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

This standard is issued under the fixed designation D XXXX; 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 parenthesis indicates the year of last approval. A subscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

**INTRODUCTION**

The test method described in this standard 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 assessment of the test results obtained on those oils by the laboratory (see 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 which 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 A4.).

**1. Scope**

1.1 This test method is used to evaluate automotive engine oils (SAE<sup>3</sup> 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). An oil is evaluated for its ability to protect high-temperature, 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 The unit values stated in this document shall be regarded as the standard.

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

1.4 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.

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## 2. Referenced Documents

### 2.1 ASTM Standards<sup>4</sup>:

D56 Test Method for Flash Point by Tag Closed Tester<sup>5</sup>

D86 Test Method for Distillation of Petroleum Product

D156 Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method)<sup>5</sup>

D235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvents)<sup>5</sup>

D287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)<sup>5</sup>

D323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)<sup>5</sup>

D381 Test Method for Distillation

D445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic

Viscosity)<sup>5</sup>

D525 Test Method for Oxidation Stability

D664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration<sup>5</sup>

D873 Test Method for Potential Gums

D1133 Test Method for Kauri-Butanol Value of Hydrocarbon Solvents<sup>5</sup>

D1250 Guide for Petroleum Measurement Tables<sup>5</sup>

D1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method<sup>5</sup>

D1353 Test Method for Nonvolatile Matter in Volatile Solvents for Use in Paint, Varnish, Lacquer, and Related Product

D2422 Classification of Industrial Fluid Lubricants by Viscosity System<sup>5</sup>

D2699 Test Method for Knock Characteristics of Motor Fuels by the Research Method<sup>6</sup>

D2789 Test Method for Hydrocarbon Specification

D3120 Test Method for Trace Quantities of Sulfur in Light Liquid Petroleum Hydrocarbons by Oxidative Microcoulometry<sup>7</sup>

D3606 Test Method for Benzene

D4057 Summary of Sampling Procedures and Applicability

D4175 Terminology Relating to Petroleum, Petroleum Products, and Lubricants<sup>7</sup>

D4485 Standard Specification for Performance of Automotive Engine Oils<sup>7</sup>

D5059 Test Method for Lead

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications<sup>8</sup>

E270 Definitions of Terms Relating to Liquid Penetrant Inspection<sup>9</sup>

RR: D-2-1218 Instrumentation Task Force Report

2.2 Military Specification:

MIL-L-2104E, Lubricating Oil, Internal Combustion Engine, Tactical Service<sup>13</sup>

2.3 SAE Standards:

J183, Engine Oil Performance and Engine Service Classification (Other Than "Energy-Conserving")<sup>10</sup>

J304, Engine Oil Tests<sup>10</sup>

2.4 Others:

Laboratory Equipment Corp.- Instructions for Assembly and Disassembly of the CLR Oil Test Engine<sup>16</sup>

Lubricant Test Monitoring System<sup>2</sup> (**LTMS**)

### 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 5302)

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-*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. (D 5119)

3.1.2 *blowby, n- in internal combustion engines*, the combustion products and unburned air-and-fuel mixture that enter the crankcase. (D 5302)

3.1.3 *critical parts, n-*those components used in the test, which are known to affect test severity.

3.1.4 *EWMA, n-* abbreviation for exponentially-weighted moving average.

3.1.5 *LTMS, adj-* abbreviation for Lubricant Test Monitoring System, an analytical in which ASTM calibration test data are used to manage lubricant engine test precision and severity (bias). (D 5533)

- 3.1.6 *noncompounded engine oil (build-up 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)
- 3.1.7 *non standard test*, *n*-a test that is not conducted in conformance with the requirements in the standard test method; such as running an uncalibrated test stand, using different test equipment, applying different equipment assembly procedures, or using modified operating conditions. (D 5844)
- 3.1.8 *TDC*, *adj*- abbreviation for Top Dead Center; used with the degree symbol to indicate the angular position of the crankshaft relative to its position at the point of uppermost travel of the piston in the cylinder.
- 3.1.9 *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. ( D 2509 and D 2782)
- 3.1.10 *test start*, *n*- introduction of test oil into the engine. (D 5533)

### 3.2 Descriptions of Terms Particular 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.(D 5119)
- 3.2.2 *BTDC*, *adj*- abbreviation for Before Top Dead Center; used with the degree symbol to indicate the angular position of the crankshaft relative to its position at the point of uppermost travel of the piston in the cylinder. (D 5533)
- 3.2.3 *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, □-h flush and 40 hours at test conditions. (See 10.1.3.1, exception for 10-h stay in grade test) (D 5119)
- 3.2.4 *calibrated power section/test stand combination*, *n*-one which has completed an operationally valid reference oil test within the previous 6 months, the results of which fall within industry severity and precision limits as published by the TMC. (D 5119)
- 3.2.5 *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. (D 5119)
- 3.2.6 *emergency shutdown*, *n*-the procedure for turning off the engine's ignition without using the prescribed engine cool-down period.(D 5119)
- 3.2.7 *new power section*, *n*-an engine power section consisting of either a new crankcase or complete power section which has no previous oil test history.
- 3.2.8 *off-gas*, *n*-gas exiting the power section crankcase breather. (D 5119)
- 3.2.9 *off-test time*, *n*-any time that the engine is not operating at the prescribed test conditions. (D 5119.)
- 3.2.10 *oil gallery side cover plate*, *n*-crankcase cover plate which 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 which 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>16</sup> after completion of either a conditioning test run or a full-length CLR engine oil test. (D 5119)

3.2.14 *reference oil test, n*-a standard 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. (D 5119)

3.2.15 *4 run-in and flush, n*-the initial 4 h operation of a new, rebuilt, or reconditioned power section at the beginning of either a conditioning test run or a full-length test. (D 5119)

3.2.16 *scheduled downtime, n*-off-test time which is specifically allowed to include warm-up and cool-down periods. (D 5119)

3.2.17 *shutdown, n*-the procedure for turning off the engine's ignition following the prescribed engine cool-down period. (D 5119)

3.2.18 *standard test, n*-an operationally valid, full-length test conducted with a calibrated power section and test stand in accordance with the conditions listed in this test method. (D 5119)

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 A16. of this document.

3.2.20 *test oil, n*-an oil subjected to an engine oil test. 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 which is a candidate for approval against engine oil specifications. (D 5119)

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, etc., to provide a means for mounting and operating a power section in order to conduct a Sequence VIII engine oil test. (D 5119)

#### **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.

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 forty hours under specified conditions (Table 2). At the end of each 10-h of test conditions a sample of the test lubricant 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 The Sequence VIII engine oil test method is also used to evaluate the SIG capabilities of multiviscosity grade 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<sup>5</sup>.

