosity grades) intended for use in spark-ignition gasoline engines. The test procedure is conducted using a carbureted, spark-ignition Cooperative Lubrication Research (CLR) Oil Test Engine (also referred to as the Sequence VIII test engine in this test method) run on unleaded fuel. An oil is evaluated for its ability to protect the engine and the oil from deterioration under high-temperature and severe service conditions. The test method can also be used to evaluate the viscosity stability of multiviscosity-graded oils. Companion test methods used to evaluate engine oil performance for specification requirements are discussed in the latest revision of Specification D 4485.

1.2 Correlation of test results with those obtained in automotive service has not been established. Furthermore, the results obtained in this test 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. The test can be used to compare one oil with another.

1.3 The values stated in SI units are to be regarded as standard, except for (1) volume which is given in the metric, but non-SI, litre, (2) certain tube measurements which are given in the inch-pound unit, (3) cylinder bore and stroke in both SI and inch-pound units (the inch-pound being the standard) and (4) piston displacement given in metric (non-SI) and inch-pound unit (the inch-pound being the standard). In respect to (3) and (4) the inch-pound units are shown first and the SI units in parenthesis.

1.4 *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.* Specific precautionary statements are provided throughout this test method.

1.5 This test method is arranged as follows:

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<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.B0.01 on Passenger Car Engine Oils.

Current edition approved Aug. 10, 2001. Published October 2001.

<sup>2</sup> ASTM Test Monitoring Center, 6555 Penn Avenue, Pittsburgh, PA 15202-4489.

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## 2. Referenced Documents

### 2.1 ASTM Standards:

- D 235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvents)<sup>3</sup>
  - D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (the Calculation of Dynamic Viscosity)<sup>4</sup>
  - D 2422 Classification of Industrial Fluid Lubricants by Viscosity System<sup>4</sup>
  - D 4485 Specification for Performance of Engine Oils<sup>5</sup>
  - D 5119 Test Method for Evaluation of Automotive Engine Oils in the CRC L-38 Spark-Ignition Engine<sup>5</sup>
  - D 5302 Test Method for Evaluation of Engine Oils for Inhibition of Deposit Formation and Wear in a Spark-Ignition Internal Combustion Engine Fueled with Gasoline and Operated under Low-Temperature, Light-Duty Conditions<sup>5</sup>
  - D 5533 Test Method for Evaluation of Automotive Engine Oils in the Sequence IIIIE, Spark-Ignition Engine<sup>6</sup>
  - D 5844 Test Method for Evaluation of Engine Oils for Inhibition of Rusting (Sequence IID)<sup>6</sup>
  - D 6202 Test Method for Automotive Engine Oils on the Fuel Economy of Passenger Cars and Light-Duty Trucks in the Sequence VIA Spark-Ignition Engine<sup>6</sup>
  - E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>7</sup>
- ### 2.2 SAE Standards:<sup>8</sup>
- J183, Engine Oil Performance and Engine Service Classification (Other Than “Energy-Conserving”)
  - J304, Engine Oil Tests

## 3. Terminology

### 3.1 Definitions:

- 3.1.1 *air-fuel ratio, n*—in internal combustion engines, the mass ratio of air-to-fuel in the mixture being induced into the combustion chambers. **D 6202**
- 3.1.2 *automotive, adj*—descriptive of equipment associated with self-propelled machinery, usually vehicles driven by internal combustion engines. **D 4485**
- 3.1.3 *blind reference oil, n*—a reference oil, the identity of which is unknown by the test facility.
  - 3.1.3.1 *Discussion*—This is a coded reference oil that is submitted by a source independent from the test facility. **D 5844**
- 3.1.4 *blowby, n*—in internal combustion engines, the combustion products and unburned air-and-fuel mixture that enter

<sup>3</sup> Annual Book of ASTM Standards, Vol 06.04.

<sup>4</sup> Annual Book of ASTM Standards, Vol 05.01.

<sup>5</sup> Annual Book of ASTM Standards, Vol 05.02.

<sup>6</sup> Annual Book of ASTM Standards, Vol 05.03

<sup>7</sup> Annual Book of ASTM Standards, Vol 14.02

<sup>8</sup> Available from Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096. Request SAE Handbook Vol 3. This Standard is not available separately.

the crankcase.

**D 5302**

3.1.5 *critical parts, n*—those components used in the test that are known to affect test severity.

3.1.6 *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. **D 5119**

3.1.6.1 *Discussion*—In this test method noncompounded oil is also known as build-up oil. This discussion does not appear in Test Method D 5119.

3.1.7 *non-standard test, n*—a test that is not conducted in conformance with the requirements in the standard test method; such as running on an uncalibrated test stand, using different test equipment, applying different equipment assembly procedures, or using modified operating conditions. **D 5844**

3.1.8 *test start, n*—introduction of test oil into the engine. **D 5533**

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

3.1.9.1 *Discussion*—Wear generally occurs between two surfaces moving relative to each other, and is the result of mechanical or chemical action or by a combination of mechanical and chemical actions. **D 5302**

### 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 CLR engine.

3.2.1.1 *Discussion*—This definition was modified to embrace the CLR engine. The definition in Test Method D 5119 embraces the L-38 engine.

3.2.2 *build-up oil, n*—see 3.1.6, noncompounded engine oil.

3.2.3 *calibrated 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 Sequence VIII 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 test, n*—a test of an engine oil conducted using a power section and a test stand that runs 4-h run-in, 2-h flush and 40 h at test conditions. (See 10.1.3.1, exception for 10-h stay in grade test).

3.2.7 *new power section, n*—an engine power section consisting of either a new crankcase or complete power section that has no previous oil test history.

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

3.2.9 *off-test time, n*—any time that the engine is not operating at the prescribed test conditions.

3.2.10 *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 assembly.

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

3.2.12 *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.

3.2.13 *reconditioned power section, n*—an engine power section which has been disassembled, cleaned, and reassembled according to the detailed procedures<sup>9</sup> after completion of either a conditioning test run or a full-length CLR engine oil test.

3.2.14 *reference oil test, n*—a standard Sequence VIII 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 4 2-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 Sequence VIII test conducted with a calibrated power section and test stand in accordance with the conditions listed in this test method.

3.2.19 *stay-in-grade (stripped viscosity), n*—the viscosity of the test oil after removal of volatile components and solids, according to the procedure shown in Annex A14.

3.2.20 *test oil, n*—an oil subjected to a Sequence VIII 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 oil or a commercially available oil. Often, it is an oil that is a candidate for approval against engine oil specifications.

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 a Sequence VIII engine oil test.

### 3.3 *Acronyms:*

3.3.1 *BTDC, adj*—before top dead center

3.3.1.1 *Discussion*—It is used with the degree symbol to indicate the angular position of the crankshaft from its position at the point of uppermost travel of the piston in the cylinder.

