Designation: D 5533 – 98$^{\epsilon 1}$

An American National Standard

Standard Test Method for Evaluation of Automotive Engine Oils in the Sequence IIIE, Spark-Ignition Engine[1]

This standard is issued under the fixed designation D 5533; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

ϵ[1] NOTE—Figure 15 was deleted and Figs. 14 and 17 were corrected editorially in March 1999.

INTRODUCTION

The test method described in this standard can be used by any properly equipped laboratory, without the assistance of anyone not associated with that laboratory. However, the ASTM Test Monitoring Center (TMC) [2] provides reference oils and an assessment of the test results obtained on those oils by the laboratory (see Annex A1). By this means, the laboratory will know whether their use of the test method gives results statistically similar to those obtained by other laboratories. Furthermore, various agencies require that a laboratory utilize the TMC services in seeking qualification of oils against specifications. For example, the U.S. Army imposes such a requirement, in connection with several Army engine lubricating oil specifications.

Accordingly, this test method is written for use by laboratories which utilize the TMC services. Laboratories which 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 Annex A1). Users of this test method shall contact the ASTM Test Monitoring Center to obtain the most recent of these.

1. Scope

1.1 This test method covers an engine test procedure for evaluating automotive engine oils for certain high-temperature performance characteristics, including oil thickening, sludge and varnish deposition, and oil consumption, as well as engine wear. Such oils include both single viscosity grade and multiviscosity grade oils which are used in both spark-ignition, gasoline-fueled engines, as well as in diesel engines. [2]

NOTE 1—Companion test methods used to evaluate engine oil performance for specification requirements are discussed in SAE J304.

1.2 The values stated in either acceptable SI units or in other units shall be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other, without combining values in any way.

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 This test method is arranged as follows:

[1] 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.

The multi-cylinder engine test sequences were originally developed in 1956 by an ASTM Committee D-2 group. Subsequently, the procedures were published in an ASTM special technical publication. The Sequence IIIE method was published as Research Report RR:D02-1225, dated April 1, 1988.

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[2] ASTM Test Monitoring Center, 6555 Penn Ave., Pittsburgh, PA 15206-4489. For other information, refer to Research Report RR:D02-1225 Multicylinder Test Sequences for Evaluating Automotive Engine Oils—Part 2 Sequence IIIE. This research report and this test method are supplemented by Information Letters and memoranda issued by the ASTM Test Monitoring Center. This edition incorporates revisions in all information letters through No. 98–1.

2. Referenced Documents

2.1 *ASTM Standards:*

D 16 Definitions of Terms Relating to Paint, Varnish, Lacquer, and Related Products[3]

D 86 Test Method for Distillation of Petroleum Products[4]

D 130 Test Method for Detection of Copper Corrosion from Petroleum Products by the Copper Strip Tarnish Test[4]

D 156 Test Method for Saybolt Color of Petroleum Products (Saybolt Chromometer Method)[4]

D 235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)[5]

D 287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)[4]

D 323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)[4]

D 381 Test Method for Existent Gum in Fuels by Jet Evaporation[4]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)[4]

D 525 Test Method for Oxidation Stability of Gasoline (Induction Period Method)[4]

D 1266 Test Method for Sulfur in Petroleum Products (Lamp Method)[4]

D 2422 Classification of Industrial Fluid Lubricants by Viscosity System[4]

D 2699 Test Method for Knock Characteristics of Motor Fuels by the Research Method[6]

D 2700 Test Method for Knock Characteristics of Motor and Aviation Fuels by the Motor Method[6]

D 2982 Test Methods for Detecting Glycol-Base Antifreeze in Used Lubricating Oils[7]

D 3237 Test Method for Lead in Gasoline by Atomic Absorption Spectrometry[7]

D 4175 Terminology Relating to Petroleum, Petroleum Products, and Lubricants[7]

D 4485 Specification for Performance of Engine Oils[7]

D 5119 Test Method for Evaluation of Automotive Engine Oils in the CRC L-38 Spark-Ignition Engine[8]

D 5302 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Deposit Formation and Wear in a Spark-Ignition Internal Combustion Engine Fueled with Gasoline and Operated Under Low-Temperature, Light-Duty Conditions[8]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[9]

E 270 Definitions of Terms Relating Liquid Penetrant Examination[10]

E 344 Terminology Relating to Thermometry and Hydrometry[11]

E 380 Practice for Use of the International System of Units (SI)[9] (The Modernized Metric System)

E 1119 Specification for Industrial Grade Ethylene Glycol[12]

G 40 Terminology Relating to Wear and Erosion[13]

2.2 *Military Specification:*[14]

MIL-L-2104, Lubricating Oil, Internal Combustion Engine, Tactical Service

2.3 *SAE Standards:*[15]

J183, Engine Oil Performance and Engine Service Classification (Other Than "Energy-Conserving")

J304, Engine Oil Tests

3. Terminology

3.1 *Definitions:*

3.1.1 *blowby, n—in internal combustion engines*, the combustion products and unburned air-and-fuel mixture that enter the crankcase.

3.1.2 *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.

3.1.3 *calibrate, v*—to determine the indication or output of a measuring device with respect to that of a standard. **E 344**

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

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

3.1.6 *debris, n—in internal combustion engines*, solid contaminant materials unintentionally introduced into the engine or resulting from wear.

3.1.7 *engine oil, n*—a liquid that reduces friction or wear, or both, between the moving parts within an engine, and also serves as a coolant. **D 4485**

3.1.8 *free piston ring, n— in internal combustion engines*, a piston ring which will fall in its groove under the force of its own weight when the piston is moved from a vertical (axis orientation) to a horizontal position.

[3] *Annual Book of ASTM Standards*, Vol 06.01.
[4] *Annual Book of ASTM Standards*, Vol 05.01.
[5] *Annual Book of ASTM Standards*, Vol 06.04.
[6] *Annual Book of ASTM Standards*, Vol 05.04.
[7] *Annual Book of ASTM Standards*, Vol 05.02.
[8] *Annual Book of ASTM Standards*, Vol 05.03.
[9] *Annual Book of ASTM Standards*, Vol 14.02.
[10] Discontinued, see 1991 *Annual Book of ASTM Standards*, Vol 03.03.
[11] *Annual Book of ASTM Standards*, Vol 14.03.
[12] *Annual Book of ASTM Standards*, Vol 15.05.
[13] *Annual Book of ASTM Standards*, Vol 03.02.
[14] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.
[15] Available from Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096-0001. These standards are not available separately. Order either the SAE Handbook Vol 3, or the SAE Fuels and Lubricants Standards Manual HS-23.

3.1.8.1 *Discussion*—In determining this condition, the ring may be touched slightly to overcome static friction.

3.1.9 *lubricant*, *n*—any material interposed between two surfaces that reduces the friction or wear, or both, between them.

3.1.10 *noncompounded engine oil*, *n*—a lubricating oil having a viscosity within the range of viscosities of oils normally used in engines, and that may contain anti-foam agents or pour depressants, or both, but not other additives. **D 5119**

3.1.11 *non-reference oil*, *n*—any oil other than a reference oil; such as a research formulation, commercial oil, or candidate oil. **Subcommittee B Glossary**[16]

3.1.12 *oxidation*, *n*—*of engine oil*, the deterioration of the oil which is observed as increased viscosity, sludge formation, varnish formation, or a combination thereof, as a result of chemical and mechanical action. **D 5119**

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

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

3.1.14 *rust (coatings)*, *n*—the reddish material, primarily hydrated iron oxide, formed on iron or its alloys resulting from exposure to humid atmosphere or chemical attack. **D 16**

3.1.15 *scoring*, *n*—*in tribology*, a severe form of wear characterized by the formation of extensive grooves and scratches in the direction of sliding. **G 40**

3.1.16 *scuffing*, *n*—*in lubrication*, surface damage resulting from localized welding at the interface of rubbing surfaces with subsequent fracture in the proximity of the weld area. **D 4175**

3.1.17 *sludge*, *n*—*in internal combustion engines*, a deposit, principally composed of insoluble resins and oxidation products from fuel combustion and the lubricant, which does not drain from engine parts but can be removed by wiping with a cloth; see 3.1.18.[17,18]

3.1.18 *used oil*, *n*—any oil that has been in a piece of equipment (for example, an engine, gearbox, transformer, or turbine), whether operated or not. **D 4175**

3.1.19 *varnish*, *n*—*in internal combustion engines*, a hard, dry, generally lustrous, deposit which can be removed by solvents but not by wiping with a cloth;[17,18] see 3.1.16.

3.1.19.1 *Discussion*—Varnish can be removed with the solvent specified in this test method; see 7.5.

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

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *build-up oil*, *n*—noncompounded ISO VG 32 (SAE 20) oil[18,19] used in lubricating the Sequence IIIE parts during engine assembly, and in coating parts following rating.

3.2.2 *calibrated test stand*, *n*—a test stand (see 3.2.29) on which Sequence IIIE engine oil tests are conducted within the lubricant test monitoring system as administered by the ASTM TMC (see 11.1).

3.2.3 *Central Parts Distributor (CPD)*—[18,20]*n*—the manufacturer and supplier of many of the parts and fixtures used in this test method.

3.2.3.1 *Discussion*—Because of the need for rigorous inspection and control of many of the parts used in this test method, and because of the need for careful manufacture of special parts and fixtures used, a company having the capabilities to provide the needed services has been selected as the official supplier for the Sequence IIIE test method. This company, Bowden Manufacturing Corp.,[18,20] works closely with the original parts suppliers, with the Test Developer,[21] and with the ASTM groups associated with the test method to help ensure that the equipment and materials used in the method function satisfactorily.

3.2.4 *controlled primary parameter*, *n*—a test parameter over which the testing laboratory has direct control, that has the potential for significant impact on test severity should there be a large difference between the test average and the target specification.

3.2.5 *controlled secondary parameter*, *n*— a test parameter over which the testing laboratory has direct control, that has less potential for significant impact on test severity than a controlled primary parameter, should there be a large difference between the test average and the target specification.

3.2.6 *correction factor*, *n*—a mathematical adjustment to a test result to compensate for industry-wide shifts in severity.

3.2.7 *CPD Special Test Parts (STP)*, *n*—parts that do not meet all the definitions of critical parts, non-production parts, or SPO parts, but must be obtained from the Central Parts Distributor.

3.2.8 *critical parts (CP)*, *n*—those components used in the test, which are known to affect test severity.

3.2.8.1 *Discussion*—They must be obtained from the Central Parts Distributor, who will identify them with either a serial number or a batch lot control number.

3.2.9 *EWMA*, *n*—exponentially-weighted moving average.

3.2.10 *lead salts*, *n*—salt formations which develop on the central contact area of a piston skirt after the piston has been removed from the engine following a Sequence IIIE test.

[16] Available from the secretary of D02.B0 Subcommittee, J. L. Newcombe, Exxon Chemical Co., 26777 Central Park Blvd., Ste 300, Southfield, MI 48076-4172.

[17] Teri-Towels have been found suitable for use in this test method; they are available from local suppliers of Kimberley Clark products.

[18] The sole source of supply of the material or apparatus known to the committee at this time is noted in the adjoining footnote. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

[19] Use only EF-411, a noncompounded ISO VG 32 (SAE 20) (see Classification D 2422) oil available from Mobil Oil Corp., P.O. Box 66940, AMF O'Hare, IL 60666, Attention: Illinois Order Board. Specify P/N 47503-8.

[20] The supplier of many of the parts and fixtures used in this test method, referred to as the Central Parts Distributor, is Bowden Manufacturing Corp., 4590 Beidler Rd., Willoughby, OH 44094.

[21] Special parts can be made by any capable independent machine shop, using the drawings available from the ASTM Test Monitoring Center, or they can be obtained by contacting the Central Parts Distributor or the Sequence IIIE Test Developer, General Motors North American Operations Research and Development, Fuels and Lubricants Department, 30500 Mound Rd., Box 9055, Warren, MI 48090-9055.

3.2.11 *Lubricant Test Monitoring System, LTMS, n*—an analytical system in which ASTM calibration test data are used to manage lubricant test precision and severity (bias).

3.2.12 *LTMS date, n*—the date the test was completed unless a different date is assigned by the TMC.

3.2.13 *LTMS time, n*—the time the test was completed unless a different time is assigned by the TMC.

3.2.14 *non-production parts (NP), n*—these are components used in the test, which are available only through the Central Parts Distributor or the Test Developer.

3.2.15 *participating laboratory, n*—a laboratory equipped to conduct Sequence IIIE tests, which conducts reference oil tests in cooperation with the ASTM TMC, in order to have calibrated test stands available for candidate oil testing.

3.2.16 *primary validity parameter, n*—a test parameter which has the potential for significant impact on test severity, should there be large deviations in individual readings from the test specification for that parameter.

3.2.17 *reference oil test, n*—a standard Sequence IIIE engine oil test of a reference oil designated by the ASTM TMC.

3.2.18 *SA, n*—severity adjustment.

3.2.19 *secondary validity parameter, n*—a test parameter which has less potential for significant impact on test severity than a primary validity parameter, should there be large deviations in individual readings from the test specification for that parameter.

3.2.20 *service parts operations parts (SPO), n*—these test components are obtained from General Motors Corporation.

3.2.21 *sluggish piston ring, n*—one that is not free; it offers resistance to movement in its groove, but it can be pressed into or out of the groove under moderate finger pressure; when so moved, it does not spring back.

3.2.22 *special validity parameter, n*—a parameter which has the potential for significant impact on severity, should there be large deviations in individual readings from the test specification for that parameter, but which is of such a nature that special consideration is required to determine its impact in a given Sequence IIIE test.

3.2.23 *standard test, n*—an operationally-valid, full-length Sequence IIIE test conducted on a calibrated test stand in accordance with the conditions listed in this standard.

3.2.23.1 *Discussion*—Such a test is also termed a valid test.

3.2.24 *stuck lifter, n*—a used lifter in which the plunger remains in a depressed position upon removal of the lifter from the engine, rather than being forced against the pushrod seat by the internal spring so that the seat bears against the lifter retainer clip.

3.2.25 *stuck piston ring, n*—one that is either partially or completely bound in its groove; it cannot be readily moved with moderate finger pressure.

3.2.25.1 *Discussion*—If the original oil ring land deposit rating for an individual piston is ≥2.6, any sticking of the rings on that piston is not considered to be oil related. If the rating is <2.6, any sticking is considered to be oil related.

3.2.26 *Test Developer, n*—the group or agency which developed the Sequence IIIE test method before its standardization by ASTM, and which continues to be involved with the test in respect to modifications in the test method, development of Information Letters, supply of test parts, etc.

3.2.26.1 *Discussion*—As defined in Committee D02.B0.08 Regulations Governing the American Society for Testing and Materials Test Monitoring System, "'Test Developer' shall refer to those individual companies which have developed and/or are responsible for supplying the basic hardware for the tests referred to in Paragraph 2.1 (Article 2—Purpose of the Test Monitoring System)." In the case of the Sequence IIIE test, the Test Developer is General Motors Research.[21]

3.2.27 *test full mark, n*—the oil level established after the timing run, but before the break-in portion of the procedure.

3.2.28 *test oil, n*—an oil subjected to a Sequence IIIE engine oil test.

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

3.2.29 *test stand, n*—a suitable foundation (such as a bedplate) to which is mounted a dynamometer, and which is equipped with suitable supplies of electricity, compressed air, etc., to provide a means for mounting and operating an engine in order to conduct a Sequence IIIE engine oil test.

3.2.30 *test start, n*—introduction of test oil into the engine

4. Summary of Test Method

4.1 A 3.8-L (231-in.^{3}) V-6 engine[18,22] is completely disassembled, solvent-cleaned, measured, and rebuilt; new parts are installed as specified.

4.2 The engine is installed on a test stand equipped with the appropriate accessories for controlling speed, load, and various other engine operating parameters.

4.3 The engine is charged with the test oil.

4.4 The engine is operated for 10 min to set the ignition timing, and for 4 h to break in the parts.

4.5 Following the break-in, the engine is operated under non-cyclic, moderately high speed, load, and temperature conditions for 64 h, in 8-h segments.

4.6 The initial oil level in the oil pan is determined after the 10-min ignition timing operation, and the oil level is redetermined after the break-in and after each 8-h segment, in order to measure oil consumption during the test.

4.7 Used oil samples are taken after the 10-min ignition timing operation and after each 8-h test segment; kinematic viscosity at 40°C (104°F) is determined for each of the nine samples; the percentage change in viscosity of the eight latter samples is determined relative to the viscosity of the first sample.

4.8 At the conclusion of the test, the engine is disassembled, and the parts are visually inspected to determine the extent of deposits formed. In addition, wear measurements and visual ratings are obtained for the critical valve train components. Weight losses are determined for two connecting rod bearings.

5. Significance and Use

5.1 This test method was developed to evaluate automotive

[22] A Buick 3.8-L (231-in.^{3}) V-6 engine must be used; purchase it from the Central Parts Distributor.

engine oils for protection against oil thickening and engine wear during high-speed, high-temperature service.

5.2 The increase in oil viscosity obtained in this test indicates the tendency of an oil to thicken because of oxidation. In automotive service, such thickening can cause oil pump starvation and resultant catastrophic engine failures.

5.3 The deposit ratings for an oil indicate the tendency for the formation of deposits throughout the engine, including those which can cause sticking of the piston rings in their grooves, and the sticking of plungers in hydraulic valve lifters. The former can be involved in the loss of compression pressures in the engine, and the latter is related to valve train noise and wear.

5.4 The camshaft and lifter wear values obtained in this test provide a measure of the anti-wear quality of an oil under conditions of high unit pressure mechanical contact.

5.5 The test method was developed to correlate with field experience using oils of known good and poor protection against oil thickening and engine wear.[23]

5.6 The Sequence IIIE engine oil test is used in specifications and classifications of engine lubricating oils, such as the following:

5.6.1 Specification D 4485,

5.6.2 Military Specification MIL-L-2104, and

5.6.3 SAE Classification J 183.

6. Apparatus

6.1 *Laboratory*—Observe the following laboratory conditions to ensure good control of test operations, and good repeatability:

6.1.1 Maintain the ambient laboratory atmosphere relatively free of dirt, dust, and other contaminants.

6.1.2 Control the temperature of the room in which parts measurements are made so that the temperature for after-test measurements is within a range of ±3°C (±5°F) relative to the temperature for the before-test measurements. If difficulties with parts fits are encountered, consider the effects of temperature coefficient of expansion. See 6.2.

6.1.3 Filter the air in the engine build-up area, and control its temperature and humidity to prevent accumulation of dirt or rust on engine parts.

6.1.4 If an engine is assembled in an area of controlled environment and moved to a non-controlled area, provide suitable protection of the engine so that moist air cannot enter the engine and promote rusting before the test.

6.1.5 Do not permit air from fans or ventilation systems to blow directly on an engine mounted on a test stand.

6.2 *Drawings*—Obtain the equipment drawings referenced in Annex A3 of this test method from the ASTM TMC. Because the drawings may not be to scale, when using them to fabricate special parts, use the dimensions specified. Do not use a drawing as a pattern. Drawing dimensions are considered to be correct when the temperature of the equipment is 22°C (72°F), unless otherwise specified.

6.3 *Specified Equipment*—Use the equipment specified in the procedure whenever possible. Substitution of equivalent equipment is allowed, but only after equivalency has been proven to the satisfaction of the ASTM TMC, the Test Developer, and the ASTM Sequence IIIE Surveillance Panel. See Fig. 1 and Fig. 2 for general views of the engine and attached apparatus used in this test method.

6.3.1 Do not use heat lamps or fans directed at the engine, and do not use insulation on the engine, for temperature control.

6.4 *Test Engine*—The test engine is a 1986–87 3.8-L (231-in.^{3}) V-6 engine[21] with an 8.0:1 compression ratio, equipped with the specified two-barrel carburetor. See Fig. 3. (Procure the block for this engine from the recommended source.[19]) Rebuild the engine as specified in this test method.

6.4.1 *Engine Parts*—Use the engine parts included in Annex A2 and Annex A3.

6.4.1.1 Use all engine parts as received from the supplier, either the Central Parts Distributor or an original equipment manufacturer dealer[24] unless modifications are specified in this test method, or unless defects in the parts require that they be returned to the supplier.

6.4.1.2 Do not divert to other applications, any parts obtained for use in Sequence IIIE testing.

6.4.1.3 Before disposing of Sequence IIIE engine parts, render them useless for automotive engine applications.

6.4.1.4 Use serialized engine bearing kits; do not substitute other bearings.

6.4.2 *Hold-Back Fixture*—Use the hold-back fixture shown in drawing RX-118641-A2 to restrict axial movement of the camshaft. See Fig. 4.

NOTE 2—RX and BX drawings referenced in this test method are listed in Annex A3.

6.5 *Engine Speed and Load Control*— Use dynamometer speed and load control systems with which the speed and power limits specified in Section 12 can be maintained.

6.6 *Engine Cooling System*—Use an external engine cooling system, such as shown in drawing RX-116681-D, to maintain the specified engine coolant temperature during both the operating and the shutdown portions of the test. The system must incorporate the following features:

6.6.1 No pressurization,

6.6.2 Coolant flow rate of 151 ± 3.8 L/min (40± 1 gal/min),

6.6.3 Capacity of 85.2 ± 9.5 L (22.5 ± 2.5 gal),

6.6.4 A sharp-edge orifice meter, utilizing a 50.8-mm (2.0-in.) orifice plate, such as that shown in drawings RX-116645-D through RX-116650-D and RX-119051-A3[18,20] for the measurement of coolant flow rates,

6.6.5 A system to control the coolant flow rate, such as that shown in drawing RX-117161-C,[21] and

6.6.6 Low-point drains to ensure draining all of the flushing water prior to installing a fresh glycol mixture.

6.7 *Flushing Tank*—Use a flushing tank such as that shown in drawings RX-116924-C, RX-117230-E, and RX-117231-C to circulate the cleaning agents. Use plumbing materials which are impervious to the acidic cleaning agents (stainless steel has

[23] Bergin, S. P., and Smolenski, D. J., "Development of the ASTM Sequence IIIE Engine Oil Oxidation and Wear Test," SAE 881576.

[24] Some of the engine parts are available from local General Motors dealers. See Table A2.3.

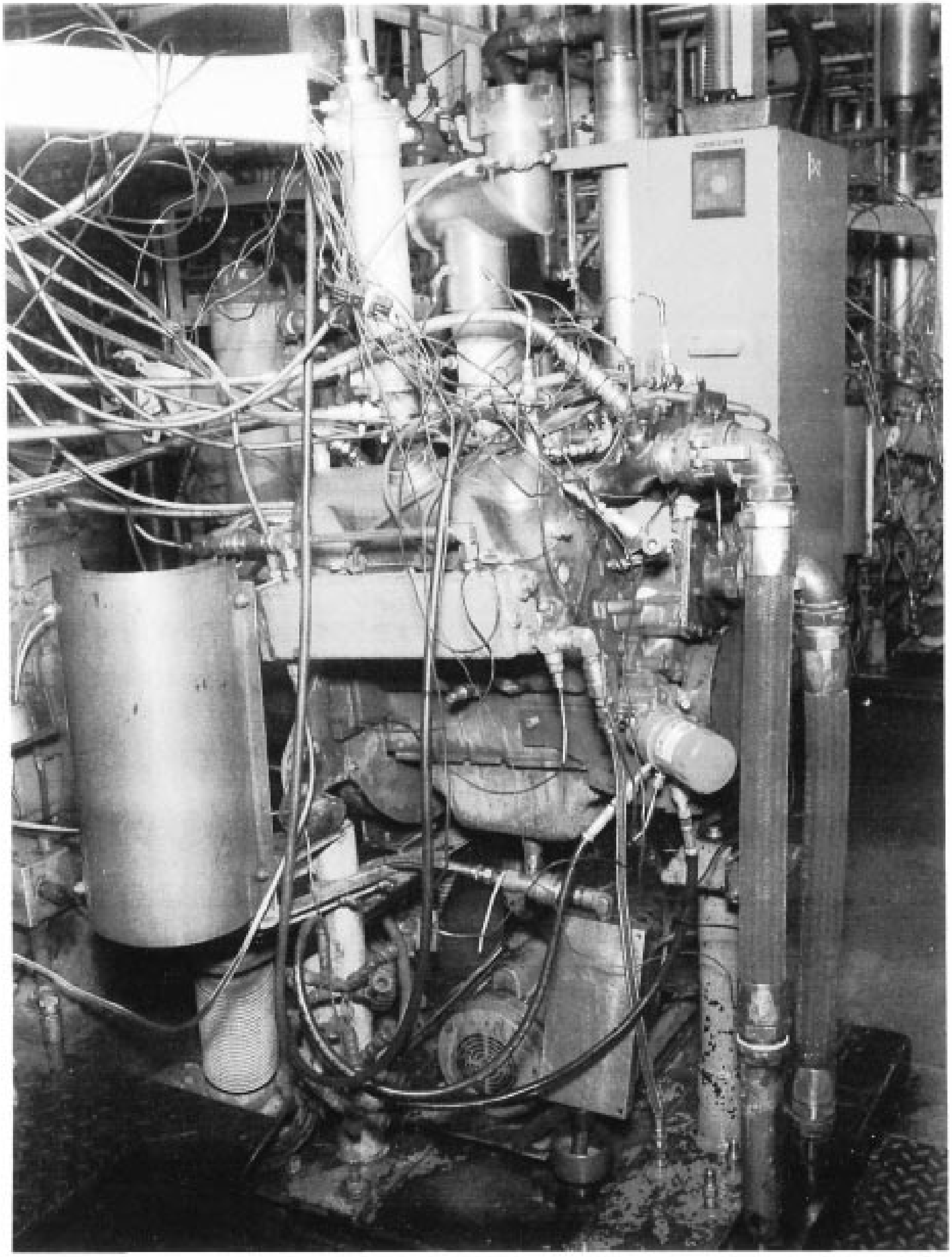

FIG. 1 Sequence IIIE Test Engine and Attached Apparatus—View 1

been found satisfactory).

6.8 *Coolant Mixing Tank*—Use a mixing tank such as that shown in drawing RX-117350-D to premix the engine coolant.

6.9 *Jacketed Rocker Cover, Intake Manifold Crossover, and*

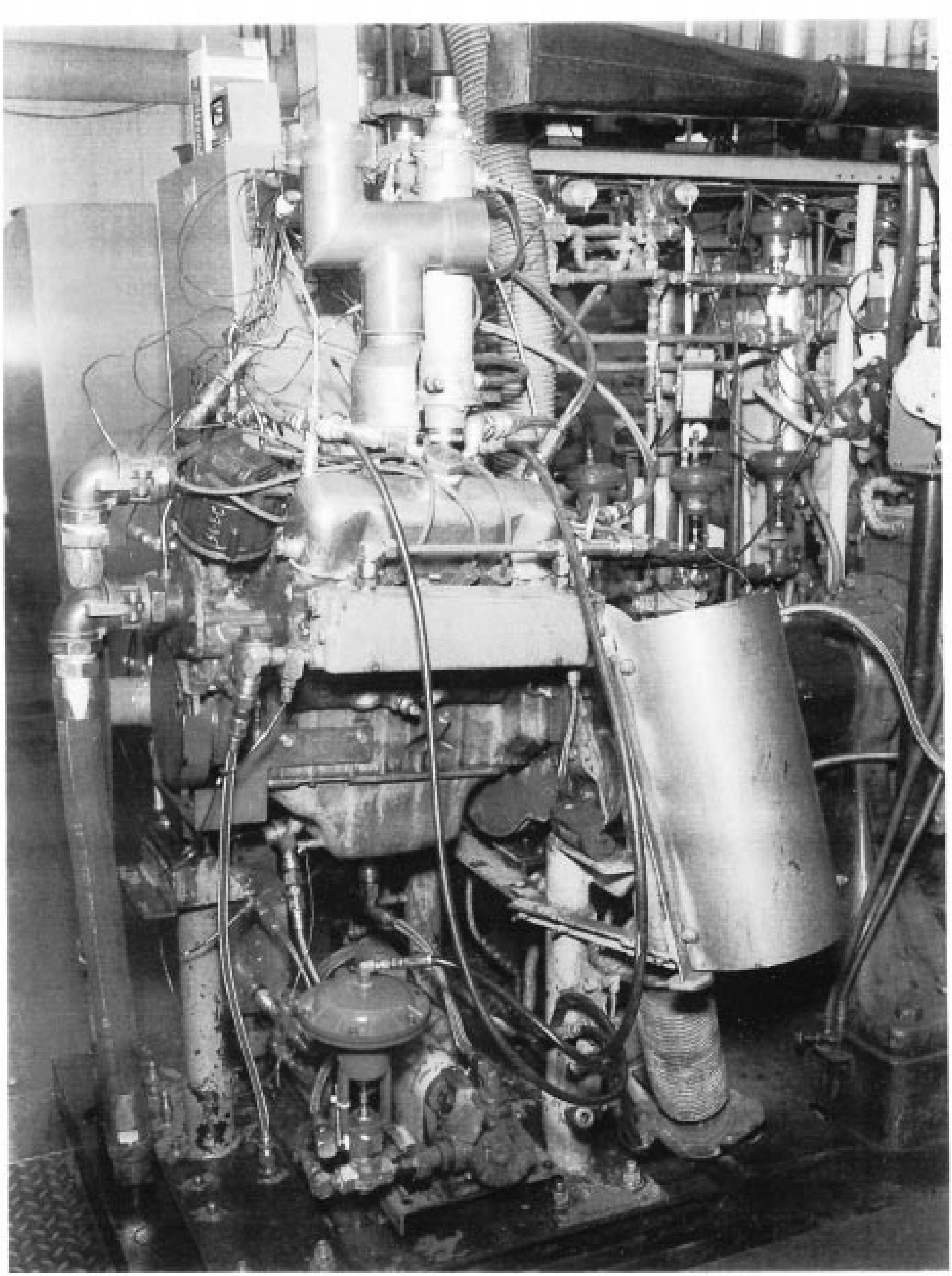

FIG. 2 Sequence IIIE Test Engine and Attached Apparatus—View 2

Breather Tube Cooling Systems—Provide external cooling systems, one for the rocker covers (non-production parts) and intake manifold crossover, and one for the breather tube. Use

FIG. 3 Sequence IIIE Test Engine Carburetor

pumps, flowmeters, plumbing connections, and heat exchangers such as shown in drawings BX-350-1, RX-117290-C, RX-117731-C, and RX-118615-E to maintain the specified operating conditions. The systems must incorporate the following features:

6.9.1 For the rocker covers and intake manifold crossover system, a pump and flowmeter with which engine coolant can be supplied at 113 ± 2.8°C (235.4 ± 5°F) and 11.4 ± 3.8 L/min (3 ± 1 gpm) [5.7 ± 1.9 L/min (1.5 ± 0.5 gpm) per rocker cover].

6.9.1.1 Provisions for maintaining the rocker cover coolant pressure at 27.5 ± 6.9 kPa (4.0 ± 1.0 psi).

6.9.2 For the breather tube system, a pump and flowmeter with which coolant can be supplied at 40 ± 1.1°C (104 ± 2.0°F) and 11.4 ± 3.8 L/min (3 ± 1 gpm).

6.9.2.1 Provisions for maintaining the breather tube coolant outlet pressure at 27.5 ± 6.9 kPa (4.0 ± 1.0 psi).

6.9.3 For each of the two systems, low-point drains to allow for removal of all coolant.

6.10 *External Oil-Cooling System*—Incorporate an external oil-cooling system, such as shown in drawing RX-116680-C, to maintain the specified oil temperature. The system consists of a positive displacement pump[18,25] that delivers a flow of 21.8 ± 0.95 L/min (5.75 ± 0.25 gpm) at 1140 r/min, no relief valve, calibrated with build-up oil[18,20] at 29.4 ± 0.6°C (85 ± 1°F) as shown in drawing RX-116680-C, a linear control valve,[18,26] and heat exchanger Part BX-350-1.[18,20] See Fig. 5.

6.10.1 Check the condition of the positive displacement pump for the following:

6.10.1.1 The flow rate must be that shown in drawing RX-116680-C.

6.10.1.2 The speed must be 1140 ± 20 r/min under Sequence IIIE operating conditions.

[25] An oil pump that has been found suitable for this application is Viking Model G4125, 21.8 ± 0.95 L/min (5.75 ± 0.25 gal/min) at 1140 r/min, with 0.13 mm (0.005 in.) rotor to end plate clearance, no relief valve. It is available through local Viking distributors or Houdaille Industries, Inc., Viking Pump Division, George and Wyeth Sts., Cedar Falls, IA 50613.

[26] An oil control valve that has been found suitable is Part 2735, type 75S 3W, trim A linear control valve available from Badger Meter Inc., Precision Products Div., 6116 E. 15th St., Tulsa, OK 74112.

FIG. 4 Sequence IIIE Test Engine Disassembled Camshaft Hold-Back Fixture

6.10.2 Do not use cuprous lines or fittings in the oil-cooling system.

6.10.3 Do not use magnetic plugs in the oil-cooling system.

6.10.4 Install suitable fittings in the engine oil pan, as shown in drawing RX-118626-A1, to accommodate the oil lines.

6.10.5 Use minimum-length oil lines to the heat exchanger and valve(s) in order that the total external oil volume, including that of the oil in the lines, heat exchanger, valves, pump, and sensing elements, is 739 ± 59 mL (25 ± 2 oz).

6.10.6 Use suitable hose and fittings when plumbing the oil-cooling system.[18],[27]

6.10.7 If quick disconnect-type fittings are installed, use only the straight-through type, such as those shown in drawings RX-116680-C and RX-118618-C.

6.10.7.1 Maintain all couplings, O-rings, and hoses to minimize air leaks on the suction side.

6.10.8 Prior to each reference oil test or after any system component, except external heat exchanger or heat exchanger core, is replaced, the volume and flow rate of the external oil system should be verified according to the following procedures:

6.10.8.1 Clean the external oil system and air blow dry (see 10.1). Connect oil lines to a calibration oil pan firmly mounted at engine height. A drain valve should be installed in place of the drain plug or at the lowest point of the pan. The pan outlet fitting should be capable of being plugged with a rubber stopper or modified with a ½-in. NPT thread. Weigh, at room temperature, 4320 mL (146 oz) of aliphatic naphtha (see 7.4) (**Warning**—see Note 3) with a boiling point greater than 149°C (300°F) to determine the weight per volume (grams/mL). Carefully add aliphatic naphtha to oil pan. Operate oil pump alternately one minute on and one minute off while cycling the three-way control valve. Repeat cycling of the pump several times to purge all air from the system. Turn off oil pump. Firmly insert rubber stopper or screw ½-in. NPT plug in pan outlet fitting at bottom of pan to keep oil lines filled with aliphatic naphtha when the pan is drained. Drain aliphatic naphtha remaining in the pan using the pan drain valve, manually scraping any residual aliphatic naphtha into the drain using a plastic scraper. Measure the weight of the removed aliphatic naphtha and subtract from the initial weight (less the weight of the container). Repeat the above process until the weight measurement repeats within 4 % (equivalent to 30 mL (1 oz) volume of aliphatic naphtha). Determine if the external oil system meets the test specification of 739 ± 59 mL (25 ± 2oz). If necessary, adjust length of oil lines or fitting size to obtain the required volume and recheck system volume using the above procedure. Note that the system flow rate shall be rechecked when any component is replaced.

NOTE 3—**Warning:** Combustible. Health Hazard.

6.10.8.2 Clean the external oil system and air blow dry (see 10.1). Connect oil lines to calibration oil pan firmly mounted at engine height. Insert a calibrated flow meter in oil return line. Use a flow meter[18,28] with minimum pressure drop and restriction to flow. The flow meter should be calibrated using build-up oil at 29.4°C (85°F). Observe typical 10× diameter straight pipe rule before and after meter to reduce flow disturbance. Add 4320 mL (146 oz) of build-up oil[18] to the oil pan. Operate oil pump while cycling the three-way control valve to purge air from the system (excessive air in oil will cause erroneous flow measurement, particularly with turbine meters). With the three-way control valve set at 50 %, record flow rate when reading has stabilized and the oil temperature measures 28.9 to 30.0°C (84 to 86°F) on sump thermocouple. Determine if the oil system meets test specified flow rate of 21.8 ± 0.95 L/min (5.75± 0.25 gpm). If necessary, adjust pump clearance or replace pump, then recheck flow rate using the above procedure.

[27] A hose which has been found suitable for most of the system is polytetrafluoroethylene 2807-8 [11 mm (0.43 in.) inside diameter]. For the oil pan-to-pump inlet line, use polytetrafluoroethylene 2807-10 [13 mm (0.51 in.) inside diameter]. Such types of hose and suitable fittings can be obtained from Aeroquip Corp., Industrial Division, 1225 W. Main St., Van Wert, OH 45891.

[28] A Cox Model AN10 Turbine Meter has been found suitable and can be obtained from local suppliers of Cox products.

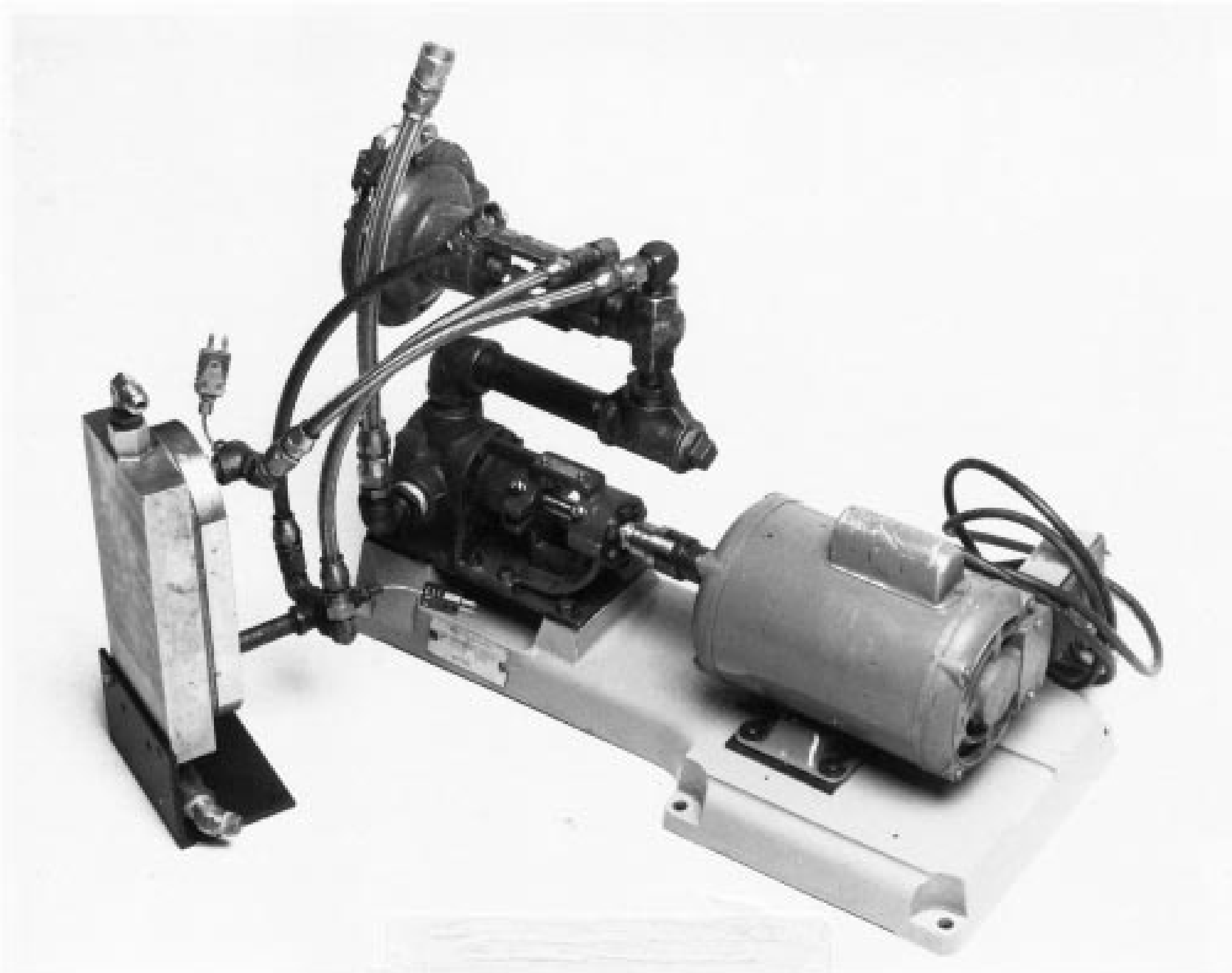

FIG. 5 Sequence IIIE Test Engine External Oil-Cooling System

6.11 *Fuel System*—Use a pressurized fuel system, including a pressure regulator,[18,29] to provide 28 ± 7 kPa (4 ± 1 psi) fuel pressure at the carburetor. Incorporate shutoff valves[18,30] in the system so that no fuel pressure is present at the carburetor during engine shutdowns.

6.12 *Carburetor Air Supply Humidity, Temperature, and Pressure*—Maintain the carburetor intake air at a moisture content of 11.4 ± 0.7 g/kg of dry air (80.0 ± 5 grains/lb of dry air),[18,31] a dry bulb temperature of 27 ± 1.5°C (80.6 ± 2.7°F), and a static pressure of 0.050 ± 0.025 kPa (0.2 ± 0.1 in. of water) measured at the carburetor inlet.

6.12.1 Use a system such as that shown in drawings RX-117375-C and RX-117376-C to control the moisture content and temperature of the carburetor air. Maintain the air supply duct surface temperature above the dew point to prevent condensation.

6.12.2 Use a method of controlling the flow of air, and thereby the air pressure, to the carburetor such as that shown in drawing RX-117162-C. Use carburetor inlet adapters and gaskets such as shown in drawings BX-395-1 and RX-118616-E, as well as gasket BX-361-1, respectively. See Fig. 6. Position the adapter so that the air enters the adapter from the left rear of the engine. Remove the humidified air supply from the carburetor when the engine is not running; leave it disconnected for the timing run.

6.13 *Temperature Measurement*—Use iron-constantan (Type J) thermocouples or platinum resistance thermocouples for temperature measurement.[18,32] Other temperature sensors that give the same results may be used, provided that they are approved by the ASTM TMC.

[29] A fuel pressure regulator which has been found suitable can be obtained from Fisher Governor Co., 1900 Fisher Building, Marshalltown, IA 50158.

[30] A fuel shut-off valve which has been found suitable is Part X5D30280, which can be obtained from Skinner Precision Industries, Inc., Skinner Electric Valve Division, 95 Edgewood Ave., New Britain, CT 06050.

[31] A humidity-measuring device which has been found suitable is the Alnor 7300 Dewpointer, without radium source, which is available through local distributors or Alnor Instrument Co., 7555 N. Linden Ave., Skokie, IL 60077.

[32] Thermocouples and packing glands (Part MPG-125-A-T) which have been found suitable are obtainable from Conax Corp., 2300 Walden Ave., Buffalo, NY 14225.

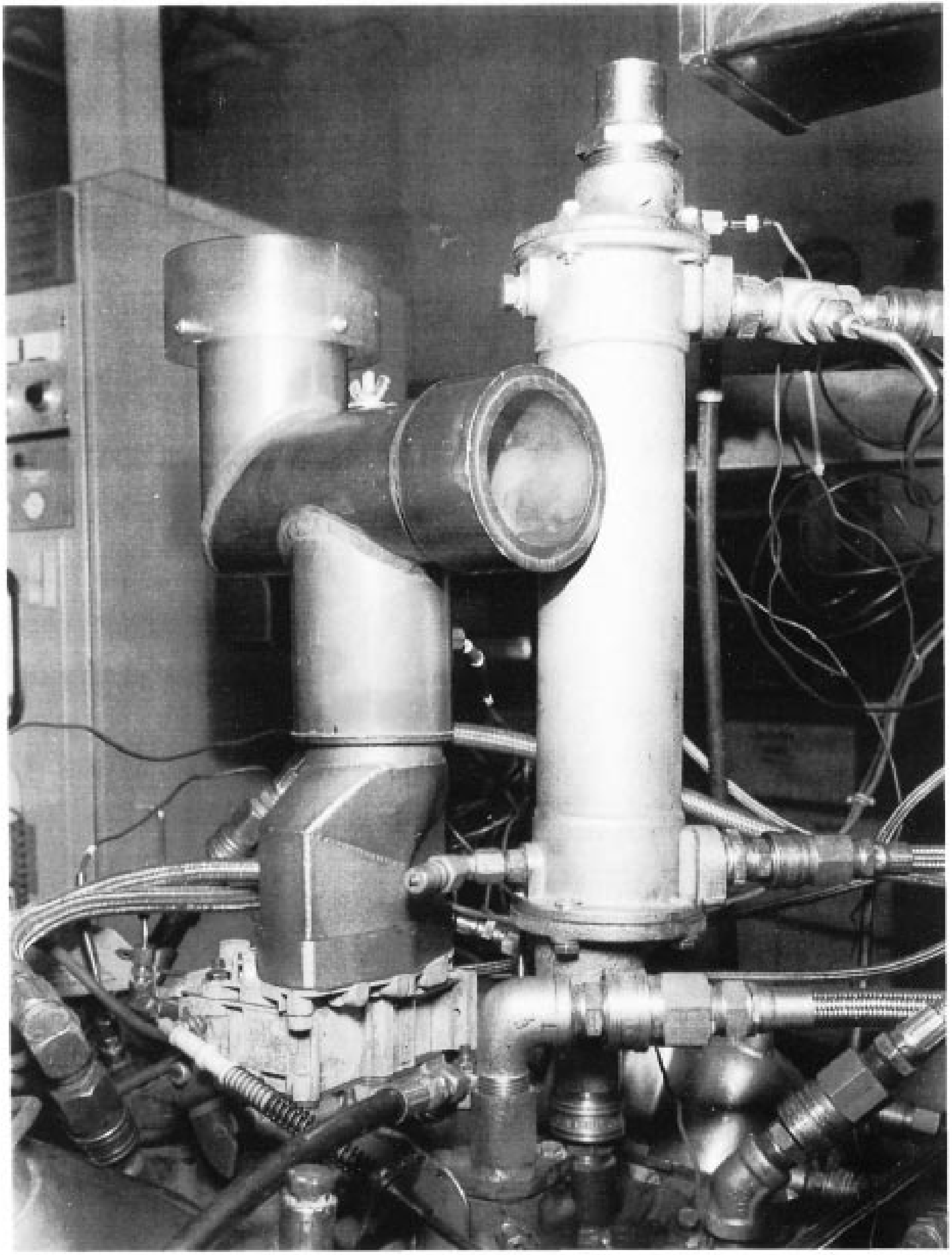

FIG. 6 Sequence IIIE Test Engine Carburetor Inlet Adapters and Breather Tube

6.13.1 *Thermocouple Location*—Locate the sensing tip of all thermocouples in the center of the stream of the medium involved, unless otherwise specified.