5.4.2 API Publication 1509 Engine Oil Licensing and Certification System<sup>12</sup>.

5.4.3 SAE Classification J304<sup>10</sup>.

## 6. Apparatus

6.1 Laboratory Equipment Corporation—The *document Instructions for Assembly and Disassembly of the CLR Oil Test Engine*<sup>16</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 Laboratory Equipment Corporation test engine and associated parts.

6.1.1 Test Engine can be obtain from the Laboratory Equipment Corporation (Labeco<sup>14</sup>). The test engine is known by various designations such as the Labeco engine, the CLR engine, or the Sequence VIII (as used in this test method). It is comprised of two principal units, the power section and the accessory case (Figure 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 (42.5in.<sup>3</sup>).

6.1.2 Test Bearing-An SAE H-24 alloy connecting rod bearing, Labeco 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, 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<sup>17</sup> the oil seal, connecting rod journal and main bearing journals. When refinishng a crankshaft using this 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:

S = Standard Crankshaft

C = Chrome Crankshaft

R = Reconditioned Crankshaft

6.2 Fabricated or Specially Prepared Items:

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

6.2.2 Crankcase Ventilation System - Figure 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. 2, with provisions for draining and cleaning. The volume of the rocker cover air tank shall be 3.79 to 5.68 L. The volume of the off-gas tank shall be 37.85 to 45.42 L. Fabricate both tanks from non-corrosive material. Locate the tanks as shown in Fig. 2.

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>19</sup> capable of measuring 0 to 20 L/min. An optional Dwyer rotameter, model no. RMC-101<sup>18</sup>, with a

range of 0 to 1420 SLh 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 3/8 in. inside diameter.

6.2.2.3 When a closed loop automated control system is employed, use a Badger<sup>20</sup> meter research control valve, model no. 1002-GCN36-SVCSSC-LN36<sup>21</sup>, to control the rocker cover air flow. When using a manual control system instead of the automated system, install a Swagelok 3/8 in. metering valve, part no. SS-6L<sup>45</sup>, to control the air flow into the rocker cover.

6.2.2.4 Figure 3 shows the details of the rocker cover inlet for the crankcase ventilation air. Braze one half of a 1/8-in. by 6.4-mm brass tubing connector to the cover as shown. Use 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<sup>45</sup> as shown in Fig. 2 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. 5) of the engine power section. Figure A10.1 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-□ in.<sup>22</sup>, with orifice plate, F-150-1/8 in., and a Rosemount differential pressure transducer, model no. 1151DP-3-S-22-D1B2<sup>23</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.2.

6.2.2.7 When a closed loop automated control system is employed, use a Badger<sup>20</sup> 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 3/8 inch metering valve, part no. SS-6L, to control the crankcase vacuum. Both systems are shown in Fig. 2.

6.2.2.8 Use a Vaccom<sup>24</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<sup>18</sup> Magnehelic, model 2320, or a Sensotech<sup>25</sup> pressure transducer, model no. TJE-756-05, to measure the rocker cover air pressure. Convert the measured value to in. kPa for use in off-gas measurement calculation (see 11.6.1) Locate the sensor at the inlet of the rocker cover air flow apparatus as shown in Fig. 2.

6.2.2.10 Crankcase Off-gas Inlet Pressure - Use a Dwyer<sup>18</sup> Magnehelic, model 2320, or a Sensotech<sup>25</sup> 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. 2.

6.2.2.9 Rocker Cover Air Inlet Temperature - Measure the rocker cover inlet air temperature with a 1/8 inch 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. 2.

6.2.2.10 Crankcase Off-gas Inlet Temperature - Measure the off-gas temperature with a 1/8 inch 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. 2.

6.3 Oil Filter-Install, a Racor<sup>26</sup>, Model LFS-5528 is the specified oil filter as shown in Fig. 6. Use suitable hydraulic hose and fittings<sup>27</sup>.

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



6.4 Oil Heater-Install the oil heater as shown in Fig. 7, refer to Fig. 5 for details on oil line connections. Use suitable hydraulic hose and fittings.<sup>27</sup>

6.5 Power Section Cooling System-Install a non-pressurized cooling system consisting of a heat exchanger, water pump, coolant throttling valve, sight glass, and tower. Use American Standard Schedule 40, or equivalent, 3/4-in. non-galvanized pipe fittings and apply sealant to the threads during assembly.

6.5.1 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>28</sup>.

6.5.2 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.

6.5.3 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>29</sup> part no. 1P831 has been found suitable.

6.5.4 Install a sight glass<sup>30</sup> located downstream of the cylinder head to permit detection of air entrainment.

6.5.5 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 must have a minimum capacity of 7.5 L.

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

6.5.8 Ignition System- An electronic ignition system is required. The required system is illustrated in Figs. A13.1 through A13.10. Other electronic ignition system configurations shall be reviewed and approved by the TMC and the Sequence VIII Surveillance Panel, prior to use.

#### 6.6 Instruments and Controls:

6.6.1 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, are required.

6.6.2 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.

6.6.3 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:

6.6.3.1 Calibrated (use sample gases) electronic exhaust gas analyzer. Use chart in Annex A15 to determine air-fuel ratio.

6.6.3.2 AFR Analyzer/Lambda Meter- The air fuel ratio analyzer shall meet the following specifications:

Measurement Range	AFR: 11.00 to 18.00
	with H/C = 1.85, O/C = 0.00

6.6.3.3 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.

#### 6.6.4 Pressure Measurement:

6.6.4.1 Crankcase Vacuum-As shown in Fig. 2, 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. 5 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.

6.6.4.2 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.

6.6.4.3 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.

6.6.4.4 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. 5.

6.6.5 Temperature Measurement - The test requires the accurate measurement of oil and coolant temperature. Care must be taken to assure temperature measurement accuracy. Follow the guidelines outlined by the Research Report RR:D02:1218<sup>4</sup> report.

6.6.5.1 All temperature devices shall be checked for accuracy at the temperature levels at which they are to be used. Iron-Constantin (Type J) thermocouples are specified for temperature measurement.

6.6.5.2 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 lab ambient.

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

6.6.5.4 System quality shall be adequate to permit calibration to  $\pm 0.56\text{ }^{\circ}\text{C}$  for individual thermocouples.

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

6.6.6.1 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.

6.6.6.2 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.

6.6.6.3 Oil Gallery Temperature-Measure oil gallery temperature at the front main bearing passage ( See Fig. 4). The immersion length for these thermocouples is 35 mm.