3.3.2 *EWMA, n*—exponentially-weighted moving average

3.3.3 *LTMS, n*—Lubricant Test Monitoring System

3.3.3.1 *Discussion*—An analytical system in which ASTM calibration test data are used to manage lubricant engine test precision.

<sup>9</sup> Refer to Instructions for Assembly and Disassembly of the CLR Oil Test Engine, available from Test Engineering, Inc., 12718 Cimarron Path, San Antonio, TX 78249.

**TABLE 2 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, kg/h (lb/h)	2.15 ± 0.11 (4.75 ± 0.25)
Air-fuel ratio	14.0 ± 0.5
Jacket outlet coolant Temperature, °C (°F)	93.5 ± 1 (200 ± 2)
Difference between jacket Inlet and jacket outlet Coolant temperatures, °C (°F)	5.6 ± 1 (10 ± 2)
Gallery oil temperature, °C (°F)	
SAE 5W, 10W	135 ± 1 (275 ± 2)
SAE 20, 30, 40, 50, and multiviscosity-graded oils	143.5 ± 1 (290 ± 2)
Spark advance, °BTDC	35 ± 1
Oil pressure, kPa (psi)	276 ± 14 (40 ± 2)
Crankcase vacuum, Pa (in. H <sub>2</sub> O)	500 ± 120 (2 ± 0.5)
Exhaust back pressure, Pa (in. Hg)	0 to 3.4 (0 to 1)
Crankcase off-gas, SCFH	30 ± 1
Blowby, SCFH	record

3.3.4 *SIG*, *adj*—stay-in-grade  
 3.3.4.1 *Discussion*—Capability of multiviscosity-graded oil to stay in grade under test conditions (see 4.5).  
 3.3.5 *TDC*, *adj*—top dead center  
 3.3.5.1 *Discussion*—It is used with the degree symbol to indicate the angular position of the crankshaft from its position at the point of uppermost travel of the piston in the cylinder.

**4. Summary of Test Method**

4.1 Before every Sequence VIII engine oil test, the power section of the CLR oil test engine 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.B0.01 Sequence VIII Test Surveillance Panel), and other specified parts as required are installed.

4.2 The power section is installed on an accessory case/test stand. Unleaded fuel is used for the test.

4.3 The engine is first operated for 4 h according to a run-in-and-flush schedule shown in Table 1.

4.4 The engine is then operated for 40 h under specified conditions (Table 2). At the end of each 10-h of test conditions, a sample of the test oil is drained from the power section and fresh oil is returned to the power section for continuation of the test.

4.5 An oil sample is taken at the end of the first 10-h of test conditions. When multiviscosity-graded oils are being tested, this sample is used to determine the stay-in-grade (SIG) capabilities of the test oil.

4.6 At the completion of the test, the connecting rod bearing weight loss is determined.

**5. Significance and Use**

5.1 This test method is used to evaluate automotive engine oils for protection of engines against bearing weight loss.

5.2 This test method is also used to evaluate the SIG capabilities of multiviscosity-graded oils.

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

5.4 *Use*—The Sequence VIII test method is useful for engine oil specification acceptance. It is used in specifications and classifications of engine lubricating oils, such as the following:

5.4.1 Specification D 4485.

5.4.2 API Publication 1509 Engine Oil Licensing and Certification System.<sup>10</sup>

5.4.3 SAE Classification J304.

**6. Apparatus**

6.1 *Test Engineering, Inc.*—The document “Instructions for Assembly and Disassembly of the CLR Test Engine”<sup>9</sup> 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 test engine from Test Engineering Inc. (TEI).<sup>9</sup> The test engine is known by various designations such as the L-38 engine, the CLR engine, or the Sequence VIII engine (as used in this test method). It comprises two principal units, the power section and the accessory case (Fig. 1). The power section is a single-cylinder, spark-ignition unit with 96.5-mm (3.80-in.) bore and 95.2-mm (3.75-in.) stroke, displacing 0.696 L (42.5 in.<sup>3</sup>).

6.1.2 *Test Bearing*—SAE H-24 alloy connecting rod bearing, TEI Part No. 100034-1, from a batch approved by the ASTM Sequence VIII Test Surveillance Panel.

6.1.3 *Test Engine Crankshaft*—Obtain a crankshaft for the CLR test engine, Part No. 100039-1, from TEI. 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 test method.

**TABLE 1 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

<sup>10</sup> American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005.

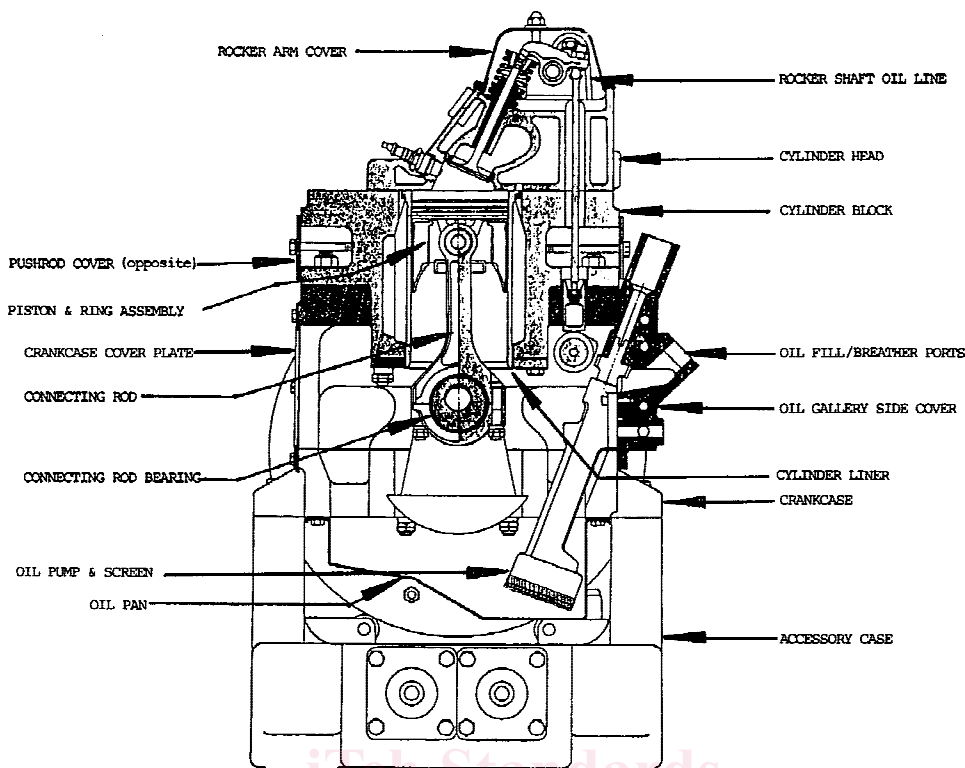


FIG. 1 Sequence VIII Power Section

6.1.3.2 The crankshaft may be refinished by chrome plating<sup>11</sup> the oil seal, connecting rod journal, and main bearing journals. When refinishing a crankshaft using this test method, all journals listed shall be chrome plated.