6.13.1.1 *Oil Filter Adapter*—Install the thermocouple[18,33] in the tapped hole in the oil filter adapter, as shown in drawing RX-118613-C. See Fig. 7.

6.13.1.2 *Oil Pan (Sump)*—Install the thermocouple[18,34] in the oil sump as shown in drawing RX-118626-A, with the tip extending 38 mm (1.5 in.) into the oil pan. See Fig. 8. [The oil temperature indicated at this point is generally within 1.5°C (2.7°F) of the temperature measured at the filter adapter.]

6.13.1.3 *Engine Coolant In*—Install the thermocouple[18,33] in the coolant inlet adapter as shown in drawing RX-118608-D. See Fig. 9.

6.13.1.4 *Engine Coolant Out*—Install the thermocouples[18,33] for the coolant outlets as shown in drawing RX-118609-A1. See Fig. 10.

6.13.1.5 *Intake Manifold Mixture*—Install the thermocouple[18,33] using a reducer in the ¼-in. NPT hole located on the No. 6 cylinder leg of the intake manifold as shown in drawing RX-118615-E. See Fig. 11.

6.13.1.6 *Rocker Cover Coolant Out*—Locate the thermocouple[18,35] for each rocker cover within 76 mm (3 in.) of the coolant-out fitting in the cover.

6.13.1.7 *Intake Manifold Crossover Coolant Outlet*—Install the thermocouple[18,35] as specified in drawing RX-118615-E.

6.13.1.8 *Breather Tube Coolant Out*—Locate the thermocouple[18,33] within 76 mm (3 in.) of the coolant-out fitting in the breather tube.

6.13.1.9 *Blowby Gas*—Install the thermocouple[18,33] at the outlet of the breather tube, through which the blowby gas flows. Locate the thermocouple tip at the center of the outlet.

6.13.1.10 *Fuel*—Install the thermocouple[18,35] in a tee fitting in the fuel line within 51 mm (2 in.) of the carburetor fuel inlet.

6.13.1.11 *Carburetor Air*—Install the thermocouple[18,33] as shown in drawing BX-395-1. See Fig. 6.

6.13.1.12 *Ambient Air*—Install the thermocouple[18,35] approximately 76 mm (3 in.) directly below the external oil system return line oil pan fitting.

6.14 *Air-to-Fuel Ratio Determination*— Determine the engine air-to-fuel ratio by measuring the CO, CO_2, and O_2 components of the exhaust gas sample with either an Orsat apparatus[36] or electronic exhaust gas analysis equipment.[18,37] When using electronic exhaust gas analyzers, take particular care to ensure that the exhaust gas sample is dried prior to introducing it to the analyzer. Take the exhaust gas samples from the top holes of the exhaust manifold exit flanges.

6.15 *Exhaust and Exhaust Back Pressure Systems*:

6.15.1 *Exhaust Manifolds and Pipes*—Install water-cooled exhaust manifolds[18,38] as shown in drawing RX-118614-D (see Fig. 12), using 102-mm (4-in.) stainless steel exhaust pipe,[18,39] immediately prior to charging the engine with test oil. Orient the manifolds so that the exhaust exits the manifolds at either the rear or front of the engine.

6.15.2 *Water-Jacketed Exhaust Pipes*—If a test laboratory chooses to use either jacketed exhaust pipes or external water spray, they must be applied on the portions of the exhaust system extending below the test bed or floor level. Do not use water-jacketed exhaust pipes on the sections of exhaust pipe extending from the exhaust manifold to the test bed or floor level. Do not apply an external water spray to the exhaust pipes above the test bed or floor level. Do not introduce cooling water into the exhaust streams at any point of the exhaust system.

6.15.3 *Exhaust Sample Lines*—Install exhaust sample lines at the top holes of the two exhaust manifold exit flanges. Do not interconnect these lines; they are used to take samples from each bank for air-to-fuel ratio determinations.

6.15.4 *Back-Pressure Lines*—To permit measurement of the back pressure in each exhaust manifold, install exhaust back-pressure lines from the bottom holes of the exhaust manifold exit flanges (location shown in drawing RX-118614-D) to traps located ahead of the manometers. Orient the lines so that any liquid accumulating in them will drain to the traps. Retain about 20 mm (¾ in.) of liquid in the traps to ensure that closed systems exist.

6.16 *Blowby Flow Rate Measurement System*

6.16.1 Use the sharp-edge orifice meter shown in drawing RX-116169-C to measure engine blowby flow rates. Connect the meter to a surge tank (drawing RX-117431-C) and to other

FIG. 7 Sequence IIIE Test Engine Oil Filter Adapter

[33] A thermocouple which has been found suitable is Conax J-SS-12-G-PG 76 mm (3 in.).

[34] A thermocouple which has been found suitable is Conax J-SS-12-G-PG 51 mm (2 in.).

[35] A thermocouple which has been found suitable is Conax J-SS-G-12-G-PG 51 mm (2 in.).

[36] Orsat analysis apparatus is commercially available.

[37] An electronic exhaust gas analyzer which has been found suitable is Horiba MEXA 554GE, available from Horiba Instruments, Inc., 1021 Duryea Ave., Irvine Industrial Complex, Irvine, CA 92714.

[38] A water-cooled exhaust manifold which has been found suitable is Barr Marine Part BV6-1-75, available from Barr Marine Products Co., 1505 Ford Rd., P.O. Box 408, Cornwells Heights, PA 19020.

[39] Stainless steel exhaust pipe which has been found suitable is Flexonic Part RT 10E, available from local distributors or Flexon Industries, 666 Washington Ave., Belville, NJ 07109.

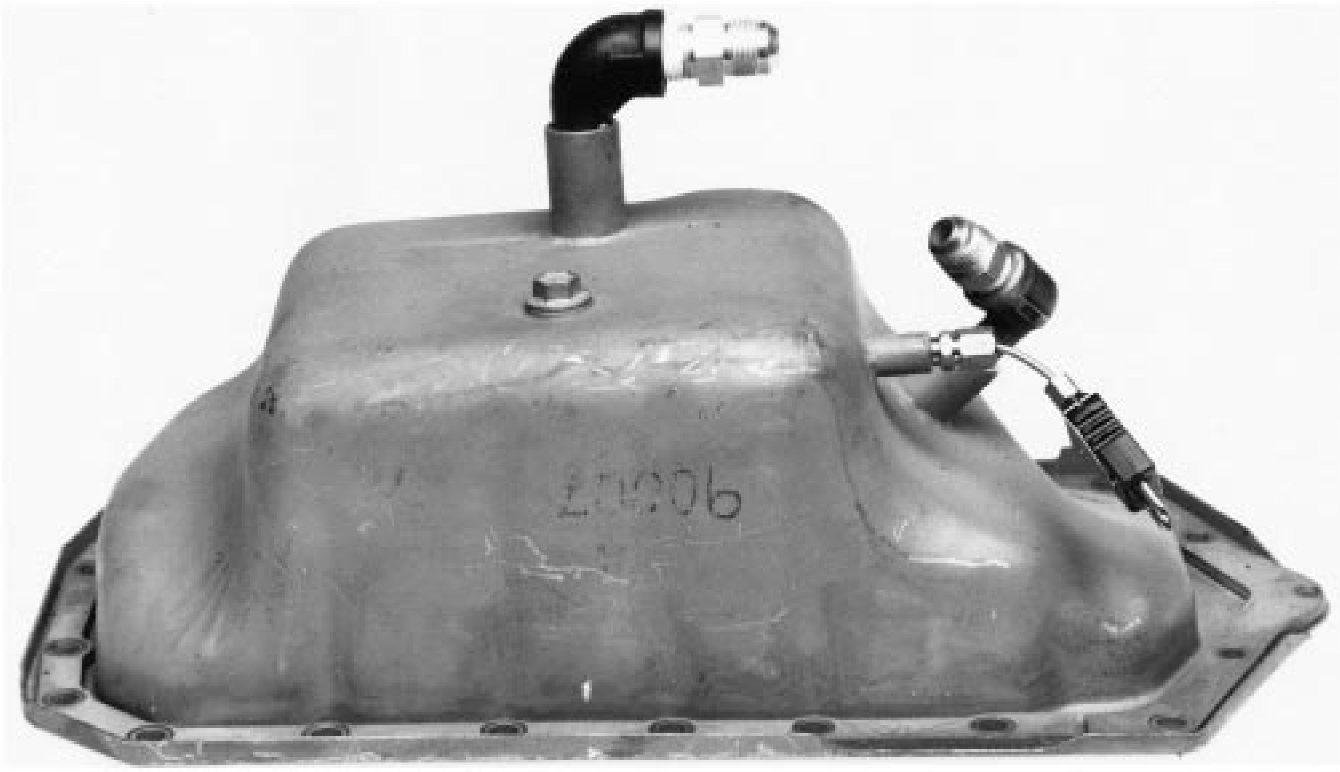

FIG. 8 Sequence IIIE Test Engine Oil Pan

equipment shown in drawings RX-117726-C, RX-117727-C, RX-117294-A, and RX-117729-C.

6.16.2 Mount the meter in a horizontal position with a minimum blowby gas inlet line straight run length of 15 cm (6 in.) upstream and 8 cm (3 in.) downstream. All bends in the blowby gas inlet and outlet lines shall be large enough in radius to eliminate reduction of inside diameters. Although the orientation of the orifice meter has no influence on the blowby measurement, within ± 1.0 % of the volume read over a range of 7.1 to 141.6 L/min (0.25 to 5.0 ft^3/min), it could have an influence on entrained contaminant accumulations deposited on the orifice plate surfaces.

6.16.3 Keep the blowby gas inlet line length from the breather tube to the blowby cart to a minimum. Shorter line lengths will reduce line losses, contaminant accumulations, and excessive temperature losses between the breather tube and the orifice plate.

6.17 *Pressure Measurement and Pressure Sensor Location*—Use pressure sensors such as pressure gages or manometers, or electronic transducers, located as indicated, and following the established guidelines:[40]

6.17.1 *Intake Manifold Vacuum*—Use either a manometer or a vacuum gage having a range of 0 to 100 kPa (0 to 20 in. Hg) and scale graduations of 0.5 kPa (0.1 in. Hg). Connect the manometer or gage to the ⅛ in. NPT hole located at the rear of the carburetor base as shown in drawing RX-118617-E.

6.17.2 *Engine Oil Gallery Pressure*—Use a gage having a range of 0 to 700 kPa (0 to 100 psi) and scale graduations of 5 kPa (1 psi). Connect the gage to the location shown in drawing RX-118613-C.

6.17.3 *Oil Pump Outlet Pressure*—Use a gage having a range of 0 to 700 kPa (0 to 100 psi) and scale graduations of 5 kPa (1 psi). Connect the gage to the location shown in drawing RX-118613-C.

6.17.4 *Rocker Cover Coolant Pressure*— Use a pressure gage having a range of 0 to 100 kPa (0 to 15 psi) and scale graduations of 5 kPa (1 psi). Measure the pressure at the top front coolant-outlet fitting of each rocker cover as described on drawing RX-118615-E.

6.17.5 *Breather Tube Coolant Pressure*— Use a pressure gage having a range of 0 to 100 kPa (0 to 15 psi) and scale graduations of 5 kPa (1 psi). Connect the gage to the coolantoutlet fitting of the breather tube as shown in drawing RX-118615-E.

6.17.6 *Exhaust Back Pressure*—Use either a manometer or pressure gage having a range of 0 to 10 kPa (0 to 40 in. of water) and scale graduations of 25 Pa (0.1 in. of water). Connect the manometer or gage to the bottom holes of the exhaust manifold exit flanges as shown in drawing RX-118614-D.

6.17.7 *Carburetor Inlet Air Pressure*— Use either a manometer or a pressure gage having a range of 125 Pa (0.5 in. of water) and scale graduations of 5.0 Pa (0.02 in. of water). If a manometer is used, install a condensate trap between the manometer and the carburetor inlet adapter to protect against the possibility of momentary interruption of air flow or any other transient condition that might result in manometer fluid entering the engine intake system. Connect the manometer or

[40] See the 1987-04-02 Instrumentation Task Force Report to the ASTM Committee D02.B0.08 Technical Guidance Committee.

FIG. 9 Sequence IIIE Test Engine Coolant Inlet Adapter

FIG. 10 Sequence IIIE Test Engine Coolant Outlet Adapter

gage to the carburetor air inlet adapter as shown in drawing BX-395-1.

6.17.8 *Crankcase Pressure*—Use a gage or manometer having a range of − 125 to + 125 Pa (−0.5 to + 0.5 in. of water) and scale graduations no greater than 5.0 Pa (0.02 in. of water).[18,41]

6.17.8.1 If a manometer is utilized in this application, install a condensation trap to eliminate the possibility of manometer fluid accidentally entering the crankcase.

6.17.8.2 Connect the gage or manometer to the location shown in drawing RX-118633-A3.

6.17.8.3 Do not apply any external means at the breather tube to influence the crankcase pressure reading.

7. Reagents and Materials

7.1 *Test Fuel*—Use only fuel from approved batches of GMR 995 test fuel[18,42] (**Warning**—see Note 4) (see Annex A4, Table A4.1), observing the following:

NOTE 4—**Warning:** Flammable. Health Hazard.

7.1.1 Make certain that all tanks used for transportation and storage are clean before they are filled with test fuel.

7.1.2 Verify that at least 1420 L (375 gal) of test fuel (**Warning**—see Note 4) is available for use before initiating a test.

7.2 *Additive Concentrate for the Coolant*—Blend the additive concentrate for the engine coolant system, and for the rocker cover and breather tube coolant system, using ethylene glycol [18,43] meeting Specification E 1119 (**Warning**—see Note 5) plus the coolant additive[18,44] at a concentration of 15.625 mL/L (0.125 pt/gal) (**Warning**—see Note 6).

NOTE 5—**Warning:** Combustible. Health Hazard.

NOTE 6—**Warning:** See the appropriate materials safety data sheet.

7.3 *Coolant Preparation*—Prepare the coolant blend for the engine coolant system, and for the rocker cover and breather tube coolant system, in the following manner:

7.3.1 Do not apply heat either during, or following, the coolant preparation.

7.3.2 Use a container of a size adequate to hold the entire coolant blend required by both systems. See drawing RX-117350-D for an example of a suitable container.

7.3.3 Add the required amount of glycol (**Warning**—see Note 5) to the container.

7.3.4 Add the required amount of additive concentrate to the container.

7.3.5 Agitate the blend in the container for 30 min.

7.3.6 Within 2 h, add the blend to the engine coolant system, and to the rocker cover and breather coolant system.

7.4 *Pre-Test Cleaning Materials*—Use the cleaning materials (see Note 7) specified in the following list for cleaning of

[41] A gage which has been found suitable is Magnehelic Gauge Model No. 2301 available from Dwyer Instrument Co., P.O. Box 373, Michigan City, IN 46360.

[42] Sequence IIIE test fuel (GMR-995) from approved batches can be ordered from Phillips 66 Co., Philter Marketing Service, P.O. Box 968, Borger, TX 79008.

[43] Ethylene glycol meeting this specification is available from Dow Chemical Co., 2040 Dow Center, Midland, MI 48674.

[44] Pencool 2000 Coolant Additive is required for use in the Sequence IIIE test. The Pencool 2000 Coolant Additive can be obtained from The Penray Cos., Inc., 1801 Estes Ave., Elk Grove, IL 60007.

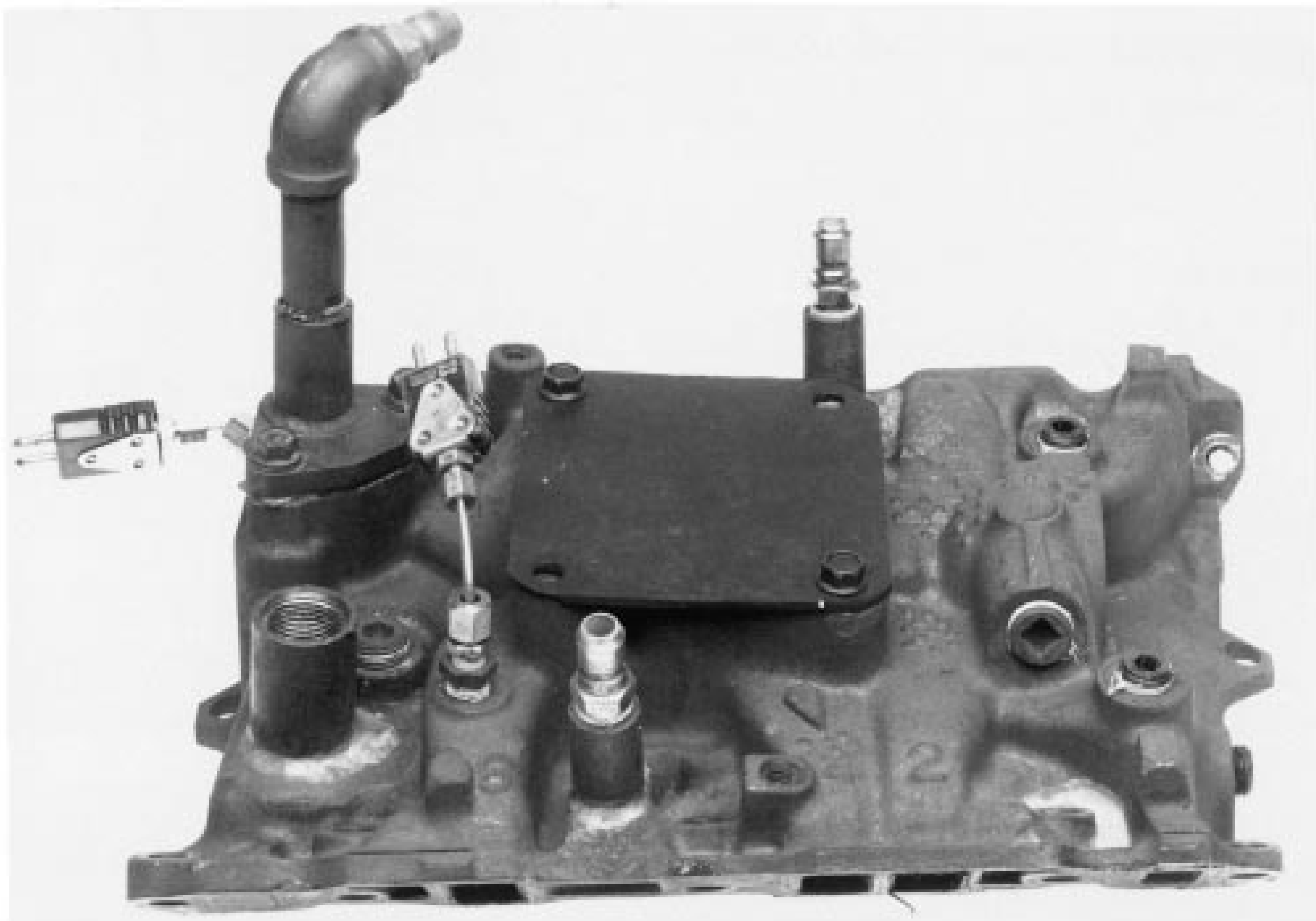

FIG. 11 Sequence IIIE Test Engine Intake Manifold

parts to be used in the test. Use no substitutes (see Note 8).

7.4.1 Commercial cleaning agent[18,45] (see Note 9),

7.4.2 Petroleum ether[18,46] (see Note 10),

7.4.3 Aliphatic naphtha meeting Specification D 235 Type I regular mineral spirits (Stoddard solvent) requirements, with a boiling point of 149–204°C (300–400°F)[46] (see Note 3), and

7.4.4 Sequence IIIE test component cleaner,[18,47] a mixture (by mass) of:

94 parts oxalic acid[18,48] (see Note 11)
6 parts dispersant[18,49] (see Note 11).

NOTE 7—**Warning:** See the appropriate materials safety data sheet.

NOTE 8—Only these specific materials and sources have been found satisfactory. If chemicals other than these are proposed for use, equivalency must be proven and approval obtained from the ASTM TMC.

NOTE 9—**Warning:** Corrosive. Health Hazard.

NOTE 10—**Warning:** Flammable. Health Hazard.

NOTE 11—**Warning:** Corrosive. Health Hazard.

7.5 *Post-Test Cleaning Materials*—Blend the solvent as specified in Table 1, which is used as a rating aid.

7.5.1 The tetrahydrafuran[18,50] (THF) (see Note 15) used shall meet the following specifications:

NOTE 12—**Warning:** The THF should be inhibited by butylated hydroxytoluene (BHT) so that explosive hazards upon drying are limited.

7.5.1.1 99.5 + % THF,

7.5.1.2 Inhibited with 0.025 % BHT, and

7.5.1.3 Less than 0.03 % water.

7.6 *Sealing and Anti-seize Compounds*— Use the sealing and anti-seize compounds specified in the following list. See Note 13 and Note 14.

7.6.1 Sealing compound for the intake port areas of the intake manifold gasket,[18,51]

[45] The commercial cleaning agent, Oakite 811, and the Oakite Parts Cleaner, have been found suitable. They are available from Oakite Products, Inc., 50 Valley Rd., Berkley Heights, NJ 07922.

[46] Petroleum ether and aliphatic naphtha are available from local petroleum product suppliers.

[47] The blended cleaner has been found suitable. It is available from Wrico Corp., 4835 Whirlwind, San Antonio, TX 78217.

[48] Oxalic acid (55-lb bags) and sodium carbonate (50-lb bags) are available from Ashland Chemical Co., P.O. Box 391, Ashland, KY 41114. If permitted by the hazardous materials disposal practices in a laboratory, sodium carbonate can be used to neutralize the oxalic acid in used Sequence IIIE Test component cleaner.

[49] Petro Dispersant Number 425 Powder (50-lb bags) is available from Witco Corp., 3230 Brookfield, Houston, TX 77045.

[50] Tetrahydrafuran which has been found suitable is THF, catalog number 14722-2, available from Aldrich Chemical Company, Inc., 1001 W. St. Paul Ave., Milwaukee, WI 53233.

[51] Perfect Seal Number 4 Brush-Type Sealing Compound, Part GM3D (16-oz container), must be used. It can be ordered from P.O.B. Sealants Inc., 11102 Kenwood Rd., Cincinnati, OH 45242.

FIG. 12 Sequence IIIE Test Engine Water-Cooled Exhaust Manifolds

TABLE 1 Post-Test Cleaning Materials[A]

Component	Volume %
Ethyl acetate[B]	37.5
Denatured alcohol (No. 30)[C]	27.5
Butyl alcohol[D]	5.0
Tetrahydrofuran[B]	30.0

[A]Only the specific materials indicated in Table 1 have been found satisfactory. No other chemicals may be used.

[B]Note 1—**WARNING**—See the appropriate materials safety data sheet.

[C]Note 2—**WARNING**—Flammable. Denatured alcohol cannot be made non-toxic. Health Hazard.

[D]Note 3—**WARNING**—Flammable. Health Hazard.

Note 4—**WARNING**—Flammable. Health Hazard.

7.6.2 Sealing compound for the rear main seal,[18,52]

7.6.3 Non-hardening sealing compound for the water ports of the intake manifold gasket,[18,53]

[52] Loctite Superbonder 414 has been found suitable. It is available from local distributors of Permatex products, or can be found by contacting Permatex Company, Inc. (Loctite Corporation), 18731 Cranwood Parkway, P.O. Box 7138, Cleveland, OH 44128-7138.

[53] Permatex Number 2 non-hardening sealer for the water ports, and cylinder head bolts, have been found suitable. They are available from local distributors of Permatex products, or they can be found by contacting Permatex Company, Inc. (Loctite Corporation), 18731 Cranwood Parkway, P.O. Box 7138, Cleveland, OH 44128-7138.

7.6.4 Sealing compound for the cylinder head bolts,[18,53]

7.6.5 Anti-seize compound for the exhaust manifold and pipe bolts,[18,54]

7.6.6 High-temperature silicone sealer for use as substitute for rear main bearing cap side seals,[18,55]

7.6.7 Weather-strip adhesive for the rocker arm cover gaskets, and[18,56]

7.6.8 Perfect Seal No. 4 Aerosol Spray Gasket Sealing Compound, Part No. GM3MA[18,57], is specified for the cylinder head gaskets.

NOTE 13—**Warning:** See the appropriate materials safety data sheet.

NOTE 14—Except for the high-temperature silicone sealer, only the specific materials and sources indicated in 7.6 have been found satisfactory. If materials other than these are proposed for use, equivalency must be proven and approval obtained from the ASTM TMC.

8. Hazards

8.1 *General*—The environment involved with any engine test is inherently hazardous. Serious injury of personnel and damage to facilities can occur if adequate safety precautions are not taken. However, as evidenced by the fact that many thousands of engine tests are successfully conducted each year, it is possible to take adequate precautions.

8.2 *Caveat*—The following paragraphs do not cover all possible safety-related problems associated with Sequence IIIE testing. See 1.3.

8.3 *Personnel*—Carefully select and train personnel who will be responsible for the design, installation, and operation of Sequence IIIE test stands. Make certain that the test operators are capable of handling the tools and facilities involved, and in observing all safety precautions, including avoiding contact with either moving or hot test parts.

8.4 *Personnel Protection Facilities*— Provide the following personnel protection facilities:

8.4.1 Provide safety shower and eye-rinse equipment in close proximity to the facilities used for parts cleaning, engine build-up, engine test operation, and parts rating.

8.4.2 Provide, and require the use of, appropriate face masks, eye protection, chemical breathers, gloves, etc. in all aspects of Sequence IIIE testing.

8.4.3 Provide dry chemical fire extinguishers for putting out fires.

8.4.4 Advise personnel not to use water to attempt to extinguish fires involving fuel, oil, or glycol.

8.4.5 Equip test stands with automatic fire extinguishing equipment.

8.4.6 Install suitable guards around all external moving parts, or hot parts.

8.4.7 Advise personnel not to work alongside the engine and coupling shaft when the engine is operating at high speeds.

8.4.8 Provide barrier protection between the engine and coupling shaft, and operating personnel.

8.4.9 Prohibit the wearing of loose or flowing clothing by personnel working near a running engine.

8.4.10 Advise personnel regarding the possibility of exothermic reactions with some of the chemicals used in the Sequence IIIE test.

8.5 *Safety Equipment and Practices*— Observe the following in order to establish and maintain safe working conditions for Sequence IIIE testing:

8.5.1 Provide the proper tools for conducting the Sequence IIIE test.

8.5.2 Require regular inspection and approval by the laboratory safety department of the facilities used for Sequence IIIE testing.

8.5.3 Properly install all fuel lines, oil lines, and electrical wiring; and maintain them in good condition.

8.5.4 Select and install coolant hoses and clamps with special care in order to prevent coolant leaks and possible fires.

8.5.5 Do not permit tripping hazards to exist in any of the areas involved with the Sequence IIIE testing.

8.5.6 Keep the outer surfaces of the engine, other equipment, and the floor area free of fuel and oil.

8.5.7 Do not allow the accumulation of containers of oil or fuel in Sequence IIIE test areas.

8.5.8 Demand that personnel be alert for leaking fuel, exhaust gas, oil, or coolant, and that they take action to stop such leaks.

8.5.9 Equip the test stand with an automatic fuel shutoff valve designed to turn off the fuel supply to the engine whenever the engine is not running.

8.5.10 Make provision for manual, remote operation of the fuel shutoff valve.

8.5.11 Install suitable interlocks to shut down the engine when any of the following develop: loss of dynamometer field current, engine overspeeding, loss of engine oil pressure, failure of the exhaust system, failure of the room ventilation, activation of the fire protection system, excessive vibration, etc.

8.5.12 In case of injury, seek medical attention immediately, and report the incident to the proper administrative people.

9. Test Oil Sample Requirements

9.1 *Selection*—The supplier of the test oil sample shall determine that it is representative of the lubricant formulation being evaluated and that it is not contaminated.

9.2 *Quantity*—The supplier shall provide approximately 15 L (4 gal) of the test oil sample.

NOTE 15—A Sequence IIIE Test can be conducted with only 10.5 L (2.75 gal) of test oil, provided that no spillage or leakage occurs during test preparation. The greater quantity is specified to accommodate such spillage and leakage.

9.3 *Storage Prior to Test*—The test laboratory shall store the test oil sample in a covered building to prevent contamination by rainwater.

[54] Anti-seize compounds which have been found suitable are Fel-Pro C-100, available from Fel-Pro, Inc., 7450 N. McCormick Blvd., Skokie, IL 60076 and Permatex anti-seize compound [Part 80078 (133K) 8-oz brush-top container], available from local distributors of Permatex products. It can also be found by contacting Permatex Company, Inc. (Loctite Corporation), 18731 Cranwood Parkway, P.O. Box 7138, Cleveland, OH 44128.

[55] GM high-temperature silicone sealer, Part 12346193 or 12346192, available from General Motors dealers, has been found suitable.

[56] Use only 3M Super Weather-Strip Adhesive, part number 051135-08001 available from Minnesota Mining and Manufacturing Co., AC & S Division, Department TR, 3M Center, 223-6 N.E., St. Paul, MN 55144-1000.

[57] The sole source of supply of the supply of the sealant known to the committee at this time is P.O.B. Sealants Inc., 11102 Kenwood Rd., Cincinnati, OH 45242.

10. Preparation of Apparatus

10.1 *Oil Heat Exchanger Cleaning*—Clean both the oil and water sides of the oil heat exchanger as follows (both sides may be flushed at the same time):

10.1.1 Replace the oil heat exchanger core after tests which have high camshaft-plus-lifter or where high viscosity increase, or both.

10.1.2 Use the oil heat exchanger flushing apparatus shown in drawing RX-117374-R.

10.1.3 Flush the water side of the oil heat exchanger for ½ h with a solution of 20 g/L of Sequence IIIE test component cleaner (**Warning**—see Note 11) (see 7.4) in water at a temperature of 60 ± 2.8°C (140 ± 5°F) and a flow rate of approximately 15 L/min (4 gpm).

10.1.3.1 Drain the water side of the oil heat exchanger and rinse it (one pass) with water at a temperature of 48.9 ± 2.8°C (120 ± 5°F) to a neutral pH; air dry.

10.1.4 Flush the oil side of the oil heat exchanger for ½ h with 100 % commercial cleaning agent (**Warning**—see Note 9) at a temperature of 60 ± 2.8°C (140 ± 5°F) and a flow rate of approximately 9.5 L/min (2.5 gpm).

10.1.4.1 Drain the oil side of the oil heat exchanger and rinse it with aliphatic naphtha (**Warning**—see Note 3) until solvent is clear; air dry.

10.1.5 After a cleaned oil heat exchanger has been reinstalled, and before each test, flush the pump, hoses, oil heat exchanger, and proportioning valve used on the external oil system with aliphatic naphtha (**Warning**—see Note 3) until clean, and air dry. Cycle the proportioning valve and manually rotate the external oil pump shaft while drying with air to ensure that all the solvent has been removed from the system. During the air drying step, take appropriate steps to prevent high-speed spinning of the pump rotor and resultant damage to the pump.

10.2 *Engine Parts Cleaning*—All non-aluminum engine parts, with the exception of the crankshaft may be cleaned using Model Number 300 LX-P-2x dishwater type parts cleaning machine[58]. After machine cleaning, clean the parts according to the procedures described in 10.3-10.18. Operate the parts cleaning machine according to the following instructions:

10.2.1 Operate the machine at 60°C (140°F).

10.2.2 Use Natural Orange Cleaning Agent, part number NAT-50 or NAT-50-2[18,58], mixed at a concentration of 12 to 24 g/L (0.1 to 0.2 lb/gal).

10.2.3 Wash time shall be no less than 30 min.

10.2.4 Change machine filters, water, and so forth, according to good laboratory practice.

10.3 *Jacketed Rocker Cover Cleaning*—Before every test, prepare the jacketed rocker covers according to the following procedure:

10.3.1 Plug the coolant passages with a ⅜ in. NPT pipe plug.

10.3.2 Brush the cover with commercial cleaning agent (**Warning**—see Note 9) and scrub with a wire brush or abrasive cloth[59]. Rinse with warm water.

10.3.3 Spray with a 50/50 mixture of aliphatic naphtha/build-up oil (**Warning**—see Note 3).

10.3.4 Every ten runs, or more frequently if necessary, clean the coolant passages with nitric or muriatic acid (**Warning**—see Note 16) to remove the deposits inside the jacket. Use acids in proper and safe concentrations.

NOTE 16—**Warning:** Corrosive. Health hazard.

10.3.5 After cleaning, pressure check the covers for leaks with air (**Warning**—see Note 17) at 69 kPa (10 psi) maximum. Do not use pressures greater than this value in order to prevent permanent distortion of the covers.

NOTE 17—**Warning:** For technical use only.

10.4 *Breather Tube Cleaning*—Immediately after completing a Sequence IIIE test, remove the stainless steel breather tube BX-212-1, and prepare it for reuse according to the following procedure:

10.4.1 Disassemble the breather tube.

10.4.2 Plug the coolant passages with a ⅜ in. NPT pipe plug.

10.4.3 Brush the breather tube with commerical cleaning agent (**Warning**—see Note 9) and scrub with a wire brush or abrasive cloth.[59] Rinse with warm water.

10.4.4 Spray with a 50/50 mixture of aliphatic naphtha/build-up oil (**Warning**—see Note 3).

10.4.5 Brush each tube with a nylon or stainless steel bristle brush.[60]

10.4.6 Every ten runs, or more frequently if necessary, clean the coolant pasages with nitric or muriatic acid (**Warning**—see Note 16) to remove the deposits inside the jacket. Use acids in proper and safe concentrations.

10.4.7 After cleaning the coolant side of the breather tube, pressure check it with air at 70 kPa (10 psi). **Warning**—see Note 17.)

10.5 *Cleaning of Special Stainless Steel Parts*—Polish all special stainless steel parts (other than the breather tube; see 10.3) with abrasive cloths.[18,59]

10.6 *Intake Manifold Cleaning*—Before every test, prepare the intake manifold according to the following procedure:

10.6.1 Remove the EGR plate.

10.6.2 Brush breather tube mount fitting with a 25 mm (1 in.) wire brush to prevent additive carryover.

10.6.3 Brush the intake manifold with commerical cleaning agent (**Warning**—see Note 9) and scrub with a wire brush or abrasive cloth.[59] Rinse with warm water.

10.6.4 Spray with a 50/50 mixture of aliphatic naphtha/build-up oil (**Warning**—see Note 3).

10.6.5 Remove all deposits from the top of the coolant crossover passage (base of intake runners).

10.6.6 Prevent exposure of the coolant crossover passage to the commercial cleaning agent.

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[58] The sole source of supply of the cleaning machine and cleaning agent known to the committee at this time is Better Engineering Manufacturing, 8361 Town Center Court, Baltimore, MD 21236-4964.

[59] 400-grit abrasive 3M cloth or 3M Elek-tro Cloth 400J have been found suitable. The 3M products are available from Minnesota Mining and Manufacturing Co., AC & S Division, Department TR, 3M Center, 223-6 N.E., St. Paul, MN 55144-1000.

[60] A .25-caliber rifle cleaning rod and a non-cuprous brush have been found suitable.

10.7 *Precision Rocker Shaft Follower Cleaning*—Before every test, soak bearings in post-test cleaning solvent (**Warning**—see Note 12) for a minimum of 15 min. See 7.5 for composition of solvent. Remove from solvent and wipe dry. Submerge bearings in a 50:50 mixture of aliphatic naphtha (**Warning**—see Note 3) and build-up oil in an ultrasonic cleaner. Operate cleaner for a minimum of 10 min (add no heat to solution). Remove from cleaner and power spray with aliphatic naphtha and air dry each bearing, but do not use compressed air to spin the bearing. Soak each bearing in build-up oil. Ensure no contact with water during the cleaning process.

10.8 *Engine Block Cleaning*—Prepare the engine block according to the following:

10.8.1 Remove the debris in all tapped holes using bottoming taps of the appropriate sizes. Scrape all residual gasket material and sealing compounds, if any, from sealing surfaces.

10.8.2 On a new engine block, physically remove all sand and slag deposits, and any other debris, from the water jacket using a sharp-ended drill rod of 6 mm (0.25 in.) diameter.

10.8.3 Thoroughly clean the block prior to honing as follows:

10.8.3.1 Remove the crankshaft, main bearings, and bearing caps.

10.8.3.2 Brush the engine block with commerical cleaning agent (**Warning**—see Note 9) and scrub with a wire brush or abrasive cloth.[59] Brush the oil passages with a wire or nylon brush. Do not submerge the block in the commercial cleaning agent (**Warning**—see Note 9). Prevent cleaner or oil from entering the engine coolant passages. Rinse with warm water.

10.8.3.3 Spray with a 50/50 mixture of aliphatic naphtha/build-up oil (**Warning**—see Note 3).

10.8.4 If the block is cleaned in a heated bath, allow it to cool before honing.

10.8.5 See 10.19.7 for the honing procedure.

10.8.6 After the cylinder walls have been honed, clean the engine block again by spraying with aliphatic naphtha (**Warning**—see Note 3). Spray with a 50/50 mixture of aliphatic naphtha/build-up oil (**Warning**—see Note 3). After cleaning the block, repeatedly coat the cylinder walls with build-up oil and wipe them to remove the oil, using a soft, lint-free, clean cloth.[17] Replace soiled cloths with clean cloths frequently. Repeat the process until no honing particles are visible on the cloth.

10.8.7 As an alternative to the procedure in 10.8.6, the following procedure may be used:

10.8.7.1 Spray the engine block (including all oil galleries) with aliphatic naphtha. (**Warning**—see Note 3) Then, use a high-pressure spraying device (**Warning**—see Note 18) [having an output pressure of 7,000 kPa (1,000 psi) and switchable from soap to rinse]. Thoroughly clean the entire engine block (that is, lifter valley, crankcase section, oil galleries, and coolant passages), with a soap[61] and tap water mixture at a temperature of 60 to 82°C (140 to 180°F) followed by a clear-water rinse. To reduce the possibility of rapid rusting after washing the engine block, do not exceed the recommended temperatures.

NOTE 18—**Warning:** For technical use only.

10.8.7.2 If the procedure in 10.8.7.1 is used, after pressure cleaning, spray the engine block (including all oil gallaries) first with aliphatic naphtha (**Warning**—see Note 3) followed by a 50/50 mixture of aliphatic naphtha and build-up oil. Using this 50/50 mixture, wipe out the cylinder bores with clean cloth towels intil all honing residue is removed.

10.8.7.3 AIr dry the engine block, using clean dry shop air (**Warning**—see Note 17), and coat the cylinder walls with build-up oil using soft, lint-free, clean cloths.

10.8.7.4 Check the cylinder finish. If it is not within specified limits, re-hone the block.

10.9 *Cylinder Head Cleaning*—Clean the cylinder heads according to the following:

10.9.1 Using a flexible probe, explore all accessible water passages to detect any material which would interfere with coolant flow.

10.9.2 Using a 10-mm wire brush, extending two-thirds the length of the cylinder head from freeze plug hole to freeze plug hole, clean all core sand and casting slag from the cylinder heads to ensure unrestrained coolant flow.

10.9.3 Clean the cylinder heads according to the recommended engine block cleaning procedure (10.8).

10.9.4 Air dry the cylinder heads. (**Warning**—see Note 17).

10.10 *Crankshaft Cleaning*—Before every test, prepare the crankshaft according to the following procedure:

10.10.1 Brush the crankshaft with commerical cleaning agent (**Warning**—see Note 9) and scrub with a wire brush or abrasive cloth.[59] Brush the oil passages with a nylon brush. Rinse with warm water.

10.10.2 Spray with a 50/50 mixture of aliphatic naphtha/build-up oil (**Warning**—see Note 3).

10.10.3 After polishing, clean crankshaft by spraying with aliphatic naphtha (**Warning**—see Note 3) and brushing the oil passages with a nylon brush. Spray with a 50/50 mixture of aliphatic naphtha/build-up oil (**Warning**—see Note 3).

10.11 *Connecting Rod Cleaning*—Before every test, prepare the connecting rods according to the following procedure:

10.11.1 Remove the connecting rod bolts.

10.11.2 Brush the connecting rods with commerical cleaning agent (**Warning**—see Note 9) and scrub with a wire brush or abrasive cloth.[59] Rinse with warm water.

10.11.3 Spray with a 50/50 mixture of aliphatic naphtha/build-up oil (**Warning**—see Note 3).

10.12 *Oil Pan Cleaning*— Before every test, prepare the oil pan according to the following procedure:

10.12.1 Brush the oil pan with commerical cleaning agent (**Warning**—see Note 9) and scrub with a wire brush or abrasive cloth.[59] Clean the underside of the baffle in the oil pan. Rinse with warm water.

10.12.2 Spray with a 50/50 mixture of aliphatic naphtha/build-up oil (**Warning**—see Note 3).

10.13 *Front Cover Cleaning*—Before every test, prepare the front cover according to the following procedure:

10.13.1 Brush the front cover with commerical cleaning

[61] Tide laundry detergent has been found suitable; it is commercially available. An equivalent can be used.

agent (**Warning**—see Note 9) and scrub with a wire brush or abrasive cloth.[59] Avoid contacting the front seal with commerical cleaning agent. Rinse with warm water.

10.13.2 Spray with a 50/50 mixture of aliphatic naptha/build-up oil (**Warning**—see Note 3).

10.14 *Oil Filter Adapter Block Cleaning*—Before every test, prepare the oil filter adapter block according to the following procedure:

10.14.1 Wash the oil filter adapter block with commerical cleaning agent (**Warning**—see Note 9). Rinse with warm water.

10.14.2 Completely disassemble oil filter adapter block and wash with aliphatic naphtha (**Warning**—see Note 3).

10.14.3 Replace fixture O-rings before every test.

10.15 *Oil Pump Cover Plate Cleaning*—Before every test, prepare the oil pump cover plate according to the following procedure:

10.15.1 Disassemble and wash the oil pump cover plate with commerical cleaning agent (**Warning**—see Note 9). Rinse with warm water.

10.15.2 Rinse oil filter adapter block with aliphatic naphtha (**Warning**—see Note 3).

10.15.3 Rinse pressure relief and filter bypass valves in both directions with aliphatic naphtha (**Warning**—see Note 3) to assure that no oil is trapped inside.

10.16 *Valve Rotator, Spring, and Keeper Cleaning*—Before every test, prepare the valve rotators, springs, and keepers according to the following procedure:

10.16.1 Rinse the valve rotators, springs, and keepers with aliphatic naphtha (**Warning**—see Note 3) and blow dry.

10.16.2 Oil with build-up oil prior to assembly.

10.17 *Piston Cleaning*— Before every test, prepare the pistons according to the following procedure:

10.17.1 Spray the pistons with aliphatic naphtha (**Warning**—see Note 3) and air dry.

10.17.2 The pistons shall not be wiped or polished in any manner prior to assembly.

10.18 *Cleaning of Remaining Engine Parts*—Clean all remaining engine parts (those not listed in 10.1-10.17) thoroughly prior to engine assembly according to the following procedure:

10.18.1 Degrease them first, and then brush them with commerical cleaning agent (**Warning**—see Note 9) (Prevent contact by the cleaner of nonferrous parts.) Rinse with warm water.