6.6.6.4 Crankcase Off-Gas Temperature Measurement- The off-gas temperature must be measured at the outlet side of the crankcase breather assembly. Fig. 2 shows a recommended system.

6.7 Procurement of Parts-Obtain information concerning the CLR Oil Test Engine (see 6.1.1) and parts from Labeco<sup>14</sup>. Users of this test method must comply with CLR Oil Test Engine Shop Manual<sup>16</sup> and the latest supplements (Information Letters and Memoranda) available from the TMC.<sup>2</sup>

## 7. Reagents and Materials

### 7.1 Cleaning Materials:

7.1.1 Abrasive Paper<sup>32</sup>, 400-, 600-, 800-grit, wet or dry,

7.1.2 Crocus Cloth<sup>32</sup>,

7.1.3 Mylar Tape<sup>32</sup>,

7.1.4 Penmul<sup>®</sup> L460<sup>33</sup>,

Note-2: **Warning Combustible. Health hazard.**

7.1.5 Pentane (Solvent), 99+ %, high-performance liquid chromatography grade,

Note-3: **Warning Flammable. Health hazard.**

7.1.6 Stoddard Solvent,<sup>34</sup> Specification D 235<sup>5</sup>, Type I, and

Note-4: **Warning Combustible. Health hazard.**

7.1.6 Tap Water, heated to 66°C to 82°C.

7.2 Expendable Power Section-Related Items:

7.2.1 Sealing Compounds- Approved sealing compounds, including pipe thread compound and gasket cement are:

7.2.1.1 Perfect Seal Sealant No. 4<sup>35</sup>,

7.2.1.2 Permatex Ultra Blue 77B<sup>35</sup>,

7.2.1.3 Permatex 3H, Permatex High Tack 99 MA<sup>35</sup>,

7.2.1.4 Dow Corning High Vacuum Grease<sup>35</sup>,

7.2.1.5 Dow Corning RTV Gray 3154<sup>35</sup>, and

7.2.1.6 Petroleum Jelly<sup>35</sup>.

7.2.2 Power Section Build-up<sup>36</sup> oil.

7.3 Power Section Coolant<sup>37</sup>- Use deionized or distilled water for the power section coolant, plus a suitable inhibitor such as Pencil<sup>37</sup> at 31 mL of Pencil 2000/L. 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 8 L (2 gal.) of reference oil is required for each reference test.

7.5 Test Fuel- The test fuel is Specified Fuels and Chemicals<sup>38</sup> KA24E Test Fuel. The specification for KA24E Test Fuel is given in Test Method DXXXX, Sequence IVA Test Procedure.

7.5.1 Fuel Batch Approval- New batches of KA24E Test Fuel are approved for use by the Sequence IVA Surveillance Panel. See Section 7, Reagents and Materials, of Test Method DXXXX, The Sequence IVA Test Procedure, for details of the fuel batch approval procedure.

7.5.2 Fuel Batch Analysis- See Section 7, Reagents and Materials, of Test Method DXXXX for information on analyses of fuel batches.

7.5.3 Laboratory Storage Tank Fuel Analysis- See Section 7, Reagents and Materials, of Test Method DXXXX for information on laboratory storage tank fuel analysis.

7.5.4 Fuel Batch Shipment and Storage- See Section 7, Reagents and Materials, of Test Method DXXXX for information on laboratory storage tank fuel analysis.

Note-6: **Warning Flammable. Health hazard.**

8.2 Test Oil 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 Instruction for Assembly and Disassembly of the CLR Oil Test Engine<sup>16</sup> 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 must be reconditioned as described in 9.4 before conducting a test. (A conditioning run on a reference oil will 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<sup>16</sup>. 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 memorandums issued by the TMC shall supersede this manual. Failure to follow the instructions provided in this document and related TMC information letters and/or memorandums 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 A15 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,

9.4.1.2 H-24 alloy connecting rod test bearing,

9.4.1.3 All gaskets, seals, and O-rings, and

9.4.1.4 All parts which are excessively worn or which 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.

9.4.2 Documented Parts-The parts supplier will provide records stating source codes and additional information such as batch code, lot number, etc. It will be the responsibility of the laboratory to maintain records documenting these parts by proper identification numbers. The parts that require documentation are:

Crankshafts, camshafts, connecting rod bearings, crankshaft main bearings, camshaft bearings, piston rings, connecting rods, pistons, and 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 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 the oil gallery side cover plate. Clean this cover plate thoroughly using Penmul<sup>33</sup> (Note 9) and a fiber brush or swab, then rinse the cover plate with tap water heated to 150 to 180°F (65.5 to 82.0°C), and rinse it again with Stoddard Solvent<sup>34</sup> (Note 9). Carefully spray the oil pump, oil pressure regulator, and distributor with Stoddard Solvent<sup>34</sup> to remove deposits. Disassemble, inspect, and clean the crankcase breather with Stoddard Solvent.

Note-8: Warning Combustible Health hazard.

9.4.3.2 Power Section-Dismantle the power section completely before each test and thoroughly clean the parts by soaking them in Penmul<sup>33</sup> 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 tap water heated (65.5 to 82.0°C) to remove all traces of Penmul, and then rinse them with Stoddard Solvent<sup>34</sup>.

Note-9: Caution Insufficient rinsing may allow Penmul carryover to the test oil causing increased severity in H-24 alloy bearing weight loss.

9.4.3.3 Alternate Methods- The above parts may be cleaned using a heated bath or temperature controlled automated parts washer, allow it to cool before assembly or measurements are taken. The proceeding, 9.4.3.4 Protection of Parts, applies to either of the methods used for parts cleaning.

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: Sludge trap, oil passages in crankshaft, in cylinder block, oil passages in crankcase, oil passages to valve lifters, oil passage to rocker assembly and 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<sup>33</sup> 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<sup>34</sup> and air dry. Prior to every test between references, the oil heater may be cleaned by circulating Stoddard Solvent<sup>34</sup> through it for 15 minutes and then air dry.

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 A11. (Fresh, clean Stoddard Solvent<sup>34</sup> and pentane shall be used for cleaning.)

Note-10: Warning Flammable. Health hazard.

9.4.4 Cylinder Liner Finishing-To minimize the effect of changes in oil consumption, a new Labeco cylinder liner shall be finished according to the honing procedure in A8. The method for finishing a used liner is at the laboratories judgement.

9.4.4.1 Cleaning Procedure and Rust Prevention-After the desired finish is achieved, spray the liner with Stoddard Solvent<sup>34</sup>, 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<sup>36</sup> until the wiping material appears clean after wiping. Coat the liner with build-up oil<sup>36</sup>.