6.1.3.3 To identify the crankshaft being used in a power section the following identification is required:

- (1) S = standard crankshaft,
- (2) C = chrome crankshaft, and
- (3) R = reconditioned crankshaft.

6.1.4 *Test Engine Piston*—Obtain a piston for the CLR test engine, TEI Part No. 2405, from TEI. If desired, a piston may be reused if it meets the piston-to-liner clearance specifications. Pistons used in the CLR test engine for L-38 testing, or any other testing using leaded fuel, shall not be reused in Sequence VIII testing. Used pistons shall be cleaned according to the following procedure before installation in the test engine.

6.1.4.1 Clean the piston crown of any carbon deposits using aliphatic naphtha and 3M fine-grade Scotch Brite pads. Wet the cleaning pad in the solvent and scrub the deposit. Repeat until all carbon is removed.

6.1.4.2 Spray piston with clean solvent and air dry.

6.1.5 *Piston Ring Assembly*—Use a Dana/Perfect Circle piston ring assembly, Part No. 41274, in the Sequence VIII test engine.<sup>12</sup>

6.2 *Fabricated or Specially Prepared Items:*

6.2.1 A typical Sequence VIII engine test stand configuration is shown in Fig. 2.

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 tanks shown in Fig. 3, with provisions for draining and cleaning. The volume of the rocker cover air tank shall be 3.8 to 5.7 L (1 to 1.5 gal). The volume of the off-gas tank shall be 38 to 45 L (10 to 12 gal). 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 meter<sup>13</sup> capable of measuring 0 to 20 L/min. An optional Dwyer rotameter, Model No. RMC-101,<sup>14</sup> with a range of 0 to 1420 L/h may be used for ease of adjustments; however, actual

<sup>11</sup> 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. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,<sup>1</sup> which you may attend. Chrome plating of crankshaft journals by other vendors is not permitted at this time.

<sup>12</sup> The Dana/Perfect Circle piston ring assembly Part No. 41274, is available from Dana Corp., Perfect Circle Division, 1883 E. Laketon Ave., Product Distribution Center, Muskegon, MI 49442-6123. This piston ring assembly is the only one known to be available to the committee at this time.

<sup>13</sup> Sierra Side Track flow meters are available from Sierra Instruments Inc., 5 Harris Ct, Building L, Monterey, CA 93940.

<sup>14</sup> Dwyer instrumentation may be obtained from Dwyer Instruments Inc., P.O. Box 60725, Houston, TX 77205.

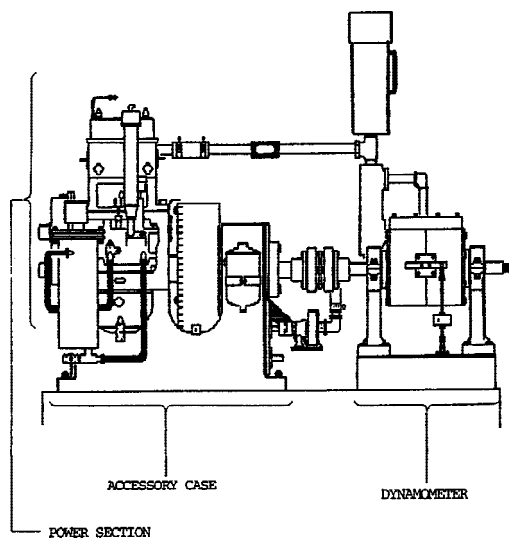


FIG. 2 Typical Sequence VIII Engine Test Stand

measurements shall be taken with the Sierra flow meter. All piping and tubing used to flow air into the rocker cover shall be nominal  $\frac{3}{8}$ -in. I.D.

6.2.2.3 When a closed loop automated control system is employed, use a Badger<sup>15</sup> meter research control valve, Model No. 1002-GCN36-SVCSC-LN36,<sup>16</sup> to control the rocker cover air flow. When using a manual control system instead of the automated system, install a Swagelok  $\frac{3}{8}$ -in. metering valve, Part No. SS-6L<sup>17</sup>, to control the air flow 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  $\frac{1}{8}$ -in. (3.2-mm) 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<sup>17</sup> as shown in Fig. 5 using American Standard Schedule 40, or equivalent, non-galvanized 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. A8.1 shows freeze plug detail in an alternative configuration to that in Fig. 5.

6.2.2.6 *Crankcase Off-Gas Flow*—Measure the crankcase off-gas flow by using a Daniels Honed Orifice Flange Flow Section, Model No. H1905T- $\frac{1}{2}$  in.,<sup>18</sup> with orifice plate, F-150- $\frac{1}{8}$  in., and a Rosemount differential pressure transducer, Model No. 1151DP-3-S-22-D1B2<sup>19</sup>. 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, to control the crankcase vacuum. When using a manual control system instead of the automated control system, install a Swagelok  $\frac{3}{8}$ -in. metering valve, Part No. SS-6L, to control the crankcase vacuum. Both systems are shown in Fig. 3.

6.2.2.8 Use a Vaccom<sup>20</sup> vacuum aspirator, Model No. JD-90M, or a vacuum pump as a vacuum source.

6.2.2.9 *Rocker Cover Air Inlet Pressure*—Use a Dwyer Magnehelic, Model No. 2320, or a Sensotech<sup>21</sup> pressure transducer, Model No. TJE-756-05, to measure the rocker cover air pressure. Convert the measured value to kPa for use in off-gas measurement calculation (see 11.4.1) Locate the sensor at the inlet of the rocker cover air flow apparatus as shown in Fig. 3.

6.2.2.10 *Crankcase Off-Gas Inlet Pressure*—Use a Dwyer Magnehelic, Model No. 2320, or a Sensotech pressure transducer, Model No. TJE-756-05, to measure the off-gas air pressure. Locate the sensor at the inlet of the off-gas air flow apparatus as shown in Fig. 3.

6.2.2.11 *Rocker Cover Air Inlet Temperature*—Measure the rocker cover inlet air temperature with a  $\frac{1}{8}$ -in. J-type thermocouple. Position the thermocouple tip in the middle of the air stream and expose no more than 50 mm of the sheath to ambient air. Locate the thermocouple at the inlet of the rocker cover air measurement apparatus as shown in Fig. 3.

6.2.2.12 *Crankcase Off-Gas Inlet Temperature*—Measure the off-gas temperature with a  $\frac{1}{8}$ -in. J-type thermocouple. Position the thermocouple tip in the middle of the air stream and expose no more than 50 mm of the sheath to ambient air. Locate the thermocouple at the inlet of the off-gas flow measurement apparatus as shown in Fig. 3.