10.18.2 Spray with a 50/50 mixture of aliphatic naphtha/build-up oil (**Warning**—see Note 3).

10.19 *Engine Build-up Procedure*—Use forms such as those shown in Annex A2 and Annex A6 and Appendix X1 and Appendix X2 (Figs. A2.2, A6.9, X1.1, X1.2, X1.4, X2.1, and X2.2) and build the engine according to the following:

10.19.1 *General Information*—Use the service parts (see Table A2.3) and build-up procedures stated in the parts book and service manual[62] appropriate to the Sequence IIIE test engine, unless special or modified parts or procedures are specified in this test method. [19,20,21] See 6.4. Make and record measurements specified in this test method, of the cylinders, pistons, rings, bearings, valve train, cam, and lifters. These measurements will provide evidence of conformance to the specifications of the method, and will provide baselines for determining engine wear which occurs during a Sequence IIIE test on a lubricant. Handle camshaft, lifters, and pistons with gloved hands at all times.

10.19.2 *Special Parts*—Use the special parts listed in Annex A2, and others specified in the following text.

10.19.3 *Hardware Information*—Complete Fig. X1.1 and Fig A2.2[63] for the test to be run.

10.19.4 *Sealing Compound Applications*— Use sealing compounds as follows:

10.19.4.1 Use the specified sealing compound[18,51] on both sides of the intake manifold gasket areas adjacent to the intake ports. Apply the compound with a small mohair paint roller 48 mm (1⅞ in.) outside diameter by 76 mm (3 in.) wide. Store unused quantities of the compound in a small desiccator.[18,64] Use either ethyl alcohol (minimum 180 proof) or commercially pure isopropyl alcohol (**Warning**—see Note 19) to remove the compound from metal surfaces.

NOTE 19—**Warning:** Flammable. Health Hazard.

10.19.4.2 Coat the undersides of the rear main seal with a suitable sealing compound before installing it in the engine block and bearing cap.

10.19.4.3 Apply a nonhardening sealing compound[18,53] on all intake manifold gasket water ports, to the tapered ends of the front and rear elastomeric intake manifold seals[18,65] which are adjacent to the cylinder heads, and on the mating end surfaces of the rear main oil seal. Also apply the compound to the rear main bearing cap surfaces which mate with the block.

10.19.4.4 Apply an anti-seize compound[18,54] to the exhaust manifold and pipe bolts.

10.19.4.5 Use a weather-strip adhesive[18,56] on the rocker cover gaskets.

10.19.4.6 Use a high-temperature silicone sealer in place of the rear main bearing cap side seals.

10.19.5 *Fastener Torque Specifications and Torquing Procedures*—Use the following specifications and torquing procedures when installing bolts in the engine:

10.19.5.1 *Main Bearing Cap Bolts*—Use the new bolts supplied with the engine bearing kit. Apply build-up oil to the threads, and to the surfaces of the bolts which contact the main bearing caps. In order to prevent hydraulic lock, do not apply oil to the tapped holes in the cylinder block. Install the bolts finger tight, and tighten them further with the specified torque wrench.[18,66] First apply a torque of 35 N·m (26 lbf·ft); then rotate each bolt 46° clockwise.

[62] Refer to the 1986 or 1987 Buick Service Manual.

[63] This figure may be completed using a personal computer and EXCEL spreadsheet software; contact the ASTM Test Monitoring Center for more information.

[64] A Sargent-Welch S-25140 desiccator has been found suitable; it may be ordered from Sargent-Welch Scientific Co., 7300 N. Linder Ave., P.O. Box 1026, Skokie, IL 60077.

[65] Intake manifold seals (rubber), BX-306-1, obtained from the Central Parts Distributor, have been found suitable.

[66] The sole source of supply of the torque wrench known to the committee at this time is SPS Technologies, Assembly Systems Division, Highland Ave., Jenkintown, PA 19046.

10.19.5.2 *Cylinder Head Bolts*—The cylinder head bolts, GM Part Nos. 25527831 (short) and 25525953 (long), are of special design for yield applications and shall be installed using the SPS Torque Sensor I torque wrench[18,66] only. Replace the bolts after each test. Use new bolts for torque plate applications, they require specific preparation and installation procedures as outlined in 10.19.7.5 for the honing operation. The same bolts used for the torque plate application should be used for the cylinder head installation. Keep the bolts in their same locations, they require a slightly different preparation as outlined in 10.19.33.

10.19.5.3 *Intake Manifold Bolts*—Thoroughly clean the intake manifold bolts, and coat them with build-up oil. Install them finger tight, and tighten them further in the proper sequence.[62] First apply 47 N·m (35 lbf·ft) torque, then 61 N·m (45 lbf·ft), and, finally, 61 N·m (45 lbf·ft) once again.

10.19.5.4 *Connecting Rod Bolts*—Install the bolts finger tight and tighten them further with the SPS Technologies Torque Sensor I wrench.[18,66] Use the wrench with the Mode switch set to *angle control* and use a snug setting of 27 N·m (20 lbf·ft) and an angle setting of 50° to tighten the bolts.

10.19.5.5 *Torques for Miscellaneous Bolts, Studs, and Nuts*—Use the torques for miscellaneous bolts, studs, and nuts given in Table 2.

10.19.6 *Parts Replacement*—See 10.19.1 and 10.19.2 for information regarding parts. Replace test parts as follows:

10.19.6.1 Install the new parts listed in Table 3 for each test.

10.19.6.2 Install the new parts listed in Table 4, only if the used part is no longer suitable for test purposes.

10.19.6.3 The Central Parts Distributor will include in each shipment of the Critical Parts listed in Table 3 and Table 4, a Critical Parts Accountability Form; see Fig. A2.1. Examine the parts received for acceptability. For any unacceptable parts, complete a Critical Parts Accountability Form, including the reason for rejection. Send monthly copies of the completed form by telephone facsimile transmission to the ASTM TMC, the Central Parts Distributor, and the Test Developer. Retain all rejected parts; ship the accumulated parts to the Central Parts Distributor on the next April 15 or October 15, or earlier as directed by the Central Parts Distributor.

10.19.7 *Engine Block Preparation*—Prepare the engine block as follows:

10.19.7.1 Install new cup-type engine block freeze plugs; use a driver to facilitate this replacement.

TABLE 2 Torques for Miscellaneous Bolts, Studs, and Nuts

Threaded Component	Torque, N·m (lbf·ft)
Bolts for main bearing caps 1, 2, 3, and 4	See 10.10.5.1
Flywheel bolts	81 (60)
Connecting rod bolts	See 10.10.5.4
Timing gear to camshaft bolts	42 (31)
Front cover to block	30 (22)
Crankshaft balance bolt	271 (200)
Rocker arm shaft bolts	34 (25)
Rocker arm cover bolts	9 (7)
Oil pump cover plate, front cover housing	11 (8)
Oil pan bolts	9 (7)
Carburetor to intake manifold bolts	26 (19)
Stud, camshaft hold-back	47 (35)
Locknut, camshaft hold-back bearing	41 (30)
Bearing, rocker arm retaining	See 10.10.37

TABLE 3 New Parts Required for Each Test

Part Name	Part Classification[A]
Bearing kit, engine[B]	STP
Bearings, camshaft	STP
Bearings, connecting rod	STP
Bearings, main	STP
Bolts, main bearing cap	CP
Bolts, head, short (4)	SPO
Bolts, head, long (12)	SPO
Bearing, camshaft hold-back[C]	
Camshaft	CP
Chain, engine timing	SPO
Cylinder head assemblies	CP
Gasket, EGR crossover	SPO
Gasket, exhaust manifold	SPO
Gasket, front timing cover	SPO
Gasket, fuel pump	SPO
Gasket, oil filter[D]	NP
Gasket, oil pump pick-up	SPO
Gasket, oil pan	SPO
Gaskets, head	SPO
Gaskets, intake manifold[E]	NP
Gaskets, rocker cover[F]	SPO
Gear, camshaft sprocket	SPO
Gear, crankshaft sprocket	SPO
Oil filter[G]	CP
Piston rings[H]	CP
Pistons[I]	CP
Rocker arm retainers	SPO
Rocker arm shafts	SPO
Rocker arms, (RH) and (LH)	SPO
Seal, crankshaft rear main	NP
Seals, intake manifold, front and rear[J]	NP
Seals, intake valve stem	CP
Spark plugs, two sets per test	SPO
Spring, belleville, camshaft hold-back[K]	CP
Valve lifters[L]	CP
Valve rotators[M]	CP
Valve springs[N]	CP
Valves, exhaust	SPO
Valves, intake	SPO

[A] CP = critical parts,
NP = non-production parts,
SPO = service parts operations, and
STP = CPD special test parts.
[B] Obtain engine bearings from the Central Parts Distributor.
[C] The Andrews bearing, Part Number D1, has been found suitable. It is available from Detroit Ball Bearing Co., Sterling Heights, MI 48312.
[D] Oil filter gaskets, BX-303-1, obtainable from the Central Parts Distributor, have been found suitable.
[E] Intake manifold gaskets, BX-300-2, obtainable from the Central Parts Distributor, have been found suitable.
[F] Obtain rocker cover gaskets, Part 25523348, from a local General Motors Dealer.
[G] A new BX-307-2 (PF-47, controlled batch lot) engine oil filter is required. Obtain it from the Central Parts Distributor.
[H] Obtain Sequence IIIE test piston rings, BX-314-1, from the Central Parts Distributor.
[I] Obtain Sequence IIIE test pistons, BX-312-1 (Grade 5) and BX-313-1 (Grade 13), from the Central Parts Distributor.
[J] Intake manifold seals (rubber) BX-306-1, obtained from the Central Parts Distributor, have been found suitable.
[K] Obtain belleville spring, part BX-360-1, from the Central Parts Distributor.
[L] Obtain valve lifters, BX-302-1, from the Central Parts Distributor.
[M] Valve rotators, Part Number BX-305-1 (TRW No. RC155), may be ordered from the Central Parts Distributor.
[N] Obtain valve springs for the Sequence IIIE test, BX-308-1, from the Central Parts Distributor.

10.19.7.2 Install the main bearing caps, without the bearings in place. Use retaining bolts of the normal type and size, but do not use the new bolts supplied with the engine bearing kit. Tighten the retaining bolts using the procedure in 10.19.5.1.

10.19.7.3 To prevent entry of honing fluid into the coolant

TABLE 4 New Parts to be Used for Each Test, as Necessary

Part Name	Part Classification[A]
Balancer, harmonic	STP
Bearing, rocker arm retaining	STP
Block, engine	STP
Bolts, flywheel	SPO
Bolts, intake manifold (3⁄8-16 by 15⁄8 in.), (6)	SPO
Bolts, intake manifold, front, special, (1)	SPO
Bolts, intake manifold (3⁄8-16 by 13⁄8), (3)	SPO
Cover, front timing	STP
Crankshaft	STP
Dipstick, calibrated (see Fig. 13)	NP
Dipstick, hole plug (see Fig. 13)	NP
Flywheel	NP
Gasket, carburetor-to-manifold	SPO
Indicator, timing	STP
Keys, valve spring cap	SPO
Pump, engine oil (overhaul kit)	SPO
Pushrods	SPO
Rods, connecting	STP
Screen, oil pick-up	SPO
Shaft, precision rocker arm	STP
Washer, camshaft thrust	SPO

[A] CP = critical parts,
NP = non-production parts,
SPO = service parts operations, and
STP = CPD special test parts.

passages of the engine block, cover and seal the coolant inlet passages and freeze plug openings. Close the petcocks, if any were previously installed; if not, install 1⁄4-in. NPT pipe plugs. See 10.21.6.

10.19.7.4 Using a 30-cm (12-in.) smooth file, deburr the surfaces of the block which mate with the cylinder heads to ensure adequate gasket seating.

10.19.7.5 The honing torque plates[18 ,67] shall be used with the proper washers and spacers, supplied with the honing torque plates, to pre-stress the engine block for honing. Clean the threaded bores for the cylinder head attachment bolts using a bottoming tap before each installation of the torque plates. The torque plates require the use of new head gaskets, SPO Part No. 25525919, along with new cylinder head torque-to-yield fasteners, SPO Part Nos. 25525953 (long) and 25527831 (short), to obtain the proper cylinder bore distortion for each application for honing. Leave the sealing and thread locking compounds on the fasteners for the torque plate installation. Coat each fastener with build-up oil and use the following procedure for yield application:

(*a*) *Yield-Type Fastener Installation Procedure Using the SPS Torque Sensor I Wrench,*[18 ,66] torque the cylinder head fasteners in stages following the proper sequence[62] to, 27 N·m (20 lbs·ft), 54 N·m (40 lbs·ft) and 81 N·m (60 lbs·ft). After the 81 N·m sequence, set the SPS Torque Sensor I Wrench Joint switch to S for soft joint setting. Set the Mode switch to JCS-TEL with a snug-torque of 81 N·m (60 lb·ft). With the angle end coder attached for yield tightening, tighten the cylinder head fasteners in sequence to their yield clamp load, indicated by an audible tone and green light on the SPS torque wrench when used as directed for yield applications. To more closely duplicate cylinder bore distortions during testing, fastener locations should be noted to keep the fasteners in the same locations for test application as during torque plate installation.

10.19.7.6 Check the main bearing bore clearances using a mandrel, part BX-398-1, according to the following procedure:

(*a*) Starting from the front of the block, slide the mandrel through all four main bearing bores. If excessive resistance is encountered while inserting the mandrel, remove the mandrel from the engine block and inspect the main bearing bores for burrs, nicks, dirt, alignment problems, or any abnormalities. Use 400 grit paper, a scotch brite pad, or a fine stone to carefully remove any nicks, burrs, scratches, or dirt. Then use a clean shop towel with aliphatic naphtha to wipe the affected surfaces. Reinstall the mandrel to ensure that it can freely pass through all four main bearing bores. If the mandrel will not clear the bores after the above steps have been completed, the block should not be used. Notify the Test Developer and the Central Parts Distributor of the problem. After honing, the above proceure should be repeated prior to final engine build. The mandrel is an alignment and clearance gage only, not an assembly tool. The mandrel should not be in the bores when installing the main bearing caps or torquing the main bearing bolts.

10.19.7.7 Use a honing machine[18,68] to hone the cylinder walls. Select the machine settings shown in Table 5 to give a cross-hatch pattern of 30 to 40°.

10.19.7.8 Equip the honing machine with a fiber mat, part CV-1100.[18,68]

10.19.7.9 The flow rate of the honing lubricant should be approximately 7.6 L/min (2 gal/min). The honing fluid should not contain an excessive amount of honing debris. In addition, no solvents are to be introduced into the honing fluid or used to clean the honing stones or guides. Only honing fluid is permitted to clean honing stones or guides.

10.19.7.10 Replace the honing fluid, filters, and fiber mats used in the honing machine every 15 h of the honing machine operation. Use the honing machine hour meter to determine hours of operation.

10.19.7.11 Use the stones indicated in Table 5; strive to achieve the microfinishes in 10.19.7.11.

10.19.7.12 Hone the cylinder walls without the main bearings in place, but with all bearing caps installed, to achieve the following cylinder bore specifications. Record all measurements on Fig. X1.1.

TABLE 5 Honing Machine Setup

	CK-10	CV-616
Spindle speed, r/min	155	170
Stroke rate, strokes/min	46	57
Feed ratchet position	3- or 30-tooth gear	2 or 3
Stone number		
Roughening	JHU 525	JHU 525
Finishing	JHU 820	JHU 820

[67] The B-H-J Torque Plate, part GM-3.8/3E-R-S-T-HT, is available from B-H-J Products, Inc., 37530 Enterprise Ct., Newark, CA 94560.

[68] Sunnen honing machines, oil, and stones which have been found suitable are ffecttest either Model CV-616 or Model CK-10; oil, CK-50; and stones, JHU 55 and 820. They can be purchased from Sunnen Products Co., 7910 Manchester Ave., St. Louis, MO 63143.

Microfinish (AA):
0.50 to 0.76 µm (20 to 30 µin.)—following roughening operation
0.23 to 0.28 µm (9 to 11 µin.)—following finishing operation
Piston Ring Travel Area:
Maximum allowable variation in diameter—0.010 mm (0.0004 in.)
Maximum allowable taper—0.010 mm (0.0004 in.)

10.19.7.13 Clean the engine block following honing according to 10.8.6.

10.19.8 *Piston Fitting and Numbering*—Fit the pistons to the cylinders according to recommendations.[62] The maximum permissible cylinder wall-to-piston clearance is defined as a fit resulting in a 13.4 N (3 lbf) pull with a 0.13 mm (0.005 in.) feeler gage located between the piston and cylinder wall. Fittings using measurements of bore size and piston diameter are allowed. Use only the specified (see 10.19.6.1 and Table 3) code pistons and ring sets. Number the pistons with odd numbers in the left bank from front to rear and with even numbers in the right bank from front to rear (the same numbers appear on the intake manifold legs).

10.19.9 *Piston Ring Fitting*—Grind the ends of the top and second rings using a ring grinder[18,69] to achieve the specified engine blowby flow rate. Refer to drawings RX-118358-B, RX-118359-B, RX-118361-A, RX-118362-A, and RX-118604-B. Remove all burrs from the rings with a fine stone prior to inserting them in the cylinder bore. Use a ring gap feeler gage[18,70] to measure the gap, with the ring positioned in the cylinder bore with a piston ring depth gage (drawing RX-118602-B). Rings shall be positioned at 23.67 mm below the cylinder block deck surface during gap measurement. Ring gap adjustment may be performed with or without honing torque plates installed. Remove all burrs from the rings with a fine stone prior to installing them on the pistons. *Do not round over the edges of the ring ends.*

10.19.9.1 For a laboratory with no prior experience with the Sequence IIIE test procedure, for the first test on a new engine, try a gap of 0.97 mm (0.038 in.) for the top and second rings. Modify the compression ring gaps on subsequent tests as necessary to achieve the specified engine blowby flow rate.

10.19.9.2 Cut the same gap on the top compression ring for all six pistons. Also, cut the same gap on the bottom compression ring for all six pistons. The top and bottom ring gaps may differ.

10.19.10 *Pre-Test Camshaft and Lifter Measurements*—Measure the camshaft lobes and lifter lengths, prior to engine assembly, according to the following procedure:

NOTE 20—When these parts are removed from the packages as received from the supplier, and if they are not to be measured and installed in the engine immediately, coat them with build-up oil.

10.19.10.1 Remove any burrs on the push-rod-seat end of the hydraulic valve lifters, Part BX-302-1 (see Table 3), using 400-grit emery paper.

10.19.10.2 Clean the camshaft lobes and lifters with aliphatic naphtha (**Warning**—see Note 3); blow dry them with clean, dry shop air. (**Warning**—see Note 17)

10.19.10.3 See 13.11.2 through 13.11.5 for details of the measurement procedure.

10.19.10.4 Measure the maximum pre-test dimension of each camshaft lobe, transverse to the camshaft axis to the nearest 0.0025 mm (0.0001 in.). This dimension is at the front edge of the lobe for lobe numbers 1, 3, 7, 9, and 11; and at the rear edge of the lobe for all other lobes (lobes are numbered from the front to the rear of the camshaft). Record the measurements on Fig. X2.1.

10.19.10.5 Measure the pre-test length of the lifters at the center of the lifter foot to the nearest 0.0025 mm (0.0001 in.). Record the measurements on Fig. X2.1.

10.19.10.6 Mark the left bank hydraulic valve lifters with odd numbers (1, 3, 5, 7, 9, 11) from front to rear and those for the right bank with even numbers (2, 4, 6, 8, 10, 12) from front to rear. Use an electro-mechanical scribing device. Do not place any marks on the lifter feet.

NOTE 21—Mark the lifters *after* measuring them to preclude any effect on the lifter length caused by heating during the marking process.

10.19.10.7 Coat the camshaft and lifters with build-up oil to prevent rusting.

10.19.11 *Camshaft Bearing Installation*— Install the camshaft bearings (see Table 3), using the cam bearing installation tool.[18,71] Minor modifications to the tool may be made to make the tool easier to use.

10.19.12 Verify the camshaft bearing clearances using three stainless steel balls of 45.3644 mm (1.7860 in.), 45.4152 mm (1.7880 in.), and 45.4406 mm (1.7890 in.) diameters,[18,20] according to the following procedure. Record clearance verification on Fig. X1.3.

10.19.12.1 Attempt to pass the 45.3644 mm (1.7860 in.) ball through all four bearing positions. If the low limit ball passes through all four positions, then the installed bearings have a clearance greater than the low end of the build specifications.

10.19.12.2 Attempt to pass the 45.4152 mm (1.7880 in.) through the No. 1 bearing position. If the ball does not pass through the No. 1 position, then the installed bearing has a clearance less than the high end of the build specification.

10.19.12.3 Attempt to pass the 45.4406 mm (1.7890 in.) ball through the Nos. 2, 3, and 4 bearing positions. If the ball does not pass through the Nos. 2, 3, and 4 positions, then the installed bearings have a clearance less than the high end of the build specifications.

10.19.12.4 Failure to successfully complete any of the above clearance verifications does not invalidate the engine build.

10.19.13 *Camshaft Preparation*—Remove any nicks, burrs, or ridges (such as any metal that was extruded around the cam sprocket bolt holes during tapping) on the thrust face of the camshaft, Part RX-8619-4[18,20], by light filing.

10.19.14 *Camshaft Installation*—Install the camshaft according to the following procedure:

10.19.14.1 Install the stainless steel hold-back stud, RX-118635-A2, in the rear of the camshaft and tighten it to 47 N·m

[69] A Sanford SG-48 ring grinder has been found suitable; it can be ordered from Sanford Manufacturing Co., P.O. Box 318, Roselle, NJ 07203.

[70] A suitable ring gap feeler gage, range 0.50 mm or smaller to 1.25 mm (0.020 to 0.050 in.) by 0.025 mm (0.001 in.) increments, Part #KS567m, can be ordered from Klopp Corp., 25150 Thomas Dr., Warren, MI 48091.

[71] Obtain the cam bearing installation tool, part BX-397-1, or a print to fabricate the tool from, from the Central Parts Distributor.

(35 lbf·ft) torque. Check the run-out at the outer end of the stud produced by rotating the camshaft on its journals in V-blocks. If the run-out is 0.25 mm (0.01 in.) or greater, replace the stud or camshaft, or both, to reduce the run-out.

10.19.14.2 Examine the thrust washer,[18 ,72] made according to print RX-118624-A3. Washers should be discarded if: when measured in at least three places, the thickness at any given point is less than 1.5494 mm (0.0610 in.), the washer shows physical damage, or the washer is not flat and parallel.

10.19.14.3 Coat the thrust washer, all camshaft surfaces, and the camshaft bearings in the engine block with build-up oil.

10.19.14.4 Install the thrust washer on the camshaft; if the washer had been previously used, identify the washer surface which had faced the engine block and orient the washer so that that surface again faces the block.

10.19.14.5 Install the camshaft in the engine block, taking care to avoid damage to the lobes, journals, and bearings.

10.19.15 *Installation of Camshaft Hold-Back Fixture*—Install the camshaft hold-back fixture, RX-118641-A2, according to the following procedure:

10.19.15.1 Identify the boss in the rear of the engine block at the end of the camshaft bore.

10.19.15.2 Measure the distance from the rear of the boss surface to the step in the camshaft bore.

10.19.15.3 Measure the distance from the surface in front of 1) the O-ring groove of the hold-back fixture to 2) the groove surface of the hold-back fixture that should fit over the boss of the engine block.

10.19.15.4 Subtract the distance determined in 10.19.15.2 from that in 10.19.15.3. Add 0.25 mm (0.010 in.) to the remainder to determine the thickness of the thrust washer to be used.

10.19.15.5 Obtain a thrust washer having a thickness within + 1.3 to − 0.0 mm (+ 0.050 to − 0.000 in.) of that determined in 10.19.15.4, machined according to drawing RX-118213-A, for use as a positioning shim to locate the camshaft hold-back fixture. (Several thrust washers may be stacked to obtain the required thickness.) Install the thrust washer(s) in the hold-back fixture.

10.19.15.6 Install the O-ring[18,73] on the fixture housing, RX-118636-A2, and coat the fixture with build-up oil.

10.19.15.7 Push the fixture onto the rear of the engine block. Seat the fixture against the block by tapping it with a rubber-faced mallet.

10.19.15.8 Confirm that there is no interference between the retainer cap of the hold-back fixture and the engine flywheel.

10.19.15.9 Soak the thrust bearing (see Table 3) in build-up oil, and install it in the fixture housing. Orient the bearing so that the end plate, that rotates independently from the bearing housing, faces outward; and that the stationary inner side plate of the bearing does not contact any part of the stud, RX-118635-A2.

10.19.15.10 Install the belleville washer in the hold-back fixture so that the small-diameter end faces outward, and the large-diameter end is seated against the thrust bearing.

10.19.15.11 Screw a new ½ in. -20UNF nylon insert hex lockout on to the hold-back stud. Tighten to apply a slight load on the Belleville washer to ensure the camshaft is seated against the front of the engine block.

10.19.15.12 Install the camshaft loading fixture assembly on the rear of the engine.

10.19.15.13 Install a dial or digital indicator on the front of the engine block using a magnetic base. Place the indicator such that the axis of the indicator is parallel to the camshaft axis. Reset the indicator to read zero at the current camshaft position.

10.19.15.14 Apply sufficient air pressure to achieve a 1112 N (250 lb) load on the rear of the camshaft.

10.19.15.15 Verify that the camshaft has moved forward. Travel will vary depending on initial preload of the Belleville washer, but should be in the range of 0.508 to 0.762 mm (0.020 to 0.030 in.).

10.19.15.16 Tighten the ½ in. -20UNF nylon insert hex loacknut using a modified ¾ in. wrench until the camshaft forward travel measures 76 µm (0.003 in.). The load on the camshaft will increase to approximately 1223 N (275 lb).

10.19.15.17 Release the camshaft load and verify that the camshaft forward travel returns to zero.

10.19.15.18 Apply sufficient air pressure to achieve a 890 N (200 lbf) load on the rear of the camshaft. Verify that the camshaft has not moved forward. Repeat this step several times. If the camshaft moves forward, remove the ½" -20UNF nylon insert hex locknut, replace it and the Belleville washer, and repeat the process (see 10.19.15.11).

10.19.15.19 Apply sufficient air pressure to achieve a 1112 N (250 lbf) load on the rear of the camshaft. Verify that the camshaft has moved forward. Repeat this step several times. If the camshaft does not move forward, remove the ½ in. -20UNF nylon insert hex locknut, replace it and the Bellevilie washer, and repeat the process (see 10.19.15.11).

10.19.15.20 Starting at a 890 N (200 lbf) load on the rear of the camshaft, increase the load in 22 to 44 N (5 to 10 lbf) increments between applications until the camshaft begins to move forward. Verify that the load is between 890 and 1112 N (200 and 250 lbf). If the load is outside this range, remove the ½ in. -20UNF nylon insert hex locknut, replace it and the Belleville washer, and repeat the process (see 10.19.15.11).

10.19.15.21 Place a new gasket (Part BX-303-1[18 ,20]) on the rear of the fixture housing.

10.19.15.22 Coat the outer surface of the gasket with build-up oil.

10.19.15.23 Screw the retainer cap, RX-118636-A2, onto the fixture and hand tighten it. Tighten the set screw. Make certain that the cam stud does not touch the inside surface of the retainer cap, and that the flywheel will not contact the outside face of the retainer cap. If such interference is encountered, contact the ASTM TMC for advice.

10.19.16 *Camshaft Sprocket, Crankshaft Sprocket, and Chain*—Install new sprockets and chain.

10.19.17 *Camshaft Thrust Button*—Do not install the camshaft thrust button and spring normally used on the production engine.

[72] Obtain the thrust washer from the Central Parts Distributor.

[73] A Parker O-ring, Part 2-132, has been found suitable. It can be ordered from local suppliers.

10.19.18 *Main Bearings*—Verify that the main bearing bore areas in the engine block and bearing caps are clean. Examine the backing material of Main Bearing No. 3 for rust. Remove any rust from the backing material by cleaning with OO steel wool coated with buildup oil, rinsing with aliphatic naphtha, and air drying. Install new main bearings in the engine block and main bearing caps, and lightly oil the bearing surfaces with build-up oil.

10.19.19 *Crankshaft*—Install the crankshaft.

10.19.20 *Main Bearing Cap Installation*— Install the main bearing caps; use a rubber or plastic mallet to seat the caps. Do not use the main bearing cap bolts to seat the caps. Install the bolts finger tight, and tighten them according to the procedure in 10.19.5.1. Measuring the bearing-to-crankshaft clearances is unnecessary; use the main bearings as received.

NOTE 22—The crankshaft may be installed without the rear main seal in place to permit checking of free crankshaft rotation. If this step is taken, remove the main bearing cap bolts, re-oil them, and re-install them in the same positions from which they were removed.

10.19.21 *Crankshaft End Play*—Measure the crankshaft end play. It should be between 0.076 and 0.28 mm (0.003 and 0.011 in.).

10.19.22 *Piston Pin Installation*—When installing the piston pins, use either a connecting rod heater or the apparatus specified in the service manual. Exercise extreme care to avoid piston pin distortion, to ensure proper connecting rod-to-piston pin alignment, and to ensure freedom of movement of the rod relative to the piston.

10.19.23 *Piston Installation*—Install the pistons according to the following procedure:

10.19.23.1 After gapping the piston rings, use a piston ring expander[18,74] to install the rings on the pistons.

10.19.23.2 Position the ring end gaps as shown in drawing RX-117372-C.

10.19.23.3 Coat the cylinder walls with build-up oil and wipe them with a clean, lint-free soft cloth; coat them again.

10.19.23.4 Coat the pistons and rings with build-up oil.

10.19.23.5 Install the pistons in the cylinders, using a ring compressor tool.[18,75]

10.19.24 *Harmonic Balancer*—Deburr the harmonic balancer keyway slot and the slot on the crankshaft with a mill file. Install the balancer on the crankshaft.

10.19.25 *Connecting Rod Bearings*—Use new connecting rod bearings for each test, as furnished in the serialized engine bearing kit. See Table 3.

10.19.25.1 Examine the backing material of the connecting rod for rust. Remove any rust from the backing material by cleaning with 00 steel wool coated with build-up oil, rinsing with aliphatic naphtha, and air drying. Clean the No. 3 and No. 5 connecting rod test bearings in either petroleum ether or pentane (**Warning**—see Note 10), air (**Warning**—see Note 17) dry them, and weigh the top and bottom halves to the nearest 0.1 g (0.0002 lb). Refer to Practice E 29 for any needed rounding; use the rounding-off method. Record the weights on Fig. X2.2. (As indicated in Fig. X2.2, at the choice of the test laboratory, the other connecting rod bearings may also be cleaned and weighed.)

10.19.25.2 Install the bearings in the connecting rods, and install the bearing caps with the rods in place on the crankshaft.

10.19.25.3 Measure the bearing clearances and side clearances. The bearing clearances must be between 0.013 and 0.066 mm (0.0005 and 0.0026 in.), and the side clearances between 0.15 to 0.58 mm (0.006 to 0.023 in.).

10.19.26 *Engine Front Cover*—Install a new front cover if the oil pump housing is worn. See 10.10.28.1.

10.19.27 *Coolant Inlet Adapter*—Replace the water pump with a coolant inlet adapter as shown in drawing RX-118608-D.

10.19.28 *Timing Mark Accuracy*—Locate the cylinder 1 piston at top dead center. Verify that the timing indicator aligns with 0° on the harmonic balancer.

10.19.29 *Oil Pump*—Rework the oil pump assembly and install it as follows:

10.19.29.1 Install either new gears, or a new front cover and new gears, as judged necessary according to the service manual.

10.19.29.2 Do not polish the oil pump relief valve.

10.19.29.3 Permanently plug (silver solder or weld) the spring-loaded by-pass valve on the top of the pick-up tube.

10.19.29.4 Install a new gasket on the oil pump tube-to-block surface.

10.19.29.5 Bolt the oil pump assembly to the engine block.

10.19.30 *Oil Dipstick Hole*—Plug the oil dipstick hole with a hole plug (Part BX-386-1[18,20]). This plug is removed and the calibrated dipstick (Part BX-384-1[18,20]) is inserted to determine the oil level at the appropriate time during a test. See Fig. 13 and Fig. 14.

10.19.31 *Oil Pan*—Modify the oil pan as indicated in drawing RX-118626-A1. Install it on the engine block, using a gasket. Do not use magnetic drain plugs in the pan.

10.19.32 *Cylinder Head Assembly*—Prepare the cylinder heads according to the following procedure:

10.19.32.1 Install new cup-type freeze plugs using the proper driver, drawing BX-371-1.[18,20]

10.19.32.2 Deburr all surfaces of the cylinder heads which mate with the engine block and the manifolds with a 30-cm (12-in.) smooth file to ensure satisfactory gasket seating.

10.19.32.3 Thoroughly clean the cylinder heads with aliphatic naphtha (**Warning**—see Note 3), and air (**Warning**—see Note 17) blow them dry prior to final assembly.

10.19.32.4 Coat the valve stems and valve guides with build-up oil.

10.19.32.5 Install the valves and lightly lap them. Clean the cylinder heads after lapping according to 10.10.9.3. The valves shall be installed in the location where lapped for final assembly.

10.19.32.6 Install new valve stem seals over the valve stems onto the valve guides. Exercise extreme care when installing the seals in order to avoid either cutting the seals or mispositioning them on the guides, thereby helping to preclude

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[74] A suitable piston ring expander is Perfect Circle Tool Part P313-S, 3.800 in., available from Dana Corp., Perfect Circle Products Division, P.O. Box 116, Richmond, IN 47374.

[75] A suitable piston ring compressor tool is Snap-On Ring Compressor Tool RC-40C, available from Dana Corp., Engine Products, P.O. Box 116, Richmond, IN 47374.

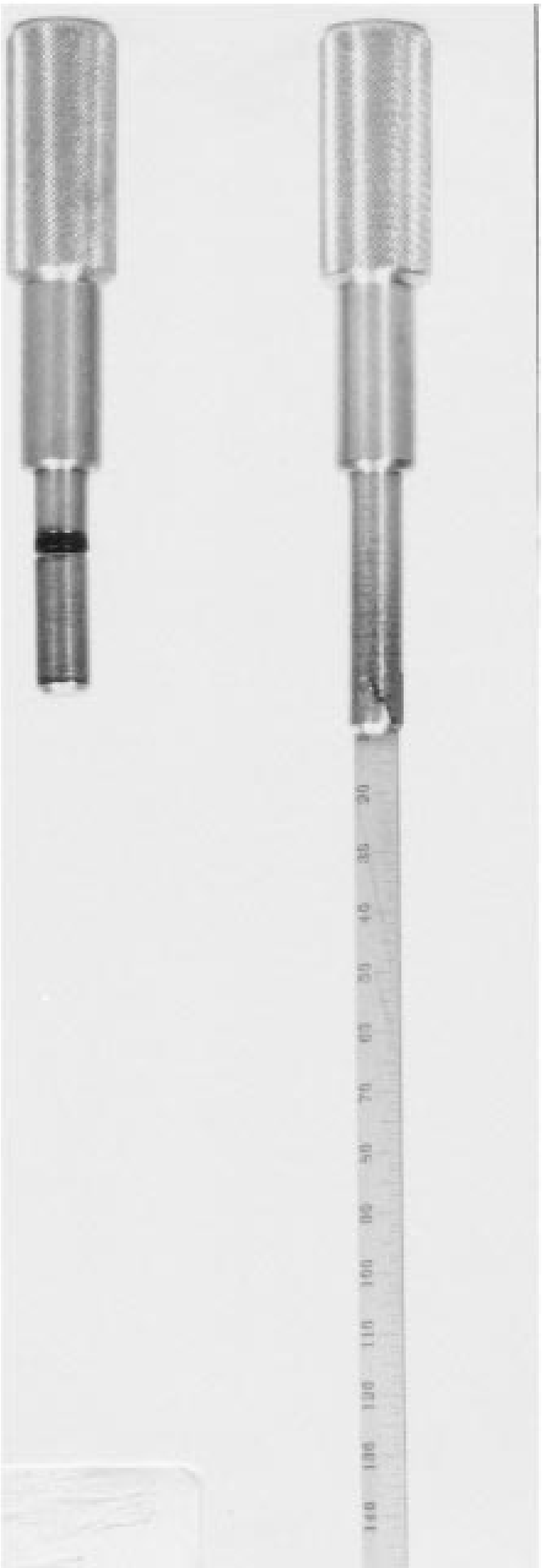

FIG. 13 Sequence IIIE Test Engine Dipstick Hole Plug and Oil Dipstick

high oil consumption.

10.19.32.7 Install new valve rotators (Part BX-305-1). See Table 3.

10.19.32.8 Install new valve springs (see Table 3). Place the smaller diameter end of the spring against the rotator.

10.19.33 *Adjustment of Valve Spring Loads*— Adjust the load of each valve spring according to the following procedure:

10.19.33.1 Before and after using the valve spring load measurement apparatus (such as Part BX-310-2[18,20]), calibrate the load cell using the following technique. Use dead weights to produce the specified load of 1023 N (230 lbf).

(*a*) *Load Cell to Load Cell Technique*—Affix load cell weight adapter plate (see Fig. 15) to calibration load cell. Zero the calibration load cell. Individually place calibrated dead weights onto calibration load cell. Verify that each dead weight indicates the appropriate load on calibration transducer readout. Repeat the calibration of the calibration load cell. The two consecutive readings shall agree within ±0.5 lbs; if not, inspect the load cell and replace, if necessary. Align calibration load cell beneath apparatus load cell. Place the air cylinder ram on the calibration load cell. Set the apparatus load cell to read the value of the calibration load cell. Apply air pressure to the aligned load cells. Vary air pressure to give several different loads, including 230 lbs. Determine that both calibration and apparatus transducer readouts indicate the same value, if not, adjust the apparatus load cell. Repeat the calibration of the valve spring load measurement apparatus. The two readings shall agree within ±0.5 lbs; if not, inspect the apparatus load cell and replace, if necessary. Retain data obtained during each calibration.

10.19.33.2 Identify the cylinder heads according to standard laboratory practice.

10.19.33.3 Install a cylinder head in the holding fixture.

10.19.33.4 Install zeroing fixture, part D4031[76], to cylinder head.

10.19.33.5 Place the air cylinder loading unit over a valve and check for proper alignment of the valve tip with the loading unit.

10.19.33.6 Position the air cylinder piston rod on the top of the valve stem.

10.19.33.7 Use a dial or digital indicator having divisions of 0.003 mm (0.0001 in.).

10.19.33.8 Position the dial indicator and its foot on the zeroing fixture in order to accurately measure the axial movement of the valve stem.

10.19.33.9 Set the air regulator for an indication of 316 kPa (46 psi) on the pressure gage.

10.19.33.10 Rapidly apply and release the air pressure three times to ensure free travel of the piston rod; adjust the air pressure to obtain a load cell reading of 104.3 kgf (230 lb), if necessary.

10.19.33.11 Release the air pressure, zero the dial indicator, rapidly apply the air pressure, and record the dial indicator reading, load cell reading, and shim thickness on Fig. X1.2.

NOTE 23—Tapping on the cylinder head or applying any additional

[76] Zeroing fixture, Part D4031, is part of the valve spring load measurement apparatus, Part BX-310-2.

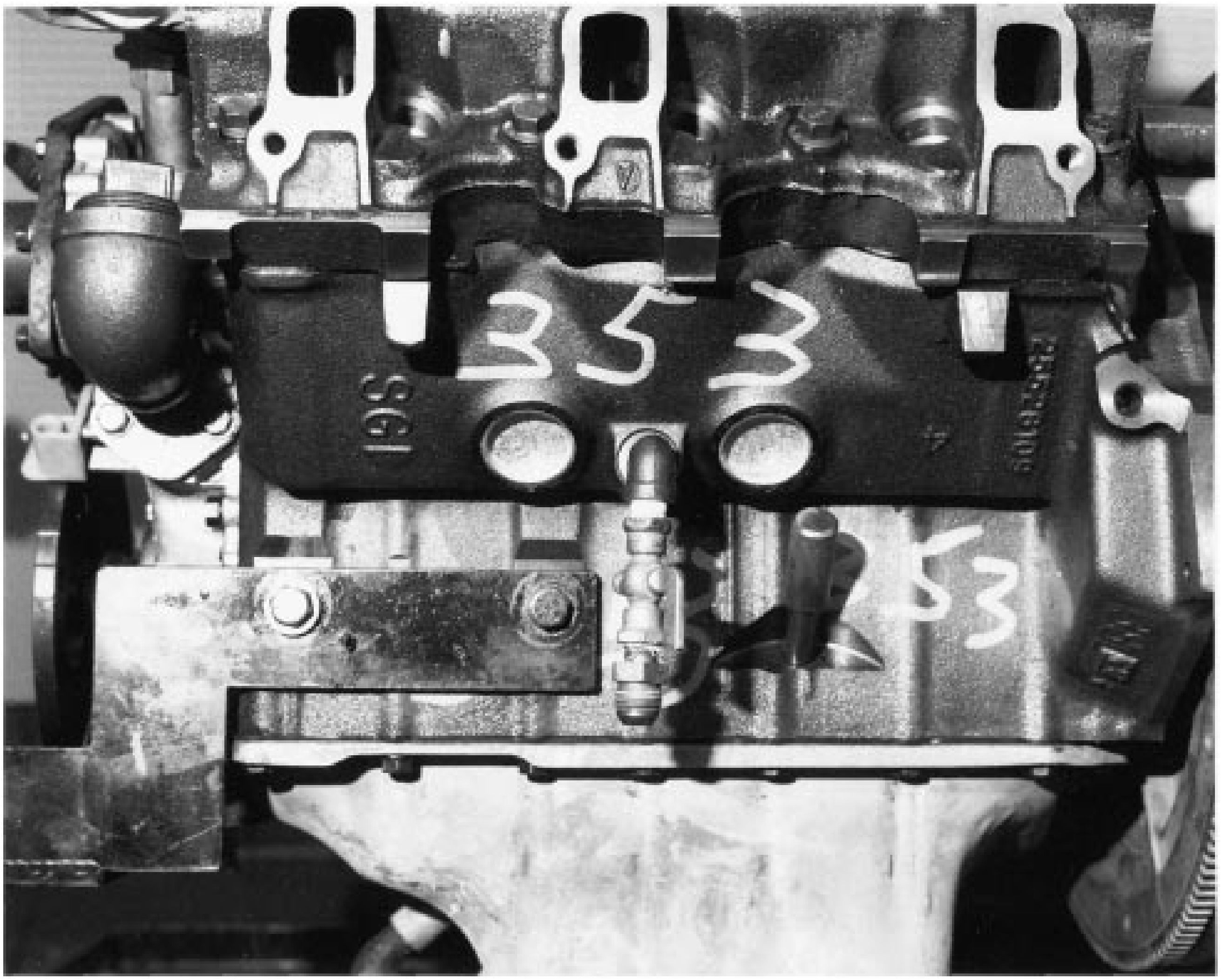

FIG. 14 Sequence IIIE Test Engine Left Petcock and Oil Dipstick Hole Plug

force on the valve spring is not permitted.

10.19.33.12 If the readings are not within the specifications of 8.9 ± 0.25 mm (0.350 ± 0.010 in.) as shown by the dial indicator, and 104.3 kgf (230 lbf) load as shown by the load cell indicator, add or remove shims, or interchange parts as necessary. Repeat steps 10.19.33.4 through 10.19.33.12.

10.19.33.13 Following the valve spring adjustment, gently tap each valve stem tip with a plastic mallet. Check for valve rotation to ensure that the valve rotators are functioning properly. If rotation does not occur with a given valve, replace the associated valve rotator, and repeat the valve spring adjustment for that valve.

10.19.34 *Cylinder Head Installation*—New head gaskets, SPO Part No. 25525919, with a very light coating of aerosol type sealing compounds[18,77] shall be used for each application. Use the same fasteners used for torque plate attachment during the honing operation for cylinder head attachment. The fasteners shall be used in their same locations as during honing to more closely duplicate the same cylinder bore distortions during test operation. Before using the fasteners for cylinder head attachment, the seal and thread locking compounds should be removed from the threads and underside of the bolt head using a wire brush. Do not use chemical cleaners to remove these coatings. Coat the threads and underside of the bolt head using non-hardening pliable sealing compound.[55] Tighten the fasteners using the following procedure:

10.19.34.1 *Yield-Type Fastener Installation Procedure*—Using the SPS Torque Sensor I Wrench[18,66], torque the cylinder head fasteners in stages following the proper sequence[18,62] to, 27 N·m (20 lbs·ft), 54 Nm (40 lbs·ft) and 81 Nm (60 lbs·ft). After the 81 Nm sequence, set the SPS Torque Sensor I Wrench Joint switch to S for soft joint setting. Set the Mode switch to JCS-TEL with a snug-torque of 81 Nm (60 lb·ft). With the angle end coder attached for yield tightening,

[77] Perfect Seal Number 4 Aerosol Spray Gasket Sealing Compound, Part Number GM3MA, must be used. It can be ordered from P.O.B. Sealants Inc., 11102 Kenwood Rd., Cincinnati, OH 45242.