9.4.5 Piston-to-Sleeve-Determine the piston-to-sleeve clearance in accordance with the procedure given in A6.

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 A17.

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 sand paper, standard crocus cloth<sup>32</sup>, or Mylar<sup>32</sup> 3 $\mu$  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 sand paper with build-up oil<sup>36</sup> or the Mylar<sup>32</sup> tape with Stoddard Solvent<sup>34</sup>. Wrap the strip 1-□□□ 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 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° between each traverse. Repeat four times. If sand paper is used, complete the fourth and final polishing process using crocus cloth or Mylar tape.

9.4.7.4 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. 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 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 A2, or an equivalent method approved through 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 A3 or an equivalent method approved through the ASTM Test Monitoring Center. 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 9.4.6.1 through 9.4.6.9, 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 Instruction for Assembly and Disassembly of the CLR Oil Test Engine<sup>16</sup>. If specifications do not include a  $\pm$  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 Instruction for Assembly and Disassembly of the CLR Oil Test Engine<sup>16</sup>.

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

## 10. Calibration

Note- 12 A4 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 which 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, etc. for 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 1 test; 41 to 80 h equals 2 tests; 81 to 120 h equals 3 tests, etc.

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 Test Monitoring Center and the Sequence VIII Surveillance Panel before additional test starts are conducted. Make a note on the form shown in A18.X 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 non standard Sequence VIII tests must 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 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 X1 for a more detailed presentation of the Test Monitoring Center 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>39</sup>). The test data sheet for test reports on engine oils other than reference oils (See Fig. A16.3) 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., etc.) may be solicited to help determine the cause and extent of the problem.

10.1.4.3(a) 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.

10.1.4.3(b) 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.

10.1.4.3(c) 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,

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 Calibration of torque wrenches is required 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 ½-h flush:

11.1.1 Install the Racor oil filter bypassing the oil heater. Use a new/clean filter screen (28 micron) for each new test run-in.

11.1.2 Charge the power section with 2840.0 ml of fresh test oil. Record the date and time the oil is poured into the engine, this is 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 A9.

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 a minimum of hourly using a form of the type shown in Fig. A5.

11.1.4 Shut down the power section after 4 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. 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. 6).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 1660.0 ml of fresh test oil. Prior to starting the engine and any restarts during the ½-h flush, perform the Oil Priming Procedure in A9.

11.1.7 Flush the power section for ½ 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. A6.1 and A6.2.

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.

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 minutes. Replace or clean the filter screen in the Racor filter<sup>26</sup>. An alternate method of having two Racor filters<sup>26</sup> is allowable, one used for run-in and flush and another for test.

11.2 Test Operating Conditions- Throughout the remainder of the test, operate the power section under the conditions shown in Table 2.

11.2.1 Downtime During the 40-h test conditions-During the first 10-h of test conditions only one shutdown or one emergency shutdown is allowed and the total off-test time shall not exceed 2 h. During the forty-h test, no more than 6 h of off-test time are allowed. During the 40-h of test conditions no more than two emergency shutdowns are allowed and no more than four total shutdowns are allowed.

11.2.2 Warm-up Schedule-Charge the power section with 1660.0 ml of fresh test oil. Prior to starting the engine and any restart during the forty-h test, perform the Oil Priming Procedure in A9. Start the engine and bring engine speed up to 3150r/min. Follow the schedule in Table 3. When restarting the power section after any unscheduled or emergency shut

downs, start the warmup at the oil gallery temperature recorded when the engine is re-started and adjust the heater wattage or temperature set point, in accordance with Table 3. For example, if the oil gallery temperature is 123.9 °C when the engine is restarted, set the warm-up condition at 1900 watts or 132.2 °C for 10 minutes as shown in Table 3. The warmup shall proceed from this point and continue with the required steps in Table 3.

11.3 Air-Fuel Ratio and Spark Advance-Record and Adjust if necessary the air-fuel ratio and spark advance at h 1, 10, 20 and 30. This is the minimum requirement, additional readings are permitted. When determining the air-fuel ratio using the exhaust gas analysis measured by the calibrated electronic method, utilize Figure A14.1 in A14.

#### 11.4 Rocker Cover Air, Off-gas, and Blowby Measurement

11.4.1 Adjust the rocker cover air control valve as needed to achieve  $850 \pm 28$  Standard Liters Hour (SLH) off-gas. Observe and record the rocker cover air flow reading in SLH after the off-gas flow has been adjusted to  $850 \pm 28$  SLH. Convert the observation to standard conditions (101.3 kPa and 21°C) as follows:

$$SLH = ALH * [((BARO + GAS)/101.32 \text{ kPa}) * (294.26 \text{ K} / TEMP)]$$

where:

SLH – Off-gas in Standard Liters per Hour

ALH – actual measured Off-gas, measured in Liters per Hour

BARO - barometer reading in kPa.

GAS - gauge pressure at inlet of the off-gas measuring device in kPa

TEMP. - temperature at the inlet of the off-gas measuring device, in K

11.4.1.2 Adjust the rocker cover air control valve as needed to achieve  $850 \pm 28$  SLH off-gas.

11.4.1.3 Observe and record the rocker cover air flow reading in SLH after the off-gas flow has been adjusted to  $850 \pm 28$  SLH off-gas.

11.4.2. Blowby is the difference between the standardized off-gas flow measurement and the standardized rocker cover airflow measurement.

11.5 Unscheduled Shut Downs- There are no scheduled shut downs during the 40-h at test conditions. When possible, unscheduled shut downs are to follow the procedure below. If the following procedure is not complied with the shut down is considered an emergency shut down.

11.5.1 Turn off the oil heater and idle the power section at 1500 r/min for 10 min. (This action prevents overheating of the oil in the heater.) Allow the rocker cover fresh air input to remain on. Turn off the ignition to stop the engine. It is also acceptable to disconnect the fuel supply and allow the engine to idle to a stop before turning off the ignition. Move the piston to TDC on the compression stroke.

11.6 Oil Sampling and Oil Addition-After h 10, 20 and 30-h at test conditions, take oil purge, samples and make additions as directed in the following sections.