6.2.3 *Oil Filter*—Install a Racor,<sup>22</sup> Model LFS-62, the specified oil filter as shown in Fig. 7. Use suitable hydraulic hose and fittings.<sup>23</sup>

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

6.2.4 *Oil Heater*—Install the oil heater as shown in Fig. 8. Use suitable hydraulic hose and fittings.<sup>23</sup>

6.2.5 *Power Section Cooling System*—Install a non-pressurized cooling system consisting of a heat exchanger, water pump, coolant throttling valve, sight glass, and tower (see Fig. 9). Use American Standard Schedule 40, or equivalent,  $\frac{3}{4}$ -in. non-galvanized pipe fittings and apply sealant to the threads during assembly.

<sup>15</sup> Badger valves are available from Badger Meter Industrial Div., 6116 East 15th St., P.O. Box 581390, Tulsa, OK 74158-1390.

<sup>16</sup> The letter prior to the last dash in the model number defines the trim size. Use the trim that gives the best system control.

<sup>17</sup> 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.

<sup>18</sup> Daniels flow sections are available from Daniel Flow Products Inc., Flow Measurement Products Div., P.O. Box 19097, Houston, TX 77224.

<sup>19</sup> Rosemount transducers are available from Rosemount Inc., 4001 Greenbriar, Ste 150B, Stafford, TX 77477.

<sup>20</sup> Vaccom aspirators are available from McKenzie Air Industries, 18523 IH 35 North, Shertz, TX 78108.

<sup>21</sup> Sensotec transducers are available from Sensotec Inc., 1200 Chesapeake Ave., Columbus, OH 43212.

<sup>22</sup> Parker Hanifin Corp., Racor Division, 3400 Finch Road, Modesta, CA 95350.

<sup>23</sup> Aeroquip  $\frac{3}{8}$ -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 Sequence VIII engine oil testing.

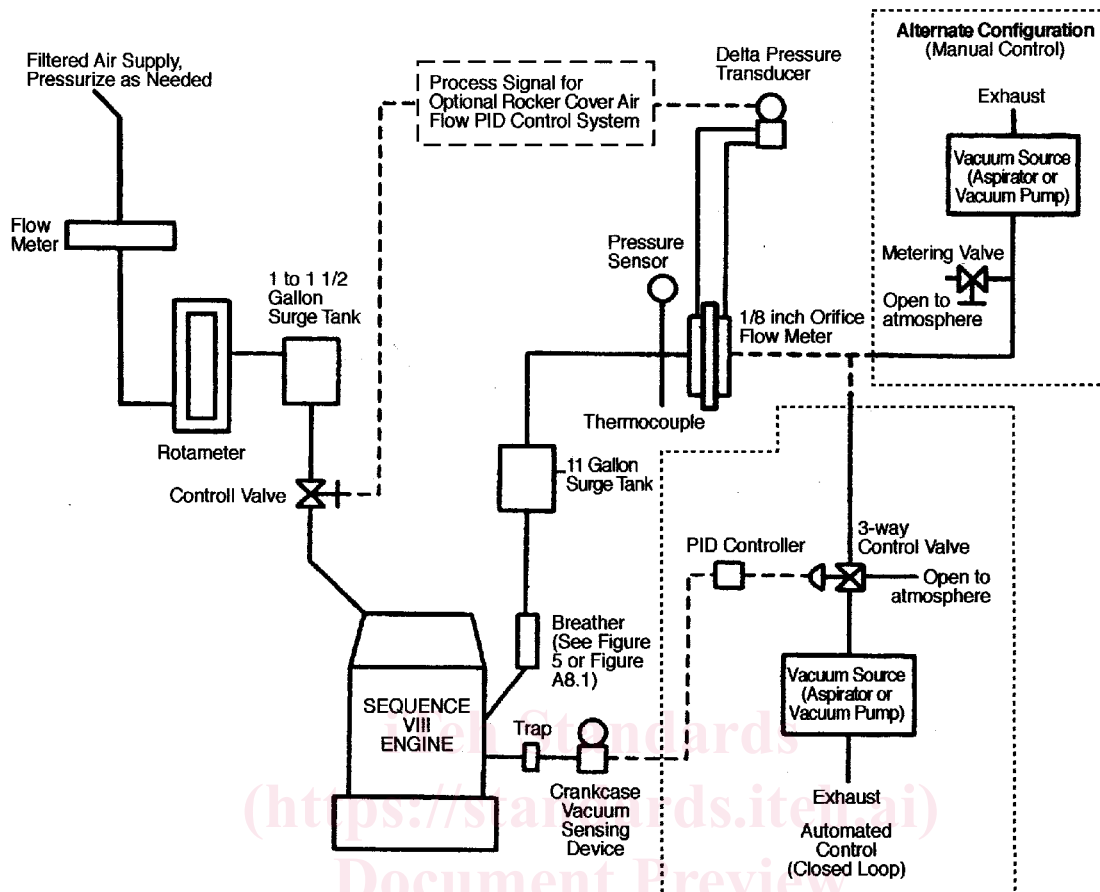


FIG. 3 Standard Crankcase Ventilation System for the Sequence VIII Power Section

6.2.5.1 Use a water-cooled heat exchanger. A heat exchanger of this type, suitable for this application, is available as American Heat Exchanger, Part Number 5-030-03014-011.<sup>24</sup>

6.2.5.2 Install a 3/4-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.

6.2.5.3 The coolant pump is to be an electrically driven centrifugal pump with a flow of approximately 18.9 L/min at 95.5 kPa of water head pressure. The Grainger<sup>25</sup> Part No. 1P831 has been found suitable.

6.2.5.4 Install a sight glass<sup>26</sup> located downstream of the cylinder head to permit detection of air entrainment.

6.2.5.5 Fabricate the tower using non-galvanized metal. Make it approximately 90 mm in diameter and 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 shall have a minimum capacity of 7.5 L.

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

6.2.7 Ignition System—An electronic ignition system is required. The required system is illustrated in Figs. A10.1 through A10.10. Other electronic ignition system configurations shall be reviewed and approved by the TMC and the Sequence VIII 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 shall have a minimum accuracy of  $\pm 0.5\%$  of reading, and load minimum measurement accuracy of  $\pm 2\%$  of reading.

6.3.2 Fuel Flowmeter or Fuel Weigh System—Use a system with a range of 0 to 4.5 kg/h, and having a minimum 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  $\pm 0.5$  air-fuel ratio number. The following are acceptable methods for determination of air-fuel ratio:

6.3.3.1 Calibrated Electronic Exhaust Gas Analyzer—Use sample gases for the calibration. Follow the directions in Annex A12 to determine air-fuel ratio.

6.3.3.2 AFR Analyzer/Lambda Meter—The air fuel ratio (AFR) analyzer shall have a measurement range of 11.00 to 18.00 for AFR with 1.85 H/C and 0.00 O/C, where: H is hydrogen, C is carbon and O is oxygen.

<sup>24</sup> Available from Compressor Engineering, 625 District Dr., Itasca, IL 60143.

<sup>25</sup> Any Grainger national branch location.