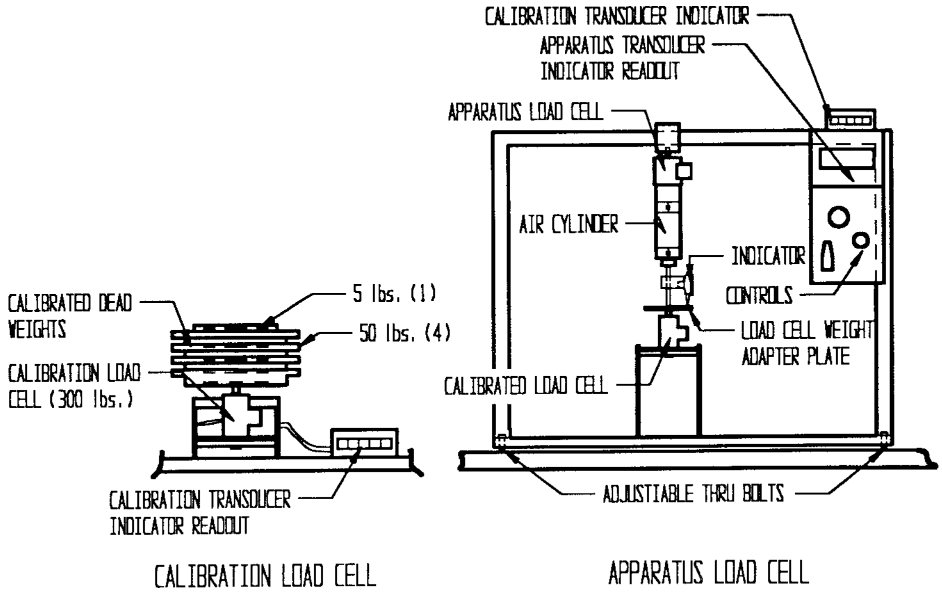

FIG. 15 Load Cell-to-Load Cell Calibration Method Diagram

tighten the cylinder head fasteners in sequence to their yield clamp load, indicated by an audible tone and green light on the SPS torque wrench when used as directed for yield applications. Care should be taken when handling the new composition gasket used in conjunction with these bolts to prevent surface or edge damage prior to installation.

10.19.35 *Hydraulic Valve Lifters*—Do not remove the oil in the new valve lifters. Fill lifters using a lifter fill chamber, Part number BX-390-1,[18,78] prior to installation.

10.19.35.1 *Lifter Fill Chamber Operation*— Install lifters in the lifter holding fixture in an upright position. Add sufficient build-up oil to cover lifters. 1000 mL has proven satisfactory. Close chamber, start vacuum pump, and hold vacuum for 10 min. Maintain 381–508 mm Hg (15–20 in. Hg) vacuum throughout filling. Release vacuum, open chamber, raise holding fixture, and allow lifters to drain for 10 min in upright position. Coat the lifter bodies with build-up oil prior to installation. Replace build-up oil in lifter fill chamber after filling three sets of lifters.

10.19.36 *Pushrods*—Clean the pushrods with aliphatic naphtha (**Warning**—see Note 3), and air (**Warning**—see Note 17) blow them dry prior to installation; make certain that the oil passages are open. Install the pushrods through the engine heads.

10.19.37 *Precision Rocker Arm Assembly*— Install the rocker arms to the precision rocker arm shafts[18 ,79], Part BX-318-2. Torque the rocker arm retainer bearing[18,80] to 26 lbf·in. maximum.

10.19.38 *Valve Train Loading*—Install the precision rocker shaft assembly according to the following:

10.19.38.1 Rotate the engine crankshaft to TDC Cylinder 4 compression and verify that the balancer reads 0° TDC.

10.19.38.2 Install the test lifters in the test engine, coating each lifter foot with build-up oil[18,19] before installation into the lifter bore.

10.19.38.3 Install the pushrods for the left blank (Cylinders 1, 3, and 5). Install the left bank precision rocker arm shaft assembly and torque the rocker arm fasteners to 35 N·m (25 lbf·ft).

10.19.38.4 Allow 10 min to elapse for the left bank lifters to leak down to their installed plunger height then remove the left bank rocker arm shaft assembly.

10.19.38.5 Rotate the engine crankshaft 360° to TDC Cylinder 1 compression and verify that the balancer reads 0° TDC.

10.19.38.6 Install the pushrods for the right bank (Cylinders 2, 4, and 6). Install the right bank precision rocker arm shaft assembly and torque the rocker arm fasteners to 35 N·m (25 lbf·ft).

10.19.38.7 Reinstall the left bank precision rocker arm shaft assembly. Slowly torque the rocker arm fasteners to 35 N·m (25 lbf·ft) while observing positions five and nine for leak down.

10.19.38.8 The crankshaft shall not be rotated until the engine start is attempted on the test stand.

10.19.39 *Intake Manifold*—Modify the intake manifold according to the following instructions:

10.19.39.1 Modify the intake manifold as shown in drawing RX-118615-E to permit the circulation of coolant.

10.19.39.2 Remove the EGR valve from the intake manifold, and install the adapter shown in drawing RX-118615-E, using a new gasket for each test.

10.19.39.3 Deburr all the surfaces of the intake manifold which mate to the cylinder heads with a 30-cm (12-in.) smooth file to ensure gasket seating.

10.19.39.4 Install the intake manifold using the special intake manifold gasket, Part BX-300-2 (see Table 3).

10.19.40 *Rocker Cover Deflectors and Stanchions*—Attach the rocker cover deflectors shown in drawing RX-118577-C to the stanchions shown in drawing RX-118576-A. See Fig. 16.

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[78] Obtain lifter fill chamber from Central Parts Distributor.

[79] Obtain precision rocker arm shaft, Part BX-318-2, from the Central Parts Distributor.

[80] Obtain rocker arm retainer bearing, Part BX-317CF-2, from the Central Parts Distributor.

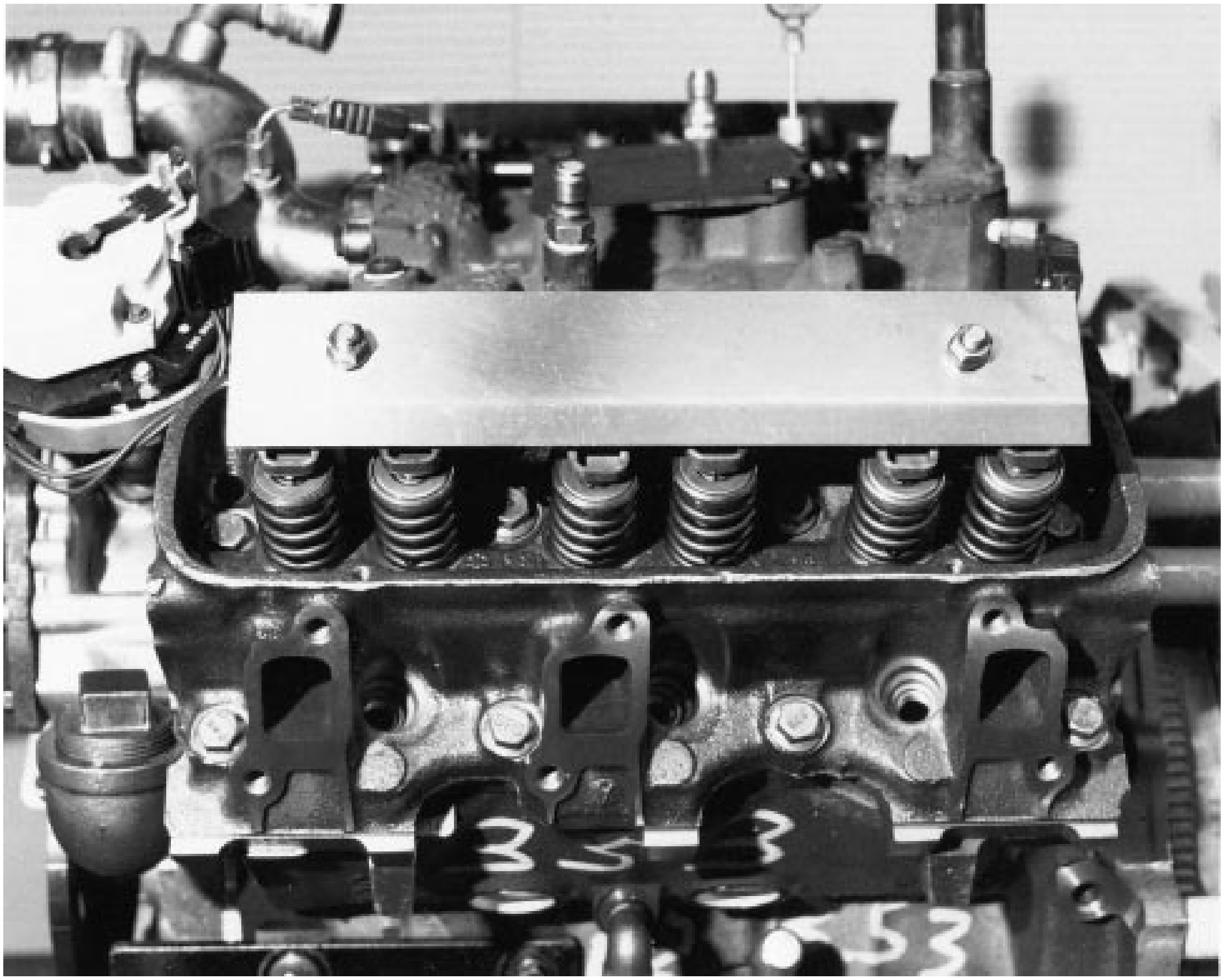


FIG. 16 Sequence IIIE Test Engine Rocker Cover Deflectors—Installed

10.19.41 *Rocker Covers*—Install the rocker cover gaskets (see Table 3) on the cylinder heads. Use a weather strip adhesive.[18,56] Install the rocker covers. See Fig. 17.

10.19.42 *Water Inlet Adapter*—Install a water inlet adapter made according to drawing RX-118608-D, using a gasket. See Fig. 9. Alternatively, use quick-disconnect, full-opening fittings[18,81] such as shown in drawings RX-118137-C and RX-118136-A.

10.19.43 *Breather Tube*—Install a breather tube[18,82] on the intake manifold. See Fig. 6. Use gaskets either made in-house or ordered from the breather tube manufacturer.

10.19.44 *Coolant Outlet Adapter*—Replace the thermostat housing with a coolant outlet adapter, fabricated from either stainless steel or non-stainless steel, using a gasket and a suitable connection as shown in drawing RX-118609-A1. See Fig. 10.

10.19.45 *Oil Fill Adapter*—Install the oil fill adapter in place of the fuel pump, drawing RX-118612-C, using a new fuel pump gasket. Install the 1½-in. NPT pipe plug.

10.19.46 *Oil Filter Adapter*—Install an oil filter adapter made according to drawings RX-118613-C and RX-118457-B. See Fig. 7. Install an oil filter. Use oil filter gaskets (Part BX-303-1). See Table 3.

10.19.47 *Oil Sample Valve*—Install suitable plumbing to the oil pressure fitting located in the oil filter adapter, drawing RX-118613-C, to permit the removal of oil samples. Select the plumbing to minimize the added volume.

10.19.48 *Ignition System*—Install ignition system components according to the following instructions:

10.19.48.1 Use high-energy ignition wires which are resistant to moisture and high temperatures.[18,83]

10.19.48.2 Use an original equipment manufacturer distributor.[18,84] Check its operation on a distributor tester. Install it in the engine.

10.19.48.3 Use new spark plugs.[85] Adjust the gaps with a

[81] Suitable quick-disconnect, full-opening fittings are available from Aeroquip Corp., Industrial Division, 1225 W. Main Street, Van Wert, OH 45891.

[82] Breather tube BX-212-1 must be used; obtain it from the Central Parts Distributor.

[83] Use AC-Delco Part 606M ignition wires.

[84] Use only an AC-Delco distributor which accommodates the 4-pin number 990 ignition module (Part 1875990).

[85] Use only AC Part R42TS spark plugs, available from General Motors dealers, or automotive parts stores.

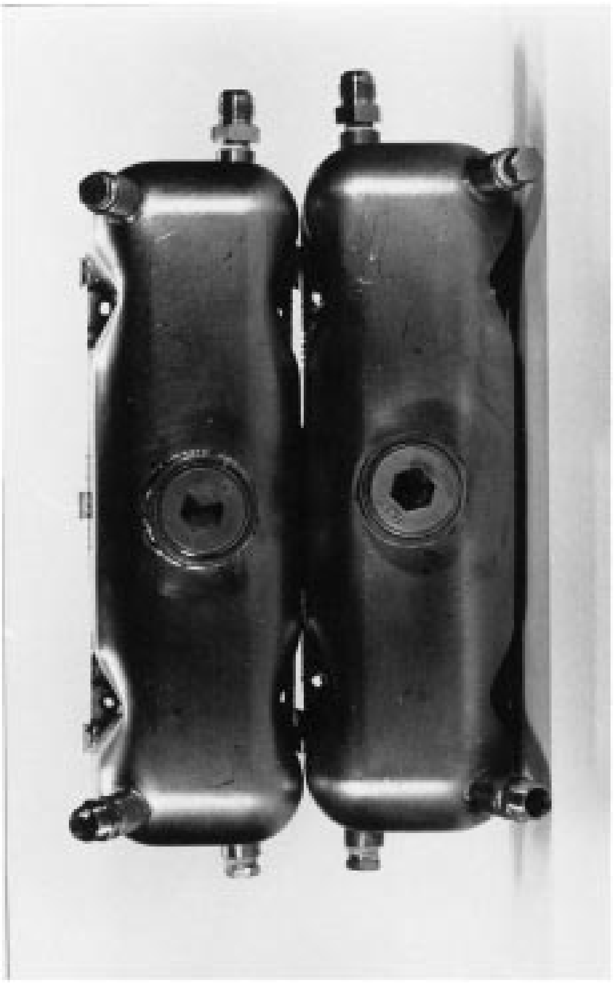


FIG. 17 Sequence IIIE Test Engine Rocker Covers

wire gage to 1.14 mm (0.045 in.). Install a set of plugs prior to test start-up and another set at the 32-hour oil level point.

10.19.49 *Carburetor*—Install and maintain the carburetor according to the following:

10.19.49.1 Use a two-barrel service carburetor supplied by the original equipment manufacturer.[24]

10.19.49.2 Modify the carburetor according to drawing RX-118617-E.

10.19.49.3 Install appropriate jet and rod combinations in the carburetor such that, together with suitable adjustment of the Fuel Mixture Control Unit, the specified air-to-fuel ratio can be maintained.

10.19.49.4 If the air-to-fuel ratio cannot be maintained within specified limits, disassemble, clean, and rebuild the carburetor.

10.19.49.5 Install the carburetor on the intake manifold using gaskets between the manifold and the air inlet adapter (drawing RX-118616-E), and between the adapter and the carburetor.

10.19.49.6 Connect the carburetor to the Fuel Mixture Control Unit, drawing BX-150-1, or equivalent.

10.19.50 *Accessory Drive Units*—Do not use any accessory drive units, such as alternators, generators, fuel pumps, power steering units, air pumps, etc.

10.19.51 *Exhaust Manifolds, Water-Cooled*— Prepare two water-cooled exhaust manifolds[18,38] (see Fig. 12) and install one on each of the two cylinder heads according to the following instructions:

10.19.51.1 Provide pressure taps for exhaust back pressure and exhaust gas analysis in each manifold exit plate as shown in drawing RX-118614-D.

10.19.51.2 Deburr all the surfaces of the exhaust manifolds which mate with the cylinder heads with a 30-cm (12-in.) smooth file to ensure proper gasket seating.

10.19.51.3 Attach the exhaust manifolds to the heads using stainless steel studs (⅜-16 × ⅜-24 × 1½ in.), stainless steel ⅜-24 nuts, and suitable gaskets,[18,86] as detailed in 6.15.1.

10.19.51.4 Connect the exhaust pipes to the manifolds using the method shown in drawing RX-118614-D.

10.19.52 *Engine Flywheel*—Modify the flywheel as shown in drawing RX-117225-C. Install it on the crankshaft.

10.19.53 *Pressure Checking of Engine Coolant System*—Pressure check the engine coolant system after assembly and before installation of the engine on the test stand, according to the following procedure:

10.19.53.1 Block the coolant outlet, and install the necessary fittings on the coolant inlet to permit pressurizing the coolant system with air, and sealing it.

10.19.53.2 Pressurize the coolant system with air to 100 kPa (30 in. of Hg) (**Warning**—see Note 17), and seal it. Monitor the pressure for 10 min. Take no corrective action if the reduction in pressure is less than 3.4 kPa (1 in. of Hg) in 10 min. If larger changes in pressure are observed, re-torque all appropriate bolts, and replace gaskets, seals, and components (including the cylinder heads and the intake manifold) as necessary. Repeat the pressure checking.

10.20 *Lifting of Assembled Engines*—Lift the assembled engines with a suitable lift chain.[18,87] Do not lift the assembled engines by the intake manifold; this practice is known to generate coolant leaks.

10.21 *Mounting the Engine on the Test Stand*—Mount the engine on the test stand according to the following:

10.21.1 Use suitable engine mounts.[18,88]

10.21.2 Mount the engine in such a manner that the carburetor mounting flange-to-intake manifold interface is horizontal.

10.21.3 Install an engine flywheel guard (drawing RX-117167-E) and a safety housing (drawing RX-117168-D).

10.21.4 Connect the engine to the dynamometer with a flywheel-to-driveshaft coupling adapter (drawing RX-117157-B) and a driveshaft.[18,89] See drawing RX-117529-D for a typical engine-dynamometer installation.

[86] Exhaust manifold gaskets can be ordered from either of two sources. For the first of these, specify McCord gasket Part 40033. Place six-month-supply orders by March 1 and September 1 with McCord Gasket Co. (JP Industries), 191-T Labodie St., Wyandotte, MI 48192. Alternatively, Fel-Pro Part SELM5 90508 is available from Fel-Pro, Inc., 7450 N. McCormick Blvd., Skokie, IL 60076.

[87] A suitable chain for lifting Sequence IIIE test engines can be ordered from Kent-Moore Corp., 29784 Little Mack, Roseville, MI 48066.

[88] Suitable motor mounts for the Sequence IIIE test engine can be ordered from American Rubber Products Co., 692 Alpha Drive, Cleveland, Ohio 44143.

[89] Driveshaft Part 1601-1608 has been found suitable; it can be ordered from Spicer Universal Joint Division, P.O. Box 955, Toledo, OH 43697-0955.

10.21.5 Fabricate and mount a blowby hood according to drawing RX-118623-A2.

10.21.6 Install a coolant drain valve in the middle of each side of the block, in the ¼-in. NPT hole. The use of street ells and petcocks has been found satisfactory. See Fig. 14. (Installation of petcocks will be assumed for the remainder of this standard.)

10.22 *External Cooling System Cleaning*— Clean the external cooling system of either a new or used test stand, or a new flushing tank assembly. Clean the used test stand system periodically, typically before a reference test. Use the following procedure:

10.22.1 Remove all galvanized materials from the system.

10.22.2 Prepare a cleaning mixture in the flushing tank (drawing RX-116924-C) by mixing 19.0 g/L Sequence IIIE test component cleaner (**Warning**—see Note 11) (see 7.4) with water. Heat the mixture to 60 ± 2.8°C (140± 5°F).

10.22.3 Circulate the mixture at 150 L/min (40 gpm) flow rate for 30 min.

10.22.4 Immediately following step 10.22.3, thoroughly flush all system components with water at 60 ± 2.8°C (140 ± 5°F).

10.23 *Engine Coolant Jacket and Intake Manifold Coolant Crossover Cleaning (Flushing)*—After the engine has been installed on the test stand, chemically clean the engine coolant jacket and intake manifold coolant crossover to ensure the proper rate of heat transfer to the jacket coolant, according to the following procedure:

10.23.1 Connect the flushing tank to the engine so that the cleaning solutions enter at the coolant outlet adapter and exit at the front of the engine block (reverse flow only for flushing) through the water inlet adapter shown in drawing RX-118608-D.

10.23.2 Plumb the coolant crossover fitting for the dual rocker cover system located in the coolant outlet adapter, drawing RX-118609-A1, with 12.7-mm (0.5-in.) steel braided line and a tee fitting connecting the coolant outlet adapter and the intake manifold. Connect the intake manifold coolant passages on either side of the carburetor mounting flange to the coolant outlet adapter. Plumb the return line from the intake manifold, which exits at the rear of the manifold, to the flush line after the flush chemicals have exited the engine block through the coolant inlet adapter. See Fig. 18.

10.23.3 For the following segments of this cleaning procedure, minimize the elapsed time between steps in order to avoid rusting of the coolant jacket.

10.23.4 Disconnect the external oil outlet line from the oil pan. Open the engine block petcocks and pass water heated to 60 to 70°C (140 to 158°F) through the engine coolant jacket for 2 min. Check for coolant leaks as evidenced by water flowing out of the oil pan. If coolant is leaking, take appropriate steps to stop the leak. If no leaking is evident, close the petcocks and fill the flushing tank engine block, and intake manifold crossover with water to provide a total volume of 38 to 45 L (10 to 12 gal).

10.23.5 Energize the flushing tank heaters. Circulate water through the engine at a flow rate of 115 to 130 L/min (30–35 gpm) through the engine and approximately 15 L/min (4 gal/min) through the intake manifold coolant crossover until the temperature of the water flowing out of the engine reaches 70 ± 3.0°C (158 ± 5.0°F).

10.23.6 While the water continues to circulate through the engine, add 19 g/L Sequence IIIE test component cleaner (**Warning**—see Note 11) (see 7.4) to the water in the flushing tank.

10.23.7 Continue to circulate the mixture through the engine for 30 min.

10.23.8 Stop the circulation pump and skim any oily surface film from the flushing tank using a suitable blotter-type material. Open the engine block petcocks, and drain the contents of the engine and flushing tank into a suitable container. Neutralize the drained material.

10.23.9 Close the engine block petcocks and flow hot tap water through the engine into a suitable container, for 2 to 5 min, until the pH of the water flowing out of the engine is neutral. Use water at a temperature of 60 to 70°C (140 to 158°F). Maintain a flow rate of 76 to 95 L/min (20 to 25 gal/min). Neutralize the drained material.

10.23.10 After flushing the engine, and prior to running a test with it, remove the four freeze plugs, and, using a flashlight, inspect the block for any remaining sand or slag by looking up through the freeze plug holes toward the cylinder head attachment bolts which protrude downward through the cylinder block deck. If deposits are present, use compressed air (**Warning**—see Note 17) and high-pressure water, together with a sharp object such as a thin-blade screwdriver, to dislodge and remove the deposits. Also, check for deposits on the jacket walls surrounding the cylinders by wiping the walls with a finger. Replace the freeze plugs, and circulate tap water through the engine for 10 min. Repeat the freeze-plug-removal, inspection, and cleaning procedure until all deposits are removed. After all deposits are removed, repeat chemical flushing procedure.

NOTE 24—Speed is essential to prevent the water jacket from air drying and oxidizing.

10.23.11 Quickly install new cup-type freeze plugs using the proper driver, drawing BX-371-1.[18,20]

10.23.12 Connect the engine to the external engine cooling system.

10.23.13 Immediately charge the engine jacket, rocker cover, and intake manifold cooling systems with coolant.

10.24 *Coolant Charging*—Charge the engine jacket, rocker cover, and intake manifold cooling systems with the specified inhibited glycol coolant (**Warning**—see Note 5), according to the following procedure:

10.24.1 To preclude contamination of the coolant system with water, install low-point drains and eliminate all traps in the system. Drain all water in the system.

10.24.2 Use a charging adapter, drawing RX-118137-C.

10.24.3 Completely fill the engine jacket, rocker cover, and intake manifold coolant circulating system with 85 ± 9.5 L (22.5± 2.5 gal) of inhibited coolant (see 7.3). (**Warning**—see Note 5) Fill the engine coolant jacket before filling the rest of the system.

10.24.4 Charge the breather tube coolant system immediately after charging the engine cooling system.

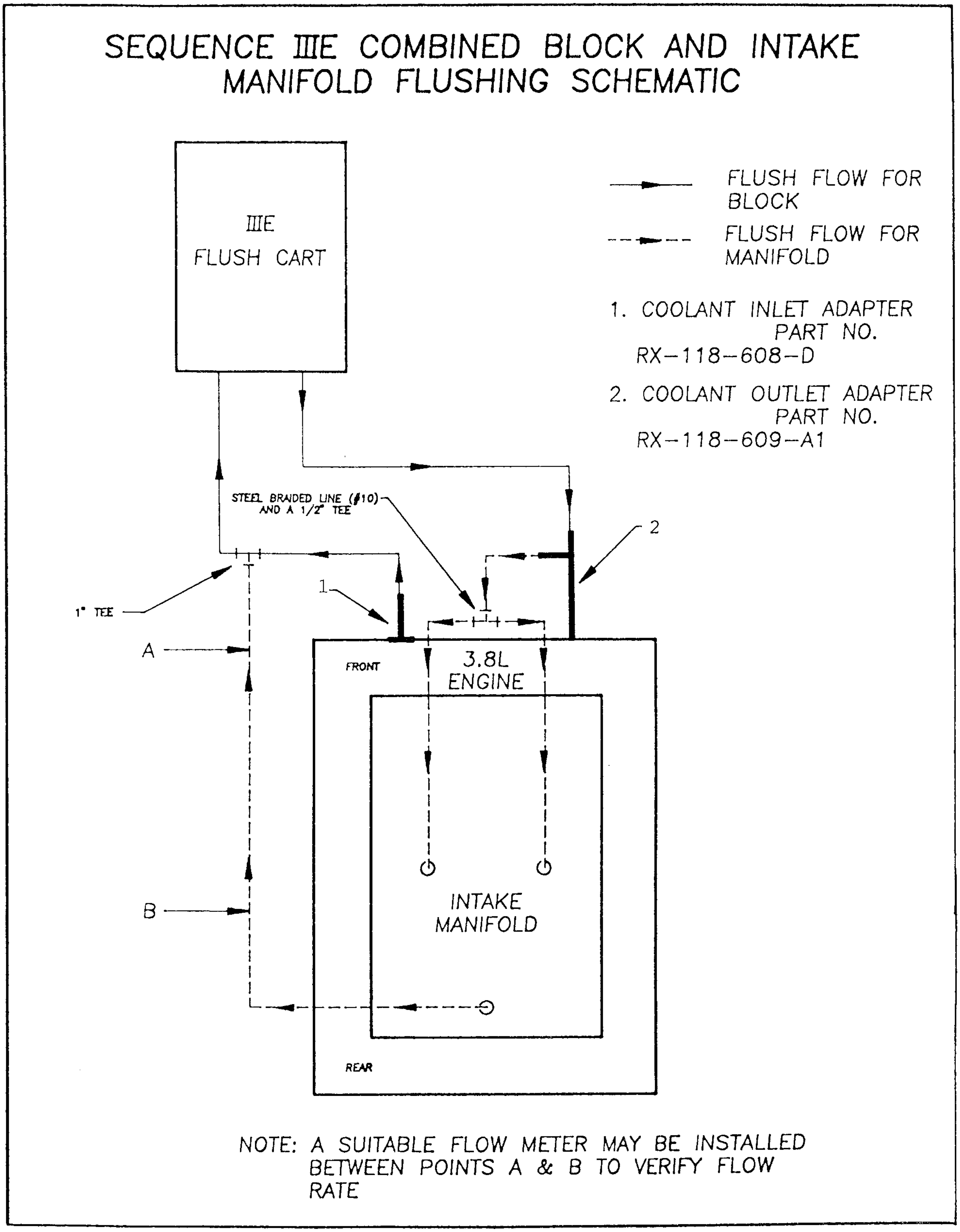


FIG. 18 Sequence IIIE Coolant Flush Plumbing Schematic

10.24.5 Cycle the circulating pump on 15 s and off 45 s for a 5-min period to aid in the removal of air and consequently decrease the time to achieve clarity of the coolant. During this period, operate any proportioning valves in the coolant system several times.

10.24.6 Until the test is started, circulate the coolant at a temperature of 48.9 ± 2.8°C (120 ± 5°F) and a flow rate of 150 L/min (40 gpm). Start the test no later than 6 h after step 10.24.5.

10.25 *Test Oil Charging*—Charge the engine and external oil system with the test engine oil as follows:

10.25.1 Install the engine oil filter adapter.

10.25.2 Install a new oil filter (see Table 3).

10.25.3 Verify that the external oil system has been cleaned and air dried according to 10.1.

10.25.4 Connect the external oil system lines to the oil pan.

10.25.5 Add an initial fill of 4.32 L (4 qt, 18 oz) of fresh test oil through the oil fill adapter.

10.26 *Engine Oil Pump Priming and Cam-and-Lifter Pre-Test Lubrication*—Prime the engine oil pump, and simultaneously apply test lubricant to the cams and lifters, according to the following instructions:

10.26.1 Modify a distributor assembly by removing the drive gear teeth, thereby making it possible to drive the oil pump by turning the distributor shaft, without turning the camshaft.

10.26.2 Replace the test distributor with the modified distributor assembly in the engine front cover assembly.

10.26.3 Fabricate an oiling wand according to Fig. X3.1.

NOTE 25—After constructing a new wand, check the spray pattern to verify that it is suitable for obtaining thorough coverage of the cams and lifters with test oil, when used as directed.

10.26.4 Insert the oiling wand in the lifter valley through the crankcase pressure tap threaded hole in the front of the engine block. Loosely engage the threads of the wand with those of the hole.

10.26.5 Connect a small oil line from the oil filter adapter sampling valve connector to the oiling wand.

10.26.6 Attach a suitable drive mechanism, such as an electric drill motor or an air-operated high-torque impact gun, to the distributor shaft.

10.26.7 Drive the engine oil pump clockwise to prime the oil pump and pressurize the oil gallery.

NOTE 26—In about 5 s of operation, the gallery will be pressurized as indicated by the sound produced by the oil pump.

10.26.8 Unscrew the oil wand from the block, and let the oil wand rest on the side of the threaded hole in the block.

10.26.9 Open the oil sampling valve to permit flow to the oil wand.

10.26.10 Continue to drive the oil pump for 1 to as long as 2 min while applying a slight fore and aft motion to the oiling wand, and simultaneously rotating it slightly back and forth, to ensure thorough pre-oiling of the camshaft and lifter set.

10.26.11 Discontinue rotating the pump, and close the oil sampling valve.

10.26.12 Disconnect the oil wand oil feed line at the filter adapter.

10.26.13 Blow clean, dry, compressed air (**Warning**—see Note 17) into the valve end of the oil line to ensure that all the test oil is returned to the engine.

NOTE 27—Wand and oil line will normally hold less than 30 mL (one fluid ounce) of oil.

10.26.14 Remove the oiling wand and the modified distributor from the engine; clean and store them for future use.

10.26.15 Install the test distributor without rotating the engine. The engine should be positioned with the No. 1 piston at top dead center on the compression stroke. See 10.19.38.5.

10.26.16 Connect the crankcase pressure line and oil sample valve fittings in preparation for testing, and proceed with the timing run operation.

10.27 *Blowby Flow Rate Measurement System Maintenance and Cleaning*—Clean the blowby sharp edge orifice meter and system monthly or sooner if the condensate level in the Norgren trap reaches half full. Clean the system according to the following instructions:

10.27.1 Use extreme care during the cleaning procedure to keep from damaging the system components. Do not use any tools or abrasive materials on the sharp edge orifice plate or other components of the sharp edge orifice meter during cleaning.

10.27.2 Gently flush the orifice plate of contaminants using aliphatic naphtha and allow it to air-dry.

10.27.3 The inlet and outlet tubes of the meter may be cleaned using nothing more harsh than a soft nylon brush, when necessary. Good laboratory practices should be followed as similiar to those used for the maintenance of any technical instruments in the testing environment.

10.27.4 High pressure air is not recommended for drying of meter components.

10.27.5 The meter shall be inspected by a qualified calibration technician if any meter components are dropped during cleaning.

10.27.6 Replace the O-rings during each cleaning to minimize the chances for leakage due to abrasion, cuts, or deposit accumulations. Coat the O-rings with a very light stopcock grease to aid in orifice plate rotation and O-ring sealing during operation.

10.27.7 Assemble the blowby meter by first securing the center retaining bolt. Once all retaining bolts are installed, apply only enough torque to adequately compress the O-rings working from the center out. Excessive torquing could warp the flanges creating an unsatisfactory seal and thereby requiring meter replacement for calibration.

10.27.8 Inspect the inclinometer used for measuring the blowby differential pressure for any evidence of irregular meniscus or badly discolored fluid and clean, if necessary. A *waxing* of the inclinometer tube surfaces and discoloration of the fluid due to contaminants, or both, will ultimately occur when exposed to various gases. These waxy surfaces will distort the meniscus, and any fluid discoloration may be indicative of a change in specific gravity. Either factor can produce erroneous differential pressure readings.

10.27.9 Inspect, purge, and clean line traps and surge tanks, as necessary, during each cleaning of the entire system. Excessive accumulations of flow constituents could ultimately entrain in the flowing blowby gas and thereby cause the readings to be non-representative of the actual blowby gas being measured.

10.27.10 Keep all lines to and from the blowby meter free of accumulated contaminants from previous tests at all times. Design blowby measurement systems to allow these lines to drain to a low point in the system, or externally out of the system, away from the sharp edge orifice meter.

11. Calibration

11.1 *Laboratory and Engine Test Stand Calibration*—To maintain testing laboratory and engine test stand calibration status for Sequence IIIE engine oil testing, follow these directions:

NOTE 28—Annex A1 and Annex A5 cover the involvement of the ASTM TMC in respect to calibration procedures and acceptance criteria for a testing laboratory and a test stand, and the issuance of Information Letters and memoranda affecting the test method.

11.1.1 *Testing of Reference Oils*—Periodically conduct tests on reference oils according to the following:

11.1.1.1 Reference oil tests on each test stand within a laboratory which is to be considered calibrated must be conducted according to ASTM Test Monitoring Center guidelines.

11.1.1.2 Obtain reference oils directly from the ASTM TMC. These oils have been formulated or selected to represent specific chemical types or performance levels, or both. They are usually supplied directly to a testing laboratory under code numbers to ensure that the laboratory is not influenced by prior knowledge of acceptable results in assessing the test results. The ASTM TMC will determine the specific reference oil to be tested by a laboratory.

11.1.1.3 Unless specifically authorized by the ASTM TMC, do not analyze reference oils, either physically or chemically. Identification of reference oils by such analyses could undermine the confidentiality required to operate an effective reference oil system. Therefore, reference oils are supplied with the explicit understanding that they will not be subjected to analyses other than those specified in this procedure, unless specifically authorized by the ASTM TMC. If so authorized, prepare a written statement of the circumstances involved, the name of the person authorizing the analysis, and the data obtained; furnish copies of this statement to both the ASTM TMC and the Test Developer.

11.1.1.4 Assign a stand test number to each Sequence IIIE test. The number shall include the test type (IIIE), the stand number, the number of Sequence IIIE tests conducted on the stand since the last reference oil test was conducted (0 to 18), and a sequential laboratory test number based on the starting date of the test. For example, IIIE-60-03-785 defines a Sequence IIIE test on stand number 60, which is the third non-reference oil test run on stand 60 since successful completion of a reference oil test, and was the 785th Sequence IIIE test in the laboratory. The only exception to this format is that the sequential laboratory test number shall be followed by the letter A for the first rerun, B for the second, etc. for invalid or unacceptable reference oil tests.

11.1.2 *Reference Oil Test Frequency*—Conduct reference oil tests according to the following frequency requirements:

11.1.2.1 For a given calibrated test stand, conduct an acceptable reference oil test after no more than 18 test starts have been conducted, or after 120 days have elapsed, whichever occurs first.

11.1.2.2 For a given testing laboratory with more than one calibrated test stand, conduct an acceptable reference oil test after no more than 90 days have elapsed since the last reference oil test.

11.1.2.3 After a laboratory reference oil test is started, non-reference oil tests may be started on any other calibrated test stands.

11.1.2.4 The ASTM TMC may schedule more frequent reference oil tests at their discretion.

11.1.2.5 Under special circumstances, such as extended downtime caused by industry-wide parts or fuel shortages, the ASTM TMC may extend the intervals between reference oil tests.

11.1.2.6 In addition to the aforementioned reference oil tests, the ASTM TMC will annually schedule on each calibrated test stand a reference oil test on a poor-quality engine oil in order to ensure that each calibrated test stand can produce adequate discrimination. In general, the ASTM TMC will not use the results of such tests in determining laboratory precision, but the ASTM TMC is authorized to so use the results, if they choose.

11.1.3 *Reporting of Reference Oil Test Results*—Report the results of all reference oil tests to the ASTM TMC according to the following directives:

11.1.3.1 Use the report forms detailed in Annex A6 (see Fig. A6.1, A6.2, and Figs. A6.4 through A6.13) in reporting all reference oil tests to the ASTM TMC. Complete all blanks. As necessary, use and attach to Fig. A6.5 additional copies of Fig A6.5 to detail the actions taken and results achieved.

11.1.3.2 Complete Fig A6.1 and submit it to the ASTM TMC with the final report.

11.1.3.3 If the test was conducted during a time extension permitted by the ASTM TMC, so indicate in the Outliers section of Fig A6.5.

11.1.3.4 For an acceptable reference oil test conducted following an unacceptable reference oil test, provide sufficient information in the Outliers section of Fig A6.5 to indicate how the problem was identified and corrected, insofar as possible, and how it was related to candidate oil tests conducted during the period of time that the problem was being solved.

11.1.3.5 Transmit by electronic means or telephone facsimile transmission to the ASTM TMC the reference oil test results (completed Fig A6.2, A6.5 through A6.9 and A6.11) immediately after completion of test analysis.

11.1.3.6 Send by mail one copy of the standard final report (completed Fig A6.5, A6.5 through A6.9, and A6.11) for the reference oil test, including photographs; as soon as possible to the Test Developer, and one copy of the report to the ASTM TMC, at the following addresses in order that the records are received within 30 days of test completion.

Test Developer	ASTM TMC
Sequence IIIE Test Coordinator General Motors NAO Research and Development Fuels and Lubricants Dept. 30500 Mound Road Warren, MI 48090-9055	Group Leader ASTM Test Monitoring Center 6555 Penn Ave. Pittsburgh, PA 15206-4489

11.1.4 *Evaluation of Reference Oil Test Results*—The ASTM TMC will evaluate the reference oil test results using Shewart and Exponentially-Weighted Moving Average (EWMA) Control Charts, consulting with the Test Developer, and working with the test laboratory in case of difficulty, as follows:

11.1.4.1 Immediately upon receipt of the telephone facsimile transmission of the reference oil test results from the test laboratory, the ASTM TMC will evaluate them to determine whether the test was properly conducted, and whether the results are in conformance with the statistically-acceptable results for the reference oil tested. The ASTM TMC will also evaluate the results in relation to current laboratory levels to determine laboratory severity and precision as well as calculate necessary severity adjustments, if any (see Annex A5 for calculation of severity adjustments). If the test is judged acceptable, the reference oil code along with the industry average for all test parameters for the reference oil will be disclosed by the ASTM TMC to the test laboratory. The ASTM TMC will convey its preliminary findings based on the limited information available to them, to the test laboratory.

11.1.4.2 Subsequently, upon receipt of the information detailed in 11.1.3.6, the ASTM TMC will review all reference oil test results and reports to determine final test acceptability.

11.1.4.3 In the event the reference oil test is unacceptable, an explanation of the problem relating to the failure should be provided by the test laboratory. If the problem is not obvious, all test-related equipment must be re-checked. Following this re-check, the ASTM TMC will assign another reference oil for testing by the laboratory.

11.1.4.4 The ASTM TMC will decide, with consultation as needed with industry experts (testing laboratories, Test Developer, members of the ASTM Technical Guidance Committee and of the Surveillance Panel, etc.), whether the reason for any failure of a reference oil test is a false alarm, testing stand, testing laboratory, or industry-related problem. Industry problems must be adjudicated by the Sequence IIIE Surveillance Panel.

11.1.5 *Status of Non-Reference Oil Tests Relative to Reference Oil Tests*—Non-reference oil tests may proceed within a given laboratory during reference oil testing based upon the following:

11.1.5.1 During the time that a reference oil test is being conducted on one test stand, non-reference oil tests may be conducted on other previously-calibrated stands. If the reference oil test is acceptable to the ASTM TMC, the non-reference oil tests will be considered to have been run in a satisfactorily-calibrated laboratory.

11.1.5.2 If a reference oil test is unacceptable, and it is determined that the problem is isolated to an individual test stand, other test stands will be considered to remain calibrated, and testing of non-reference oils may proceed on those other stands.

11.1.5.3 If a reference oil test is unacceptable, and it is determined that the problem is laboratory related, non-reference tests running during the problem period must be considered invalid unless there is specific evidence to the contrary for each test.

11.1.6 *Status of Test Stands Used for Non-Standard Tests*—If a non-standard test is conducted on a previously-calibrated test stand, conduct a reference oil test on that stand to demonstrate that it continues to be calibrated, prior to running standard tests.

11.2 *Instrumentation Calibration*—Unless otherwise specified in this standard, 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. Follow the recommendations of the Instrumentation Task Force.[90] Retain the calibrations records for a minimum of 24 months. Calibrate the following instrumentation immediately prior to each reference oil test:

11.2.1 Engine load measurement system,

11.2.2 Engine speed indicator,

11.2.3 Engine coolant flow, (Calibrate the sharp-edge orifice meter at 49°C (120°F) using a mixture of 40 % glycol and 60 % water.) **Warning**—see Note 5.

11.2.4 Temperature sensors and measurement system,

11.2.5 Electrical voltmeter (ignition voltage),

11.2.6 Pressure measurement devices,

11.2.7 Air-fuel-ratio measurement system,

11.2.8 Weighing scales (for weighing coolant additives),

11.2.9 Engine blowby flow rate measurement system (see Annex A9), and

11.2.10 Dewpoint meter.

11.3 *Camshaft Loading Fixture Assembly Calibration*—At least every six months, calibrate the camshaft loading fixture assembly using the following procedure:

11.3.1 Disassemble the camshaft loading fixture assembly.

11.3.2 Affix load cell weight adapter plate (see Fig. 16) to the camshaft loading fixture load cell.

11.3.3 Zero the load cell.

11.3.4 Place 1023 N (230 lbf) of calibrated dead weights onto the load cell.

11.3.5 Adjust the load cell readout, as necessary, to match the weight of the calibrated dead weights.

11.3.6 Reassemble the camshaft loading fixture assembly. When reassembled and mounted horizontally to an engine block, the load readout should display no more than 9 N (2 lbf) of load. If more than 9 N (2 lbf) of load is displayed, examine the camshaft loading fixture assembly for damage then recalibrate.

12. Engine Operating Procedure

12.1 *Dipstick and Hole Plug*—Remove the calibrated dipstick and close off the dipstick hole in the block with a hole plug, Part BX-386-1,[18,20] for all engine operation; during oil level determinations, re-install the calibrated dipstick. See Fig. 13 and Fig. 14.

12.2 *Oil Fill Adapter*—Install the 1½ in. NPT plug, drawing RX-118612-C, in the oil fill adapter. Keep it in place for all engine operation; remove it only to add oil to the crankcase.

[90] See the guidelines developed by the Instrumentation Task Force which were presented to the ASTM Subcommittee D02.OB Sequence IIIE Surveillance Panel in 1987-06.

12.3 *Carburetor Air Inlet Supply Line*— Remove the carburetor humidified air inlet supply any time the engine is not running.

12.4 *Engine Start-up and Shutdown Procedures*—Start and stop Sequence IIIE engines according to the following, and at the times specified in the test schedule:

12.4.1 *Start-up*—Use the following procedure in starting Sequence IIIE engines:

12.4.1.1 Set the fuel mixture control unit to normal operating pulse duration.

12.4.1.2 Start the external oil pump, turn on the fuel and ignition, and start the coolant flowing through the exhaust manifolds.

12.4.1.3 Close the throttle and repeatedly crank the engine for about 5 s at a time. If the engine does not start after three 5-s cranking periods, determine the reason and correct the problem.

12.4.1.4 During cranking, slightly open the throttle at high intake manifold vacuum to start the engine. Do not pour fuel into the carburetor or intake manifold.

NOTE 29—Avoid contaminating the test oil with raw fuel during engine cranking.

12.4.1.5 Repeat 12.4.1.3 and 12.4.1.4 if the engine fails to start.

12.4.1.6 For the ignition timing run, when the engine has been started, verify that oil pressure is adequate, and if so, follow the operating directions in 12.12.

12.4.1.7 For the break-in, when the engine has been started, verify that oil pressure is adequate, and if so, follow the operating directions in 12.13.

12.4.1.8 For the engine oil quality testing (see 12.14), when the engine has been started, verify that oil pressure is adequate, and if so, increase the speed within 2 min to 1500 r/min and the load to 6.34 kW (8.5 bhp).

12.4.2 *Shutdown*—Use the following procedure in stopping Sequence IIIE engines:

12.4.2.1 Reduce the engine speed and load to 1500 r/min and 6.34 kW (8.5 bhp) within a maximum of 30 s; remove the required oil purge or leveling sample, and analysis sample, from the engine oil sampling valve; and adjust all temperatures for engine shutdown.

12.4.2.2 With the ignition left on, shut off the fuel to the engine, and allow the engine to run out of fuel.

12.4.2.3 With the engine stopped, turn off the ignition, stop the coolant flow through the exhaust manifolds, remove the carburetor humidified air inlet supply, and continue with the oil sampling and leveling procedure (see 12.5 and 12.6).