11.6.1 Purge 60.0 ml of the engine oil into a beaker.

11.6.2 Take a 180.0 ml sample (same location as purge).

11.6.3 Add 240.0 ml of new oil into the engine along with the original purge (60.0 ml).

#### 11.7 Periodic Measurements:

11.7.1 Record, using the data log sheet shown in Fig. A6.2, the following data hourly:

11.7.1.1 Engine speed, r/min,

- 11.7.1.2 Engine load, kW,
- 11.7.1.3 Fuel flow, kg/h,
- 11.7.1.4 Oil gallery temperature, °C,
- 11.7.1.5 Oil heater input, W, (Only if used to control temp)
- 11.7.1.6 Jacket inlet coolant temperature, °C,
- 11.7.1.7 Jacket outlet coolant temperature, °C,
- 11.7.1.8 Oil pressure, kPa,
- 11.7.1.9 Crankcase vacuum, kPa,
- 11.7.1.10 Exhaust back pressure, kPa,
- 11.7.1.11 Intake air temperature, °C,
- 11.7.1.12 Intake manifold vacuum, kPa,
- 11.7.1.13 Crankcase off-gas, SL/h,
- 11.7.1.14 Rocker cover fresh air flow, m<sup>3</sup>/s, and,
- 11.7.1.15 Blowby, AL/h.

11.7.2 Record the following data at test h 1, 10, 20 and 30:

- 11.7.2.1 Air-fuel ratio, and,
- 11.7.2.2 Spark advance.

11.8 Final Drain and Oil Consumption Computation-At the completion of the 40<sup>th</sup> test hour, shut down the engine (see 11.5 ). Immediately move the piston to TDC on the compression stroke, and drain crankcase, Racor filter and oil heater. Leave the rocker cover air supply on and remove the breather tube to insure a proper drain. Measure and record the amount of oil drained. The maximum allowable oil consumption is 778 ml.

11.9 Operational Validity Criteria-The test laboratory is responsible for determining and documenting the operational validity of every engine test. In order for a test to be operationally valid, the Deviation Percentage criteria defined in 11.9.1 shall be met. In addition, the test stand, test operation, and test build-up shall conform with the published procedure/standard.

11.9.1 Deviation Percentage-Calculate the deviation percentage using the equation:

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

where:

- DP=Deviation percentage,
- M<sub>i</sub> = Magnitude of test-parameter deviation from specification limit at occurrence i,
- R = Test parameter specification range,
- T<sub>i</sub> = Length of time that test parameter was outside of specification range at occurrence i,
- n = Number of times that a test parameter deviated from test specifications limits, and

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

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

11.9.1.1 Invalidate any tests exceeding the following deviation percentages:

Primary Test Parameter, 2.5 %

Secondary Test Parameter, 5.0 %

*Primary Parameters;*

Fuel flow

Crankcase off gas

Oil gallery temperature

Coolant out temperature

Coolant delta temperature

Oil pressure

*Secondary Parameters;*

Speed

AFR

Spark advance

Exhaust pressure

Crankcase vacuum

11.10 Test Completion - Defined the end of test (EOT) time as 25 minutes after the fortieth test hour.

## 12. Determination of Test Results

### 12.1 Oil Sample Analysis:

12.1.1 Determine the viscosity of the new oil and 10 h sample at 40 and 100 °C.

12.1.2 To determine the viscosity stability of a multiviscosity-graded oil, measure the stripped viscosity of a 10-h sample of used oil. See the A16 for the specified measurement method.

12.2 Test Bearing Weight Loss Determination-Record, in milligrams, the weights of the top and bottom connecting rod test bearing halves within 4 h of conclusion of the test. If this determination is delayed longer than 4 h, the test is invalid. Clean each test bearing half, as described in A12, before weighing. Determine the weight loss of the bearing to the nearest 0.1 mg by subtracting from the initial weights recorded prior to power section run-in.

12.2.1 If applicable adjust the total bearing weight loss, according to the procedure in A7. Record the Severity Adjustments (SA) in Fig. X3.4.1.

## 13. Report

13.1 The forms required for inclusion in the test report are presented in A 18. Editorial conventions concerning the preparation of standard report forms shall be determined through contact with the TMC.

13.2 Use forms 1, 2, 4, 5, 6, 7, and 8 (See Figs. A18.1, A18.2, A18.4, A18.5, A18.6, A18.7, and A18.8) for initial transmission of reference oil tests to the TMC.

## 14. Precision Validity and Bias

14.1 Precision - Test precision is established on the basis of reference oil test results (for operationally-valid tests) monitored by the TMC. The data are reviewed semi-annually by the Sequence VIII Surveillance Panel. Contact the TMC for current industry data.

14.1.1 Test precision as established for the official acceptance of this procedure is shown in Table 4.

Note 18: Contact the TMC for up-to-date data.

14.1.2 Intermediate Precision (formerly called Repeatability) - This is defined as the difference between two results obtained on the same test oil, using the same test method in the same laboratory.

14.1.3 Reproducibility (R) - This is defined as the difference between two single and independent results obtained by different operators working in different laboratories on the same oil would, in the long run, in the normal and correct conduct of the test method, exceed the values shown in Table 5, in only one case in twenty.

14.2 Validity - The following guidelines provide a basis for judgements regarding the validity or validity of test results. The ASTM Test Monitoring Center administers reference test requirements utilizing these and other guidelines.

14.2.1 Power section/test stand Calibration Status - The essential requirements of Section 10 provide the basis for official recognition of test stand calibration.

14.2.2 Validity Interpretation of Deviant Operational Conditions - In the general case, engineering judgement at the laboratory governs the validity acceptance of tests having deviant operational history. The Test Monitoring Center is involved in this process for tests conducted using reference oils and is available for consultation for tests conducted on non-reference oils. Section 11.11 describes details operational validity.

14.3 Bias - Bias is determined by applying an acceptable statistical technique to reference oil test results and when a significant bias is determined, a severity adjustment is permitted for non-reference oil test results.

14.3.1 While no estimate of bias for this procedure is currently available, a bias for the total bearing weight loss obtained in one laboratory relative to those obtained in other laboratories may exist. See A7 for the method of determining the magnitude of, and dealing with, such bias.

## 15. Use of ASTM Rounding

15.1 Follow Practice E 294 (6.4 - 6.5) guidelines for rounding of test results, operational parameters, and engine build-up measurements.

## 16. Keywords

16.1 bearing weight loss; CLR oil test engine; copper-lead bearings; engine oil; Sequence VIII test; oil consumption; shear stability;

## **ANNEXES (Mandatory Information)**

**A1.** *{Annex deleted}*

## **A2. MEASUREMENT OF CONNECTING ROD BEARING CLEARANCE AND JOURNAL TAPER**

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

A2.2 Use measuring tools having an accuracy of at least 0.003 mm.

A2.3 Thoroughly clean the connecting rod bore with Stoddard Solvent and air dry. Use caution not to affect the original surface. Clean the connecting rod bearings according to Annex A11, step A11.1 only. Install the rod bearing halves that are to be used in the test into the proper location (top and bottom as marked). Place the connecting rod into a holding device clamping as close as possible to the large end of the connecting rod to prevent the rod from being twisted during the torquing procedure. Install lower bearing cap and apply 61 N·m torque to the bearing cap bolts.