<sup>26</sup> A sight glass of this type, suitable for this application, is available as Gitts-Part No. 3063-27, from Edward Fisher Co., 118 S. Wabash, Chicago, IL 60616.

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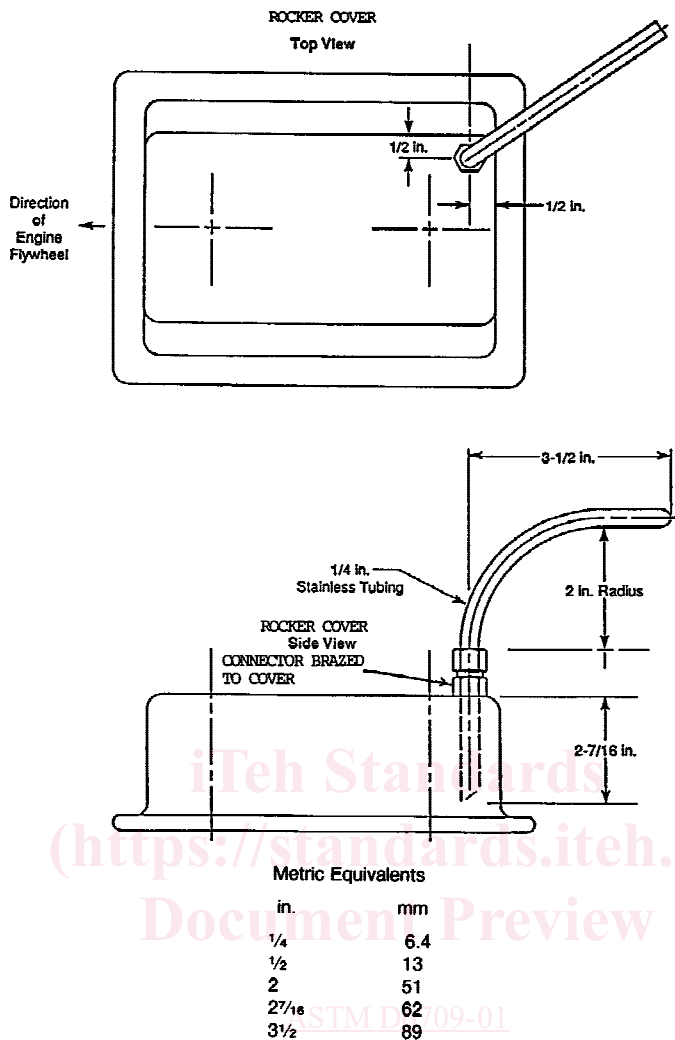


FIG. 4 Rocker Cover Air Inlet Detail

6.3.3.3 When a Lambda meter is used, the exhaust sensor location is to be within  $150 \pm 50$  mm of the cylinder head exhaust outlet mating surface.

6.3.4 Pressure Measurement:

6.3.4.1 Crankcase Vacuum—As shown in Fig. 3, connect a line trap and an appropriate sensor 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 50 Pa and 1 % accuracy in the specified range of  $.500 \pm .120$  kPa are required.

6.3.4.2 Exhaust Back Pressure—Connect an appropriate sensor to the exhaust back-pressure tap at a point within 100 mm of the cylinder head exhaust flange. Sensor accuracy of  $\pm 10$  % of reading and resolution of 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 680 Pa.

6.3.4.4 Oil Pressure—Measure the oil pressure with an appropriate sensor having an accuracy of  $\pm 2$  % and a resolution of 7 kPa, connected to the point shown in Fig. 6.

6.3.5 Temperature Measurement—The test requires the accurate measurement of oil and coolant temperature. Exercise

care to ensure temperature measurement accuracy. Follow the guidelines of Research Report RR:D02:1218.<sup>27</sup>

6.3.5.1 Check all temperature devices for accuracy at the temperature levels at which they are to be used. Iron-Constantin (Type J) thermocouples are specified for temperature measurement.

6.3.5.2 All thermocouples shall be premium grade, sheathed types with premium wire. Use thermocouples of 3.2 mm diameter. Thermocouple lengths are not specified but shall not have greater than 5 cm of thermocouple sheath exposed to ambient laboratory temperature.

6.3.5.3 Some sources of thermocouples that have been found suitable for this application are, Leeds and Northrup, Conax, Omega, Revere, and Thermo Sensor.

6.3.5.4 System quality shall be adequate to permit calibration to  $\pm 0.56$  °C for individual thermocouples.

6.3.6 Thermocouple Location and Length—All thermocouple tips shall be located in the center of the stream of the medium being measured unless otherwise specified.

<sup>27</sup> Available from ASTM International Headquarters.



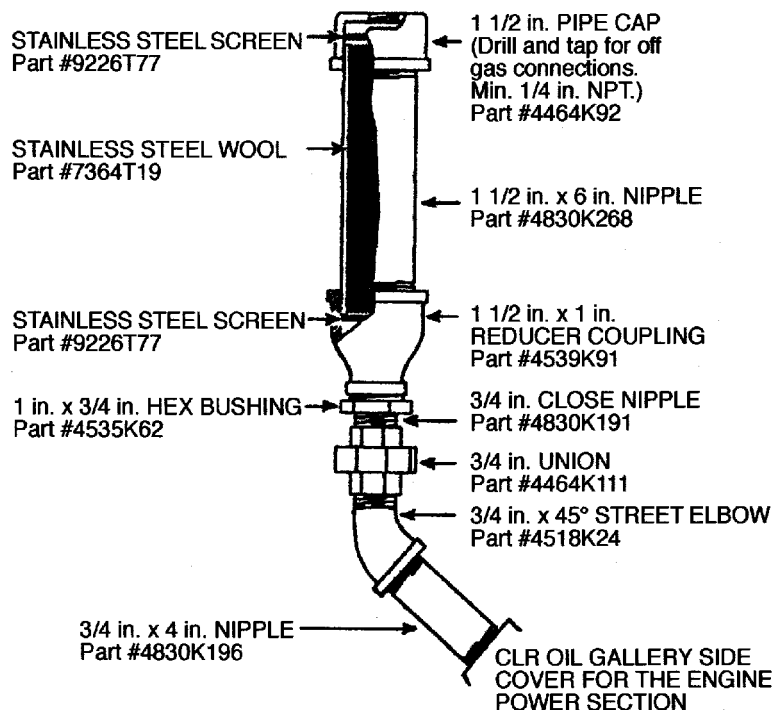


FIG. 5 Crankcase Breather Detail

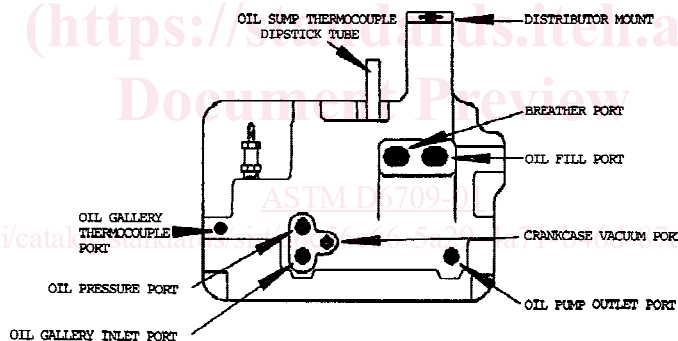


FIG. 6 Oil Gallery Side Cover

6.3.6.1 *Coolant Temperatures*—The thermocouples used to measure the coolant inlet and outlet temperatures are to be located within 100 mm of the inlet and outlet bosses on the power section.