12.4.3 *Non-Scheduled Shutdowns*—For any non-scheduled shutdowns, record in detail the time off test, the reasons for the shutdown, and any other pertinent observations. Include this record in the test note section of the final test report.

12.5 *Oil Sampling*—Take all oil samples (see Fig X4.4) from the engine oil sampling valve according to the following instructions, with the engine running:

12.5.1 Before taking the samples in each of the following steps, first remove a 473-mL (16-oz) purge sample, or leveling sample; then take the oil sample of the specified volume.

12.5.2 Take a 237-mL (8-oz) analysis sample at the end of the ignition timing run (identified as the initial sample) and at the end of the 64-h test.

12.5.3 At the end of the 4-h break-in, after taking the 473-mL (16-oz) leveling sample, add 473 mL (16 oz) of fresh oil, and as much of the leveling sample as needed, according to 12.6.9.

12.5.4 Take a 59-mL (2-oz) sample at the end of every 8 h during the test, except at 64 h when a 237-mL (8-oz) sample is taken.

12.6 *Oil Leveling*—Determine the oil level in the crankcase (see Fig. X4.4) according to the following instructions:

12.6.1 Determine the oil level after the 10-min ignition timing run, at the end of the break-in, and after each 8 h of test.

12.6.2 Stop the engine according to the procedure in 12.4.2 for 25 min to allow the oil to return to the crankcase.

12.6.3 Run the external oil circulating pump for the first 10 min; reduce the oil sump temperature to 48.9 ± 2.8°C (120± 5°F). Shut the pump off for 15 min.

12.6.4 During the 10 min in 12.6.3, add the 473-mL purge sample, or the 473 mL of fresh oil, as indicated in Fig. X4.4.

12.6.5 During the 25-min period, reduce and maintain the coolant temperatures at 48.9 ± 2.8°C (120 ± 5°F) for the coolant jacket, rocker cover, and intake manifold crossover.

12.6.6 During the 25-min period, maintain the breather tube temperature at 40 ± 2.0°C (104 ± 3.6°F).

12.6.7 Determine the oil level after the 25-min period, in mm, using the calibrated dipstick.

12.6.8 Following the ignition timing run, record the level on Fig. X4.4, according to 12.6.7. Use this level as the full mark for the test. Enter 0 (zero) mL as the computed oil level on Fig. X4.4.

12.6.9 Following the break-in and after each 8 h of the 64-h test, add oil to the crankcase from the 473-mL leveling sample to bring the level to that following the ignition timing run, as nearly as possible. Discard any excess leveling sample. Record the results on Fig. X4.4.

12.7 *Checks for Glycol Contamination*— Check the initial, 40-h, and end-of-64-h-test oil analysis samples (see Fig. X4.4) for glycol contamination using A.1.2.1 of Test Methods D 2982, according to the following procedure:

12.7.1 If the glycol contamination of the initial sample is positive, check a sample of the fresh oil using Test Methods D 2982 (A.1.2.1).

12.7.1.1 If the fresh oil indicates glycol contamination of the same level as that of the initial sample, no additional analyses are required; continue the test.

12.7.2 If either the initial, 40-h, or end-of-test sample shows a consistently higher level of glycol contamination than that of the fresh oil by Test Methods D 2982, the test must either be aborted (if it is still in progress) or invalidated (if it has been completed). Completely rebuild the engine.

12.7.3 Record all evidence of contamination of the oil samples with glycol coolant on Fig.A6.2 or Fig. A6.3, as appropriate, which is part of the final test report.

12.8 *Air-to-Fuel-Ratio Measurement and Control*—Measure and control air-to-fuel ratio according to the following:

12.8.1 By means of exhaust gas analysis, measure the volume percent of CO_2, CO, and O_2, using either an Orsat apparatus or an electronic gas analyzer.

12.8.2 Enter either Fig A7.1 or Table A7.1, constructed for the Sequence IIIE fuel, with the CO_2, CO, and O_2 values to determine the air-to-fuel ratio.

12.8.3 For air-to-fuel ratios greater than 15:1 (lean), when the analysis shows a CO concentration in the exhaust gas, correct the analysis as follows:

12.8.3.1 Determine the corrected O_2 using this relationship:

$$\text{Observed } \% \, O_2 - 0.5 \, (\text{observed } \% \, CO) = \text{Corrected } O_2 \quad (1)$$

12.8.3.2 Determine the corrected CO_2 using this relationship:

$$\text{Observed } \% \, CO_2 - 0.5 \text{ observed } \% \, CO = \text{Corrected } CO_2 \quad (2)$$

12.8.3.3 Enter either Fig. X7.1 or Table A7.1 with the corrected O_2 and CO_2 values to determine the air-to-fuel ratios for the two gases, which must agree within 0.5 air-to-fuel ratio.

12.8.4 Control the air-to-fuel ratio to 16.5 ± 0.5 by means of the fuel mixture control unit.

12.8.4.1 Make all air-to-fuel ratio adjustments during the break-in, using the fuel mixture control unit, within the first 15 min at each condition.

12.8.4.2 Measure the air-to-fuel ratio during the 64-h test period, in the last 30 min of each hour indicated in Fig. X4.3.

12.9 *Blowby Flow Rate Measurement*—Measure the engine blowby flow rate according to the following instructions, and within 15 min of the end of each period indicated in Fig. X4.3:

12.9.1 Observe the following requirements:

12.9.1.1 Measure the blowby flow rate at the breather tube outlet.

12.9.1.2 Verify that the dipstick hole is plugged according to 12.1.

12.9.1.3 Verify that the crankcase oil fill adapter is plugged according to 12.2.

12.9.1.4 Connect a surge tank, drawing RX-117431-C, to the breather tube.

12.9.1.5 Connect the blowby flow rate meter to the surge tank.

12.9.1.6 Where permanently installed blowby meters are not used, portable cart applications are allowed. However, position the cart near the testing area for a sufficient time period to assure temperature stabilization of the system components prior to any blowby measurements being taken. Temperature stabilization is necessary to reduce condensate precipitation of the blowby gases. The moisture content of blowby gases are generally between 17 and 20 g/g (120 to 140 grains per lb). Correction factors are based on this and other average Orsat data of the blowby gases. Therefore, it is important that the blowby gases being measured at the orifice plate be as close in molecular composition and temperature as possible to the blowby gases exiting the breather tube.

12.9.1.7 The exhaust line for the engine blowby gas being measured shall not be evacuated nor directed toward any low pressure evacuation systems.

12.9.2 Select an orifice size such that the observed blowby flow ΔP lies in the midrange of the calibration curve. Record the orifice size used.

12.9.3 Control the crankcase pressure at 0 ± 12.4 Pa (0.0 ± 0.05 in. of water).

12.9.4 Maintain blowby gas flow through the orifice meter for 2 min or more to ensure flow stability, prior to taking the actual readings. Due to the relatively low flow rates, allow time for the engine blowby gas to *fill* the system and further enhance temperature stabilization.

12.9.5 Record the uncorrected blowby flow rate in L/min on Fig. X4.2, and correct it for an atmospheric pressure of 100 kPa (29.70 in. Hg) and a temperature of 37.8°C (100°F), using the correction factors given in Table A8.1 and Table A8.2.

12.9.5.1 Alternatively, correct the blowby flow rate using the following equations, on which Tables A8.1 and A8.2 are based:

$$CF_{SI} = \left(3.1002\left(\frac{P_{kPa}}{273.15 + t_{°C}}\right)\right)^{0.5} \quad (3)$$

$$CF_{in.-lb} = \left(18.844\left(\frac{P_{in.\,Hg}}{459.67 + t_{°F}}\right)\right)^{0.5} \quad (4)$$

12.9.6 Disconnect the surge tank from the breather tube.

12.9.7 Direct the blowby gas into the vent hood, drawing RX-118623-A2, at all times other than when the blowby flow rate is being measured. Refer to the drawing for proper orientation of the vent hood and the breather tube outlet.

12.10 *NO_x Determinations*—Measure NO_x concentrations using suitable exhaust gas analysis equipment.

12.11 *Data Recording*—At hourly intervals, except as indicated in 12.11.1, measure and record the data for the parameters listed in Table 6.

12.11.1 Measure the ignition timing, air-to-fuel ratios, blowby flow rate, NO_x concentration, and dew point at the hours shown in Fig. X4.3.

12.11.2 Record the test data for the items listed in Table 6, on Fig. X4.2, Fig. X4.1a, and Fig. X4.1b.

12.12 *Ignition Timing Run (10 min)*—After the engine is charged with the test oil, the oil pump primed, and the cam lobes and lifters pre-lubricated (see 10.26), conduct the 10-min ignition timing run.

12.12.1 Do not connect the carburetor humidified air source to the engine.

12.12.2 Start the external oil pump and start the engine (see 12.4.1). Begin timing the 10-min run.

12.12.3 Maintain the ignition voltage at 13 V, minimum.

12.12.4 Make certain that coolant is flowing through the water-cooled exhaust manifolds.

12.12.5 Control the jacket, rocker cover, intake manifold crossover coolant, and oil sump temperatures at 48.9 ± 2.8°C (120± 5°F), and the breather tube coolant temperature at 40.0 ± 2.0°C (104 ± 3.6°F) during the timing run.

12.12.6 Set the engine speed at 1500 r/min, no load; operate for 2 min to set the ignition timing at 36° BTDC.

12.12.7 Operate the engine at 1500 r/min, 6.34 kW (8.5 bhp) for the remainder of the 10 min.

12.12.8 Ten minutes after the ignition timing run start, and just prior to stopping the engine, remove a 473-mL (16-oz) purge sample, then take the initial, 237-mL (8-oz), 0-h oil sample (see 12.5 and Fig. X4.4).

12.12.9 Stop the engine (see 12.4.2).

TABLE 6 Data to be Recorded

Units	Parameter
	Engine
r/min	Speed
kW (bhp)	Power
°BTDC[A]	Ignition timing
	Temperatures
°C (°F)	Oil filter adapter
°C (°F)	Oil sump
°C (°F)	Jacket coolant inlet
°C (°F)	Jacket coolant outlet
°C (°F)	Intake manifold mixture
°C (°F)	Rocker covers (both right and left) coolant outlet
°C (°F)	Crossover coolant outlet
°C (°F)	Breather tube coolant outlet
°C (°F)	Breather tube blowby gas outlet
°C (°F)	Fuel
°C (°F)	Carburetor air dry bulb
°C (°F)	Carburetor air dew point
°C (°F)	Ambient air
°C (°F)	Water-cooled exhaust manifold, coolant out, right and left
	Vacuum
kPa (in. Hg)	Intake manifold
	Pressures
kPa (psi)	Engine oil gallery
kPa (psi)	Oil pump outlet
kPa (psi)	Rocker covers (both right and left system) coolant outlets
kPa (psi)	Breather tube system coolant outlet
kPa (psi)	Water-cooled exhaust manifold coolant back pressure
kPa (in. H_2O)	Exhaust back pressure (right and left)
kPa (in. H_2O)	Exhaust back pressure differential between banks
kPa (in. H_2O)	Carburetor air
kPa (in. H_2O)	Crankcase
	Flow Rates
L/m (gpm)	Jacket coolant
L/m (gpm)	Crossover and combined rocker cover coolant
L/m (gpm)	Breather tube system coolant
L/m (gpm)	Water cooled exhaust manifold

[A]BTDC = Before Top Dead Center.

12.12.10 Follow 12.6 to determine the oil level after drain-down, mm; record the value on Fig. X4.4. Use this level as the full mark for the test.

12.13 *Break-In (4 h)*—Following the ignition timing run (see 12.12) and establishment of the oil level after drain-down, conduct the 4-h break-in.

12.13.1 Start the engine (see 12.4.1).

12.13.2 Connect the carburetor humidified air inlet supply to the engine.

12.13.3 Maintain the ignition voltage at 13 V, minimum.

12.13.4 Make certain that coolant is flowing through the water-cooled exhaust manifolds.

12.13.5 Operate the engine for the 4-h break-in under the conditions specified in Table 7. Begin timing the 1 h for Stage 1 when all test conditions are reached.

12.13.6 Check the ignition timing and adjust it as necessary, at the start of each of the 4 h. See Fig. X4.3.

12.13.7 Measure the air-to-fuel ratio during the first 15 min of each of the 4 h. See Fig. X4.3. Adjust the ratio to 16:5, using only the fuel mixture control unit.

12.13.8 Include the time involved in making the transition from one stage to the next as part of the 1 h for that next stage.

12.13.9 For all other parameters during Stages 1, 2, and 3, operate under the conditions specified in Table 7 except for blowby flow rate and intake manifold vacuum. Simply report the measurements for the latter two parameters.

12.13.10 At the beginning of Stage 3, when the engine is running at 3000 r/min and 31.8 kW (42.6 bhp), check the ignition timing and adjust it to 40° BTDC, if necessary.

12.13.11 For all other parameters during Stage 4, operate under the conditions specified in Table 7.

12.13.12 Record actual test operating conditions on Fig. X4.1a and Fig. X4.1b.

12.13.13 At the completion of the break-in, reduce the engine speed to 1500 r/min and the load to 6.34 kW (8.45 bhp). Take a 473-mL (16-oz) leveling sample, and stop the engine (see 12.4.2 and Fig. X4.4).

12.13.14 Re-torque the exhaust manifold bolts. See Fig. X4.3.

12.13.15 Follow 12.6 to determine the oil level after drain-down, mm; record the value on Fig. X4.4.

12.13.16 Record on Fig. X4.4 the amount of leveling sample added, the amount of leveling sample discarded, and the resulting dipstick level.

12.13.17 Calculate the computed oil level, and record it on Fig. X4.4.

12.13.18 If all of the leveling sample is added and the crankcase oil level is below the full mark (see 12.6.8), continue the test at the lower level.

12.14 *Engine Oil Quality Testing (64 h)*— After completing all phases of the ignition timing run and the break-in, conduct the 64-h engine oil quality evaluation portion of the test,

TABLE 7 Break-In Operating Conditions

Break-In	Stage 1	Stage 2	Stage 3	Stage 4
Time, h	1	1	1	1
Speed, r/min	1500 ± 20	2500 ± 20	3000 ± 20	3000 ± 20
Power, kW	6.3 ± 1.5	21.2 ± 1.5	31.8 ± 1.5	50.6 ± 1.5
(bhp)	(8.5 ± 2)	(28.4 ± 2)	(42.6 ± 2)	(67.8 ± 2)
Ignition timing, °BTDC	36	40	40	40
Air-to-fuel ratio	16.5± 0.5	16.5 ± 0.5	16.5 ± 0.5	16.5 ± 0.5
Exhaust back pressure, kPa	0.25 ± 0.17	1.24 ± 0.37	2.49 ± 0.50	5.00 ± 0.75
(in. H_2O)	(1.0± 0.7)	(5.0 ± 1.5)	(10.0 ± 2.0)	(20.0 ± 3.0)
Temperatures				
Oil filter adapter, °C	95.0 ± 1.1	95.0 ± 1.1	110.0 ± 1.1	149.0 ± 1.1
(°F)	(203 ± 2.0)	(203 ± 2.0)	(230 ± 2.0)	(300.2 ± 2.0)
Coolant out, °C	95 ± 3.0	95 ± 3.0	95 ± 3.0	115 ± 2.0
(°F)	(203 ± 5.4)	(203 ± 5.4)	(203 ± 5.4)	(239 ± 3.6)
Breather tube out, °C	40 ± 2.0	40 ± 2.0	40 ± 2.0	40± 2.0
(°F)	(104± 3.6)	(104 ± 3.6)	(104 ± 3.6)	(104 ± 3.6)

according to the following procedure:

12.14.1 Start the engine (see 12.4.1).

12.14.2 Connect the carburetor humidified air inlet supply to the engine.

12.14.3 Maintain the ignition voltage at 13 V, minimum.

12.14.4 Operate the engine under the test conditions listed in Table 8, as qualified regarding mid-limit operation in 12.14.6 through 12.14.9, and Table 9. Record all operational data on Fig. X4.1b and Fig. X4.2.

12.14.5 For each 8-h segment of the 64-h engine oil quality testing, test time is counted from the moment when all the test conditions listed in Table 9 are reached and stabilized. Allow from 15 to 30 min for stabilization of test conditions, as measured from the time of engine start-up.

12.14.6 For a controlled, primary parameter (see Table 9), the average of the recorded data must be no further from the target mean than 12.5 % of the allowable control range. For example, if a specified temperature is 100 ± 2°C, the average must be within the range of 100 ± 0.5°C.

12.14.7 For a controlled secondary parameter, the average of the recorded data must be no further from the target mean than 25 % of the allowable control range. For example, if a specified temperature is 100 ± 2°C, the average must be within the range of 100 ± 1.0°C.

12.14.8 Report averages to the nearest tenth of a unit. Refer to Practice E 29 for rounding; use the rounding-off method.

12.14.9 Use the mid-limit ranges specified in Table 9.

12.14.10 At the start of engine hours 1, 17, 33, 49, and 64, check the ignition timing; readjust to 40° BTDC, if necessary. See Fig. X4.3. Record any adjustment made on a supplemental report page.

12.14.11 During the last 30 min of engine hours 1, 17, 33, 49, and 64, measure and record the air-to-fuel ratio observed for both right and left banks. See Fig. X4.3. Adjust the ratio to 16.5 ± 0.5 using the fuel mixture control unit. If the ratio cannot be achieved with the control unit alone, change the carburetor, or the carburetor jets and rods.

12.14.12 Measure blowby flow rate during the last 15 min of the engine hours indicated in Fig. X4.3.

12.14.13 In conjunction with the air-to-fuel ratio measurements for engine hours 1 and 33 (see 12.14.11), measure exhaust gas NO_x concentration. See Fig. X4.3.

12.14.14 Verify the accuracy of the carburetor air dew point reading at the carburetor air tee during the last 30 min of engine hours 1 and 33. See Fig. X4.3.

12.14.15 At the end of 32 engine hours, during the oil level shutdown, re-torque the exhaust manifold bolts, and install a new set of spark plugs. See Fig. X4.3.

12.14.16 Every 8 h, conduct the oil sampling and oil leveling according to 12.5 and 12.6. See Fig. X4.4. Record the

TABLE 9 Mid-Limit Operation Ranges for Primary and Secondary Parameters

	Specified Operating Range	Mid-Limit Range for Parameter Average[A]
Primary Parameter		
Engine power output, kW	50.6 ± 1.5	50.6 ± 0.4
Oil temperature, filter adapter,° C	149.0 ± 1.1	149.0 ± 0.3
Coolant temperature (jacket out),° C	115.0 ± 1.1	115.0 ± 0.3
Coolant, jacket flow rate, L/min	151.0 ± 3.8	151.0 ± 1.0
Secondary Parameter		
Engine speed, r/min	3000 ± 20	3000 ± 10
Coolant temperature, breather tube out,	40.0 ± 1.1	40.0 ± 0.6
°C at L/min	11.4 ± 3.8	11.4 ± 1.9
Exhaust back pressure, kPa	5.0 ± 0.75	5.0 ± 0.4
Rocker cover/crossover flow rate, L/min	11.4 ± 3.8	11.4 ± 1.9

[A]Except for engine speed, the mid-limit range was first calculated and then rounded up to the nearest tenth of a unit. Practice E 29 was used; the rounding-off method was applied.

TABLE 8 Engine Oil Quality Testing Conditions

Parameter	Limits		English-to-Metric Multiplier[A]
	Metric	English	
Speed, r/min	3000 ± 20		...
Power, kW (bhp)	50.6 ± 1.5	(67.8 ± 2.0)	0.746
Oil temperature, filter adapter, °C (°F)	149.0 ± 1.1	(300.2 ± 2.0)	[B]
Oil pressure pump outlet, kPa (psi) min	207	(30)	6.895
Coolant temperature, jacket out, °C (°F)	115.0 ± 1.1	(239.0 ± 2.0)	[B]
Coolant temperature, jacket in, °C (°F)	110.0 ± 1.1	(230.0 ± 2.0)	[B]
Coolant, jacket flow rate, L/min (gal/min)	151 ± 3.8	(40 ± 1)	3.785
Coolant temperature, rocker cover out,° C (°F)	113.0 ± 2.8	(235.4 ± 5.0)	[B]
at L/min (gal/min) combined	11.4 ± 3.8	(3.0 ± 1.0)	3.785
Coolant temperature, breather tube out,° C (°F)	40.0 ± 1.1	(104.0 ± 2.0)	[B]
at L/min (gal/min)	11.4 ± 3.8	(3.0 ± 1.0)	3.785
Air-to-fuel ratio	16.5 ± 0.5		
Carburetor, air temperature, °C (°F)	27.0 ± 1.5	(80.6 ± 2.7)	[B]
Carburetor, air humidity, dew point,° C (°F)	16.1 ± 1.1	(61 ± 2.0)	[B]
Carburetor, pressure, kPa (in. H_2O)	0.05 ± 0.025	(0.2 ± 0.1)	0.249
Blowby flow rate,[C] L/min (ft^3/min) at 37.8°C (100°F) and 100 kPa (29.7 in. Hg)	45.3 ± 5.6	(1.6± 0.2)	28.3
Minimum average	42.4	(1.50)	
Intake manifold vacuum, kPa (in. Hg)	27 ± 7	(8 ± 2)	3.38
Breather tube and rocker cover back pressure, kPa (psi)	27.6 ± 6.9	(4.0 ± 1.0)	6.895
Exhaust back pressure (right and left) kPa (in. H_2O)	5.0 ± 0.7	(20.0 ± 3.0)	0.249
Exhaust back pressure, max differential kPa (in. H_2O) (record absolute value)	±0.19	(±0.75)	0.249
Exhaust manifold flow rate, L/min (gal/min) per manifold	7.6 ± 1.9	(2.0 ± 0.5)	3.785
Exhaust manifold coolant back pressure, kPa (psi)	76 ± 62	(11 ± 9)	6.895

[A] The multipliers are included for purposes of performing engineering calculations, and are equivalent to the conversion factors found in Practice E 380, but rounded to a number of significant figures sufficient to provide adequate precision in Sequence IIIE testing. Practice E 29 was used for rounding off the multipliers; the rounding-off method was applied.

[B]t°C = (t°F − 32)/1.8.

[C]This parameter is controlled during the engine build procedure.

time when the final (64-h) leveling is completed; be aware that most of the engine disassembly must be completed within 4 h of this time. See 13.1.1.

12.15 *Test Termination*—Terminate the test as follows:

12.15.1 Terminate the test whenever the oil level is more than 828 mL (28 oz) below the test full mark.

12.15.2 Do not terminate the test solely on the basis of percent change in engine oil viscosity.

12.15.3 Terminate the test at the completion of the 64-h engine oil quality testing, following the taking of the leveling and analysis samples, engine shutdown, and leveling procedure.

12.15.3.1 Drain the oil sump.

12.15.3.2 Drain the breather tube cooling system.

12.15.3.3 Drain the engine coolant.

12.15.3.4 Immediately flush the glycol side of the external engine cooling system with water at a temperature of 49°C (120°F) until the flush water is clear.

12.15.3.5 Within 15 min of completing the final leveling procedure, flush the external oil-cooling system, including lines, pump, heat exchanger, and valves, with commercial cleaning agent (**Warning**—see Note 9) until it is clean; rinse with aliphatic naphtha. (**Warning**—see Note 3)

12.15.3.6 Remove the external oil heat exchanger, and clean it according to 10.1.

12.15.3.7 Remove the engine from the test stand, and transport it to the engine disassembly area for determination of test results.

13. Determination of Test Results

13.1 In addition to recording the data on the figures specified in the following sections, record the data on the end-of-test portion of Fig. A2.2 for both reference oils (mandatory) and non-reference oils (optional).

13.2 *Engine Disassembly*—Disassemble the engine according to the following instructions, in preparation for inspection, rating, and measurement:

13.2.1 Plan the disassembly so that the parts to be rated for sticking, deposits, and plugging (pistons, rocker covers, rocker cover deflectors, front cover, oil pump screen, oil rings, hydraulic lifters, and oil pump) are removed from the engine within 4 h of the completion of the oil leveling step in 12.14.16.

13.2.2 Remove the components from the top of the engine in order to gain access to the cylinder bores.

13.2.3 Remove the carbon deposits from the top portion of the cylinder walls, above the top compression ring travel, before removing the pistons from the engine.

13.2.4 Disassemble the remainder of the engine. Record the time when the pistons are removed from the engine.

13.3 *Preparation of Parts for Rating of Sticking, Deposits, and Plugging*—Prepare the specified parts for rating according to the following instructions:

13.3.1 Check all piston rings for freedom of action in the grooves as the pistons are removed from the engine. See 13.5.1 through 13.5.1.3.

13.3.2 Do not remove the piston rings from the pistons.

13.3.3 If the piston skirts cannot be rated immediately after the pistons are removed from the engine, store the pistons in a vacuum desiccator for no longer than 64 h before rating. Do not wipe the pistons before storing them. See 13.7.

13.3.4 Physically position all parts to be rated for sludge deposits and plugging (pistons, rocker covers, rocker cover deflectors, front cover, oil pump screen, and oil rings) so that the excess oil can flow off and out of them; do not disturb the parts for 8 h before rating them.

13.4 *Rating Environment and Procedures*— Establish the proper environment for parts rating according to the following instructions:

13.4.1 Rate all parts against a white background.

13.4.2 Rate piston skirt deposits and oil ring land deposits under a lamp with two 15-watt cool-white fluorescent tubes which together produce 350 to 500 fc (3800 to 5400 lx) at the rating surface.

13.4.3 Rate parts for sludge and plugging under cool-white fluorescent overhead lighting of 350 to 500 fc (3800 to 5400 lx).

13.4.4 If multiple ratings are deemed necessary of a given part or parts, consensus rating may be used according to the following:

13.4.4.1 The raters shall be from the laboratory in question, no outside raters can be used.

13.4.4.2 No averaging of ratings is permitted.

13.4.4.3 Only one rating value is to be reported and is to be agreed to by the raters involved.

13.4.4.4 The use of consensus rating shall be noted in Fig. A6.5.

13.5 *Part Sticking*—Rate the specified parts for sticking according to the following instructions:

13.5.1 *Piston Ring Sticking*—Rate the piston rings for sticking as follows:

13.5.1.1 See Section 3 for the definition of stuck and sluggish rings.

13.5.1.2 Align the ring gaps of the free piston rings at the center of the thrust side of the piston for photographic purposes.

13.5.1.3 Determine which rings are stuck or sluggish, and record the piston number and ring identification (for example, piston No. 3, top ring) for such rings on Fig. A6.12, and Fig. A6.2 or Fig. A6.3, as appropriate.

13.5.2 *Hydraulic Valve Lifter Sticking*— Inspect all the hydraulic valve lifters for sticking.

13.5.2.1 See Section 3 for the definition of stuck lifter.

13.5.2.2 For a stuck lifter, following wear measurements (see 13.11), disassemble the lifter, photograph the parts, and include a copy of the photograph in the test report; alternatively, include the actual stuck lifter(s) with the test report.

13.5.2.3 Record the number of stuck lifters on Fig. A6.2 or A6.3, as appropriate.

13.6 *Sludge Rating*—Rate the specified parts for sludge accumulation to the nearest hundredth of a number. Refer to Practice E 29 for any needed rounding; use the rounding-off method. Proceed according to the following instructions:

13.6.1 Use CRC Manual 12[91] in rating parts for sludge accumulation.

[91] Rating Manuals No. 12 and No. 14 are available from Coordinating Research Council, Inc., 219 Perimeter Center Parkway, Atlanta, GA 30346.

13.6.2 Rate the two rocker cover deflectors. Record the results on Fig X6.1 and Fig X6.2 or Fig X6.3, as appropriate.

13.6.3 Rate the two rocker covers. Record the results on Fig X6.1, and Fig X6.2 or A6.3, as appropriate.

13.6.4 Rate the entire oil-exposed surface of the front cover. Record the results on Fig A6.2, Fig A6.3, and X5.1, as appropriate.

13.6.5 Calculate the average of the five sludge ratings determined in 13.6.2, 13.6.3, and 13.6.4. Record the rating on Fig A6.2 or Fig A6.3, as appropriate.

13.7 *Piston Skirt Deposits Rating*—Rate the piston skirts for deposits, to a tenth of a number. Average the results and report them to the nearest hundredth of a number. Proceed according to the following instructions:

13.7.1 Rate the piston skirt deposits immediately upon removal of the pistons from the engine, if possible, to avoid the rating complication caused by the formation of lead salts on the skirts. See 13.3.3.

13.7.2 Do not remove the piston rings.

13.7.3 Gently wipe off any excess oil from the piston skirts with a soft cloth.

13.7.4 Do not apply any used oil or any build-up oil to the skirts at any time.

13.7.5 Use the rating procedures contained in CRC Manual 14 with the following revisions:

13.7.5.1 Use a value of 9.5 on the CRC Scale, not 10.0, for a piston skirt free of deposit.

13.7.5.2 Use Supplemental Piston Photographs—Set A for initial ratings.

13.7.5.3 Use CRC Manual 14 photographs for upgrade ratings.

13.7.6 Proceed with the rating of the piston skirts according to the following detailed instructions:

13.7.6.1 For any area of the piston skirts covered by lead salts, consider the area to have been covered by deposits which were scuffed or peeled from the surface, in accordance with Section I.C in CRC Manual 14. That is, rate that area the same as the adjacent area.

13.7.6.2 Include any varnish deposits within the central skirt contact area in both the initial and after-solvent-cleaned ratings.

13.7.6.3 Rate worn portions of the central skirt contact area, in which no lead salts are evident, on the basis of the existing condition per Section I.C of CRC Manual 14.

13.7.6.4 Record the initial ratings on Fig A6.10.

13.7.6.5 Dip a soft cloth in the organic solvent specified in Table 1.

13.7.6.6 With the solvent applied to the cloth, wipe an area across the center of the skirt [about 20 mm, (¾ in.)], from the bottom of the skirt, of one index finger width [about 10 mm (½ in.)], parallel to the tooling marks on the skirt. Wipe from one edge of the skirt to the other, and back, applying moderate finger pressure.

13.7.6.7 Dip a clean area of the cloth in the solvent, and wipe the skirt again, over the same area.

13.7.6.8 Dip a clean area of the cloth in the solvent, and wipe the skirt for the third time.

13.7.6.9 Outline the solvent-wiped area with a permanent black marker.

13.7.6.10 Rate the solvent-wiped area according to Manual 14 (use the original photo set, not the supplemental pistons photo—Set A), assuming that it is 100 % of the rating area, following the same guidelines as used for the initial rating. Do not assign a rating to this area lower than the rating made prior to wiping the area. Record this rating as the secondary rating on Fig A6.10.

13.7.6.11 Subtract this rating from 9.50 (the rating for a clean, used piston skirt with no stain).

13.7.6.12 Compare the difference to the maximum allowed upgrade of 0.80 rating number. If the difference is less than 0.80, use it as the upgrade value. If it is 0.80 or more, use 0.80 as the upgrade value. Record the value determined in the adjustment column of Fig A6.10.

13.7.6.13 Add the initial and adjustment numbers to obtain the adjusted ratings in Fig A6.10.

13.7.6.14 Calculate the average thrust and anti-thrust values and record on Fig A6.10 and Fig A6.2 or Fig A6.3, as appropriate. Calculate the average of the values of the twelve skirts, and record it as the reported engine average on Fig A6.10 and Fig A6.2 or Fig A6.3, as appropriate.

13.7.6.15 For tests run using batch code four or five pistons, add 0.14 merits to the reported engine average and record it as the final APV of Fig A6.2 or A6.3, as appropriate.

13.7.7 Report any unusual piston skirt deposits observed on the comments section of Fig A6.10.

13.8 *Oil Ring Land Deposits Rating*— Rate the piston oil ring land (the face of the land above the oil ring) deposits to the nearest hundredth of a number. Refer to Practice E 29 for any needed rounding; use the rounding-off method. Proceed according to the following instructions:

13.8.1 Rate the piston oil ring land deposits immediately upon removal of the pistons from the engine, if possible. See 13.3.3.

13.8.2 Do not remove the piston rings.

13.8.3 Gently wipe off any excess oil from the piston oil ring lands with a soft cloth.

13.8.4 Do not apply any used oil or any build-up oil to the oil ring lands.

13.8.5 Use the rating procedures contained in CRC Manual 14 with the following exceptions:

13.8.5.1 Use CRC Manual 14 (non-rubbing scale) for deposit levels above 3.0.

13.8.5.2 Use IIIE Ring Land Deposit Rating Aid for deposit levels of 3.0 and below.

13.8.6 Rate only the deposits present, ignoring any area where the deposits have flaked or chipped off. Consider the remaining, unchipped area as 100 % of the rated land area.

13.8.7 Record the percentage of chipped areas on Fig. A6.12.

13.8.8 Record the rating results on Fig. A6.12 and Fig. X5.4.

13.8.9 Calculate the average of the six ratings; record this average non-adjusted oil ring land deposit (ORLD) on Fig. A6.12 and A6.2 or A6.3, as appropriate.

13.8.10 Calculate the adjusted oil ring land deposits rating using this equation:

$$ORLD_{\text{adjusted}} = (ORLD \times 1.16) + 0.48. \quad (5)$$

Record the result as the reported engine average *ORLD* on Fig. A6.12, and on Fig. A6.2 and Fig. A6.3, as appropriate.

NOTE 30—The adjusted *ORLD* rating for an *ORLD* rating greater than 8.20 will be greater than 10.0. Do not report a value greater than 10.0.

13.8.11 Record the original (non-adjusted; see 13.8.6) and adjusted (see 13.8.10) ratings on Fig. A6.2 or Fig. A6.3, as appropriate.

13.9 *Part Plugging Observations*—Rate the specified parts for plugging to the nearest whole percentage number. Refer to Practice E 29 for any needed rounding; use the rounding-off method. Proceed according to the following instructions:

13.9.1 Rate the oil pump screen for percent plugging by debris. Do not blow the retained oil from the screen. Report the plugging on Fig. A6.2 or A6.3, as appropriate.

13.9.2 Rate the oil rings for percent plugging of the rail separators. Record the results on Fig. A6.12.

13.9.2.1 Calculate the average percent plugging. Record the answer on Fig A6.12.

13.9.2.2 Record the average on Fig. A6.2 or A6.3, as appropriate.

13.10 *Visual Inspection for Scuffing and Wear*—Visually inspect the parts specified for scuffing and wear according to the following instructions:

13.10.1 Inspect the camshaft lobes for scuffing. Record those found to be scuffed on Fig. X2.1. Determine the total number scuffed, and record the total on Fig. X2.1, and Fig. A6.2 or A6.3, as appropriate.

13.10.2 Inspect the lifter feet for scuffing. Record those found to be scuffed on Fig. X2.3. Determine the total number scuffed, and record the total on Fig. X2.3 and Fig. X2.2 or Fig. X2.3, as appropriate.

13.10.3 Inspect the valve stem tips for evidence that a valve rotator failed to induce valve rotation. Record incidents of non-rotation in the test report. In a case of non-rotation, omit the rating of the associated valve stem tip and rocker arm pad in 13.10.4 and 13.10.5.

13.10.4 Inspect the valve stem tips. Determine the number scuffed, worn, or both scuffed and worn. Record the totals on Fig. A6.2 or A6.3, as appropriate.

13.10.5 Inspect the rocker arm pads. Determine the number scuffed, worn, or both scuffed and worn. Record the totals on Fig. A6.2 or A6.3, as appropriate.

13.11 *Post-Test Camshaft and Lifter Wear Measurements*—Measure the wear of the camshaft lobes and lifters to the nearest 0.0025 mm (0.0001 in.). Refer to Practice E 29 for any needed rounding; use the rounding-off method. Proceed according to the following procedure:

13.11.1 Clean the camshaft lobes and lifters with aliphatic naphtha (**Warning**—see Note 3); blow dry them with clean, dry shop air. (**Warning**—see Note 17.)

13.11.2 Store the camshaft and lifters in a temperature-controlled room for at least 90 min before making dimensional measurements, to ensure temperature stabilization. The temperature of the post-test measurement room must be within 3°C (5°F) of the temperature of the pre-test measurement room.

13.11.3 Use dimensional measuring equipment accurate to 0.0025 mm (0.0001 in.). Before each measurement session, use standards traceable to the National Institute of Standards and Technology, to ensure measuring equipment accuracy. Include standards having length values within 1.3 mm (0.05 in.) of the typical lifter and lobe measurements taken. Use the same equipment and standards for post-test measuring as were used for pre-test measuring. If a calibration shift between pre-test and post-test measurements is detected, evaluate the shift to determine its effect on the wear measurements. Record the results of the evaluation, and any corrective action taken.

13.11.4 Measurements on a camshaft and the lifters used in a given test must be made by the same person if the measurement equipment utilized is operator-sensitive (that is, if a micrometer is used with which the operator determines the spindle pressure).

13.11.5 When measuring the camshaft and the lifters, take precautions to prevent any influence of body heat on the measurements.

13.11.6 Measure the maximum dimension of each camshaft lobe, transverse to the camshaft axis. This dimension is at the front edge of the lobe for lobe numbers 1, 3, 7, 9, and 11; and at the rear edge of the lobe for all other lobes (lobes are numbered from the front to the rear of the camshaft). Record the measurements on Fig. X2.1.

13.11.7 Measure the length of the lifters at the center of the lifter foot. Record the measurements on Fig. X2.2.

13.11.8 Calculate the wear for each camshaft lobe and lifter by subtracting the after-test measurement from the before-test measurement. Record the results on Fig. X2.3and Fig A6.11.

13.11.9 Calculate the cam-plus-lifter wear by adding the values obtained in 13.11.8. Record the results on Fig. A6.11.

13.11.10 Determine the maximum, minimum, and average camshaft-lobe, valve-lifter, and cam-plus-lifter wear. Record the values on Fig. A6.11.

13.11.11 Record the maximum, minimum, and average cam-plus-lifter wear on Fig. A6.2 and Fig. A6.3, as appropriate.

13.11.12 If average-camshaft-plus-lifter wear is less than or equal to zero, then report 0 µm as the average-camshaft-plus-lifter wear value on Fig. A6.2 or A6.3, as appropriate, and note this change on Fig. A6.5. In addition, report Not Applicable (NA) as the transformed value of the wear result and also apply no severity adjustment to the test result.

13.11.13 If maximum-camshaft-plus-lifter wear is less than or equal to zero, then report 0 µm as the maximum-camshaft-plus-lifter wear value on Fig. A6.2 or A6.3, as appropriate and note this change on Fig. A6.5. In addition, report NA as the transformed value of the wear result.

13.12 *Connecting Rod Bearing Weight Loss*— Determine the connecting rod bearing weight loss according to the following procedure:

13.12.1 Do not rub or brush the bearings.

13.12.2 Dip the pre-weighed bearing halves in petroleum ether (**Warning**—see Note 10), and air. (**Warning**—see Note 17) dry them.

13.12.3 Inspect the bearings. Record any unusual observations.

13.12.4 Weigh the pre-weighed bearing halves to the nearest 0.1 mg (2.2×10^{-7} lb). Refer to Practice E 29 for any needed rounding; use the rounding-off method. Record the results on Fig. X2.2.

13.12.5 Calculate the bearing weight loss by subtracting the after-test weight from the before-test weight. Record the results on Fig. X2.2.

13.12.6 Record the bearing weight loss for bearings Nos. 3 and 5 on Fig A6.2 or A6.3, as appropriate.

13.13 *Viscosity Test*—Determine the viscosity of a sample of the fresh test oil and of the nine analysis samples (see Fig. X4.4) according to the following instructions:

13.13.1 Do not filter the samples.

13.13.2 Use Test Method D 445.

13.13.3 Use either the Cannon-Fenske Routine Viscometer of the Ostwald Type for Transparent Liquids, or the Cannon-Fenske Opaque Viscometer of the Reverse-Flow Type for Transparent and Opaque Liquids.

13.13.4 Conduct the measurement at 40°C (104°F).

13.13.5 Record the results on Fig. A6.2 or A6.3, as appropriate.

13.13.6 Critically examine the relationship of the viscosity of the initial oil sample to that of the new oil. The viscosity of the initial sample can legitimately be as much as 10 cSt less than that of the new oil, because of permanent shearing effects. If the difference is greater than 10 cSt, explore possible causes such as failure to purge the oil sample line [removing the 473-mL (16-oz) purge sample] prior to withdrawing the 237-mL (8-oz) analysis sample, an excessive amount of build-up oil in the system, or failure to air-dry the external oil circulating system to remove cleaning solvents. Any of these causes may be the basis for invalidating the test.

13.13.7 Calculate the change in viscosity in centistokes, from the value for the initial sample, for the last eight samples. Record the changes on either Fig. A6.2 or Fig. A6.3.

13.13.8 Calculate the percent change in viscosity, from the value for the initial sample, for the last eight samples. Record the percent changes on Fig. A6.8, and on Fig. A6.2 or Fig. A6.3, as appropriate.

13.13.9 Determine the number of hours to 375 % viscosity increase in the following manner:

13.13.9.1 If the viscosity of the test oil increased by more than 375 % in less than 64 h of engine oil quality testing, use straight-line interpolation between the two time points that span 375 % viscosity increase to determine the time to 375 % viscosity increase to the nearest tenth of an hour.

13.13.9.2 If the viscosity of the test oil had not increased by as much as 375 % in 64 h of engine oil quality testing, apply the following equation to determine the number of hours to 375 % viscosity increase; round the result to the nearest tenth of an hour. Refer to Practice E 29; use the rounding-off method.

$$\text{Hours to 375 \% viscosity increase} = \frac{\ln(\text{viscosity increase at 64 h} + 100) - 6.163}{-0.072} + 64 \quad (6)$$

13.13.9.3 Enter the number of hours determined in either 13.13.9.1 or 13.13.9.2 on Fig. A6.2 or Fig. A6.3.

13.14 *Blowby Flow Rate Measurements*— Plot blowby flow rate measurements on Fig A6.7. List explanations for any out-of-limit measurements on Fig A6.5.

13.15 *Oil Consumption Computation*—Compute the oil consumption for the test as follows:

13.15.1 Refer to Fig. X4.4.

13.15.2 Determine the total fresh oil added to the engine during the break-in and 64-h test periods in Step 8 of Fig. X4.4. Enter the total in the end-of-test total column on Fig. X4.4.

13.15.3 Determine the total amount of oil discarded during the break-in and 64-h test periods in Step 11 of Fig. X4.4. Enter the total in the end-of-test total column on Fig X4.4.

13.15.4 Determine the computed oil level in millilitres at the end of the test, Step 13 in Fig X4.4. Enter the number in the end-of-test total column on Fig. X4.4.

13.15.5 Add the values determined in 13.15.2 and 13.15.4, and subtract the value determined in 13.15.3. Enter the remainder, which is the amount of oil consumed in the test, in the blank for Step 14 on Fig. X4.4. As one of the criteria for judging test validity, the maximum allowable oil consumption is 5090 mL (5.38 qt).

13.16 *Photographs of Test Parts*—Take color photographs of the test parts for inclusion in the test report, as follows:

13.16.1 Pistons.

13.16.1.1 Do not coat the pistons with build-up oil (for preservation) before the photographs are taken.

13.16.1.2 Align the gaps of the free (not stuck) rings (installed on the pistons) with the center of the piston skirt on the thrust side.

13.16.1.3 Select the one side of the one piston which has the lowest piston skirt varnish rating. Label the piston WPV (for worst piston varnish).

13.16.1.4 Select the one side of the one piston for which the piston skirt varnish rating is closest to the overall average piston skirt deposit rating [(thrust + anti-thrust)/2]. Label the piston APV (for average piston varnish).

13.16.1.5 Select the one side of the one piston which has the lowest oil ring land deposit rating. Label the piston WRLD (for worst ring land deposit).

13.16.1.6 Select the one side of the one piston for which the oil ring land deposit rating is closest to the overall average oil ring land deposit rating. Label the piston ARLD (for average ring land deposit).

13.16.1.7 Place identification labels or markings on the top lands of the pistons.

13.16.1.8 Photograph the thrust side of six pistons.

13.16.1.9 Photograph the anti-thrust side of six pistons.

13.16.1.10 Size the final piston photographs for inclusion in the test report so that the overall piston height is not less than 5 cm (2 in.), but small enough that three photographs can be mounted in a column on the 28-cm (11-in.) dimension of a 22 by 28-cm (8½ by 11-in.) sheet of paper.

13.16.1.11 Assemble the photographs on two pages, with the thrust side photographs on one page, and the anti-thrust photographs on the other page.

13.16.1.12 Mount the photographs on each of the two pages with the reciprocating axes of the pistons parallel to the 28-cm (11-in.) dimension of the page. Arrange the photographs in two vertical columns of three each, with the No. 1 piston in the upper left corner of the page, No. 2 piston in the upper right corner, No. 3 piston in the center of the left column, etc.

13.16.2 Parts rated for sludge.

13.16.2.1 Photograph the oil-exposed side of one rocker cover.

13.16.2.2 Photograph the oil-exposed side of one rocker cover deflector.

13.16.2.3 Photograph the oil-exposed side of the front cover.

13.16.2.4 Size the photographs of the parts rated for sludge so that the lengths of the rocker cover and deflector are at least 15 cm (6 in.), and so that the height of the front cover is at least 10 cm (4 in.).