A2.4 Measure the connecting rod bearing vertical diameter at the two points A and B indicated in Fig. A2.1. Each of the points is located 6.4 mm from each bearing edge. Record the measurements in the appropriate spaces in a table such as Table A2.1. Immediately return the connecting rod bearings to the original container filled with build-up oil after measurements are performed.

A2.5 Mount the crankshaft on a workbench with the axis horizontal and with the connecting rod bearing journal vertically upward, simulating the top-dead-center position in the engine.

A2.6 Measure the diameter of the connecting rod bearing journal of the crankshaft at the points  $A_1$ ,  $B_1$ ,  $A_2$ , and  $B_2$  indicated in Fig. A1.1. The measuring points are located 9.5 mm from each thrust face. Record the measurements in the appropriate spaces in a table such as Table A2.1.

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

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

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

## **A3. MEASUREMENT OF MAIN BEARING CLEARANCE**

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

A3.2 Use measuring tools having an accuracy of at least 0.003 mm.

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

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

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

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

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

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

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

**Table A3.1 Crankshaft Main Bearing Clearance**

Front Main Bearing <sup>A</sup>				Rear Main Bearing <sup>A</sup>			
A		B		A		B	
$A_1$		$B_1$		$A_1$		$B_1$	
$A_2$		$B_2$		$A_2$		$B_2$	
$A - A_1$		$B - B_1$		$A - A_1$		$B - B_1$	
$A - A_2$		$B - B_2$		$A - A_2$		$B - B_2$	
Min		Max		Min		Max	

<sup>A</sup> Diameters  $A_1$  and  $B_1$  are measured at points  $90^\circ$  from  $A_2$  and  $B_2$ , respectively.

#### **A4. THE ASTM TEST MONITORING CENTER CALIBRATION PROGRAM**

##### **A4.1 Conducting a Reference Oil Test:**

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

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

A4.2 New Laboratories-Laboratories wishing to become a part of the ASTM Test Monitoring System will be requested to generate both blind and non-blind tests to ensure that the laboratory is using the proper testing techniques. Information concerning fees, laboratory inspection, reagents, testing practices, appropriate committee membership, and rater training can be obtained by contacting the Test Monitoring Center Administrator.<sup>2</sup>

A4.3 Introducing New Sequence VIII Reference Oils-The calibrating reference oils produce various copper-lead bearing weight loss and deposit characteristics. When new reference oils are selected, member laboratories will be requested to conduct their share of tests to enable the TMC to establish the proper industry average and test acceptance limits. The ASTM D02.B0.01 Sequence VIII Surveillance Panel requires a minimum of four tests to be conducted prior to establishing the industry average and test acceptance targets for new reference oils. The TMC estimates that laboratories will be requested to run an average of one contributing test per year for each eight test power sections operated throughout the year.

#### A4.4 TMC Information Letters:

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

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

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

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

**A5.** *{Annex deleted}*

#### **A6. MEASUREMENT OF PISTON-TO-SLEEVE CLEARANCE**

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

A6.2 Use measuring tools having an accuracy of at least 0.003 mm.

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

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

A6.5 Heat the piston so that the piston pin can be installed without using any force. Do not exceed 65.5 °C piston temperature. Allow the piston to return to room temperature before measuring. Measure the piston skirt at the middle and bottom of the skirt as indicated in Fig. A6.2. Record the measurements in the appropriate spaces in a table such as Table A6.1.

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

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

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

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



A6.10 Calculate the piston taper according to Table A6.1.

A6.11 Calculate the piston-to-sleeve clearance according to Table A6.1.

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

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

A7.1 Complete information on the control chart technique is available in the Lubricant Test Monitoring System, available from the ASTM Test Monitoring Center.

## **A8. NEW LINER HONING PROCEDURE**

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

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

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

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

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

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

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

A8.8 This procedure is to be used only for initial new liner honing. For used liners, see Section 9.4.4 of the Sequence VIII Procedure, Test Method D XXXX.

## **A9. SEQUENCE VIII OIL PRIMING PROCEDURE**

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

A9.2 Disconnect the fuel supply.

A9.3 Remove the spark plug.

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

A9.5 Cease motoring and reinstall the spark plug.

A9.6 Start the engine.

## **A10. ALTERNATIVE CRANKCASE BREATHER CONFIGURATION**

### **A11. CONNECTING ROD BEARING CLEANING PROCEDURE**

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

A11.2 Dip the bearing halves in pentane (Note 11).

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

A11.4 Remove bearing halves from the vacuum desiccator and inspect for any traces of residue. Repeat steps A10.1 through A10.3 if any residue is evident.

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

A11.6 Coat the bearing halves with Build-up oil.

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

### **A12. SEQUENCE VIII ELECTRONIC IGNITION CONVERSION PROCEDURE**

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

A12.1.1 Ford distributor assembly,<sup>40</sup> part number D7EE-12127DA.

A12.1.2 Ford wiring harness,<sup>40</sup> part number D7JL-12A200A.

A12.1.3 Ford module,<sup>40</sup> part number D9VZ-12A199A.

A12.1.4 Ford stator assembly,<sup>40</sup> part number D5TZ-12A122A.

A12.1.5 Ford ignition coil,<sup>40</sup> part number D5AZ-12029-A.

A12.1.6 GM flat washer,<sup>41</sup> part number 1984361.

A12.1.7 Nylon flat washer,<sup>42</sup> part number 98160-0.62.

A12.1.8 Fabricated distributor shaft.<sup>43</sup>

A12.1.9 Fabricated hold down assembly.<sup>43</sup>

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

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

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

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

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

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

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

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

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

A12.11 Fabricate the distributor shaft as shown in Fig. A12.7. The shaft may also be purchased from Texas Tool Makers, Incorporated.<sup>4</sup>

A12.12 Fabricate the hold down assembly as shown in Figs. A12.8 and A12.9. The hold down assembly may also be purchased from Texas Tool Makers, Incorporated.<sup>4</sup>

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

### **A13. SYSTEM RESPONSE PROCEDURE**

A13.1 Temperatures-Remove the thermocouples from the engine locations as specified in Section 6.3.5. Allow the thermocouples to stabilize at ambient conditions, then insert them into a bucket of ice water. Record the time it takes the thermocouple to reach 63% of its final value.