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

6.3.6.3 *Oil Gallery Temperature*—Measure oil gallery temperature at the front main bearing passage (see Fig. 6). The immersion length for these thermocouples is 35 mm.

6.3.6.4 *Crankcase Off-Gas Temperature Measurement*—Measure the off-gas temperature at the outlet side of the crankcase breather assembly. Fig. 3 shows a recommended system.

6.4 *Procurement of Parts*—Obtain information on the CLR Oil Test Engine (see 6.1.1) and parts for it from TEI. Users of this test method shall comply with CLR Oil Test Engine Shop

Manual<sup>9</sup> and the latest supplements (Information Letters and Memoranda) available from the TMC.

## 7. Reagents and Materials

### 7.1 Reagents:

7.1.1 A 1:3 mixture of hydrochloric acid and deionized water. (**Warning**—The laboratory shall establish proper safety procedures for handling and disposal of this reagent.)

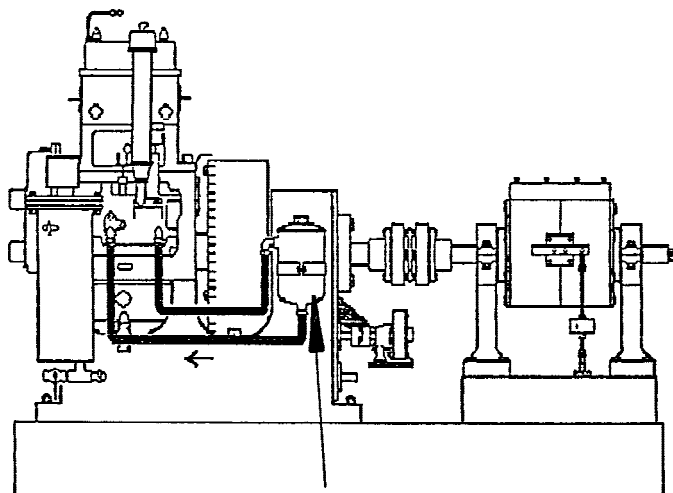
7.1.2 A 1:8 mixture of baking soda and water. (**Warning**—The laboratory shall establish proper safety procedures for handling and disposal of this reagent.)

### 7.2 Cleaning Materials:

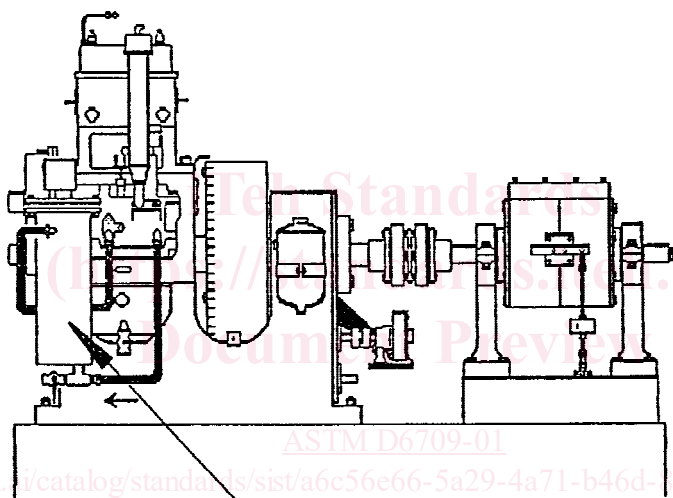
7.2.1 *Abrasive Paper*,<sup>28</sup> 400-, 600-, 800-grit, wet or dry.

7.2.2 *Crocus Cloth*.<sup>28</sup>

<sup>28</sup> The sand paper and Mylar tape may be obtained from many commercial sources.



OIL FILTER  
FIG. 7 Oil Filter Installation



OIL HEATER  
FIG. 8 Oil Heater Installation

7.2.3 Mylar Tape.<sup>28</sup>

7.2.4 Organic Solvent-Penmul L460<sup>29</sup> (**Warning**—Combustible. Health hazard).

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

7.2.6 Stoddard Solvent,<sup>30</sup> Specification D 235, Type I (**Warning**—Combustible. Health hazard).

7.2.7 Tap Water, heated to between 66 and 82°C.

7.3 Expendable Power Section-Related Items:

7.3.1 Sealing Compounds—Approved sealing compounds, including pipe thread compound and gasket cement are:

7.3.1.1 Perfect Seal Sealant No. 4,<sup>31</sup>

7.3.1.2 Permatex Ultra Blue 77B,<sup>31</sup>

<sup>29</sup> Penmul L460 is a registered trademark of, and is available from, Penetone Corp., 7400 Hudson Ave., Tenafly, NJ 07670.

<sup>30</sup> Stoddard Solvent, Specification D 235, Type I, is available from petroleum solvent suppliers.

<sup>31</sup> These may be obtained from many commercial sources.

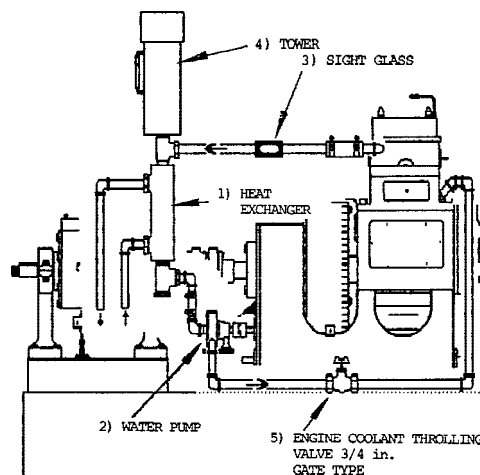


FIG. 9 Cooling System

7.3.1.3 Permatex 3H, Permatex High Tack 99 MA,<sup>31</sup>  
7.3.1.4 Dow Corning High Vacuum Grease,<sup>31</sup>

7.3.1.5 *Dow Corning RTV Gray 3154*, and<sup>31</sup>

7.3.1.6 *Petroleum Jelly*.<sup>31</sup>

7.3.2 *Power Section Build-Up Oil*.<sup>32</sup>

7.4 *Power Section Coolant*—Use deionized or distilled water for the power section coolant, plus a suitable inhibitor such as Pencoool 2000<sup>33</sup> at 31 mL of Pencoool 2000/L. Such water purchased from a commercial source is suitable.

7.5 *Reference Oils*—Conduct test 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. Use 8 L (2 gal.) of reference oil for each test.