13.16.2.5 Assemble the photographs of the parts rated for sludge on a third page.

13.17 *Retention of Representative Test Parts*—Retain for at least 6 months, all pistons and any stuck lifters, for future inspection.

13.18 *Severity Adjustments*—Calculate severity adjustments (SA) for results of non-reference engine oil tests. Use the control chart technique, described in Annex A5, for determining the laboratory bias for hours to 375 % viscosity increase, average engine sludge, average piston skirt varnish, oil ring land deposits, and average camshaft and lifter wear. Enter the adjustments on Fig. X5.2. Continue to calculate and apply each SA until calibration test results indicate that the bias for the result is no longer significant.

13.19 *Determination of Operational Validity*—Determine and document the operational validity of every Sequence IIIE test conducted, according to the following:

13.19.1 Complete the report forms to substantiate that the test stand, engine build-up, installation of the engine on the test stand, and the test operation conformed to the procedure specified in this test method.

13.19.2 Give special attention to the parameters specified in Table 10, as detailed in 13.19.3 and 13.19.4.

13.19.3 Calculate the deviation percentage, *DP*, for each of the parameters in Table 11, using the following equation, and record the results on Fig. A6.6:

$$DP = \sum_{i=1}^{i=n} \left[\frac{M_i}{0.5R} \times \frac{T_i}{D} \right] \times 100 \quad (7)$$

TABLE 10 Sequence IIIE Test Validity Requirements for Blowby Flow Rate During the 64-h Engine Oil Quality Testing Phase

Test Time, h	Requirement
Engine Build Validity	
0 to 1	Greater than or equal to 42.5 L/min (1.50 ft^3/min)
17 and 21	39.6 to 51.0 L/min (1.40 to 1.80 ft^3/min)
0 to 64	Average no greater than 51.0 L/min (1.80 ft^3/min)
Representativeness of Oil Performance (Non-Reference Oil)[A]	
0 to 64	Average in the range of 42.5 to 51.0 L/min (1.50 to 1.80 ft^3/min)
48 to 64	39.6 to 51.0 L/min (1.40 to 1.80 ft^3/min)

[A] Inspect the test records to verify that the engine was built in a valid manner.

TABLE 11 Sequence IIIE Test Validity Parameters

	D (test duration), h
Primary Validity Parameters	
Engine power	64
Oil filter adapter temperature	64
Coolant-out temperature	64
Engine coolant flow rate	64
Air-to-fuel ratio, right and left	64
Secondary Validity Parameters	
Engine speed	64
Coolant-in temperature	64
Rocker cover coolant-out temperature, right and left	64
Breather tube coolant-out temperature	64
Exhaust back pressure, right and left	64
Rocker cover flow rate	64
Breather tube flow rate	64

where:

DP = deviation %,
M_i = magnitude of test-parameter deviation from specification limit at occurrence i,
R = test parameter specification range,
T_i = length of time that test parameter was outside of specification range at occurrence i; (T_i is assumed to be no less than the recorded-data-acquisition frequency unless supplemental readings are documented.),
n = number of times that a test parameter deviated from the test specification limits, and
D = test or test-phase duration in same units as T_i.

13.19.3.1 To determine T_i for air-to-fuel ratio, plot the ratio for each bank versus engine hours, including on the graph a band of acceptable ratios from 16.0 to 17.0. Connect the measured air-to-fuel ratio data points with straight lines. For any data point lying outside the band, determine T_i by measuring the time between the intersection points of these lines with the closest line for the acceptable band.

13.19.4 Observe that in Fig. A6.6, the maximum deviation percentage limit for any primary validity parameter is 2.5 %; for any secondary test parameter, it is 5.0 %. Note any parameter that has exceeded the allowable limit on Fig A6.5 and declare the test invalid on Fig. A6.10.

13.19.5 Special validity parameters include the following: ignition timing, downtime, and blowby. Observe the following requirements for these parameters.

13.19.5.1 Inspect the ignition timing records for the test. Record on Fig A6.5 any instances in which the ignition timing deviated by more than 2° from the specified test timing. In those cases, note on Fig A6.1, indicating his or her recognition that the test is invalid.

13.19.5.2 Inspect the test records for instances of downtime (excluding the break-in phase of the test), and record any such instances on Fig. A6.5 Enter the total downtime on Fig A6.5. If the total downtime exceeds 2 h, note on Fig. A6.1 that the test is invalid.

13.19.5.3 Inspect the test records regarding blowby flow rate for conformance to the requirements in Table 10. In cases of non-conformance, note the derivation on Fig. A6.5 and note that the test is either invalid or non-representative on Fig. A6.1

13.19.5.4 Inspect the test records regarding maximum and average cam-plus-lifter wear. A test is deemed not interpretable with respect to wear if the original maximum cam-plus-lifter wear (see 13.11.12) is both six times the average cam-plus-lifter wear and also greater than 800 µm. In cases of non-conformance, note the deviation on Fig. A6.5 and note that the test is non-representative on Fig. A6.1.

14. Report

14.1 *Report Forms*—Use Figs. A6.1, A6.4 through A6.13, and A6.2 or A6.3, as appropriate, for reporting the test results for test oils and reference oils, and for summarizing the operational data.

14.1.1 In accordance with 10.19 and Section 13, use Fig. A2.2 for recording test data. However, do not submit this figure as part of the test report. Retain it for use by the ASTM TMC in future severity trend investigations.

14.2 *Use of SI Units*—Report all results in metric (SI) units. Use the multipliers given in Table 8 to convert measurements made in inch-pound units to metric units. Follow the rules for conversion in Practice E 380.

14.3 *Precision of Reported Units*—Use Practice E 29 for rounding off data; use the rounding-off method. Report the data to the same precision as indicated in the metric test limits given in Table 7 and Table 8.

14.4 *Deviations from Test Operational Limits*—In addition to any deviations specified in 13.19, report all deviations from the specified test operational limits on a supplemental page. Include the test time, magnitude, and duration of the deviations. Include deviations from specified warm-up times, scheduled and unscheduled shutdowns, and shutdown procedures.

14.5 *Oil Pressure Plot*—Include a plot of oil pressure versus test hours in the test report if the oil pressure is less than 207 kPa (30 psi) during any running time during the test.

15. Precision and Bias

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

15.1.1 Table 12 summarizes reference oil precision of the test as of January 1993.

NOTE 31—Contact the ASTM TMC for up-to-date data.

TABLE 12 Sequence IIIE Reference Oil Precision Statistics[A]

Variable	Repeatability[B] s_r[D]	Repeatability[B] r[E]	Reproducibility[C] s_R[D]	Reproducibility[C] R[E]
Non-Transformed (as-measured) Units				
Hours to 375 % viscosity increase, mm^2/s at 40°C, relative to the viscosity at the end of the 10-min timing run	5.54	15.51	5.74	16.07
Average piston varnish, merits	0.189	0.529	0.200	0.560
Oil ring land deposits, merits	0.763	2.14	0.792	2.22
Transformed Units				
Average cam plus lifter wear, ln(µm)	0.550	1.54	0.550	1.54
Average engine sludge, transformed[F]	0.169	0.473	0.171	0.479
Maximum cam plus lifter wear, ln(µm)	0.728	2.04	0.731	2.05

[A]These statistics are based on results obtained on ASTM Test Monitoring Center Reference Oils 402, 404-1, 424-1, 425-1, 425-2, 1002, and 1006.
[B]Repeatability values refer to tests run on the same oil in the same laboratory.
[C]Reproducibility values refer to tests run on the same oil in different laboratories.
[D]s = standard deviation.
[E]On the basis of test error alone, the difference, in absolute value, between two test results will be expected to exceed this value only about 5 % of the time.
[F]Transformed = −ln(10 − merit rating).

15.1.1.1 Repeatability (r) is defined as: the difference between successive results obtained by the same laboratory under constant operating conditions on the same oil, would, in the long run, in the normal and correct conduct of the test method, exceed the values shown in Table 12 in only one case in twenty.

15.1.1.2 Reproducibility (R) 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 12 in only one case in twenty.

15.2 Bias is determined by applying an acceptable statistical technique to reference oil test results and when significant bias is determined, a severity adjustment is permitted for non-reference oil test results (see Annex A5).

16. Keywords

16.1 bearing weight loss; cam and lifter wear; deposits; engine oil; engine wear; high-temperature performance; oil consumption; oil thickening; oil viscosity; oxidation resistance; Sequence IIIE test; sludge; sludge deposition; spark-ignition automotive engine; varnish; varnish deposition

ANNEXES

(Mandatory Information)

A1. THE ROLE OF THE ASTM TEST MONITORING CENTER AND THE CALIBRATION PROGRAM

A1.1 *Nature and Functions of the ASTM Test Monitoring Center (TMC)*—The ASTM TMC is a non-profit organization located in Pittsburgh, PA and is staffed to administer engineering studies; conduct laboratory visits; perform statistical analyses of reference oil test data; blend, store, 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 coordinates its activities with the test sponsors, the test developers, the surveillance panels, and the testing laboratories.

A1.2 *Rules of Operation of the ASTM TMC*—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.

A1.3 *Management of the ASTM TMC*—The management of the Test Monitoring System is vested in the Test Monitoring Board (TMB) elected by Subcommittee D02.B. The TMB selects the TMC Administrator who is responsible for directing the activities of the TMC staff.

A1.4 *Operating Income of the ASTM TMC*—The TMC operating income is obtained from fees levied on the reference oils supplied and on the calibration tests conducted. Fee schedules are established and reviewed by Subcommittee D02.B.

A1.5 *Conducting a Reference Oil Test:*

A1.5.1 For those laboratories which choose to utilize the services of the ASTM TMC in maintaining calibration of test stands, full-scale calibration testing shall be conducted at regular intervals. These full-scale tests are conducted using coded reference oils supplied by the ASTM 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 reference oil inventory at or above the minimum level specified by the TMC test engineers.

A1.5.2 When laboratory personnel decide to run a reference calibration test, they shall request an oil code from the cognizant TMC engineer. Upon completion of the reference oil test, the data shall be sent in summary form (use TMC-acceptable 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, shall 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.

A1.6 *New Laboratories*—Laboratories wishing to become a part of the ASTM Test Monitoring System will be requested to conduct reference oil tests to ensure that the laboratory is using the proper testing techniques. Information concerning fees, laboratory inspection, reagents, testing practices, appropriate committee membership, and rater training can be obtained by contacting the TMC Administrator at ASTM Test Monitoring Center, 6555 Penn Ave., Pittsburgh, PA 15206-4489.

A1.7 *Introducing New Sequence IIIE Reference Oils*—The calibrating reference oils produce various wear, oil thickening, 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 IIIE 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 normally be requested to run no more than one contributing test per year per test stand.

A1.8 *TMC Information Letters:*

A1.8.1 Occasionally, it is necessary to change the procedure, and notify the test laboratories of the change, prior to consideration of the change by either ASTM Subcommittee D02.B on Automotive Lubricants or ASTM Committee D-2 on Petroleum Products and Lubricants. In such a case, the TMC will issue an Information Letter. Subsequently, prior to each semi-annual Committee D-2 meeting, the accumulated Information Letters are balloted by ASTM Subcommittee D02.B. The ballot is reviewed at the ASTM Subcommittee D02.B meeting, and the actions taken are considered at a meeting of ASTM Committee D-2. By this means, the Society due process procedures are applied to these Information Letters.

A1.8.2 The review of an Information Letter prior to its original issue will differ according to its nature. 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 semi-annual ASTM Subcommittee D02.B meeting.

A1.8.3 Authority for the issuance of Information Letters was given by the ASTM Committee on Technical Committee Operations (COTCO) in 1984, as follows:

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

A1.9 *TMC Memoranda*—In addition to the aforementioned Information Letters, supplementary memoranda are issued. These are developed by the TMC, and distributed to the Sequence IIIE Test Surveillance Panel and to participating laboratories. They convey such information as batch approvals for test parts or materials, clarification of the test procedure, notes and suggestions for the collection and analysis of special data that the TMC may request, or for any other pertinent matters having no direct effect on the test performance, results, or precision and bias.

A1.10 *Precision Data*—The TMC determines the current Sequence IIIE test precision by analyzing results of calibration tests conducted on reference oils. Current precision data can be obtained from the TMC.

A2. SEQUENCE IIIE ENGINE TEST PARTS

A2.1 *Engine Test Parts Classification:*

A2.1.1 *Critical Parts*

These are engine parts that are known to affect test severity. They will be identified with a serial number or a batch lot control number as supplied by the Central Parts Distributor.[14] Critical parts are listed in Table A2.1.

A2.1.2 *Non-Production Parts*

These are engine parts no longer available except through the Central Parts Distributor or by special order through the Test Developer.[18,39] Non-production parts are listed in Table A2.2.

A2.1.2.1 The engine parts supplied by the Central Parts Distributor are designated by numbers with a BX prefix.

A2.1.3 *Service Parts Operations (SPO) Parts*

These are most of the remaining engine parts, and are available through local General Motors dealer networks. SPO parts are listed in Table A2.3.

TABLE A2.1 Critical Parts List

Part Name	Part No.
Piston, grade 5	BX-312-1
Piston, grade 13	BX-313-1
Piston ring set	BX-314-1
Cylinder head	BX-370-1
Oil filter	BX-307-2
Camshaft	RX-8619-4
Valve spring	BX-308-1
Valve rotator	BX-305-1
Intake valve seal	BX-316-1
Belleville washer	BX-360-1

TABLE A2.2 Non-Production Parts List

Part Name	Part No.
Flywheel	BX-301-1
Oil filter gasket	BX-303-1
Intake manifold gasket	BX-300-2
Intake manifold seal, front and rear	BX-306-1
Rear main rope packing	BX-309-1
Dipstick	BX-384-1
Rocker cover assembly	RX-118618-C

TABLE A2.3 SPO Parts

Part Number	Part Description
1241851	arm, rocker, LH
1241850	arm, rocker RH
271629	Bolt, balancer to crankshaft
25532736	Bolt, camshaft special length
1356635	Bolt, chain damper
25527831	Bolt, cylinder head attachment, yield type short (12)
25525953	Bolt, cylinder head attachment, yield type short (4)
558805	Bolt, flywheel manual transmission (Olds part no.)
25519889	Bolt, front cover, 1 required
25515641	Bolt, front cover 2 in. long
25519892	Bolt, front cover 2-¾in. long
25515639	Bolt, front cover (3)
25519891	Bolt, front cover ⅞in. long
25518193	Bolt, intake manifold (3)
25518194	Bolt, intake manifold (6)
25518190	Bolt, intake manifold special (1)
25524524	Bolt, oil pan (17)
25520079	Bolt, oil pan (3)
431503	Bolt, oil pick-up screen
25518361	Bolt, oil pump cover plate
1254198	Bolt, rocker shaft
1194360	Cap, oil pump relief valve
17111526	Carb., 2BBL
12537202	Chain, timing
1976925	Coil, distributor pick-up
1985474	Coil, ignition H.E.I.
12020132	Connector, mixture control solenoid
25532546	Damper assembly, chain
24500049	Gasket, carburetor base
25525919	Gasket, cylinder head
25536024	Gasket, EGR valve
25537228	Gasket, front timing cover
12337247	Gasket, fuel pump
17076144	Gasket kit, carburetor
12328756	Gasket kit, cylinder head
12328745	Gasket kit, engine overhaul
25521994	Gasket, oil pan
25537229	Gasket, oil pump cover
24501259	Gasket, oil pump pick-up
25515852	Gasket, oil pump relief valve
25523348	Gasket, rocker cover
1250390	Gasket, coolant outlet
1358410	Gasket, coolant inlet
1892082	Gear, distributor driven
25527727	Housing, pick-up tube and screen
17110335	Jet and Rod package, carburetor metering
17067865	Jet and Rod package, carburetor metering
17078644	Jet and Rod package, carburetor metering
838029	Keeper, retainer valve spring cap
1352537	Key, damper crankshaft balancer
25509950	Manifold, cast iron intake
1875990	Module, ignition (distributor modification necessary for use)
25536321	Pin, cylinder head dowel
12338119	Pin, dowel bell housing to transmission
25536321	Pin, front cover dowel
25513253	Plug, cup block and heads 31 mm
3835577	Plug, front oil gallery

TABLE A2.3 *Continued*

Part Number	Part Description
444777	Plug, rear oil gallery
17076144	Power kit, carburetor overhaul
12337257	Pump, engine overhaul kit (bolts, gears, cover and gasket)
25510025	Pushrod
1305044	Seal, crankshaft front rope (do not use for rear main seal)
1959331	Seal, distributor oil (distributor housing to engine block)
25508368	Seat, oil filter by-pass valve
1193966	Shredder, crankshaft front seal
1193967	Slinger, crankshaft
17111102	Solenoid kit, mixture control
1358909	Spring, chain damper
25515389	Spring, oil filter by-pass valve
25529875	Spring, oil pump relief valve
25523115	Sprocket, gear camshaft
25519954	Sprocket, gear crankshaft timing
12355107	Terminal, mixture control solenoid
1261380	Valve, exhaust standard
25512098	Valve, intake standard
25515387	Valve, oil filter by-pass
25528408	Valve, oil pump relief
25525918	Washer, balancer crankshaft
120393	Washer, front cover bolt
	Distributor Rebuild Parts List
1984360	Washer, spring distributor driven gear to housing
1976928	Housing
1959331	"O" Ring
1976930	Shaft
1976925	Pole piece with plate
1875990	Module, four pin
1892222	Retainer
1984360	Washer, spring
1984361	Washer, flat
1892082	Gear
1987049	Pin

A2.1.3.1 The engine parts supplied through General Motors Service Parts Operations are designated by numbers containing five to eight digits.

A2.1.4 *CPD Special Test Parts*

These are engine parts that do not meet all the definitions of critical parts, non-production parts, or SPO parts, but shall be obtained from the Central Parts Distributor. CPD special test parts are listed in Table A2.4.

A2.1.4.1 The parts listed in this category are to include a brief description as to whether or not it is deemed to affect test severity and why it is not classified in one of the other three classifications.

A2.1.5 There are a few other engine parts that are available from other sources identified by footnotes in the following listing.

A2.2 *Parts Procurement and Usage Guidelines:*

A2.2.1 Use all parts on a first-in, first-out basis.

A2.2.2 The maximum order quantity of Critical Parts from the Central Parts Distributor[20] is limited to a sixty day supply for any given laboratory.

A2.2.3 Order quantities for non-production parts and SPO parts are also encouraged to be as low as is feasible to ensure a timely inventory turnover.

A2.2.4 The maximum inventory for critical parts and SPO parts in a given laboratory is a six month supply.

A2.2.5 Use all parts as received unless specific modifications are prescribed in the test method.

A2.2.6 All critical parts shipped from the Central Parts Distributor will be accompanied by a critical parts accountability form (see Fig. A2.1). If any of these parts are rejected by a test laboratory, the reason for rejection shall be stated on the form. A copy shall be faxed monthly to the Test Monitoring Center, the Central Parts Distributor, and the Test Developer. All required critical parts shall be saved for return shipment to the Central Parts Distributor semi-annually on April 15 and October 15, or earlier as directed by the Central Parts Distributor.

A2.2.7 No part number deviations from the current SPO Parts List are allowed except for depletion of old stock. Deviations shall be recorded in the supplementary test notes. The current SPO Qualified Parts List may differ from that in this test method, and the TMC should be contacted for the latest version of this test.

TABLE A2.4 CPD Special Test Parts List

Part Name	Method of Part Tracking	Part No.	Affect Test Severity?	Reason For Classification
Engine bearing kit	Serialized	BX-330-2A	Yes	Six month inventory not applicable. Rejected parts must be reported in a manner similar to critical parts.
Engine block	Serialized	BX-380-2	Yes	Six month inventory not applicable.
Crankshafts	Serialized	BX-304-1	Yes	Six month inventory not applicable.
Oil heat exchanger	Not applicable	BX-350-1	Yes	Six month inventory not applicable.
Breather tube	Serialized	BX-350-1	Yes	Six month inventory not applicable.
Valve lifters	Batch controlled	BX-302-1	Yes	Six month inventory not applicable. Rejected parts must be reported in a manner similar to critical parts.
Front cover assemblies	Not applicable	BX-325-1	Yes	Non-serialized build out material. Rejected parts must be reported in a manner similar to critical parts.
Connecting rods	Not applicable	BX-326-1	Yes	Non-serialized build out material. Rejected parts must be reported in a manner similar to critical parts.
Precision rocker shaft assembly	Serialized	BX-317-2	Yes	Six month inventory not applicable.
Harmonic balancer	Serialized	BX-320-2	Yes	Six month inventory not applicable.
Timing indicator	Serialized	BX-319-2	Yes	Six month inventory not applicable.
Lifter fill chamber	Not applicable	BX-390-1	Unknown	Required test apparatus.
Main bearing bore mandrel	Not applicable	BX-391-1	Unknown	Required test apparatus.

CRITICAL PARTS ACCOUNTABILITY FORM

CUSTOMER		
PACKING LIST		
DATE SHIPPED		
PART NUMBER		
DESCRIPTION		
QUANTITY SHIPPED		
P.O.		
SERIAL NO. / BATCH CODE	**TEST NUMBER**	**REJECTION / COMMENTS**

FIG. A2.1 Critical Parts Accountability Form

A2.3 *Sequence IIIE Test Hardware Tracking*—For each test, complete all hardware information in Fig. A2.2 Fig. A2.3.

A2.3.1 For reference oil tests, complete the test results section of Fig. A2.2.

LAB ENGINE NUMBER	BLOCK SERIAL NUMBER	ENGINE REBUILD ID				REBUILD COMPLETE DATE	PISTON		RING BATCH CODE	RING GAP AVERAGE		CAMSHAFT		LIFTERS	
		BLOCK HONE	HEAD ASSMBY	PISTON RING GAP	BLOCK ASSMBY		BATCH CODE	GRADE		TOP	2ND	SERIAL NUMBER	POUR CODE	ETCH CODE	BOX CTRL NBR
YY12312	YYXXX	XXX	XXX	XXX	XXX	CCYYMMDD	BC123	XX	BCXXX	N.NNN	N.NNN	XYYXXXX	XNNN	XN	WXXXXX or XXXXXX/XXXXXX

LAB ENGINE NUMBER	THRUST WASHER SIZE (IN.)		BEARING KIT SERIAL NUMBER	INTAKE MANIFOLD SERIAL NUMBER	OIL PAN SERIAL NUMBER	CRANK SHAFT SERIAL NUMBER	ROCKER SHAFT ASSEMBLY SERIAL NUMBER		HARMONIC BALANCER SERIAL NUMBER	TIMING INDICATOR SERIAL NUMBER	CYLINDER HEAD SERIAL NUMBER	
	THRUST VALUE	MIN D VALUE					LEFT	RIGHT			LEFT	RIGHT
YY12312	N.NNN	N.NNNN	YYXXXX	YYXXX	YYXXX	YYXXX	YYXXXX	YYXXXX	YYXXXX	YYXXXX	CC-C-XXXXXX	CC-C-XXXXXX

LAB ENGINE NUMBER	VALVE			FRONT COVER SERIAL NUMBER	DISTRIBUTOR LAB NUMBER	ROCKER COVER SERIAL NUMBER		BT SERIAL NUMBER	GLYCOL BATCH RECEIVE DATE	NALCOOL 2000 BATCH NUMBER	FUEL BATCH GMR 995-	CARB LAB NUMBER	OIL FILTER BATCH CODE
	SPRING BATCH CODE	SEAL BATCH CODE	ROTATOR BATCH CODE			LEFT	RIGHT						
YY12312	BCNNN	BCNNN	BCNNN	YYXXX	YY12312	YY123	YY123	YY123	YYMMDD	XNXNNNX	NN	YY12	BC123

LAB ENGINE NUMBER	LAB TEST NUMBER	REF OR CANDIDATE CODE	VALID INVALID NOT REP	EOT DATE	CMIR CODE	REF OIL CODE
YY12312	IIIE NNNN-NN-NNNN	R OR C	V/I/NR	YYMMDD	NNNNNNX	NNNNN

LAB ENGINE NUMBER	RATED OR MEASURED PARTS															
	ENGINE SLUDGE			PISTON SKIRT VARNISH				RING LAND DEPOSIT			MAX C + L WEAR		AVG C + L WEAR			
	ORIG AVG	SA	ADJ AVG	ORIG AVG	CORR AVG	SA	ADJ AVG	ORIG AVG	SA	ADJ AVG	ORIG MAX	CORR MAX	ORIG AVG	CORR AVG	SA	ADJ AVG
YY12312	N.NN	N.NN	N.NNN	N.NN	N.NN	N.NN	N.NN	N.NN	N.NN	N.NN	NNN	NNN	NN.N	NN.N	N.NNN	NN

FIG. A2.2 Sequence IIIE Hardware Data Spreadsheet

A2.3.2 For non-reference oil tests, the test results sections of Fig. A2.2 are optional.

A2.3.3 Record the information in Fig. A2.2 in an electronic format. Any software may be used, however, the data shall be able to be made available in a format readable by Microsoft Excel.

LAB ENGINE NUMBER	CALCULATED VISCOSITY VALUES													OIL CONS. (L)	ROD BEARING WT. LOSS AVG (mg)
	VIS NEW	VIS INIT.	VIS 8	VIS 16	VIS 24	VIS 32	VIS 40	VIS 48	VIS 56	VIS 64	HOURS TO 375 %				
											ORIG HRS	SA	ADJ HRS		
YY12312	NN.NN	NN.N	N	N	N	N	N	N	N	N	N	N.N	N	N.NN	NN.N

LAB ENGINE NUMBER	EXHAUST ANALYSIS				ENGINE BLOWBY (L/m)			REMARKS AND COMMENTS
	NOX AVG	AIR-FUEL-RATIO MAX	MIN	AVG	MAX	MIN	AVG	
YY12312	NNNN	NN.NN	NN.NN	NN.NN	NN.NN	NN.NN	NN.NN	

FIG. A2.2 Sequence IIIE Hardware Data Spreadsheet *(continued)*

A3. SEQUENCE IIIE BLUEPRINT LISTING

A3.1 An alphabetical listing of blueprints required to run a Sequence IIIE test is presented in Table A3.1.

TABLE A3.1 Alphabetical Print Listing

Print Number	Title of Print
RX-118638-A3	Adjusting nut, camshaft hold-back bearing
RX-117726-C	Assembly automatic blowby
RX-117162-C	Auto-carburetor air circuit
RX-117462-C	Auto-exhaust back pressure circuit
RX-117161-C	Auto-water flow circuit
RX-117727-C	Automatic blowby measurement
RX-117376-C	Automatic carburetor air temperature control schematic
RX-117375-C	Automatic dew point control
RX-118625-A2	Baffle oil pan (1985 and 1986)
RX-117431-C	Blowby gas surge tank
RX-118361-A	Bracket, clamp mounting for Sanford SG 48 ring grinder
RX-117294-A	Bushing, blowby adapter
RX-118641-A2	Camshaft rear hold-back assembly
RX-118624-B	Camshaft thrust washer
RX-118636-A2	Cap, camshaft hold-back retainer
RX-118616-E	Carburetor air inlet adapter
RX-118617-E	Carburetor modification
RX-118608-D	Coolant inlet adapter
RX-117350-D	Coolant mixing tank
RX-118609-A1	Coolant outlet adapter
RX-117157-B	Coupling adapter, flywheel
RX-118633-A3	Crankcase pressure tap location
RX-117529-D	Engine dynamometer installation
RX-117167-E	Engine flywheel guard, lower
RX-117168-D	Engine flywheel guard, upper
RX-116169-C	Flow meter (multiple orifice) blowby
RX-116924-C	Flushing tank
RX-117231-C	Flushing tank schematic
RX-117230-E	Flushing tank system piping layout
RX-117374-R	Flushing tank-oil heat exchanger and rocker cover
RX-117225-C	Flywheel rework
RX-328873-B	Fuel mixture control unit
RX-118639-A2	Gage, lifter bore for cam taper
RX-118623-A2	Hood, blowby vent
BX-395-1	Intake air horn

TABLE A3.1 *Continued*

Print Number	Title of Print
RX-118615-E	Intake manifold modification and coolant schematic
RX-118136-A	Lock clip (evertite connector)
RX-118637-A3	Locknut, camshaft hold-back bearing
RX-118358-B	Modification to Sanford SG 48 ring grinder
RX-117730-C	Mounting plate automatic blowby
RX-118612-C	Oil fill adapter
RX-118613-C	Oil filter adapter
RX-118457-B	Oil filter adapter fitting
RX-118626-A1	Oil pan modification (1986 and 1987)
RX-118618-C	Oil temperature control system
RX-117372-C	Piston ring location
RX-118607-D	Plate, engine front support
RX-118634-A2	Retainer, thrust bearing camshaft hold-back
RX-118359-B	Ring clamp for Sanford SG 48 ring grinder
RX-118602-B	Ring depth gage
RX-118604-B	Ring grinder table for Sanford SG 48 ring grinder
RX-118362-A	Ring guide for Sanford SG 48 ring grinder
RX-118576-A	Rocker cover deflector stanchion
RX-118577-C	Rocker cover deflector
RX-117290-C	Schematic, breather tube and rocker cover system
RX-117731-C	Schematic, breather tube temperature control system Sequence III
RX-116681-D	Schematic, cooling water to and from engine
RX-116680-C	Schematic, oil temperature control system
RX-116645-D	Sharp edge orifice water flow meter, upper tube section
RX-116646-D	Sharp edge orifice water flow meter, lower tube section
RX-116647-B	Sharp edge orifice water flow meter, bottom support
RX-116648-B	Sharp edge orifice water flow meter, top flange
RX-116649-A	Sharp edge orifice water flow meter, plate
RX-116650-D	Sharp edge orifice water flow meter assembly
RX-118635-A2	Stud, camshaft hold-back
RX-118794-E	Support, bore roughness tester
RX-118614-D	Water cooled exhaust manifold schematic
RX-118580-D	Water cooled rocker cover assembly
RX-118137-C	Water in and out coolant and flushing tank—Evertite
RX-118640-A3	Wrench, camshaft hold-back adjusting nut lock
RX-116169-A1	Flow meter (multiple orifice) blowby
BX-395-1	Intake air horn
RX-116645-D	Sharp edge orifice water flow meter, upper tube

TABLE A3.1 *Continued*

Print Number	Title of Print
RX-116646-D	Sharp edge orifice water flow meter, lower tube
RX-116647-B	Sharp edge orifice water flow meter, bottom tube
RX-116648-B	Sharp edge orifice water flow meter, top flange
RX-116649-A	Sharp edge orifice water flow meter, plate
RX-116650-D	Sharp edge orifice water flow meter, assembly
RX-116680-C	Schematic, oil temperature control system
RX-116681-D	Schematic, coolant water to and from engine
RX-116924-C	Flushing tank
RX-117157-B	Coupling adapter, flywheel
RX-117161-C	Auto-water flow circuit
RX-117162-C	Auto-carburetor air circuit
RX-117167-E	Engine flywheel guard, lower
RX-117168-D	Engine flywheel guard, upper
RX-117225-C	Flywheel rework
RX-117230-E	Flushing system piping layout
RX-117231-C	Flushing tank schematic
RX-117290-C	Schematic, breather tube and rocker cover Sequence II
RX-117294-A	Bushing blowby adapter
RX-117349-A	Dipstick cap
RX-117350-D	Coolant mixing tank
RX-117372-C	Piston ring location
RX-117374-R	Flushing tank, oil heat exchanger and rocker cover
RX-117375-C	Automatic dew point control
RX-117376-C	Automatic carburetor air temperature control schematic
RX-117431-C	Blowby gas surge tank
RX-117462-C	Auto-exhaust back pressure circuit
RX-117529-D	Engine dynamometer installation
RX-117726-C	Assembly automatic blowby
RX-117727-C	Automatic blowby measurement
RX-117730-C	Mounting plate auto blowby
RX-117731-C	Schematic, breather tube temperature control system
RX-118136-A	Lock clip (Evertite connector)
RX-118137-C	Water in and out coolant and flushing tank
RX-118358-B	Modification to Sanford SG 48
RX-118359-B	Ring clamp for Sanford SG 48

TABLE A3.1 *Continued*

Print Number	Title of Print
RX-118361-A	Bracket, clamp mounting for Sanford SG 48
RX-118362-A	Ring guide for Sanford SG 48
RX-118457-B	Oil filter adapter fitting
RX-118576-A	Rocker cover deflector stanchion
RX-118577-C	Rocker cover deflector
RX-118580-D	Water cooled rocker cover assembly
RX-118601-B	Intake manifold flushing plates
RX-118602-B	Ring depth gage
RX-118604-B	Ring grinder table for Sanford SG 48
RX-118607-D	Plate, engine front support
RX-118608-D	Coolant inlet adapter
RX-118609-A1	Coolant outlet adapter
RX-118612-C	Oil fill adapter
RX-118613-C	Oil filter adapter
RX-118614-D	Water cooled exhaust manifold schematic
RX-118615-E	Intake manifold modification and coolant schematic
RX-118616-E	Carburetor air inlet adapter
RX-118617-E	Carburetor modification
RX-118618-C	Oil temperature control system
RX-118623-A2	Hood, blowby vent
RX-118624-A3	Camshaft thrust washer
RX-118625-A2	Baffle oil pan (1985 and 86)
RX-118626-A1	Oil pan modification (1985 and 86)
RX-118632-A3	Gage, camshaft for thrust washer thickness
RX-118633-A3	Crankcase pressure tap location
RX-118634-A2	Retainer, thrust bearing
RX-118635-A2	Stud, camshaft
RX-118636-A2	Cap, retainer
RX-118637-A3	Locknut, bearing preload adjusting nut
RX-118638-A3	Adjusting nut, bearing preload
RX-118639-A2	Gage, lifter bore for cam taper
RX-118640-A3	Adjusting nut lock wrench
RX-118641-A2	Camshaft rear hold-back assembly
RX-118794-E	Support, bore roughness tester
RX-328873-B	Fuel mixture control unit

A4. SEQUENCE IIIE TEST FUEL ANALYSIS

A4.1 See Table A4.1.

A5. SEQUENCE IIIE TEST CONTROL CHART TECHNIQUE FOR DEVELOPING AND APPLYING SEVERITY ADJUSTMENTS (SA)

A5.1 *Procedure:*

A5.1.1 Apply the technique to all operationally valid calibration tests.

A5.1.2 Record the completion of calibration tests according to end-of-test date and time, using the 24-h clock.

A5.1.3 Convert test results to transformed units according to Table A5.1.

A5.1.4 Obtain the test oil means and standard deviations from the ASTM TMC.

A5.1.5 Calculate the standardized test result, Y_i, as follows:

$$Y_i = \frac{(\text{test result} - \text{applicable test oil mean})}{\text{standard deviation}} \quad \text{(A5.1)}$$

A5.1.6 Report the calibration test results to the ASTM TMC in order of test completion.

A5.1.7 When the results of two tests are available, begin plotting the results in order of test completion.

A5.1.8 Calculate the exponentially-weighted moving average (EWMA) results using the following equation:

$$Z_i = 0.2(Y_i) + 0.8(Z_{i-1}) \quad \text{(A5.2)}$$

where:

Z_s = 0,
Y_i = standardized test result, and
Z_i = EWMA of standardized test result at test order *i*.

A5.1.9 Round the EWMA thus obtained to three places after the decimal.

A5.1.10 If the absolute value of the rounded EWMA exceeds 0.653, apply a severity adjustment (SA) to the results of non-reference tests subsequently obtained.

A5.1.11 Calculate the SA and enter it on Fig. X5.2 in accordance with the examples in A5.2.

A5.1.12 Apply the SA thus determined to the results of non-reference tests conducted following the calibration test. When a subsequent calibration test is conducted, re-calculate the SA.

A5.2 *Examples of EWMA and SA Calculations:*

TABLE A4.1 Typical Analysis of Sequence IIIE Test Fuel (GMR 995)

Fuel Characteristic	Analytical Result	ASTM Test Method
Gravity, API at 15.56°C (60°F)	67.9	D 287
Distillation		D 86
Initial boiling point	40.0°C (104°F)	
5 % distilled	53.5°C (128°F)	
10 % distilled	56.5°C (134°F)	
20 % distilled	70.5°C (159°F)	
30 % distilled	79.5°C (175°F)	
40 % distilled	88.5°C (191°F)	
50 % distilled	95.5°C (204°F)	
60 % distilled	101.0°C (214°F)	
70 % distilled	107.0°C (225°F)	
80 % distilled	123.0°C (253°F)	
90 % distilled	144.5°C (292°F)	
95 % distilled	163.0°C (325°F)	
End point	223.5°C (434°F)	
Recovery, %	98.0	
Residue, %	0.8	
Loss, %	1.2	
Reid vapor pressure	50.3 kPa (7.3 psi)	D 323
Color	red	D 156
Doctor	negative	D 235
Corrosion	1-A	D 130
Total sulfur, mass %	0.063	D 1266
ASTM gum, mg/100 mL	0.4	D 381
Oxidation stability, min	1600 +	D 525
Tetraethyllead content, mL/gal	3.90	D 3237
Lead content, g/gal	4.12	D 3237
Research octane no.	98.0	D 2699
Motor octane no.	91.9	D 2700

TABLE A5.1 Calibration Test Result Transformation Formulae

Test Parameter	Transformation Formula
Hours to 375 % viscosity increase	no transformation required
Average engine sludge (AES)	−[ln(10 − AES)]
Average piston skirt varnish	no transformation required
Oil ring land deposits	no transformation required
Average cam-plus-lifter wear (ACLW)	ln(ACLW)

A5.2.1 *Hours to 375 % Viscosity Increase SA:*

A5.2.1.1 Given Information—Oil, 402; applicable test oil mean = 61.2; standard deviation = 7.19; test result = 45.0.

A5.2.1.2 As indicated in Table A5.1, no transformation is required.

A5.2.1.3 Calculate the standardized test result using equation A5.1:

$$Y_2 = (45.0 - 61.2)/7.19 = -2.253 \quad (A5.3)$$

A5.2.1.4 Say $Z_1 = -0.438$. Then, using equation A5.2:

$$EWMA = Z_i = 0.2(-2.253) + 0.8(-0.438) = -0.801 \quad (A5.4)$$

A5.2.1.5 Since |−0.801| > 0.653, apply an SA, in accordance with A5.2.1.6 through A5.2.1.8.

A5.2.1.6 Convert the EWMA to measured units; multiply (−0.801) by the standard deviation for the hours to 375 % viscosity increase for oil 424-1. (The standard deviation for oil 424-1 is used because the result for this oil is close to the pass limit.)

A5.2.1.7 Multiply the transformed EWMA from A5.2.1.6 by (−1), and round the result to one place after the decimal.

A5.2.1.8 Enter the rounded number in the Severity Adjustment blank on Fig. X5.2. Add to the preceding value on X5.2 to obtain the final Adjusted Hours to 375 % VI.

A5.2.2 *Average Engine Sludge SA*:

A5.2.2.1 Given information: oil 402; applicable test oil mean = 0.50; standard deviation = 0.176; test result = 8.86.

A5.2.2.2 Using the formula in Table A5.1, the transformed test result is: − ln(10 − 8.86) = −0.131. Enter this value on Fig. X5.2 in the Average − Transformed Units blank.

A5.2.2.3 Calculate the standardized test result using equation A5.1:

$$Y_2 = (-0.131 - 0.50)/0.176 = -3.585 \quad (A5.5)$$

A5.2.2.4 Say $Z_1 = -0.745$. Then, using equation A5.2:

$$EWMA = Z_i = 0.2(-3.585) + 0.8(-0.745) = -1.313 \quad (A5.6)$$

A5.2.2.5 Since |−1.313| > 0.653, apply an SA, according to A5.2.2.6 through A5.2.2.9.

A5.2.2.6 Convert the EWMA to transformed units; multiply (−1.313) by the standard deviation for the average engine sludge for oil 424-1. (The standard deviation for oil 424-1 is used because the result for this oil is close to the pass limit.)

A5.2.2.7 Multiply the transformed EWMA from A5.2.2.6 by (−1), and round the result to three places after the decimal.

A5.2.2.8 Enter the rounded number in the Severity Adjustment − Transformed Units Blank on Fig. X5.2. Add to the preceding value in Fig. X5.2 to obtain the adjusted average − transformed units value.

A5.2.2.9 Multiply the sum from A5.2.2.8 by (−1), determine the antilog of the result, and round the antilog to two places after the decimal. Subtract the resultant value from 10, and enter the difference in the Adjusted Average blank on Fig. X5.2.

A5.2.3 *Average Piston Skirt Varnish SA*:

A5.2.3.1 Given information: oil 402; applicable test oil mean = 8.90; standard deviation = 0.220; test result = 6.99.

A5.2.3.2 As indicated in Table A5.1, no transformation is required.

A5.2.3.3 Calculate the standardized test result using equation A5.1:

$$Y_2 = (6.99 - 8.90)/0.220 = -8.682 \quad (A5.7)$$

A5.2.3.4 Say $Z_1 = -0.697$. Then, using equation A5.2:

$$EWMA = Z_i = 0.2(-8.682) + 0.8(0.697) = -1.179 \quad (A5.8)$$

A5.2.3.5 Since |−1.179| > 0.653, apply an SA, according to A5.2.3.6 through A5.2.3.8.

A5.2.3.6 Convert EWMA to transformed units; multiply (−1.179) by the standard deviation for average piston skirt varnish for oil 424-1. (The standard deviation for oil 424-1 is used because the result for this oil is close to the pass limit.)

A5.2.3.7 Multiply the transformed EWMA from A5.2.3.6 by (−1), and round the result to two places after the decimal.

A5.2.3.8 Enter the rounded number in the Severity Adjustment blank on Fig. X5.2. Add to the preceding value in Fig. X5.2 to obtain the final adjusted average.

A5.2.4 *Oil Ring Land Deposits SA*:

A5.2.4.1 Given information: oil 424-1; applicable test oil mean = 3.33; standard deviation = 0.540; test result = 5.00.

A5.2.4.2 As indicated in Table A5.1, no transformation is required.

A5.2.4.3 Calculate the standardized test result using equation A5.1:

$$Y_2 = (5.00 - 3.33)/0.540 = 3.093 \quad (A5.9)$$

A5.2.4.4 Say Z_1 = 0.300. Then, using equation A5.2:

$$EWMA = Z_i = 0.2(3.093) + 0.8(0.300) = 0.859 \quad (A5.10)$$

A5.2.4.5 Since |0.859| > 0.653, apply an SA, according to A5.2.4.6 through A5.2.4.8.

A5.2.4.6 Convert EWMA to measured units; multiply (0.859) by the oil ring land deposit standard deviation for oil 424-1.

A5.2.4.7 Multiply the EWMA in measured units from A5.2.4.6 by (−1), and round the result to two places after the decimal.

A5.2.4.8 Enter the rounded number in the Severity Adjustment blank on Fig. X5.2. Add to the preceding value in Fig. X5.2 to obtain the final adjusted average.

A5.2.5 *Average Cam-plus-Lifter Wear SA*:

A5.2.5.1 Given information: oil 424-1; applicable test oil mean = 2.37; standard deviation = 0.320; test result = 20.

A5.2.5.2 Using formula A5.2 in Table A5.1, the transformed test result is: ln(20) = 2.996. Enter this value on Fig. X5.2 in the Average − Transformed Units blank.

A5.2.5.3 Calculate the standardized test result using equation A5.1:

$$Y_2 = (2.996 - 2.37)/0.320 = 1.956 \quad (A5.11)$$

A5.2.5.4 Say Z_1 = 0.714. Then, using equation A5.2:

$$EWMA = Z_i = 0.2(1.956) + 0.8(0.714) = 0.962 \quad (A5.12)$$

A5.2.5.5 Since |0.962| > 0.653, apply an SA, according to A5.2.5.6 through A5.2.5.9.

A5.2.5.6 Convert the EWMA to transformed units; multiply 0.962 by the standard deviation for the average cam-plus-lifter wear for oil 424-1.

A5.2.5.7 Multiply the transformed EWMA from A5.2.5.6 by (−1), and round the result to three places after the decimal.

A5.2.5.8 Enter the rounded number in the Severity Adjustment − Transformed Units blank on Fig. X5.2. Add it to the preceding value in Fig. X5.2 to obtain the Adjusted Average − Transformed Units value.

A5.2.5.9 Determine the antilog of the Adjusted Average − Transformed Units from A5.2.5.8, and round it to the nearest whole unit. Enter this number on Fig. X5.2 in the space for Adjusted Average.

A6. SEQUENCE IIIE TEST REPORTING

A6.1 The standardized report form package detailed in A6.2 shall be used to report all Sequence IIIE non-reference oil and reference oil tests.

A6.2 *Test Report Forms with Data Dictionary Variable Mneumonics* —The following report forms contain field names for all reported variables. These variables are for use in data communication as being developed by the Data Communication Task Force. See Figs. A6.1-A6.13.

A6.3 *Test Report Variable Data Dictionary*—The following is a complete data dictionary of the field names used in A6.2. See Figs. A6.14-A6.26.

A6.4 *Reporting Reference Oil Test Results:*

A6.4.1 *Reporting Preliminary Reference Oil Test Results*—Report preliminary reference oil test results to the TMC via telecopier facsimile using forms shown in Fig. A6.2, Figs. A6.5-A6.9, and Fig. A6.11.