A13.2 Pressures and Vacuums-First perform a leak-down on the measurement system to ensure there are no air leaks by following the test below:

A13.2.1 Disconnect the sensor lines at the engine locations as specified in Section 6.3.4. Connect an air line to the sensor line and pressurize the line slightly above the specified range required (test specification). Isolate the air pressure in the sensor line and remove the source from the sensor line. If the system leaks down, repair the leak before proceeding.

A13.2.2 After completion of the leak down step, determine the system response. Connect an air line to the sensor line and pressurize the system to the specified mean range. Let the system stabilize, then quickly release pressure, record the time to reach 63% of its final value.

A13.2.3 For vacuums, follow the above procedure replacing air pressure with vacuum.

### A13.3 Fuel Flow

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

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

A13.4 Speed- Using a frequency counter, inject a frequency so that the system readout stabilizes at the test specified mean value. Use a frequency device to determine the engine speed. Disconnect the frequency device, measure and record the time required to reach 63% of the final value.

A13.5 Load -Place a weight on a measurement device and let reading stabilize. Quickly remove the weight, measure and record the time required to reach 63% of the final value. Weights used shall represent the normal readout value. For manual measurements a stopwatch with 0.1 second increments is required.

## A14. AIR-FUEL RATIO MEASUREMENT

Correct carbon monoxide (CO) or carbon dioxide (CO<sub>2</sub>) measurements to an oxygen-free basis, using the formulas below, prior to determining air-fuel ratio. Use corrected CO or CO<sub>2</sub> value and Figure A14.1 to determine air-fuel ratio.

$$\frac{\text{Observed Percent } CO_2 * 100}{100 - 5(\text{Observed Percent } O_2)} = \text{Corrected } CO_2$$

$$\frac{\text{Observed Percent } CO * 100}{100 - 5(\text{Observed Percent } O_2)} = \text{Corrected } CO$$

## A15 LEAD DECONTAMINATION PARTS/PROCEDURE

A15.1 The following procedure is to be used for lead decontamination of CLR test engine that previously ran using a lead base fuel.

A15.1.2 Parts to be cleaned:

- A15.1.2.1 Inside of crankcase
- A15.1.2.2 Bottom of cylinder jug assembly
- A15.1.2.3 Cylinder head assembly
- A15.1.2.4 Inside of intake manifold
- A15.1.2.5 All crankcase cover plates (front and both sides)
- A15.1.2.6 Oil pan
- A15.1.2.7 Rocker cover
- A15.1.2.8 Oil heater and canister
- A15.1.2.9 Blowby tube assembly
- A15.1.2.10 Camshaft and gear
- A15.1.2.11 Crankshaft and gear
- A15.1.2.12 Oil pump assembly

A15.1.2.13 Any other parts that may have come in contact with lead.

A15.2 Reagents:

A15.2.1 1:3 mixture of hydrochloric acid to deionized water

A15.2.2 1:8 mixture of baking soda and water

*Note: Lab shall establish proper safety procedures for handling and disposal of these reagents.*

A15.3 Cleaning Procedure

A15.3.1 Prior to acid cleaning all parts shall have all sludge and varnish deposits removed.

A15.3.2 Using a lint free towel or parts washing brush apply the 1:3 mixture of hydrochloric acid and deionized water to all parts.

A15.3.3 Apply 1:8 mixture of baking soda and water after approximately 60 seconds.

A15.3.4 It is recommended to repeat A15.3.2 and A15.3.3.

A15.3.5 Apply the build-up oil to insure that rust does not form.

A15.3.6 Clean engine according to procedure either method in 9.4.2 may be used.

A15.4 Future Cleaning after Lead Decontamination

A15.4.1 Once the engine parts have been decontaminated they must be processed in a lead free environment. If they were to come into contact with a lead contaminated cleaning material or run using a fuel containing  $\leq 0.01$  gm/gal of lead they would require that the lead decontamination cleaning procedure be repeated.

**A16. STAY IN GRADE OIL ANALYSIS PROCEDURE**

A16.1 Determine the ability for the test oil (multiviscosity oils only) to stay in grade by measuring the shear stability using the following method.

A16.1.1 Weigh 25 grams of the test oil sample taken at 10 hours into a 50 mL three-necked round bottom flask equipped with a thermometer, gas inlet tube, stirrer and distillation side arm.

A16.1.2 Heat the sample at  $120 \pm 5$  °C in a vacuum of 100 mm of mercury with a nitrogen sparge for one hour. Warmup time to meet the specified temperature shall not be considered as part of the one hour.

A16.1.3 Filter the stripped sample through a 0.5 micron filter pad.

A16.1.4 Determine the kinematic viscosity at 100 °C of the filtered sample using ASTM D455.

**A17. CRANKSHAFT REAR SEAL CONDITIONING PROCEDURE**

A17.1 The following procedure is for preparation of the rear oil seal crankshaft surface. This is to help prevent rear seal related oil leaks.

A17.1.1 Prepare a 25.4 mm wide and 600 mm long section 120 grit abrasive paper.

A17.1.2 Looking from the back of the crankshaft forward, the paper is moved across the seal surface in a counter-clockwise direction with a front to back motion using a spiraling motion that produces scratches with a approximate  $5^0$  to  $10^0$

helix angle. Between 5 to 10 strokes shall produce the proper surface finish.

A17.1.3 Using 9.4.7.10, clean the crankshaft to insure that no abrasive remains on the crankshaft.

**A18 SEQUENCE VIII ENGINE TEST EVALUATION FORMS**

## **A19. DATA DICTIONARY**



## APPENDIXES

(Non Mandatory Information)

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

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

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

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

### X2. SUGGESTED METHOD FOR SALVAGING CAMSHAFT BEARING JOURNALS

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

X2.1.1 Build up material on the journals by flame spraying. The following material has proven successful:  
Met-Caloy Number 2<sup>44</sup> (mass percent) 0.32 % carbon 0.50 % silicon 0.50 % magnesium 0.02 % phosphorus 0.02 % sulfur  
13.5 % chrome Balance-iron

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

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

### X3. Data Log Sheets

X3.1 Examples of suitable log sheets are shown in Fig. X3.1 and X3.2.

Foot Notes:

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.B0.01 on Passenger Car Engine Oils.

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

<sup>3</sup> Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096.

<sup>4</sup> Documents available from: ASTM, 1916 Race Street, Philadelphia, PA 19103.

<sup>5</sup> Annual Book of ASTM Standards, Vol 05.01.

<sup>6</sup> Annual Book of ASTM Standards, Vol 05.04.