7.6 *Test Fuel*—Use Haltermann Products KA24E Test Fuel.<sup>34</sup> The specification for KA24E Test Fuel is available from Haltermann Products. (**Warning**—Flammable. Health hazard.)

7.6.1 *Fuel Batch Approval*—New batches of KA24E Test Fuel are approved for use by Subcommittee D02.B Sequence IVD Surveillance Panel.

7.6.2 *Fuel Batch Analysis*—Details are available from Subcommittee D02.B Sequence IVD Surveillance Panel.

7.6.3 *Laboratory Storage Tank Fuel Analysis*—Details are available from Subcommittee D02.B Sequence IVD Surveillance Panel.

7.6.4 *Fuel Batch Shipment and Storage*—Details are available from Subcommittee D02.B Sequence IVD Surveillance Panel.

## 8. Test Oil Sample Requirements

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 12.1.1.

8.3 *Quantity*—Approximately 7 L of fresh oil is required to complete the test. It is recommended that a test laboratory have approximately 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 10.2.

9.1.2 *Preventive Maintenance*—Refer to and comply with “instructions for Assembly and Disassembly of the CLR Oil

Test Engine” regarding details pertaining to care and maintenance of the accessory case.

9.2 *Conditioning Test Run on Power Section*—A new 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 reference oil shall not qualify as a reference test. Testing can commence only after a conditioning run and a reconditioning.)

9.3 *General Power Section Rebuild Instructions*—Assemble the power section according to the detailed instructions found in the assembly manual. Compliance with all provisions of the assembly manual is mandatory. However, in cases of disparity, the explicit instructions contained in this test method take precedence over the service manual. Information letters and memoranda issued by the TMC shall supersede this manual. Failure to follow the instructions provided in this document and related TMC information letters or memoranda, or both, may cause incorrect test results.

9.4 *Reconditioning of Power Section After Each Test*—Recondition a previously used power section before the start of a new test. Power sections previously used with leaded fuel shall be decontaminated using the procedure shown in Annex A13 before use. Follow the parts replacement and cleaning 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,

NOTE 1—A used piston may be reused if it meets the requirements of 6.1.4.1.

9.4.1.2 H-24 alloy connecting rod test bearing,

9.4.1.3 All gaskets, seals, O-rings, and

9.4.1.4 All parts that are excessively worn or that do not permit maintenance of the operating clearances specified in this method or in “Instructions for Assembly and Disassembly of the CLR Oil Test Engine”.

9.4.2 *Documented Parts*—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. The parts that require documentation are: (1) crankshafts, (2) camshafts, (3) connecting rod bearings, (4) crankshaft main bearings, (5) camshaft bearings, (6) piston rings, (7) connecting rods, (8) pistons, and (9) cylinder sleeves.

9.4.2.1 *Critical Parts*—The crankshaft and connecting rod are considered critical parts. If either is replaced during a reference period it will void the calibration status of the stand/power section. A reference oil test meeting the calibration requirements of Section 10 is required before continuing non-reference oil testing.

9.4.3 *Parts Cleaning Procedures:*

9.4.3.1 *Oil Pump, Oil Pressure Regulator, Distributor, and Crankcase Breather*—Remove the distributor and crankcase breather. Remove the oil pump and oil pressure regulator with

<sup>32</sup> Noncompounded oil ISO VG 46 (SAE 20) (see Classification D 2422) is available through lubricant marketers. One supplier is Exxon-Mobil Oil Corp. The Exxon-Mobil product is designated EF-411, and is available from Exxon-Mobil Oil Corp., P.O. Box 66940, AMF O'Hare, IL 60666, Attn: Illinois Order Board.

<sup>33</sup> The sole source of supply of Pencoool 2000 known to the committee at this time is The Penray Co, Inc., 1801 Estes Ave., Elk Grove, IL 60007. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,<sup>1</sup> which you may attend.

<sup>34</sup> Haltermann Products KA24E Test Fuel is available from Haltermann Products, Ten Lamar, Ste 1800, Houston, TX 77002.

the oil gallery side cover plate. Clean this cover plate thoroughly using Penmul<sup>29</sup> (**Warning**—Combustible. Health hazard.) and a fiber brush or swab, then rinse the cover plate with tap water heated to 65 to 82°C (150 to 180°F), and rinse it again with Stoddard Solvent<sup>30</sup> (**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.

9.4.3.2 *Power Section*—Dismantle the power section completely before each test and thoroughly clean the parts by soaking them in Penmul for a minimum of 4 h. Remove remaining deposits on the crankshaft using fine or very fine 3M Scotch Brite pads. After the minimal 4-h soak and cleaning period, rinse the parts in hot tap water (65 to 82°C) to remove all traces of Penmul, and then rinse them with Stoddard Solvent<sup>30</sup>. (**Warning**—Insufficient rinsing may allow Penmul carryover to the test oil causing increased severity in H-24 alloy bearing weight loss.)

9.4.3.3 *Alternative Methods*—The above-noted parts may be cleaned using a heated bath or temperature controlled automated parts washer. Allow the parts to cool before assembly or measurement. Protect parts cleaned by either method in accordance with 9.4.3.4.

9.4.3.4 *Protection of Parts*—Immediately after cleaning, protect all parts against moisture and contamination by the use of build-up oil, vapor-proof plastic bag, or both. Give special attention to cleaning the following: (1) sludge trap, (2) oil passages in crankshaft, in cylinder block, in crankcase and to valve lifters, (3) oil passage to rocker assembly, and (4) oil passage to timing gear oil jet.

9.4.3.5 *Oil Heater Cleaning*—Prior to each reference oil test, clean the oil heater case and inner cartridge with Penmul 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 and air dry. Prior to every test between references, the oil heater may be cleaned by circulating Stoddard Solvent through it for 15 min and then air drying.

9.4.3.6 *H-24 Alloy 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 according to the procedure given in Annex A9. (Fresh, clean Stoddard Solvent and pentane shall be used for cleaning.) (**Warning**—Flammable. Health hazard.)

9.4.4 *Cylinder Liner Finishing*—To minimize the effect of changes in oil consumption, a new TEI cylinder liner shall be finished according to the honing procedure in Annex A6. The method for finishing a used liner is at the laboratory's judgment.

9.4.4.1 *Cleaning Procedure and Rust Prevention*—After the desired finish is achieved, spray the liner with Stoddard Solvent, and air dry it. Apply build-up oil to the liner surface. Wipe the liner interior with a cloth or paper towel wetted with

build-up oil until the wiping material appears clean after wiping. Coat the liner with build-up oil.

9.4.5 *Piston-to-Sleeve*—Determine the piston-to-sleeve clearance in accordance with the procedure given in Annex A4.

9.4.6 *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 Annex A15.

9.4.7 *Crankshaft Journal Conditioning*:

9.4.7.1 Use crankshafts with all journals having out-of-round measurements of 0.025 mm or less.

9.4.7.2 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.