A6.4.2 *Final Reference Oil Test Report*—A final reference oil test report shall include all forms, with Fig. A6.3 omitted, in the standardized report form package. See Fig. A6.1, Fig. A6.2, and Figs. A6.4-A6.13.

A6.5 *Reporting Non-reference Oil Test Results*—A final non-reference oil test report shall include all forms, with Fig. A6.2 omitted, in the standardized report form package. See Fig. A6.1, and Figs. A6.3-A6.13.

REPORT ON
SEQUENCE IIIE EVALUATION

VERSION 19980403

CONDUCTED FOR

TSTSPON1

TSTSPON2

LABVALID	V = VALID
	I = INVALID
	N = RESULTS CANNOT BE INTERPRETED AS REPRESENTATIVE OF OIL PERFORMANCE (NON-REFERENCE OIL) AND SHALL NOT BE USED FOR MULTIPLE TEST ACCEPTANCE

Test Number		
Test Stand: STAND	Stand Test Number: STRUN	Lab Test Number: LABRUN
Oil Code[A]: CMIR/OILCODE		
Formulation/Stand Code: FORM		
Alternate Codes: ALTCODE1	ALTCODE2	ALTCODE3
EOT Date: DTCOMP	EOT Time: EOTTIME	

In my opinion this test OPVALID been conducted in a valid manner in accordance with Test Method D5533 and the appropriate amendments through the information letter system. The remarks included in the report describe the anomalies associated with this test.

The test stand and laboratory have been calibrated in accordance with the requirements specified in Test Method D5533 and the appropriate amendments through the information letter system.

[A] CMIR or Non-reference Oil Code

SUBMITTED BY:

SUBLAB
Testing Laboratory

SUBSIGIM
Signature

SUBNAME
Typed Name

SUBTITLE
Title

FIG. A6.1 Sequence IIIE Test Report Cover

LAB: LAB	OIL CODE: CMIR	
TEST STAND NO.: STAND	TEST NO.: STAND - STRUN -LABRUN	TEST LENGTH: TESTLEN
SAE VISCOSITY : SAEVISC	EOT DATE: DTCOMP	EOT TIME: EOTTIME
FUEL BATCH: FUELBTID	START DATE: DTSTRT	START TIME: STRTTIME
INTERNAL OIL CODE: LABOCODE		ENGINE NO.: ENGINENO

VISCOSITY INCREASE DATA (cSt AT 40°C)

HOURS	VISCOSITY [A]	CHANGE [A]	PERCENT [A]
NEW OIL	VNEW		
INITIAL[B]	VINI		
8	VIS_H008	DVISH008	PVISH008
16	VIS_H016	DVISH016	PVISH016
24	VIS_H024	DVISH024	PVISH024
32	VIS_H032	DVISH032	PVISH032
40	VIS_H040	DVISH040	PVISH040
48	VIS_H048	DVISH048	PVISH048
56	VIS_H056	DVISH056	PVISH056
64	VIS_H064	DVISH064	PVISH064

HOURS TO 375% VIS. INCREASE HRTO375
FINAL HRS. TO 375% VIS. INCREASE FNL375

[A] If TVTM report as 99999.9, 9999.9, or 99999 respectively.
[B] At end of timing run

WEAR CAM POURCODE CAMPOUR

CAM-PLUS-LIFTER	µm
MAX.	MAXCLW
MIN.	MINCLW
AVG.	AVGCLW
FINAL ACLW	FNLACLW
FINAL MCLW	FNLMCLW

ROD BRG. WT. LOSS

	mg
ROD NUMBER 3	BWL3
ROD NUMBER 5	BWL5
AVERAGE	AVGBWL

SLUDGE

		MERITS
FRONT COVER		FCS
ROCKER	RIGHT	RCSR
COVERS (RC)	LEFT	RCSL
RC BAFFLE	RIGHT	RCBSR
RC BAFFLE	LEFT	RCBSL
	AVG.	AES
	FINAL AES	FNLAES
OIL SCREEN DEBRIS %		OSCREEN

SCUFFED (S) AND/OR WORN (W) PARTS

	NUMBER S	W	S&W
CAM	CAMSCUF		
LIFTERS	LFTSCUF		
VALVE STEM TIPS	VSTS	VSTW	VSTSW
ROCKER ARM PADS	ROCKS	ROCKW	ROCKSW

OIL CONSUMPTION (L) OILCON AT OCONHRS HOURS

VARNISH PISTON SKIRT

	MERITS
THRUST	PSVTH
ANIT-THRUST	PSVAT
AVERAGE	AVGPSV
FINAL APV	FNLAPV

PISTON BATCH CODE PISTBAT

RING AREA

OIL RING PLUGGING, %	ORPAVG
NUMBER OF OIL-STUCK RINGS	OSTUKT
NUMBER OF STUCK RINGS	STUKT
NUMBER OF SLUGGISH RINGS	SLUGT

NUMBER OF STUCK LIFTERS LFTSTK

COMPRESSION RING GAPS

	MILS
Top Ring Gap	TRINGGAP
Bottom Ring Gap	BRINGGAP

OIL RING LAND DEPOSITS

	MERITS
ORIGINAL	AVGORLD
FINAL ORLD	FNLORLD
INDUSTRY OIL CODE	IND
INDUSTRY AVERAGE HOURS TO 375% V.I.	IAVGHRS

FIG. A6.2 Sequence IIIE Reference Test Results

LAB: LAB	OIL CODE: OILCODE	
FORMULATION/STAND CODE: FORM		
TEST STAND NO.: STAND	TEST NO.: STAND - STRUN - LABRUN	TEST LENGTH: TESTLEN
SAE VISCOSITY : SAEVISC	EOT DATE: DTCOMP	EOT TIME: EOTTIME
FUEL BATCH: FUELBTID	START DATE: DTSTRT	START TIME: STRTTIME
INTERNAL OIL CODE: LABOCODE	ENGINE NO.: ENGINENO	

VISCOSITY INCREASE DATA (cSt AT 40°C)

HOURS	VISCOSITY[A]	CHANGE[A]	PERCENT[A]
NEW OIL	VNEW		
INITIAL[B]	VINI		
8	VIS_H008	DVISH008	PVISH008
16	VIS_H016	DVISH016	PVISH016
24	VIS_H024	DVISH024	PVISH024
32	VIS_H032	DVISH032	PVISH032
40	VIS_H040	DVISH040	PVISH040
48	VIS_H048	DVISH048	PVISH048
56	VIS_H056	DVISH056	PVISH056
64	VIS_H064	DVISH064	PVISH064
HOURS TO 375% VIS. INCREASE			HRT0375
CORRECTED HOURS TO 375% V.I.			CORR375
SEVERITY ADJUSTMENT			SAHRS
FINAL HOURS TO 375% V.I.			FNL375

WEAR CAM POURCODE CAMPOUR

CAM-PLUS-LIFTER	µm	TRANS. UNITS[C]
MAX.	MAXCLW	TMAXCLW
MIN.	MINCLW	
ACLW	AVGCLW	TAVGCLW
CORRECTED ACLW	CORACLW	CORTACLW
FINAL MCLW	FNLMCLW	FNLTMCLW
SEVERITY ADJ.		SAACLW
FINAL ACLW	FNLACLW	FNLTACLW

ROD BRG. WT. LOSS

	mg
ROD NUMBER 3	BWL3
ROD NUMBER 5	BWL5
AVERAGE	AVGBWL

SLUDGE

		MERITS	TRANS. UNITS[E]
FRONT COVER		FCS	
ROCKER	RIGHT	RCSR	
COVERS (RC)	LEFT	RCSL	
RC BAFFLE	RIGHT	RCBSR	
RC BAFFLE	LEFT	RCBSL	
AES		AES	TAES
CORRECTED AES		CORAES	CORTRAES
SEVERITY ADJUSTMENT			SAAES
FINAL AES		FNLAES	FNLTAES
OIL SCREEN DEBRIS %		OSCREEN	

SCUFFED (S) AND/OR WORN (W) PARTS

	NUMBER S	NUMBER W	NUMBER S&W
CAM	CAMSCUF		
LIFTERS	LFTSCUF		
VALVE STEM TIPS	VSTS	VSTW	VSTSW
ROCKER ARM PADS	ROCKS	ROCKW	ROCKSW

OIL CONSUMPTION (L) OILCON AT OCONHRS HOURS

VARNISH PISTON SKIRT

	MERITS
THRUST	PSVTH
ANTI-THRUST	PSVAT
AVERAGE	AVGPSV
PISTON BATCH CORRECTED APV	CORPSV
CODE PISTBAT SEVERITY ADJUSTMENT	SAPSV
FINAL APV	FNLAPV

RING AREA

OIL RING PLUGGING, %	ORPAVG
NUMBER OF OIL-STUCK RINGS	OSTUKT
NUMBER OF STUCK RINGS	STUKT
NUMBER OF SLUGGISH RINGS	SLUGT
NUMBER OF STUCK LIFTERS	LFTSTK

OIL RING LAND DEPOSITS

	MERITS
ORIGINAL	AVGORLD
CORRECTED ORLD	CORORLD
SEVERITY ADJ.	SAORLD
FINAL ORLD	FNLORLD

A If TVTM report as 99999.9, 9999.9, or 99999 respectively.

B At end of timing run

C Transformed values for Severity Adjustments only

FIG. A6.3 Sequence IIIE Non-Reference Test Results

Laboratory: LAB	EOT Date: DTCOMP
Test Number: STAND - STRUN - LABRUN	EOT Time: EOTTIME
Oil Code: CMIR/OILCODE	
Formulation/Stand Code: FORM	

	SPEC	MAX.	MIN.	AVG.
Speed (r/min)	3000 ± 20	XRPM	IRPM	ARPM
Power (kW)	50.6 ± 1.5	XPWR	IPWR	APWR
OIL:				
Temp. Filter Block (°C)	149.0 ± 1.1	XOILTEM	IOILTEM	AOILTEM
Temp. Sump (°C)	REPORT	XSUMPT	ISUMPT	ASUMPT
Pump Outlet Pressure (kPa)	207 min	XOPUMPP	IOPUMPP	AOPUMPP
Gallery Pressure (kPa)	REPORT	XOILPRS	IOILPRS	AOILPRS
COOLANT:				
Engine Out (°C)	115 ± 1.1	XCOLOUT	ICOLOUT	ACOLOUT
Engine In (°C)	110 ± 1.1	XCOLIN	ICOLIN	ACOLIN
Engine Flow (L/min)	151 ± 3.8	XCOLFLO	ICOLFLO	ACOLFLO
Breather Tube Out (°C)	40 ± 1.1	XBTOT	IBTOT	ABTOT
Left Cover Out (°C)	113 ± 2.8	XLCOUT	ILCOUT	ALCOUT
Right Cover Out (°C)	113 ± 2.8	XRCOUT	IRCOUT	ARCOUT
Rocker Cover Flow (L/min)	11.4 ± 3.8	XRCFLO	IRCFLO	ARCFLO
Breather Tube Flow (L/min)	11.4 ± 3.8	XBTFLO	IBTFLO	ABTFLO
CARBURETOR:				
Air-Fuel Ratio	16.5 ± 0.5	XAFR	IAFR	AAFR
NOx, ppm	REPORT	XNOX	INOX	ANOX
Fuel Inlet Temp. (°C)	REPORT	XFINL	IFINL	AFINL
Air Temp. (°C)	27 ± 1.5	XAIRTP	IAIRTP	AAIRTP
Humidity Dew Pt. (°C)	16.1 ± 1.1	XDEWPT	IDEWPT	ADEWPT
Pressure (kPa)	0.05 ± 0.025	XCARBP	ICARBP	ACARBP
Ambient Air Temp. (°C)	REPORT	XAMBAT	IAMBAT	AAMBAT
Blowby Gas Out Temp. (°C)	REPORT	XBBGAST	IBBGAST	ABBGAST
Blowby (L/min, corrected)	45.3 ± 5.6	XBLOBY	IBLOBY	ABLOBY
Right Exhaust Pressure (kPa)	5.0 ± 0.75	XREXP	IREXP	AREXP
Left Exhaust Pressure (kPa)	5.0 ± 0.75	XLEXP	ILEXP	ALEXP
Diff. Exhaust Pressure (kPa)	0.0 ± 0.19	XDIFEXP	IDIFEXP	ADIFEXP
Intake Vacuum (kPa)	27 ± 7	XINTV	IINTV	AINTV
Intake Mixture Temp. (°C)	REPORT	XINTMX	IINTMX	AINTMX
Crankcase Pressure (kPa)	REPORT	XCCASEP	ICCASEP	ACCASEP
Spark Timing, BTDC	40°	XSPKTIM	ISPKTIM	ASPKTIM

OIL CONSUMPTION DATA:

HOURS	BREAK-IN	8	16	24	32	40	48	56	64
LEVEL (ml) low	OILLHBRK	OILLH008	OILLH016	OILLH024	OILLH032	OILLH040	OILLH048	OILLH056	OILLH064

Glycol Contamination Data:

Sample	Initial	40 hr.	E.O.T.
Positive or Negative	GLYCHINI	GLYCH040	GLYCHEOT

FIG. A6.4 Sequence IIIE Operational Summary

Unscheduled Downtime & Maintenance Summary

Laboratory: LAB	EOT Date: DTCOMP
Test Number: STAND - STRUN- LABRUN	EOT Time: EOTTIME
Oil Code: CMIR/OILCODE	
Formulation/Stand Code: FORM	

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

Total Comments & Outliers	TOTCOM
OCOMH001	

FIG. A6.5 Sequence IIIE Downtime and Outlier Report Form

Laboratory: LAB	EOT Date: DTCOMP
Test Number: STAND - STRUN- LABRUN	EOT Time: EOTTIME
Oil Code: CMIR/OILCODE	
Formulation/Stand Code: FORM	

Primary Parameter	Maximum Permitted Deviation Percentage	Calculated Deviation Percentage	Mid Limit Operation Specification Range	Test Average Value
Engine Power	2.5%	PWRDP	50.6 ±0.375 kW	APWR
Oil Filter Block Temperature	2.5%	OILFBDP	149.0 ±0.275 °C	AOILTEM
Coolant Out Temperature	2.5%	COLOUTDP	115.0 ±0.275 °C	ACOLOUT
Coolant Flow Rate	2.5%	COLFLODP	151.0 ±0.959 L/min	ACOLFLO
Secondary Parameter				
Engine Speed	5%	RPMDP	3000 ±10 r/min	ARPM
Coolant In Temperature	5%	COLINDP		
Rocker Cover Coolant Out Temperature, Left	5%	LRCTPDP		
Rocker Cover Coolant Out Temperature, Right	5%	RRCTPDP		
Breather Tube Coolant Out Temperature	5%	BTOTDP	40.0 ±0.55 °C	ABTOT
Rocker Cover/Crossover Coolant Flow Rate	5%	RCFLODP	11.4 ±1.9 L/min	ARCFLO
Breather Tube Flow Rate	5%	BTFLODP	11.4 ±1.9 L/min	ABTFLO
Exhaust Back Pressure, Left	5%	LEXPDP	5.0 ±0.375 kPa	ALEXP
Exhaust Back Pressure, Right	5%	REXPDP	5.0 ±0.375 kPa	AREXP
Special Parameters				
Air-to-Fuel Ratio, Left	2.5%	LATFDP		
Air-to-Fuel Ratio, Right	2.5%	RATFDP		

FIG. A6.6 Sequence IIIE Deviation Percentage and Mid Limit Operation Report Form

Laboratory: LAB	EOT Date: DTCOMP
Test Number: STAND - STRUN- LABRUN	EOT Time: EOTTIME
Oil Code: CMIR/OILCODE	
Formulation/Stand Code: FORM	

Blowby Plot

BLOWBYIM

Test Hours	1	5	9	13	17	21	25	29	33
Blowby, L/min	BLWBH001	BLWBH005	BLWBH009	BLWBH013	BLWBH017	BLWBH021	BLWBH025	BLWBH029	BLWBH033
Test Hours	37	41	45	49	53	57	61	64	Average
Blowby, L/min	BLWBH037	BLWBH041	BLWBH045	BLWBH049	BLWBH053	BLWBH057	BLWBH061	BLWBH064	ABLOBY

FIG. A6.7 Sequence IIIE Blowby Form

Laboratory: LAB	EOT Date: DTCOMP
Test Number: STAND - STRUN- LABRUN	EOT Time: EOTTIME
Oil Code: CMIR/OILCODE	
Formulation/Stand Code: FORM	

VISINIM

FIG. A6.8 Sequence IIIE Viscosity Increase Plot

Laboratory: LAB	EOT Date: DTCOMP
Test Number: STAND - STRUN - LABRUN	EOT Time: EOTTIME
Oil Code: CMIR/OILCODE	
Formulation/Stand Code: FORM	

Build Completion Date: BUILDDT	Piston Code: Batch (Code): PISTBAT Size (Grade): PISTSIZE
Block Serial Number: BLOCKSN	
Crankshaft Serial Number: CRANKSN	
Camshaft Serial Number: CAMSN	Piston Ring Batch Code: RINGCODE
Lifter Codes: Box Control Number: LFTBXNO Code: LFTCODE	Oil Filter Batch Code: OILFIBAT
	Intake Valve Seals Batch Code: INVSLBAT
	Valve Rotators Batch Code: RTRBAT
	Valve Springs Batch Code: VALSPBAT
Cylinder Head Serial Number: Left: LHEADSN Right: RHEADSN	
Bearing Kit Serial Number: BRNGSN	
Rocker Shaft Serial Number: Left: LRKRSNO Right: RRKRSNO	
Harmonic Balancer ID: HMBALID	
Timing Indicator ID: TMGINDID	

FIG. A6.9 Sequence IIIE Hardware Information

Laboratory: LAB	EOT Date: DTCOMP
Test Number: STAND - STRUN- LABRUN	EOT Time: EOTTIME
Oil Code: CMIR/OILCODE	
Rater: APVRATER	Rating Date: RATEDATE
Formulation/Stand Code: FORM	

Piston Skirt Varnish

Thrust

	CRC Manual 14 Initial	CRC Manual 14 Secondary	Adjustment (0.8 Max.)	Adjusted Rating
1.	PSVTH11	PSVTH21	PSVADJT1	PSVTH1
2.	PSVTH12	PSVTH22	PSVADJT2	PSVTH2
3.	PSVTH13	PSVTH23	PSVADJT3	PSVTH3
4.	PSVTH14	PSVTH24	PSVADJT4	PSVTH4
5.	PSVTH15	PSVTH25	PSVADJT5	PSVTH5
6.	PSVTH16	PSVTH26	PSVADJT6	PSVTH6

Anti-Thrust

	CRC Manual 14 Initial	CRC Manual 14 Secondary	Adjustment (0.8 Max.)	Adjusted Rating
1.	PSVAT11	PSVAT21	PSVADJA1	PSVAT1
2.	PSVAT12	PSVAT22	PSVADJA2	PSVAT2
3.	PSVAT13	PSVAT23	PSVADJA3	PSVAT3
4.	PSVAT14	PSVAT24	PSVADJA4	PSVAT4
5.	PSVAT15	PSVAT25	PSVADJA5	PSVAT5
6.	PSVAT16	PSVAT26	PSVADJA6	PSVAT6

Thrust: PSVTH Anti-Thrust: PSVAT Reported Engine Average: AVGPSV

Comments: AVPISCOM

FIG. A6.10 Sequence IIIE Average Piston Varnish Rating Summary

Laboratory: LAB	EOT Date: DTCOMP
Test Number: STAND - STRUN- LABRUN	EOT Time: EOTTIME
Oil Code: CMIR/OILCODE	
Formulation/Stand Code: FORM	

NUMBER	CAMSHAFT LOBE, µm	VALVE LIFTER, µm	CAM & LIFTER WEAR, µm
1	CAMW01	LFTW01	CLW01
2	CAMW02	LFTW02	CLW02
3	CAMW03	LFTW03	CLW03
4	CAMW04	LFTW04	CLW04
5	CAMW05	LFTW05	CLW05
6	CAMW06	LFTW06	CLW06
7	CAMW07	LFTW07	CLW07
8	CAMW08	LFTW08	CLW08
9	CAMW09	LFTW09	CLW09
10	CAMW10	LFTW10	CLW10
11	CAMW11	LFTW11	CLW11
12	CAMW12	LFTW12	CLW12
MAXIMUM	MAXCW	MAXLFTW	MAXCLW
MINIMUM	MINCW	MINLFTW	MINCLW
AVERAGE	AVGCW	AVGLFTW	AVGCLW

FIG. A6.11 Sequence IIIE Valve Lifter and Camshaft Wear Data

Laboratory: LAB	EOT Date: DTCOMP
Test Number: STAND - STRUN- LABRUN	EOT Time: EOTTIME
Oil Code: CMIR/OILCODE	
Rater: RLDRATER	Rating Date: RATEDATE
Formulation/Stand Code: FORM	

	ORIGINAL	% CHIPPED
1.	ORLD1	ORCHIP1
2.	ORLD2	ORCHIP2
3.	ORLD3	ORCHIP3
4.	ORLD4	ORCHIP4
5.	ORLD5	ORCHIP5
6.	ORLD6	ORCHIP6

ORIGINAL ORLD AVERAGE RATING (UNCORRECTED) AVGORLD

CORRECTED ORLD AVERAGE RATING (ORIGINAL X 1.16) + 0.48 CORORLD

	% Oil Ring Plug	Stuck[A]	(TBON) Oil Stuck[A]	Slug.
1.	ORP1	STUK1	OSTUK1	SLUG1
2.	ORP2	STUK2	OSTUK2	SLUG2
3.	ORP3	STUK3	OSTUK3	SLUG3
4.	ORP4	STUK4	OSTUK4	SLUG4
5.	ORP5	STUK5	OSTUK5	SLUG5
6.	ORP6	STUK6	OSTUK6	SLUG6
Total[B]	ORPT	STUKT	OSTUKT	SLUGT
Average	ORPAVG			

T = Top Compression Ring
B = Bottom Compression Ring
O = Oil Ring
N = None

[A] Stuck rings on individual pistons with an unadjusted oil ring land deposit rating greater than or equal to 2.6 are judged to be non-oil related.

[B] Stuck ring total includes oil stuck ring results.

FIG. A6.12 Sequence IIIE Oil Ring Land Deposit Rating Summary

Laboratory: LAB	EOT Date: DTCOMP
Test Number: STAND - STRUN - LABRUN	EOT Time: EOTTIME
Oil Code: CMIR/OILCODE	
Formulation/Stand Code: FORM	

PARAMETER (1)	SENSING DEVICE (2)	CALIBRATION FREQUENCY (3)	RECORD DEVICE (4)	OBSERVATION FREQUENCY (5)	RECORD FREQUENCY (6)	LOG FREQUENCY (7)	SYSTEM RESPONSE (8)
Temperature							
Oil Filter Block	OFILSENS	OFILCALF	OFILRECD	OFILOBSF	OFILRECF	OFILLOGF	
Oil Sump	OSTSENS	OSTCALF	OSTRECD	OSTOBSF	OSTRECF	OSTLOGF	
Fuel	FTEMSENS	FTEMCALF	FTEMRECD	FTEMOBSF	FTEMRECF	FTEMLOGF	
Breather Tube Gas Outlet	BGASSENS	BGASCALF	BGASRECD	BGASOBSF	BGASRECF	BGASLOGF	
Breather Tube Coolant Outlet	BTCTSENS	BTCTCALF	BTCTRECD	BTCTOBSF	BTCTRECF	BTCTLOGF	
Coolant Outlet	COTSENS	COTCALF	COTRECD	COTOBSF	COTRECF	COTLOGF	
Coolant Inlet	CITSENS	CITCALF	CITRECD	CITOBSF	CITRECF	CITLOGF	
Carb Air	CARBSENS	CARBCALF	CARBRECD	CARBOBSF	CARBRECF	CARBLOGF	
Intake Manifold	IMANSENS	IMANCALF	IMANRECD	IMANOBSF	IMANRECF	IMANLOGF	
Rocker Cover Coolant Outlet	RCCTSENS	RCCTCALF	RCCTRECD	RCCTOBSF	RCCTRECF	RCCTLOGF	
Exhaust Manifold Water Coolant Outlet	EXMWSENS	EXMWCALF	EXMWRECD	EXMWOBSF	EXMWRECF	EXMWLOGF	
Intake Manifold Exhaust Crossover Coolant Outlet	IMECSENS	IMECCALF	IMECRECD	IMECOBSF	IMECRECF	IMECLOGF	
Pressure							
Crankcase	CRNKSENS	CRNKCALF	CRNKRECD	CRNKOBSF	CRNKRECF	CRNKLOGF	CRNKSYSR
Oil Pump Outlet	OPMPSENS	OPMPCALF	OPMPRECD	OPMPOBSF	OPMPRECF	OPMPLOGF	OPMPSYSR
Engine Oil Gallery	OILGSENS	OILGCALF	OILGRECD	OILGOBSF	OILGRECF	OILGLOGF	OILGSYSR
Carb Inlet Air	CRBISENS	CRBICALF	CRBIRECD	CRBIOBSF	CRBIRECF	CRBILOGF	CRBISYSR
Exhaust Back Pressure	EXPRSENS	EXPRCALF	EXPRRECD	EXPROBSF	EXPRRECF	EXPRLOGF	EXPRSYSR
Intake Vacuum	INTVSENS	INTVCALF	INTVRECD	INTVOBSF	INTVRECF	INTVLOGF	INTVSYSR
Rocker Cover Coolant Outlet	RCCPSENS	RCCPCALF	RCCPRECD	RCCPOBSF	RCCPRECF	RCCPLOGF	RCCPSYSR
Breather Tube Coolant Outlet	BTCPSENS	BTCPCALF	BTCPRECD	BTCPOBSF	BTCPRECF	BTCPLOGF	BTCPSYSR
Flow							
Jacket Coolant Cover Flow	JCSENS	JCCALF	JCRECD	JCOBSF	JCRECF	JCLOGF	JCSYSR
Rocker Cover Coolant Flow	RCCSENS	RCCCALF	RCCRECD	RCCOBSF	RCCRECF	RCCLOGF	RCCSYSR
Breather Tube Coolant Flow	BTCSENS	BTCCALF	BTCRECD	BTCOBSF	BTCRECF	BTCLOGF	BTCSYSR
Other							
AFR Measurement	AFRSENS	AFRCALF	AFRRECD	AFROBSF	AFRRECF	AFRLOGF	AFRSYSR
Blowby Gas	BLWGSENS	BLWGCALF	BLWGRECD	BLWGOBSF	BLWGRECF	BLWGLOGF	BLWGSYSR
Intake Air Humidity	IAHMSENS	IAHMCALF	IAHMRECD	IAHMOBSF	IAHMRECF	IAHMLOGF	IAHMSYSR
Load	LOADSENS	LOADCALF	LOADRECD	LOADOBSF	LOADRECF	LOADLOGF	LOADSYSR

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

FIG. A6.13 Sequence IIIE Characteristics of the Data Acquisition System

3-apr-1998

Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
10	1	IIIE	VERSION	8	0	C	YYYYMMDD	IIIE VERSION 19980403
20	1	IIIE	TSTSPON1	40	0	C		CONDUCTED FOR, FIRST LINE
30	1	IIIE	TSTSPON2	40	0	C		CONDUCTED FOR, SECOND LINE
40	1	IIIE	LABVALID	1	0	C	V, I OR N	TEST LAB VALIDATION(V, I OR N)
50	1	IIIE	STAND	5	0	C		STAND
60	1	IIIE	STRUN	4	0	C		STAND RUN
70	1	IIIE	LABRUN	5	0	C		LAB RUN NUMBER
80	1	IIIE	OILCODE	38	0	C		NON-REFERENCE OIL CODE
90	1	IIIE	CMIR	6	0	C		CMIR
100	1	IIIE	FORM	38	0	C		FORMULATION/STAND CODE
110	1	IIIE	ALTCODE1	10	0	C		ALTERNATE OIL CODE 1
120	1	IIIE	ALTCODE2	10	0	C		ALTERNATE OIL CODE 2
130	1	IIIE	ALTCODE3	10	0	C		ALTERNATE OIL CODE 3
140	1	IIIE	OPVALID	7	0	C	HAS/HAS NOT	OPERATIONAL VALIDITY CODE (HAS/HAS NOT)
150	1	IIIE	DTCOMP	8	0	C	YYYYMMDD	COMPLETED DATE(YYYYMMDD)
160	1	IIIE	EOTTIME	5	0	C	HH:MM	COMPLETED TIME (HH:MM)
170	1	IIIE	SUBLAB	40	0	C		SUBMITTED BY: TESTING LABORATORY
180	1	IIIE	SUBSIGIM	70	0	C		SUBMITTED BY: SIGNATURE IMAGE
190	1	IIIE	SUBNAME	40	0	C		SUBMITTED BY: SIGNATURE TYPED NAME
200	1	IIIE	SUBTITLE	40	0	C		SUBMITTED BY: TITLE
210	2	IIIE	LAB	2	0	C		LAB CODE
220	2	IIIE	TESTLEN	3	0	N	HOURS	TEST LENGTH(HOURS)
230	2	IIIE	SAEVISC	7	0	C		SAE VISCOSITY GRADE
240	2	IIIE	FUELBTID	2	0	C		FUEL BATCH IDENTIFIER
250	2	IIIE	DTSTRT	8	0	C	YYYYMMDD	START DATE (YYYYMMDD)
260	2	IIIE	STRTTIME	6	0	C	HH:MM	START TIME (HH:MM)
270	2	IIIE	LABOCODE	12	0	C		LABORATORY INTERNAL OIL CODE
280	2	IIIE	ENGINENO	15	0	C		LABORATORY INTERNAL ENGINE NUMBER
290	2	IIIE	CAMPOUR	4	0	C		CAM POUR CODE
300	2	IIIE	VNEW	8	2	N	CST	VISCOSITY OF NEW OIL (CST)
310	2	IIIE	VINI	7	1	N	CST	VISCOSITY OF INITIAL SAMPLE AFTER TIMING RUN (CST)
320	2	IIIE	VIS_Hxxx	7	1	N	CST	VISCOSITY AT 40 °C AT XXX TEST HOURS (CST)
330	2	IIIE	DVISHxxx	7	1	N	CST	VISCOSITY INCREASE AT XXX HOURS (CST)
340	2	IIIE	PVISHxxx	6	0	N	%	% VISCOSITY INCREASE @ XXX HOURS (%)
350	2	IIIE	HRT0375	5	1	N	HOURS	HOURS TO 375% VISCOSITY INCREASE (HOURS)
360	2	IIIE	FNL375	5	1	N	HOURS	FNL HOURS TO 375% VISC. INCREASE (HOURS)
370	2	IIIE	MAXCLW	6	0	N	Micrometers	MAX CAM + LIFTER WEAR (MICROMETERS)
380	2	IIIE	MINCLW	6	0	N	Micrometers	MIN CAM + LIFTER WEAR (MICROMETERS)
390	2	IIIE	AVGCLW	6	1	N	Micrometers	AVG CAM + LIFTER WEAR (MICROMETERS)
400	2	IIIE	FNLACLW	6	1	N	Micrometers	FINAL AVG CAM + LIFTER WEAR (MICROMETERS)
410	2	IIIE	FNLMCLW	6	0	N	Micrometers	FINAL MAX CAM + LIFTER WEAR (MICROMETERS)
420	2	IIIE	BWL3	6	1	N	MG	BEARING WEIGHT LOSS NUMBER 3 (MG)
430	2	IIIE	BWL5	6	1	N	MG	BEARING WEIGHT LOSS NUMBER 5 (MG)
440	2	IIIE	AVGBWL	6	1	N	MG	BEARING WEIGHT LOSS AVG (MG)
450	2	IIIE	FCS	5	2	N	MERITS	FRONT COVER SLUDGE RATING (MERITS)
460	2	IIIE	RCSR	5	2	N	MERITS	RIGHT ROCKER COVER SLUDGE RATING (MERITS)
470	2	IIIE	RCSL	5	2	N	MERITS	LEFT ROCKER COVER SLUDGE RATING (MERITS)
480	2	IIIE	RCBSR	5	2	N	MERITS	RIGHT ROCKER COVER BAFFLE SLUDGE RATING (MERITS)
490	2	IIIE	RCBSL	5	2	N	MERITS	LEFT ROCKER COVER BAFFLE SLUDGE RATING (MERITS)
500	2	IIIE	AES	5	2	N	MERITS	AVG ENGINE SLUDGE RATING (MERITS)
510	2	IIIE	FNLAES	5	2	N	MERITS	FINAL AVG ENGINE SLUDGE RATING (MERITS)
520	2	IIIE	CAMSCUF	4	0	N	#	NUMBER OF SCUFFED CAM LOBES (#)
530	2	IIIE	LFTSCUF	4	0	N	#	NUMBER OF SCUFFED LIFTERS (#)

FIG. A6.14 Data Dictionary

3-apr-1998 Report: ASTM Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
540	2	IIIE	VSTS	4	0	N	#	NUMBER OF SCUFFED VALVE STEM TIPS (#)
550	2	IIIE	VSTW	4	0	N	#	NUMBER OF WORN VALVE STEM TIPS (#)
560	2	IIIE	VSTSW	4	0	N	#	NUMBER OF SCUFFED & WORN VALVE STEM TIPS (#)
570	2	IIIE	ROCKS	4	0	N	#	NUMBER OF SCUFFED ROCKER ARM PADS (#)
580	2	IIIE	ROCKW	4	0	N	#	NUMBER OF WORN ROCKER ARM PADS (#)
590	2	IIIE	ROCKSW	4	0	N	#	NUMBER OF SCUFFED & WORN ROCKER ARM PADS (#)
600	2	IIIE	OSCREEN	5	0	N	%	PERCENT OIL SCREEN PLUGGING (%)
610	2	IIIE	OILCON	5	2	N	L	OIL CONSUMPTION (L)
620	2	IIIE	OCONHRS	4	0	N	HOURS	OIL CONSUMPTION HOURS (HOURS)
630	2	IIIE	PSVTH	5	2	N	MERITS	THRUST SIDE PISTON SKIRT VARNISH RATING (MERITS)
640	2	IIIE	PSVAT	5	2	N	MERITS	ANTI-THRUST SIDE PISTON SKIRT VARNISH RATING (MERITS)
650	2	IIIE	AVGPSV	5	2	N	MERITS	AVG PISTON SKIRT VARNISH RATING (MERITS)
660	2	IIIE	FNLAPV	5	2	N	MERITS	FINAL AVG PISTON SKIRT VARNISH RATING (MERITS)
670	2	IIIE	PISTBAT	5	0	C		PISTON BATCH CODE
680	2	IIIE	ORPAVG	5	0	N	%	AVERAGE PERCENT OIL RING PLUGGING (%)
690	2	IIIE	OSTUKT	4	0	N	#	NUMBER OF OIL- STUCK RINGS - TOTAL (#)
700	2	IIIE	STUKT	4	0	N	#	NUMBER OF STUCK RINGS - TOTAL (#)
710	2	IIIE	SLUGT	4	0	N	#	NUMBER OF SLUGGISH RINGS - TOTAL (#)
720	2	IIIE	LFTSTK	4	0	N	#	NUMBER OF STUCK LIFTERS - TOTAL (#)
730	2	IIIE	AVGORLD	5	2	N	MERITS	OIL RING LAND DEPOSIT RATING AVG (MERITS)
740	2	IIIE	FNLORLD	5	2	N	MERITS	FINAL OIL RING LAND DEPOSIT RATING (MERITS)
750	2	IIIE	IND	6	0	C		TMC OIL CODE
760	2	IIIE	IAVGHRS	5	1	N	HOURS	INDUSTRY AVG HOURS TO 375% VISCOSITY INCREASE (HOURS)
770	2	IIIE	TRINGGAP	3	0	N	MILS	COMPRESSION RING GAPS TOP (MILS)
780	2	IIIE	BRINGGAP	3	0	N	MILS	COMPRESSION RING GAPS BOTTOM (MILS)
790	3	IIIE	CORR375	5	1	N	HOURS	NON-REF CORRECTED HOURS TO 375% VISCOSITY INCREASE (HOURS)
800	3	IIIE	SAHRS	4	1	N	HOURS	SEVERITY ADJUSTMENT - HOURS TO 375% VISCOSITY INCREASE (HOUR
810	3	IIIE	TMAXCLW	6	3	A	TRANS UNITS	NON-REFERENCE MAX CAM + LIFTER WEAR (TRANS UNITS)
820	3	IIIE	TAVGCLW	6	3	A	TRANS UNITS	NON-REFERENCE AVG CAM + LIFTER WEAR (TRANS UNITS)
830	3	IIIE	CORACLW	6	1	N	Micrometers	NON-REFERENCE CORRECTED AVG CAM + LIFTER WEAR (MICROMETERS)
840	3	IIIE	CORTACLW	6	3	A	TRANS UNITS	NON-REFERENCE CORRECTED AVG CAM + LIFTER WEAR (TRANS UNITS)
850	3	IIIE	FNLTMCLW	6	3	A	TRANS UNITS	NON-REFERENCE CORRECTED MAX CAM + LIFTER WEAR (TRANS UNITS)
860	3	IIIE	SAACLW	6	3	N	TRANS UNITS	SEVERITY ADJUSTMENT - AVG CAM + LIFTER WEAR (TRANS UNITS)
870	3	IIIE	FNLTACLW	6	3	A	TRANS UNITS	NON-REFERENCE FINAL AVG CAM + LIFTER WEAR (TRANS UNITS)
880	3	IIIE	TAES	5	2	N	TRANS UNITS	AVG ENGINE SLUDGE RATING (TRANS UNITS)
890	3	IIIE	CORAES	5	2	N	MERITS	NON-REFERENCE CORRECTED AVG ENGINE SLUDGE RATING (MERITS)
900	3	IIIE	CORTRAES	5	2	N	TRANS UNITS	NON-REF CORRECTED AVG ENGINE SLUDGE RATING (TRANS UNITS)
910	3	IIIE	SAAES	6	3	N	TRANS UNITS	SEVERITY ADJUSTMENT - AVG ENGINE SLUDGE RATING (TRANS UNITS)
920	3	IIIE	FNLTAES	5	2	N	TRANS UNITS	FINAL ENGINE SLUDGE RATING (TRANS UNITS)
930	3	IIIE	CORPSV	5	2	N	MERITS	NON-REF CORRECTED AVG PISTON SKIRT VARNISH RATING (MERITS)
940	3	IIIE	SAPSV	5	2	N	MERITS	SEVERITY ADJUSTMENT - AVG PISTON SKIRT VARNISH (MERITS)
950	3	IIIE	CORORLD	5	2	N	MERITS	NON-REFERENC CORRECTED OIL RING LAND DEPOSIT RATING (MERITS)
960	3	IIIE	SAORLD	5	2	N	MERITS	SEVERITY ADJUSTMENT - OIL RING LAND DEPOSIT (MERITS)
970	4	IIIE	XRPM	6	0	N	R/MIN	MAX ENGINE SPEED (R/MIN)
980	4	IIIE	IRPM	6	0	N	R/MIN	MIN ENGINE SPEED (R/MIN)
990	4	IIIE	ARPM	6	0	N	R/MIN	AVG ENGINE SPEED (R/MIN)
1000	4	IIIE	XPWR	5	1	N	KW	MAX POWER (KW)
1010	4	IIIE	IPWR	5	1	N	KW	MIN POWER (KW)
1020	4	IIIE	APWR	5	1	N	KW	AVG POWER (KW)
1030	4	IIIE	XOILTEM	6	1	N	°C	MAX FILTER BLOCK OIL TEMP (°C)
1040	4	IIIE	IOILTEM	6	1	N	°C	MIN FILTER BLOCK OIL TEMP (°C)
1050	4	IIIE	AOILTEM	6	1	N	°C	AVG FILTER BLOCK OIL TEMP (°C)
1060	4	IIIE	XSUMPT	6	1	N	°C	MAX SUMP OIL TEMP (°C)
1070	4	IIIE	ISUMPT	6	1	N	°C	MIN SUMP OIL TEMP (°C)

FIG. A6.15 Data Dictionary

3-apr-1998 Report: ASTM Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
1080	4	IIIE	ASUMPT	6	1	N	°C	AVG SUMP OIL TEMP (°C)
1090	4	IIIE	XOPUMPP	5	0	N	KPA	MAX OIL PUMP OUTLET PRESSURE (KPA)
1100	4	IIIE	IOPUMPP	5	0	N	KPA	MIN OIL PUMP OUTLET PRESSURE (KPA)
1110	4	IIIE	AOPUMPP	5	0	N	KPA	AVG OIL PUMP OUTLET PRESSURE (KPA)
1120	4	IIIE	XOILPRS	5	0	N	KPA	MAX OIL GALLERY PRESSURE (KPA)
1130	4	IIIE	IOILPRS	5	0	N	KPA	MIN OIL GALLERY PRESSURE (KPA)
1140	4	IIIE	AOILPRS	5	0	N	KPA	AVG OIL GALLERY PRESSURE (KPA)
1150	4	IIIE	XCOLOUT	6	1	N	°C	MAX ENGINE COOLANT OUT TEMP (°C)
1160	4	IIIE	ICOLOUT	6	1	N	°C	MIN ENGINE COOLANT OUT TEMP (°C)
1170	4	IIIE	ACOLOUT	6	1	N	°C	AVG ENGINE COOLANT OUT TEMPERATURE (°C)
1180	4	IIIE	XCOLIN	6	1	N	°C	MAX ENGINE COOLANT IN TEMP (°C)
1190	4	IIIE	ICOLIN	6	1	N	°C	MIN ENGINE COOLANT IN TEMP (°C)
1200	4	IIIE	ACOLIN	6	1	N	°C	AVG ENGINE COOLANT IN TEMPERATURE (°C)
1210	4	IIIE	XCOLFLO	6	1	N	L/MIN	MAX ENGINE COOLANT FLOW (L/MIN)
1220	4	IIIE	ICOLFLO	6	1	N	L/MIN	MIN ENGINE COOLANT FLOW (L/MIN)
1230	4	IIIE	ACOLFLO	6	1	N	L/MIN	AVG ENGINE COOLANT FLOW (L/MIN)
1240	4	IIIE	XBTOT	5	1	N	°C	MAX BREATHER TUBE OUT TEMP (°C)
1250	4	IIIE	IBTOT	5	1	N	°C	MIN BREATHER TUBE OUT TEMP (°C)
1260	4	IIIE	ABTOT	5	1	N	°C	AVG BREATHER TUBE OUT TEMP (°C)
1270	4	IIIE	XLCOUT	6	1	N	°C	MAX LEFT ROCKER COVER COOLANT OUT TEMP (°C)
1280	4	IIIE	ILCOUT	6	1	N	°C	MIN LEFT ROCKER COVER COOLANT OUT TEMP (°C)
1290	4	IIIE	ALCOUT	6	1	N	°C	AVG LEFT ROCKER COVER COOLANT OUT TEMP (°C)
1300	4	IIIE	XRCOUT	6	1	N	°C	MAX RIGHT ROCKER COVER COOLANT OUT TEMP (°C)
1310	4	IIIE	IRCOUT	6	1	N	°C	MIN RIGHT ROCKER COVER COOLANT OUT TEMP (°C)
1320	4	IIIE	ARCOUT	6	1	N	°C	AVG RIGHT ROCKER COVER COOLANT OUT TEMP (°C)
1330	4	IIIE	XRCFLO	5	1	N	L/MIN	MAX ROCKER COVER COOLANT FLOW (L/MIN)
1340	4	IIIE	IRCFLO	5	1	N	L/MIN	MIN ROCKER COVER COOLANT FLOW (L/MIN)
1350	4	IIIE	ARCFLO	5	1	N	L/MIN	AVG ROCKER COVER COOLANT FLOW (L/MIN)
1360	4	IIIE	XBTFLO	5	1	N	L/MIN	MAX BREATHER TUBE FLOW (L/MIN)
1370	4	IIIE	IBTFLO	5	1	N	L/MIN	MIN BREATHER TUBE FLOW (L/MIN)
1380	4	IIIE	ABTFLO	5	1	N	L/MIN	AVG BREATHER TUBE FLOW (L/MIN)
1390	4	IIIE	XAFR	5	1	N		MAX AIR TO FUEL RATIO
1400	4	IIIE	IAFR	5	1	N		MIN AIR TO FUEL RATIO
1410	4	IIIE	AAFR	5	1	N		AVG AIR TO FUEL RATIO
1420	4	IIIE	XNOX	6	0	N	PPM	MAX NOX (PPM)
1430	4	IIIE	INOX	6	0	N	PPM	MIN NOX (PPM)
1440	4	IIIE	ANOX	6	0	N	PPM	AVG NOX (PPM)
1450	4	IIIE	XFINL	5	1	N	°C	MAX FUEL INLET TEMPERATURE (°C)
1460	4	IIIE	IFINL	5	1	N	°C	MIN FUEL INLET TEMPERATURE (°C)
1470	4	IIIE	AFINL	5	1	N	°C	AVG FUEL INLET TEMPERATURE (°C)
1480	4	IIIE	XAIRTP	5	1	N	°C	MAX INTAKE AIR TEMPERATURE (°C)
1490	4	IIIE	IAIRTP	5	1	N	°C	MIN INTAKE AIR TEMPERATURE (°C)
1500	4	IIIE	AAIRTP	5	1	N	°C	AVG INTAKE AIR TEMPERATURE (°C)
1510	4	IIIE	XDEWPT	5	1	N	°C	MAX HUMIDITY DEW POINT (°C)
1520	4	IIIE	IDEWPT	5	1	N	°C	MIN HUMIDITY DEW POINT (°C)
1530	4	IIIE	ADEWPT	5	1	N	°C	AVG HUMIDITY DEW POINT (°C)
1540	4	IIIE	XCARBP	6	3	N	KPA	MAX CARBURETOR PRESSURE (KPA)
1550	4	IIIE	ICARBP	6	3	N	KPA	MIN CARBURETOR PRESSURE (KPA)
1560	4	IIIE	ACARBP	6	3	N	KPA	AVG CARBURETOR PRESSURE (KPA)
1570	4	IIIE	XAMBAT	5	1	N	°C	MAX AMBIENT AIR TEMP (°C)
1580	4	IIIE	IAMBAT	5	1	N	°C	MIN AMBIENT AIR TEMP (°C)
1590	4	IIIE	AAMBAT	5	1	N	°C	AVG AMBIENT AIR TEMP (°C)
1600	4	IIIE	XBBGAST	5	1	N	°C	MAX BLOWBY GAS TEMP (°C)
1610	4	IIIE	IBBGAST	5	1	N	°C	MIN BLOWBY GAS TEMP (°C)