- <sup>7</sup> Annual Book of ASTM Standards, Vol 05.02.
- <sup>8</sup> Annual Book of ASTM Standards, Vol 14.02.
- <sup>9</sup> Annual Book of ASTM Standards, Vol 03.03.
- <sup>10</sup> Order SAE Handbook Vol 3, from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001. This standard is not available separately.
- <sup>12</sup> API, 1220 L Street, Washington, D.C. 20005
- <sup>13</sup> Standardization Documents, Order Desk, Bldg. 4, Section D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Attention: NPODS.
- <sup>14</sup> Laboratory Equipment Corporation (Labeco), 156 E. Harrison Street, Mooresville, IN 46158.
- <sup>16</sup> Refer to Instructions for Assembly and Disassembly of the CLR Oil Test Engine, available from: Laboratory Equipment Corporation (Labeco), 156 E. Harrison Street, Mooresville, IN 46158.
- <sup>17</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, telephone (216) 354-7007, fax (216) 354-7080. 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, which you may attend. Chrome plating of crankshaft journals by other vendors is not permitted at this time.
- <sup>18</sup> Dwyer instrumentation may be obtained from Dwyer Instruments Inc., P.O. Box 60725, Houston, TX 77205, (713) 446-1146.
- <sup>19</sup> Sierra Side Track flow meters are available from Sierra Instruments Inc., 5 Harris Court, Building L, Monterey, CA 93940, (800) 866-0200.
- <sup>20</sup> Badger valves are available from Badger Meter Industrial Division, 6116 East 15th Street, P.O. Box 581390, Tulsa, OK 74158-1390, (918) 836-8411.
- <sup>21</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>22</sup> Daniels flow sections are available from Daniel Flow Products Inc., Flow Measurement Products Division, P.O. Box 19097, Houston, TX 77224, (713) 467-6000, FAX (713) 827-3880.
- <sup>23</sup> Rosemount transducers are available from Rosemount Inc., 4001 Greenbriar, Suite 150B, Stafford, TX 77477, (713) 274-0500.
- <sup>24</sup> Vaccom aspirators are available from McKenzie Air Industries, 18523 IH 35 North, Shertz, TX 78108, (210) 606-1240.
- <sup>25</sup> Sensotec transducers are available from Sensotec Inc., 1200 Chesapeake Avenue, Columbus, OH 43212, (800) 848-6564.
- <sup>26</sup> Parker Hannifin Corp., Racor Division, (800) 344-3286
- <sup>27</sup> Aeroquip 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.
- <sup>28</sup> Available from Compressor Engineering, 625 District Drive, Itasca, IL 60143.
- <sup>29</sup> Grainger national branch location.

<sup>30</sup> A sight glass of this type, suitable for this application, is available as Gitts-Part Number 3063-27, from Edward Fisher Company, 2118 S. Wabash, Chicago, IL 60616.

<sup>31</sup>

<sup>32</sup> The sand paper and Mylar tape may be obtained from many commercial sources.

<sup>33</sup> Penmul L460 is a registered trademark of, and is available from Penetone Corporation, 7400 Hudson Ave., Tenafly, NJ 07670.

<sup>34</sup> Stoddard Solvent, Specification D 235, Type I, is available from petroleum solvent suppliers.

<sup>35</sup> These may be obtained from many commercial sources.

<sup>36</sup> Noncompounded oil ISO VG 46 (SAE 20) (see Classification D 2422) is available through lubricant marketers. One supplier is Mobil Oil Corporation. The Mobil product is designated EF-411, and is available from Mobil Oil Corporation, P.O. Box 66940, AMF O'Hare, IL 60666, Attention: Illinois Order Board. Telephone 1-800-662-4547. Ask for P/N 47503-8.

<sup>37</sup> The sole source of supply of Pencool 2000 known to the committee at this time is The Penray Companies, Inc., 1801 Estes Avenue, 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, which you may attend.

<sup>38</sup> Specified Fuels KA24E Test Fuel is available from Specified Fuels and Chemicals, Phone 281-457-2768.

<sup>39</sup> The document Lubricant Test Monitoring System is available from the TMC.

<sup>40</sup> May be purchased from any Ford dealership.

<sup>41</sup> May be purchased from any General Motors dealership.

<sup>42</sup> May be purchased from Accurate Screw Machine Company, 19 Baltimore Street, Nutley, NJ 07110.

<sup>43</sup> May be purchased from Texas Tool Makers, Incorporated, San Antonio, TX 78216.

<sup>44</sup> Met-Caloy Number 2 can be obtained from Metco, Inc., 1101 Prospect Avenue, Westbury, NY 11590. Telephone: (516) 334-1300.

<sup>45</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. Telephone: (708) 833-0300.

<sup>46</sup> May be obtained from many commercial sources

**Table 1 Power Section Run-In Schedule**

Speed, r/min ( $\pm 25$ )	1500	2000	2500	3150
Load:w ( $\pm 150$ )	1490	2980	3730	3730
Spark Advance, °BTDC ( $\pm 1$ )	25	25	35	35
Time, min	60	60	60	60
Total Time, h	1	2	3	4

**Table 2 Test Operating Conditions**

<b>Item</b>		<b>Setting</b>
Speed, r/min		3150 ± 25
Load, kW		Adjust load to provide proper fuel flow at specified air-fuel ratio.
Fuel flow, kg/h		2.25 ± 0.11
Air-fuel ratio		13.43 ± 0.5
Jacket outlet coolant Temperature, °C		93.5 ± 1
Delta between jacket (inlet & outlet) temperatures, °C		5.6 ± 1
Gallery oil temperature, °C:	SAE 10W	135.0 ± 1
	SAE 20, 30, 40, 50, and multiviscosity-graded oils	143.5 ± 1
Spark advance, degrees BTDC		35 ± 1
Oil pressure, kPa		276 ± 14
Crankcase vacuum, kPa		0.50 ± .12
Exhaust back pressure, kPa		0 to 3.4
Crankcase off-gas, SCL/h		850 ± 28
Blowby, SCL/h		Record

**TABLE 3 Power Section Warm-up Schedule**

Time, min	Total time, min <sup>A</sup>	Heater Wattage <sup>B</sup>	Temperature Set Point <sup>B</sup>
15	15	1000	101.7 °C
10	25	1300	112.8 °C
10	35	1600	123.9 °C
10	45	1900	132.8 °C
15	60	2200, if needed	135.0 °C or 143.5 °C <sup>C</sup>

<sup>A</sup> Steady-state test time does not include warm-up time; rather, it begins only when the specified oil gallery temperature is reached.

<sup>B</sup> Either heater wattage or temperature set point control may be used for warm-up operation.

<sup>C</sup> As appropriate for test oil viscosity grade. See Table 2.

**TABLE 4 L-38 Reference Oil Test Precision Data**

*{To be determined}*