9.4.7.3 Polish the connecting rod bearing journal according to 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 abrasive paper, standard crocus cloth, or Mylar 3m tape is approved for use) 13 mm wide by 0.9 to 1.2 m long. It is necessary to wet the strip of crocus cloth or abrasive paper with build-up oil or the Mylar tape with Stoddard Solvent. Wrap the strip 1-1/2 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 only wrap it 180°. Stroke the journal with the cloth or abrasive 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° between each traverse. Repeat four times. If abrasive paper is used, complete the fourth and final polishing process using crocus cloth or Mylar tape.

9.4.7.4 Alternatively, rotate the crankshaft (for example, with a metal turning lathe,) 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. No other method of polishing process is permitted.

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

9.4.7.6 To confirm the trueness of the journal, visually check the journal with a straight edge 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 diametrical difference) of the journal between

the points. Discard any crankshafts having a connecting rod journal taper larger than 0.013 mm/25.4 mm. (Experience has shown that mechanical bearing wear with such crankshafts is unacceptably high.) The use of technology, such as surface profile measuring equipment is acceptable if approved by the TMC.

9.4.7.7 Resizing (refinishing) of the connecting rod journal is allowed only as stated in 6.1.3.2.

9.4.7.8 Determine the connecting rod bearing clearance and journal taper according to the procedure given in Annex A1, or an equivalent method approved by the TMC, prior to the initial weighing of the bearing halves. Perform the connecting rod clearances prior to the initial weighing of the bearing halves.

9.4.7.9 Determine the main bearing clearance according to the procedure given in Annex A2 or an equivalent method approved by the TMC. Perform the connecting rod clearance measurements prior to the initial weighing of the bearing halves.

9.4.7.10 After preparing the crankshaft according to 9.4.7.1-9.4.7.9, clean it thoroughly. Either pressure spray it with Stoddard Solvent or brush it with Stoddard Solvent, and air dry.

9.4.8 *Camshaft Journal Conditioning*—The camshaft journal-to-bearing clearance must be within the range of 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 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.

9.4.9 *Power Section Valve Clearances*—Make the appropriate adjustments during power section reassembly to obtain the clearances shown in the “Instructions for Assembly and Disassembly of the CLR Test Engine.” If specifications do not include an inch tolerance, the intent is to meet this value.

9.4.10 *Power Section Assembly Torque Specifications*—During power section assembly, use the torque specifications shown in the “Instructions for Assembly and Disassembly of the CLR Test Engine.”

9.4.11 *Connecting Rod Reconditioning*—When reconditioning connecting rods, the bore diameter shall be within the range of 57.8231 to 57.8358 mm.

## 10. Calibration

NOTE 2—The ASTM Test Monitoring Center Calibration Program (Annex A3) dictates specific procedures which involve coordination with the TMC in order 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 Sequence VIII 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. The only exception to this format is that the sequential total number of runs on the power section shall be followed by the letter A for the first rerun, B for the second, and so forth, for an invalid or unacceptable reference oil test.

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 6 month power section/test stand time period, whichever occurs first. When a Sequence VIII oil test is terminated after the first 10-h interval to determine the stripped viscosity of a multiviscosity-graded oil, on a calibrated Sequence VIII power section/test stand, the test is counted as one of 15 test starts allowed per reference period. Also, any tests exceeding intervals of 40 h shall be counted as more than one test each time it exceeds 40 h. For example, 0 to 40 or less h equals one test; 41 to 80 h equals two tests; 81 to 120 h equals three tests, and so forth.

10.1.3.2 When circumstances develop which are beyond a laboratory’s control, such as fuel or parts shortages, calibration periods and the number of test 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 Sequence VIII Surveillance Panel before additional test starts are conducted. Make a note on the form shown in A16.7 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.

10.1.3.3 Laboratories running non-standard Sequence VIII tests shall contact the TMC before resuming calibrated Sequence VIII 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 non-standard 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 LTMS for reference oil test acceptance criteria<sup>35</sup>). The test data sheet for test reports on engine oils other than reference oils (Fig. A16.4) shall include the test number and completion date of the power section reference oil test(s) used to calibrate the power section/test stand used for the test.

10.1.4.3 Failure of a reference oil test to meet LTMS 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 Sequence VIII 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 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 non-reference oil 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 Sequence VIII 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 (only if used),
- 10.2.6 Pressure gages,
- 10.2.7 Crankcase off-gas flowmeter,
- 10.2.8 Crankcase ventilation air flowmeter, and
- 10.2.9 Rocker cover air flowmeter.

10.3 *Calibration of AFR measurement Equipment:*

10.3.1 *Lambda Meters*, prior to each reference oil test.

10.3.2 *Exhaust Gas Analysis Meters*, prior to each reading zero and span.

10.4 Calibrate torque wrenches every six months.

## 11. Engine Operating Procedure

11.1 *Run-In and Flush*—At the beginning of each test, perform the following 4-h run-in and 2-h flush:

11.1.1 Install the Racor oil filter bypassing the oil heater (see Fig. 7). Use a new/clean filter screen (28  $\mu$ m) for each new test run-in.

11.1.2 Charge the power section with 2840 mL of fresh test oil. Record the date and time that the oil is poured into the engine. These are considered the test start date/time. Prior to starting the engine and any restarts during the 4-h run-in, perform the oil priming procedure in Annex A7.

11.1.3 Operate the power section for 4 h according to the schedule in Table 1. Maintain the oil gallery temperature no higher than 107.0°C, the oil gallery pressure at  $280 \pm 10$  kPa, and the jacket outlet temperature no higher than 93.5°C. Record data at least hourly using a form of the type shown in Fig. X3.1.

11.1.4 Shut down the power section after four running hours. Immediately move the piston to top dead center (TDC) on the compression stroke, and drain the crankcase for 10 min. Remove the crankcase breather tube to vent the power section to atmosphere during drain periods.

11.1.5 After the 4-h run-in, add the oil heater (Fig. 8). The oil heater remains in the oil circuit for the flush and steady-state portions of the test procedure. The external oil outlet shall pass through the heater, then the Racor filter before returning to the engine.

11.1.6 Charge the power section with 1660 mL of fresh test oil. Prior to starting the engine and any restarts during the 2-h flush, perform the oil priming procedure in Annex A7.

11.1.7 Flush the power section for 2 h under the following operating conditions:  $3150 \pm 25$  r/min,  $3.73 \pm 0.15$  kW,  $35 \pm 1^\circ$  before top dead center (BTDC) spark advance, 107.0°C maximum oil gallery temperature, 93.5°C maximum water jacket outlet temperature, and  $280 \pm 10$  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 Figs. X3.1 and X3.2.

11.1.7.1 *Downtime Limits, Run-in and Flush*—During the run-in interval and the flush interval (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.

<sup>35</sup> The document "Lubricant Test Monitoring System" is available from the TMC.