FIG. A6.16 Data Dictionary

3-apr-1998 Report: ASTM Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
1620	4	IIIE	ABBGAST	5	1	N	°C	AVG BLOWBY GAS TEMP (°C)
1630	4	IIIE	XBLOBY	5	1	N	L/MIN	MAX BLOWBY (L/MIN)
1640	4	IIIE	IBLOBY	5	1	N	L/MIN	MIN BLOWBY (L/MIN)
1650	4	IIIE	ABLOBY	5	1	N	L/MIN	AVG BLOWBY (L/MIN)
1660	4	IIIE	XREXP	5	2	N	KPA	MAX RIGHT EXHAUST PRESSURE (KPA)
1670	4	IIIE	IREXP	5	2	N	KPA	MIN RIGHT EXHAUST PRESSURE (KPA)
1680	4	IIIE	AREXP	5	2	N	KPA	AVG RIGHT EXHAUST PRESSURE (KPA)
1690	4	IIIE	XLEXP	5	2	N	KPA	MAX LEFT EXHAUST PRESSURE (KPA)
1700	4	IIIE	ILEXP	5	2	N	KPA	MIN LEFT EXHAUST PRESSURE (KPA)
1710	4	IIIE	ALEXP	5	2	N	KPA	AVG LEFT EXHAUST PRESSURE (KPA)
1720	4	IIIE	XDIFEXP	5	2	N	KPA	MAX DIFFERENTIAL EXHAUST PRESSURE (KPA)
1730	4	IIIE	IDIFEXP	5	2	N	KPA	MIN DIFFERENTIAL EXHAUST PRESSURE (KPA)
1740	4	IIIE	ADIFEXP	5	2	N	KPA	AVG DIFFERENTIAL EXHAUST PRESSURE (KPA)
1750	4	IIIE	XINTV	5	1	N	KPA	MAX INTAKE VACUUM (KPA)
1760	4	IIIE	IINTV	5	1	N	KPA	MIN INTAKE VACUUM (KPA)
1770	4	IIIE	AINTV	5	1	N	KPA	AVG INTAKE VACUUM (KPA)
1780	4	IIIE	XINTMX	5	1	N	°C	MAX INTAKE MIXTURE TEMP (°C)
1790	4	IIIE	IINTMX	5	1	N	°C	MIN INTAKE MIXTURE TEMP (°C)
1800	4	IIIE	AINTMX	5	1	N	°C	AVG INTAKE MIXTURE TEMP (°C)
1810	4	IIIE	XCCASEP	6	3	N	KPA	MAX CRANKCASE PRESSURE (KPA)
1820	4	IIIE	ICCASEP	6	3	N	KPA	MIN CRANKCASE PRESSURE (KPA)
1830	4	IIIE	ACCASEP	6	3	N	KPA	AVG CRANKCASE PRESSURE (KPA)
1840	4	IIIE	XSPKTIM	4	0	N	°	MAX SPARK ADVANCE BTDC (DEG)
1850	4	IIIE	ISPKTIM	4	0	N	°	MIN SPARK ADVANCE BTDC (DEG)
1860	4	IIIE	ASPKTIM	4	0	N	°	AVG SPARK ADVANCE BTDC (DEG)
1870	4	IIIE	OILLHxxx	4	0	N	ML	OIL LEVEL LOW AT XXX HOURS (ML)
1880	4	IIIE	GLYCHxxx	8	0	C		GLYCOL CONTAMINATION HOURS POSITIVE/NEGATIVE
1890	5	IIIE	DWNOCR	2	0	Z		NUMBER OF DOWNTIME OCCURRENCES
1900	5	IIIE	DOWNHxxx	6	0	C	HHH:MM	DOWNTIME TEST HOURS (HH:MM)
1910	5	IIIE	DDATHxxx	8	0	C	YYYYMMDD	DOWNTIME DATE (YYYYMMDD)
1920	5	IIIE	DTIMHxxx	6	0	C	HHH:MM	DOWNTIME TIME (HH:MM)
1930	5	IIIE	DREAHxxx	60	0	C		DOWNTIME REASON
1940	5	IIIE	TOTLDOWN	6	0	C	HHH:MM	DOWNTIME TIME TOTAL (HHH:MM)
1950	5	IIIE	TOTCOM	2	0	Z		TOTAL LINES OF COMMENTS & OUTLIERS
1960	5	IIIE	OCOMHxxx	70	0	C		OTHER DOWNTIME COMMENT XXX
1970	6	IIIE	PWRDP	5	1	N	%	ENGINE POWER CALCULATED DEVIATION % (%)
1980	6	IIIE	OILFBDP	5	1	N	%	OIL FILTER BLOCK TEMP CALCULATED DEVIATION % (%)
1990	6	IIIE	COLOUTDP	5	1	N	%	COOLANT OUT TEMP CALCULATED DEVIATION % (%)
2000	6	IIIE	COLFLODP	5	1	N	%	COOLANT FLOW RATE CALCULATED DEVIATION % (%)
2010	6	IIIE	RPMDP	5	1	N	%	ENGINE SPEED CALCULATED DEVIATION % (%)
2020	6	IIIE	COLINDP	5	1	N	%	COOLANT IN TEMP CALCULATED DEVIATION % (%)
2030	6	IIIE	LRCTPDP	5	1	N	%	LEFT ROCKER COVER COOLANT OUT TEMP CALC DEVIATION % (%)
2040	6	IIIE	RRCTPDP	5	1	N	%	RIGHT ROCKER COVER COOLANT OUT TEMP CALC DEVIATION % (%)
2050	6	IIIE	BTOTDP	5	1	N	%	BREATHER TUBE COOLANT OUT TEMP CALC DEVIATION % (%)
2060	6	IIIE	RCFLODP	5	1	N	%	ROCKER COVER/CROSSOVER COOLANT FLOW RATE DEVIATION % (%)
2070	6	IIIE	BTFLODP	5	1	N	%	BREATHER TUBE FLOW RATE CALCULATED DEVIATION % (%)
2080	6	IIIE	LEXPDP	5	1	N	%	LEFT EXHAUST BACK PRESSURE CALCULATED DEVIATION % (%)
2090	6	IIIE	REXPDP	5	1	N	%	RIGHT EXHAUST BACK PRESSURE CALCULATED DEVIATION % (%)
2100	6	IIIE	LATFDP	5	1	N	%	LEFT AIR TO FUEL RATIO CALCULATED DEVIATION % (%)
2110	6	IIIE	RATFDP	5	1	N	%	RIGHT AIR TO FUEL RATIO CALCULATED DEVIATION % (%)
2120	7	IIIE	BLOWBYIM	70	0	C		BLOWBY PLOT IMAGE
2130	7	IIIE	BLWBHxxx	5	1	N	L/MIN	TEST BLOWBY AT HOURS XXX (L/MIN)
2140	8	IIIE	VISINIM	70	0	C		VISCOSITY INCREASE PLOT VARIABLE
2150	9	IIIE	BUILDDT	8	0	C	YYYYMMDD	BUILD COMPLETION DATE (YYYYMMDD)

FIG. A6.17 Data Dictionary

3-apr-1998 Report: ASTM Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
2160	9	IIIE	BLOCKSN	5	0	C		BLOCK SERIAL NUMBER
2170	9	IIIE	CRANKSN	5	0	C		CRANKSHAFT SERIAL NUMBER
2180	9	IIIE	PISTSIZE	2	0	C		PISTON SIZE GRADE
2190	9	IIIE	CAMSN	7	0	C		CAMSHAFT SERIAL NUMBER
2200	9	IIIE	RINGCODE	5	0	C		PISTON RING CODE - PACKAGE
2210	9	IIIE	LFTBXNO	13	0	C		LIFTER BOX CONTROL NUMBER
2220	9	IIIE	LFTCODE	2	0	C		LIFTER BATCH CODE
2230	9	IIIE	OILFIBAT	5	0	C		OIL FILTER BATCH CODE
2240	9	IIIE	INVSLBAT	5	0	C		INTAKE VALVE SEALS BATCH CODE
2250	9	IIIE	RTRBAT	5	0	C		ROTATORS BATCH CODE
2260	9	IIIE	VALSPBAT	5	0	C		VALVE SPRINGS BATCH CODE
2270	9	IIIE	LHEADSN	11	0	C		LEFT HEAD SERIAL NUMBER
2280	9	IIIE	RHEADSN	11	0	C		RIGHT HEAD SERIAL NUMBER
2290	9	IIIE	BRNGSN	6	0	C		BEARING KIT SERIAL NUMBER
2300	9	IIIE	LRKRSNO	6	0	C		LEFT ROCKER SHAFT SERIAL NUMBER
2310	9	IIIE	RRKRSNO	6	0	C		RIGHT ROCKER SHAFT SERIAL NUMBER
2320	9	IIIE	HMBALID	6	0	C		HARMONIC BALANCER ID
2330	9	IIIE	TMGINDID	6	0	C		TIMING INDICATOR ID
2340	10	IIIE	APVRATER	3	0	C		AVERAGE PISTON VARNISH RATER
2350	10	IIIE	RATEDATE	8	0	C	YYYYMMDD	RATING DATE (YYYYMMDD)
2360	10	IIIE	PSVTH11	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 1 INITIAL (MERITS)
2370	10	IIIE	PSVTH21	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 1 SECONDARY (MERITS)
2380	10	IIIE	PSVADJT1	4	1	N	MERITS	PISTON SKIRT VARNISH THRUST 1 ADJUSTMENT (MERITS)
2390	10	IIIE	PSVTH1	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 1 ADJUSTED RATING (MERITS)
2400	10	IIIE	PSVTH12	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 2 INITIAL (MERITS)
2410	10	IIIE	PSVTH22	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 2 SECONDARY (MERITS)
2420	10	IIIE	PSVADJT2	4	1	N	MERITS	PISTON SKIRT VARNISH THRUST 2 ADJUSTMENT (MERITS)
2430	10	IIIE	PSVTH2	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 2 ADJUSTED RATING (MERITS)
2440	10	IIIE	PSVTH13	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 3 INITIAL (MERITS)
2450	10	IIIE	PSVTH23	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 3 SECONDARY (MERITS)
2460	10	IIIE	PSVADJT3	4	1	N	MERITS	PISTON SKIRT VARNISH THRUST 3 ADJUSTMENT (MERITS)
2470	10	IIIE	PSVTH3	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 3 ADJUSTED RATING (MERITS)
2480	10	IIIE	PSVTH14	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 4 INITIAL (MERITS)
2490	10	IIIE	PSVTH24	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 4 SECONDARY (MERITS)
2500	10	IIIE	PSVADJT4	4	1	N	MERITS	PISTON SKIRT VARNISH THRUST 4 ADJUSTMENT (MERITS)
2510	10	IIIE	PSVTH4	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 4 ADJUSTED RATING (MERITS)
2520	10	IIIE	PSVTH15	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 5 INITIAL (MERITS)
2530	10	IIIE	PSVTH25	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 5 SECONDARY (MERITS)
2540	10	IIIE	PSVADJT5	4	1	N	MERITS	PISTON SKIRT VARNISH THRUST 5 ADJUSTMENT (MERITS)
2550	10	IIIE	PSVTH5	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 5 ADJUSTED RATING (MERITS)
2560	10	IIIE	PSVTH16	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 6 INITIAL (MERITS)
2570	10	IIIE	PSVTH26	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 6 SECONDARY (MERITS)
2580	10	IIIE	PSVADJT6	4	1	N	MERITS	PISTON SKIRT VARNISH THRUST 6 ADJUSTMENT (MERITS)
2590	10	IIIE	PSVTH6	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST 6 ADJUSTED RATING (MERITS)
2600	10	IIIE	PSVAT11	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 1 INITIAL (MERITS)
2610	10	IIIE	PSVAT21	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 1 SECONDARY (MERITS)
2620	10	IIIE	PSVADJA1	4	1	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 1 ADJUSTMENT (MERITS)
2630	10	IIIE	PSVAT1	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 1 ADJUSTED RATING (MERITS)
2640	10	IIIE	PSVAT12	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 2 INITIAL (MERITS)
2650	10	IIIE	PSVAT22	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 2 SECONDARY (MERITS)
2660	10	IIIE	PSVADJA2	4	1	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 2 ADJUSTMENT (MERITS)
2670	10	IIIE	PSVAT2	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 2 ADJUSTED RATING (MERITS)
2680	10	IIIE	PSVAT13	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 3 INITIAL (MERITS)
2690	10	IIIE	PSVAT23	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 3 SECONDARY (MERITS)

FIG. A6.18 Data Dictionary

3-apr-1998 Report: ASTM Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
2700	10	IIIE	PSVADJA3	4	1	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 3 ADJUSTMENT (MERITS)
2710	10	IIIE	PSVAT3	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 3 ADJUSTED RATING (MERITS)
2720	10	IIIE	PSVAT14	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 4 INITIAL (MERITS)
2730	10	IIIE	PSVAT24	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 4 SECONDARY (MERITS)
2740	10	IIIE	PSVADJA4	4	1	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 4 ADJUSTMENT (MERITS)
2750	10	IIIE	PSVAT4	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 4 ADJUSTED RATING (MERITS)
2760	10	IIIE	PSVAT15	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 5 INITIAL (MERITS)
2770	10	IIIE	PSVAT25	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 5 SECONDARY (MERITS)
2780	10	IIIE	PSVADJA5	4	1	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 5 ADJUSTMENT (MERITS)
2790	10	IIIE	PSVAT5	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 5 ADJUSTED RATING (MERITS)
2800	10	IIIE	PSVAT16	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 6 INITIAL (MERITS)
2810	10	IIIE	PSVAT26	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 6 SECONDARY (MERITS)
2820	10	IIIE	PSVADJA6	4	1	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 6 ADJUSTMENT (MERITS)
2830	10	IIIE	PSVAT6	5	2	N	MERITS	PISTON SKIRT VARNISH ANTI-THRUST 6 ADJUSTED RATING (MERITS)
2840	10	IIIE	AVPISCOM	70	0	C		AVERAGE PISTON VARNISH RATING SUMMARY COMMENTS
2850	11	IIIE	CAMW01	5	0	N	Micrometers	CAMSHAFT WEAR LOBE 1 (MICROMETERS)
2860	11	IIIE	LFTW01	5	0	N	Micrometers	LIFTER WEAR 1 (MICROMETERS)
2870	11	IIIE	CLW01	5	0	N	Micrometers	TOTAL CAMSHAFT AND LIFTER WEAR 1 (MICROMETERS)
2880	11	IIIE	CAMW02	5	0	N	Micrometers	CAMSHAFT WEAR LOBE 2 (MICROMETERS)
2890	11	IIIE	LFTW02	5	0	N	Micrometers	LIFTER WEAR 2 (MICROMETERS)
2900	11	IIIE	CLW02	5	0	N	Micrometers	TOTAL CAMSHAFT AND LIFTER WEAR 2 (MICROMETERS)
2910	11	IIIE	CAMW03	5	0	N	Micrometers	CAMSHAFT WEAR LOBE 3 (MICROMETERS)
2920	11	IIIE	LFTW03	5	0	N	Micrometers	LIFTER WEAR 3 (MICROMETERS)
2930	11	IIIE	CLW03	5	0	N	Micrometers	TOTAL CAMSHAFT AND LIFTER WEAR 3 (MICROMETERS)
2940	11	IIIE	CAMW04	5	0	N	Micrometers	CAMSHAFT WEAR LOBE 4 (MICROMETERS)
2950	11	IIIE	LFTW04	5	0	N	Micrometers	LIFTER WEAR 4 (MICROMETERS)
2960	11	IIIE	CLW04	5	0	N	Micrometers	TOTAL CAMSHAFT AND LIFTER WEAR 4 (MICROMETERS)
2970	11	IIIE	CAMW05	5	0	N	Micrometers	CAMSHAFT WEAR LOBE 5 (MICROMETERS)
2980	11	IIIE	LFTW05	5	0	N	Micrometers	LIFTER WEAR 5 (MICROMETERS)
2990	11	IIIE	CLW05	5	0	N	Micrometers	TOTAL CAMSHAFT AND LIFTER WEAR 5 (MICROMETERS)
3000	11	IIIE	CAMW06	5	0	N	Micrometers	CAMSHAFT WEAR LOBE 6 (MICROMETERS)
3010	11	IIIE	LFTW06	5	0	N	Micrometers	LIFTER WEAR 6 (MICROMETERS)
3020	11	IIIE	CLW06	5	0	N	Micrometers	TOTAL CAMSHAFT AND LIFTER WEAR 6 (MICROMETERS)
3030	11	IIIE	CAMW07	5	0	N	Micrometers	CAMSHAFT WEAR LOBE 7 (MICROMETERS)
3040	11	IIIE	LFTW07	5	0	N	Micrometers	LIFTER WEAR 7 (MICROMETERS)
3050	11	IIIE	CLW07	5	0	N	Micrometers	TOTAL CAMSHAFT AND LIFTER WEAR 7 (MICROMETERS)
3060	11	IIIE	CAMW08	5	0	N	Micrometers	CAMSHAFT WEAR LOBE 8 (MICROMETERS)
3070	11	IIIE	LFTW08	5	0	N	Micrometers	LIFTER WEAR 8 (MICROMETERS)
3080	11	IIIE	CLW08	5	0	N	Micrometers	TOTAL CAMSHAFT AND LIFTER WEAR 8 (MICROMETERS)
3090	11	IIIE	CAMW09	5	0	N	Micrometers	CAMSHAFT WEAR LOBE 9 (MICROMETERS)
3100	11	IIIE	LFTW09	5	0	N	Micrometers	LIFTER WEAR 9 (MICROMETERS)
3110	11	IIIE	CLW09	5	0	N	Micrometers	TOTAL CAMSHAFT AND LIFTER WEAR 9 (MICROMETERS)
3120	11	IIIE	CAMW10	5	0	N	Micrometers	CAMSHAFT WEAR LOBE 10 (MICROMETERS)
3130	11	IIIE	LFTW10	5	0	N	Micrometers	LIFTER WEAR 10 (MICROMETERS)
3140	11	IIIE	CLW10	5	0	N	Micrometers	TOTAL CAMSHAFT AND LIFTER WEAR 10 (MICROMETERS)
3150	11	IIIE	CAMW11	5	0	N	Micrometers	CAMSHAFT WEAR LOBE 11 (MICROMETERS)
3160	11	IIIE	LFTW11	5	0	N	Micrometers	LIFTER WEAR 11 (MICROMETERS)
3170	11	IIIE	CLW11	5	0	N	Micrometers	TOTAL CAMSHAFT AND LIFTER WEAR 11 (MICROMETERS)
3180	11	IIIE	CAMW12	5	0	N	Micrometers	CAMSHAFT WEAR LOBE 12 (MICROMETERS)
3190	11	IIIE	LFTW12	5	0	N	Micrometers	LIFTER WEAR 12 (MICROMETERS)
3200	11	IIIE	CLW12	5	0	N	Micrometers	TOTAL CAMSHAFT AND LIFTER WEAR 12 (MICROMETERS)
3210	11	IIIE	MAXCW	5	0	N	Micrometers	MAX CAMSHAFT WEAR (MICROMETERS)
3220	11	IIIE	MAXLFTW	5	0	N	Micrometers	MAX LIFTER WEAR (MICROMETERS)
3230	11	IIIE	MINCW	5	0	N	Micrometers	MIN CAMSHAFT WEAR (MICROMETERS)

FIG. A6.19 Data Dictionary

3-apr-1998 Report: ASTM Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
3240	11	IIIE	MINLFTW	5	0	N	MIcrometers	MIN LIFTER WEAR (MICROMETERS)
3250	11	IIIE	AVGCW	5	0	N	Micrometers	AVG CAMSHAFT WEAR (MICROMETERS)
3260	11	IIIE	AVGLFTW	5	0	N	Micrometers	AVG LIFTER WEAR (MICROMETERS)
3270	12	IIIE	RLDRATER	3	0	C		OIL RING LAND DEPOSIT RATER
3280	12	IIIE	ORLD1	5	2	N	MERITS	UNCORRECTED OIL RING LAND DEPOSIT RATING 1 (MERITS)
3290	12	IIIE	ORCHIP1	5	0	N	%	OIL RING LAND DEPOSIT PERCENT CHIPPED AREAS 1 (%)
3300	12	IIIE	ORLD2	5	2	N	MERITS	UNCORRECTED OIL RING LAND DEPOSIT RATING 2 (MERITS)
3310	12	IIIE	ORCHIP2	5	0	N	%	OIL RING LAND DEPOSIT PERCENT CHIPPED AREAS 2 (%)
3320	12	IIIE	ORLD3	5	2	N	MERITS	UNCORRECTED OIL RING LAND DEPOSIT RATING 3 (MERITS)
3330	12	IIIE	ORCHIP3	5	0	N	%	OIL RING LAND DEPOSIT PERCENT CHIPPED AREAS 3 (%)
3340	12	IIIE	ORLD4	5	2	N	MERITS	UNCORRECTED OIL RING LAND DEPOSIT RATING 4 (MERITS)
3350	12	IIIE	ORCHIP4	5	0	N	%	OIL RING LAND DEPOSIT PERCENT CHIPPED AREAS 4 (%)
3360	12	IIIE	ORLD5	5	2	N	MERITS	UNCORRECTED OIL RING LAND DEPOSIT RATING 5 (MERITS)
3370	12	IIIE	ORCHIP5	5	0	N	%	OIL RING LAND DEPOSIT PERCENT CHIPPED AREAS 5 (%)
3380	12	IIIE	ORLD6	5	2	N	MERITS	UNCORRECTED OIL RING LAND DEPOSIT RATING 6 (MERITS)
3390	12	IIIE	ORCHIP6	5	0	N	%	OIL RING LAND DEPOSIT PERCENT CHIPPED AREAS 6 (%)
3400	12	IIIE	ORP1	5	0	N	%	PERCENT OIL RING PLUGGING 1 (%)
3410	12	IIIE	STUK1	3	0	C	TBON	PISTON 1 STUCK RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3420	12	IIIE	OSTUK1	3	0	C	TBON	PISTON 1 OIL STUCK RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3430	12	IIIE	SLUG1	3	0	C	TBON	PISTON 1 SLUGGISH RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3440	12	IIIE	ORP2	5	0	N	%	PERCENT OIL RING PLUGGING 2 (%)
3450	12	IIIE	STUK2	3	0	C	TBON	PISTON 2 STUCK RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3460	12	IIIE	OSTUK2	3	0	C	TBON	PISTON 2 OIL STUCK RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3470	12	IIIE	SLUG2	3	0	C	TBON	PISTON 2 SLUGGISH RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3480	12	IIIE	ORP3	5	0	N	%	PERCENT OIL RING PLUGGING 3 (%)
3490	12	IIIE	STUK3	3	0	C	TBON	PISTON 3 STUCK RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3500	12	IIIE	OSTUK3	3	0	C	TBON	PISTON 3 OIL STUCK RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3510	12	IIIE	SLUG3	3	0	C	TBON	PISTON 3 SLUGGISH RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3520	12	IIIE	ORP4	5	0	N	%	PERCENT OIL RING PLUGGING 4 (%)
3530	12	IIIE	STUK4	3	0	C	TBON	PISTON 4 STUCK RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3540	12	IIIE	OSTUK4	3	0	C	TBON	PISTON 4 OIL STUCK RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3550	12	IIIE	SLUG4	3	0	C	TBON	PISTON 4 SLUGGISH RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3560	12	IIIE	ORP5	5	0	N	%	PERCENT OIL RING PLUGGING 5 (%)
3570	12	IIIE	STUK5	3	0	C	TBON	PISTON 5 STUCK RINGS TBO-T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3580	12	IIIE	OSTUK5	3	0	C	TBON	PISTON 5 OIL STUCK RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3590	12	IIIE	SLUG5	3	0	C	TBON	PISTON 5 SLUGGISH RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3600	12	IIIE	ORP6	5	0	N	%	PERCENT OIL RING PLUGGING 6 (%)
3610	12	IIIE	STUK6	3	0	C	TBON	PISTON 6 STUCK RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3620	12	IIIE	OSTUK6	3	0	C	TBON	PISTON 6 OIL STUCK RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3630	12	IIIE	SLUG6	3	0	C	TBON	PISTON 6 SLUGGISH RINGS T=TOP,B=BOTTOM,O=OIL,N=NONE (TBON)
3640	12	IIIE	ORPT	5	0	N	%	PERCENT OIL RING PLUGGING - TOTAL (%)
3650	13	IIIE	OFILSENS	10	0	C		OIL FILTER BLOCK TEMPERATURE SENSING DEVICE
3660	13	IIIE	OFILCALF	10	0	C		OIL FILTER BLOCK TEMPERATURE CALIBRATION FREQUENCY
3670	13	IIIE	OFILRECD	3	0	C		OIL FILTER BLOCK TEMPERATURE RECORD DEVICE
3680	13	IIIE	OFILOBSF	10	0	C		OIL FILTER BLOCK TEMPERATURE OBSERVATION FREQUENCY
3690	13	IIIE	OFILRECF	10	0	C		OIL FILTER BLOCK TEMPERATURE RECORD FREQUENCY
3700	13	IIIE	OFILLOGF	9	0	C		OIL FILTER BLOCK TEMPERATURE LOG FREQUENCY
3710	13	IIIE	OSTSENS	10	0	C		OIL SUMP TEMPERATURE SENSING DEVICE
3720	13	IIIE	OSTCALF	10	0	C		OIL SUMP TEMPERATURE CALIBRATION FREQUENCY
3730	13	IIIE	OSTRECD	3	0	C		OIL SUMP TEMPERATURE RECORD DEVICE
3740	13	IIIE	OSTOBSF	10	0	C		OIL SUMP TEMPERATURE OBSERVATION FREQUENCY
3750	13	IIIE	OSTRECF	10	0	C		OIL SUMP TEMPERATURE RECORD FREQUENCY
3760	13	IIIE	OSTLOGF	9	0	C		OIL SUMP TEMPERATURE LOG FREQUENCY
3770	13	IIIE	FTEMSENS	10	0	C		FUEL TEMPERATURE SENSING DEVICE

FIG. A6.20 Data Dictionary

3-apr-1998 Report: ASTM Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
3780	13	IIIE	FTEMCALF	10	0	C		FUEL TEMPERATURE CALIBRATION FREQUENCY
3790	13	IIIE	FTEMRECD	3	0	C		FUEL TEMPERATURE RECORD DEVICE
3800	13	IIIE	FTEMOBSF	10	0	C		FUEL TEMPERATURE OBSERVATION FREQUENCY
3810	13	IIIE	FTEMRECF	10	0	C		FUEL TEMPERATURE RECORD FREQUENCY
3820	13	IIIE	FTEMLOGF	9	0	C		FUEL TEMPERATURE LOG FREQUENCY
3830	13	IIIE	BGASSENS	10	0	C		BREATHER TUBE GAS OUTLET SENSING DEVICE
3840	13	IIIE	BGASCALF	10	0	C		BREATHER TUBE GAS OUTLET CALIBRATION FREQUENCY
3850	13	IIIE	BGASRECD	3	0	C		BREATHER TUBE GAS OUTLET RECORD DEVICE
3860	13	IIIE	BGASOBSF	10	0	C		BREATHER TUBE GAS OUTLET OBSERVATION FREQUENCY
3870	13	IIIE	BGASRECF	10	0	C		BREATHER TUBE GAS OUTLET RECORD FREQUENCY
3880	13	IIIE	BGASLOGF	9	0	C		BREATHER TUBE GAS OUTLET LOG FREQUENCY
3890	13	IIIE	BTCTSENS	10	0	C		BREATHER TUBE COOLANT OUTLET SENSING DEVICE (TEMP.)
3900	13	IIIE	BTCTCALF	10	0	C		BREATHER TUBE COOLANT OUTLET CALIBRATION FREQUENCY (TEMP.)
3910	13	IIIE	BTCTRECD	3	0	C		BREATHER TUBE COOLANT OUTLET RECORD DEVICE (TEMP.)
3920	13	IIIE	BTCTOBSF	10	0	C		BREATHER TUBE COOLANT OUTLET OBSERVATION FREQUENCY (TEMP.)
3930	13	IIIE	BTCTRECF	10	0	C		BREATHER TUBE COOLANT OUTLET RECORD FREQUENCY (TEMP.)
3940	13	IIIE	BTCTLOGF	9	0	C		BREATHER TUBE COOLANT OUTLET LOG FREQUENCY (TEMP.)
3950	13	IIIE	COTSENS	10	0	C		COOLANT OUT TEMPERATURE SENSING DEVICE
3960	13	IIIE	COTCALF	10	0	C		COOLANT OUT TEMPERATURE CALIBRATION FREQUENCY
3970	13	IIIE	COTRECD	3	0	C		COOLANT OUT TEMPERATURE RECORD DEVICE
3980	13	IIIE	COTOBSF	10	0	C		COOLANT OUT TEMPERATURE OBSERVATION FREQUENCY
3990	13	IIIE	COTRECF	10	0	C		COOLANT OUT TEMPERTURE RECORD FREQUENCY
4000	13	IIIE	COTLOGF	9	0	C		COOLANT OUT TEMPERATURE LOG FREQUENCY
4010	13	IIIE	CITSENS	10	0	C		COOLANT IN TEMPERATURE SENSING DEVICE
4020	13	IIIE	CITCALF	10	0	C		COOLANT IN TEMPERATURE CALIBRATION FREQUENCY
4030	13	IIIE	CITRECD	3	0	C		COOLANT IN TEMPERATURE RECORD DEVICE
4040	13	IIIE	CITOBSF	10	0	C		COOLANT IN TEMPERATURE OBSERVATION FREQUENCY
4050	13	IIIE	CITRECF	10	0	C		COOLANT IN TEMPERATURE RECORD FREQUENCY
4060	13	IIIE	CITLOGF	9	0	C		COOLANT IN TEMPERATURE LOG FREQUENCY
4070	13	IIIE	CARBSENS	10	0	C		CARB AIR SENSING DEVICE
4080	13	IIIE	CARBCALF	10	0	C		CARB AIR CALIBRATION FREQUENCY
4090	13	IIIE	CARBRECD	3	0	C		CARB AIR RECORD DEVICE
4100	13	IIIE	CARBOBSF	10	0	C		CARB AIR OBSERVATION FREQUENCY
4110	13	IIIE	CARBRECF	10	0	C		CARB AIR RECORD FREQUENCY
4120	13	IIIE	CARBLOGF	9	0	C		CARB AIR LOG FREQUENCY
4130	13	IIIE	IMANSENS	10	0	C		INTAKE MANIFOLD TEMPERATURE SENSING DEVICE
4140	13	IIIE	IMANCALF	10	0	C		INTAKE MANIFOLD TEMPERATURE CALIBRATION FREQUENCY
4150	13	IIIE	IMANRECD	3	0	C		INTAKE MANIFOLD TEMPERATURE RECORD DEVICE
4160	13	IIIE	IMANOBSF	10	0	C		INTAKE MANIFOLD TEMPERATURE OBSERVATION FREQUENCY
4170	13	IIIE	IMANRECF	10	0	C		INTAKE MANIFOLD TEMPERATURE RECORD FREQUENCY
4180	13	IIIE	IMANLOGF	9	0	C		INTAKE MANIFOLD TEMPERATURE LOG FREQUENCY
4190	13	IIIE	RCCTSENS	10	0	C		ROCKER COVER COOLANT OUTLET SENSING DEVICE (TEMP.)
4200	13	IIIE	RCCTCALF	10	0	C		ROCKER COVER COOLANT OUTLET CALIBRATION FREQUENCY (TEMP.)
4210	13	IIIE	RCCTRECD	3	0	C		ROCKER COVER COOLANT OUTLET RECORD DEVICE (TEMP.)
4220	13	IIIE	RCCTOBSF	10	0	C		ROCKER COVER COOLANT OUTLET OBSERVATION FREQUENCY (TEMP.)
4230	13	IIIE	RCCTRECF	10	0	C		ROCKER COVER COOLANT OUTLET RECORD FREQUENCY (TEMP.)
4240	13	IIIE	RCCTLOGF	9	0	C		ROCKER COVER COOLANT OUTLET LOG FREQUENCY (TEMP.)
4250	13	IIIE	EXMWSENS	10	0	C		EXHAUST MANIFOLD WATER COOLANT OUTLET SENSING DEVICE
4260	13	IIIE	EXMWCALF	10	0	C		EXHAUST MANIFOLD WATER COOLANT OUTLET CALIBRATION FREQUENCY(
4270	13	IIIE	EXMWRECD	3	0	C		EXHAUST MANIFOLD WATER COOLANT OUTLET RECORD DEVICE
4280	13	IIIE	EXMWOBSF	10	0	C		EXHAUST MANIFOLD WATER COOLANT OUTLET OBSERVATION FREQUENCY(
4290	13	IIIE	EXMWRECF	10	0	C		EXHAUST MANIFOLD WATER COOLANT OUTLET RECORD FREQUENCY
4300	13	IIIE	EXMWLOGF	9	0	C		EXHAUST MANIFOLD WATER COOLANT OUTLET LOG FREQUENCY
4310	13	IIIE	IMECSENS	10	0	C		INTAKE MANIFOLD EXHST CROSSOVR COOLANT OUTLET SENSING DEVICE

FIG. A6.21 Data Dictionary

3-apr-1998 Report: ASTM Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
4320	13	IIIE	IMECCALF	10	0	C		INTAKE MANIFOLD EXHST CROSSOVR COOLANT OUTLET CAL. FREQUENCY
4330	13	IIIE	IMECRECD	3	0	C		INTAKE MANIFOLD EXHST CROSSOVR COOLANT OUTLET RECORD DEVICE
4340	13	IIIE	IMECOBSF	10	0	C		INTAKE MANIFOLD EXHST CROSSOVR COOLANT OUTLET OBS. FREQUENCY
4350	13	IIIE	IMECRECF	10	0	C		INTAKE MANIFOLD EXHST CROSSOVR COOLANT OUTLET REC. FREQUENCY
4360	13	IIIE	IMECLOGF	9	0	C		INTAKE MANIFOLD EXHST CROSSOVR COOLANT OUTLET LOG FREQUENCY
4370	13	IIIE	CRNKSENS	10	0	C		CRANKCASE SENSING DEVICE
4380	13	IIIE	CRNKCALF	10	0	C		CRANKCASE CALIBRATION FREQUENCY
4390	13	IIIE	CRNKRECD	3	0	C		CRANKCASE RECORD DEVICE
4400	13	IIIE	CRNKOBSF	10	0	C		CRANKCASE OBSERVATION FREQUENCY
4410	13	IIIE	CRNKRECF	10	0	C		CRANKCASE RECORD FREQUENCY
4420	13	IIIE	CRNKLOGF	9	0	C		CRANKCASE LOG FREQUENCY
4430	13	IIIE	CRNKSYSR	8	0	C		CRANKCASE SYSTEM RESPONSE
4440	13	IIIE	OPMPSENS	10	0	C		OIL PUMP OUTLET SENSING DEVICE
4450	13	IIIE	OPMPCALF	10	0	C		OIL PUMP OUTLET CALIBRATION FREQUENCY
4460	13	IIIE	OPMPRECD	3	0	C		OIL PUMP OUTLET RECORD DEVICE
4470	13	IIIE	OPMPOBSF	10	0	C		OIL PUMP OUTLET OBSERVATION FREQUENCY
4480	13	IIIE	OPMPRECF	10	0	C		OIL PUMP OUTLET RECORD FREQUENCY
4490	13	IIIE	OPMPLOGF	9	0	C		OIL PUMP OUTLET LOG FREQUENCY
4500	13	IIIE	OPMPSYSR	8	0	C		OIL PUMP OUTLET SYSTEM RESPONSE
4510	13	IIIE	OILGSENS	10	0	C		OIL GALLERY SENSING DEVICE
4520	13	IIIE	OILGCALF	10	0	C		OIL GALLERY PRESSURE CALIBRATION FREQUENCY
4530	13	IIIE	OILGRECD	3	0	C		OIL GALLERY PRESSURE RECORD DEVICE
4540	13	IIIE	OILGOBSF	10	0	C		OIL GALLERY PRESSURE OBSERVATION FREQUENCY
4550	13	IIIE	OILGRECF	10	0	C		OIL GALLERY PRESSURE RECORD FREQUENCY
4560	13	IIIE	OILGLOGF	9	0	C		OIL GALLERY PRESSURE LOG FREQUENCY
4570	13	IIIE	OILGSYSR	8	0	C		OIL GALLERY PRESSURE SYSTEM RESPONSE
4580	13	IIIE	CRBISENS	10	0	C		CARB INLET AIR SENSING DEVICE
4590	13	IIIE	CRBICALF	10	0	C		CARB INLET AIR CALIBRATION FREQUENCY
4600	13	IIIE	CRBIRECD	3	0	C		CARB INLET AIR RECORD DEVICE
4610	13	IIIE	CRBIOBSF	10	0	C		CARB INLET AIR OBSERVATION FREQUENCY
4620	13	IIIE	CRBIRECF	10	0	C		CARB INLET AIR RECORD FREQUENCY
4630	13	IIIE	CRBILOGF	9	0	C		CARB INLET AIR LOG FREQUENCY
4640	13	IIIE	CRBISYSR	8	0	C		CARB INLET AIR SYSTEM RESPONSE
4650	13	IIIE	EXPRSENS	10	0	C		EXHAUST PRESSURE SENSING DEVICE
4660	13	IIIE	EXPRCALF	10	0	C		EXHAUST PRESSURE CALIBRATION FREQUENCY
4670	13	IIIE	EXPRRECD	3	0	C		EXHAUST PRESSURE RECORD DEVICE
4680	13	IIIE	EXPROBSF	10	0	C		EXHAUST PRESSURE OBSERVATION FREQUENCY
4690	13	IIIE	EXPRRECF	10	0	C		EXHAUST PRESSURE RECORD FREQUENCY
4700	13	IIIE	EXPRLOGF	9	0	C		EXHAUST PRESSURE LOG FREQUENCY
4710	13	IIIE	EXPRSYSR	8	0	C		EXHAUST PRESSURE SYSTEM RESPONSE
4720	13	IIIE	INTVSENS	10	0	C		INTAKE VACUUM SENSING DEVICE
4730	13	IIIE	INTVCALF	10	0	C		INTAKE VACUUM CALIBRATION FREQUENCY
4740	13	IIIE	INTVRECD	3	0	C		INTAKE VACUUM RECORD DEVICE
4750	13	IIIE	INTVOBSF	10	0	C		INTAKE VACUUM OBSERVATION FREQUENCY
4760	13	IIIE	INTVRECF	10	0	C		INTAKE VACUUM RECORD FREQUENCY
4770	13	IIIE	INTVLOGF	9	0	C		INTAKE VACUUM LOG FREQUENCY
4780	13	IIIE	INTVSYSR	8	0	C		INTAKE VACUUM SYSTEM RESPONSE
4790	13	IIIE	RCCPSENS	10	0	C		ROCKER COVER COOLANT OUTLET SENSING DEVICE (PRESS.)
4800	13	IIIE	RCCPCALF	10	0	C		ROCKER COVER COOLANT OUTLET CALIBRATION FREQUENCY (PRESS.)
4810	13	IIIE	RCCPRECD	3	0	C		ROCKER COVER COOLANT OUTLET RECORD DEVICE (PRESS.)
4820	13	IIIE	RCCPOBSF	10	0	C		ROCKER COVER COOLANT OUTLET OBSERVATION FREQUENCY (PRESS.)
4830	13	IIIE	RCCPRECF	10	0	C		ROCKER COVER COOLANT OUTLET RECORD FREQUENCY (PRESS.)
4840	13	IIIE	RCCPLOGF	9	0	C		ROCKER COVER COOLANT OUTLET LOG FREQUENCY (PRESS.)
4850	13	IIIE	RCCPSYSR	8	0	C		ROCKER COVER COOLANT OUTLET SYSTEM RESPONSE (PRESS.)

FIG. A6.22 Data Dictionary

3-apr-1998 Report: ASTM Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
4860	13	IIIE	BTCPSENS	10	0	C		BREATHER TUBE COOLANT OUTLET SENSING DEVICE (PRESS.)
4870	13	IIIE	BTCPCALF	10	0	C		BREATHER TUBE COOLANT OUTLET CALIBRATION FREQUENCY (PRESS.)
4880	13	IIIE	BTCPRECD	3	0	C		BREATHER TUBE COOLANT OUTLET RECORD DEVICE (PRESS.)
4890	13	IIIE	BTCPOBSF	10	0	C		BREATHER TUBE COOLANT OUTLET OBSERVATION FREQUENCY (PRESS.)
4900	13	IIIE	BTCPRECF	10	0	C		BREATHER TUBE COOLANT OUTLET RECORD FREQUENCY (PRESS.)
4910	13	IIIE	BTCPLOGF	9	0	C		BREATHER TUBE COOLANT OUTLET LOG FREQUENCY (PRESS.)
4920	13	IIIE	BTCPSYSR	8	0	C		BREATHER TUBE COOLANT OUTLET SYSTEM RESPONSE (PRESS.)
4930	13	IIIE	JCSENS	10	0	C		JACKET COOLANT FLOW MEASUREMENT DEVICE
4940	13	IIIE	JCCALF	10	0	C		JACKET COOLANT FLOW MEASUREMENT CALIBRATION FREQUENCY
4950	13	IIIE	JCRECD	3	0	C		JACKET COOLANT FLOW MEASUREMENT RECORD DEVICE
4960	13	IIIE	JCOBSF	10	0	C		JACKET COOLANT FLOW MEASUREMENT OBSERVATION FREQUENCY
4970	13	IIIE	JCRECF	10	0	C		JACKET COOLANT FLOW MEASUREMENT RECORD FREQUENCY
4980	13	IIIE	JCLOGF	9	0	C		JACKET COOLANT FLOW MEASUREMENT LOG FREQUENCY
4990	13	IIIE	JCSYSR	8	0	C		JACKET COOLANT FLOW MEASUREMENT SYSTEM RESPONSE
5000	13	IIIE	RCCSENS	10	0	C		ROCKER COVER COOLANT FLOW MEASUREMENT SENSING DEVICE
5010	13	IIIE	RCCCALF	10	0	C		ROCKER COVER COOLANT FLOW MEASUREMENT CALIBRATION FREQUENCY
5020	13	IIIE	RCCRECD	3	0	C		ROCKER COVER COOLANT FLOW MEASUREMENT RECORD DEVICE
5030	13	IIIE	RCCOBSF	10	0	C		ROCKER COVER COOLANT FLOW MEASUREMENT OBSERVATION FREQUENCY
5040	13	IIIE	RCCRECF	10	0	C		ROCKER COVER COOLANT FLOW MEASUREMENT RECORD FREQUENCY
5050	13	IIIE	RCCLOGF	9	0	C		ROCKER COVER COOLANT FLOW MEASUREMENT LOG FREQUENCY
5060	13	IIIE	RCCSYSR	8	0	C		ROCKER COVER COOLANT FLOW MEASUREMENT SYSTEM RESPONSE
5070	13	IIIE	BTCSENS	10	0	C		BREATHER TUBE COOLANT FLOW MEASUREMENT SENSING DEVICE
5080	13	IIIE	BTCCALF	10	0	C		BREATHER TUBE COOLANT FLOW MEASUREMENT CALIBRATION FREQUENCY
5090	13	IIIE	BTCRECD	3	0	C		BREATHER TUBE COOLANT FLOW MEASUREMENT RECORD DEVICE
5100	13	IIIE	BTCOBSF	10	0	C		BREATHER TUBE COOLANT FLOW MEASUREMENT OBSERVATION FREQUENCY
5110	13	IIIE	BTCRECF	10	0	C		BREATHER TUBE COOLANT FLOW MEASUREMENT RECORD FREQUENCY
5120	13	IIIE	BTCLOGF	9	0	C		BREATHER TUBE COOLANT FLOW MEASUREMENT LOG FREQUENCY
5130	13	IIIE	BTCSYSR	8	0	C		BREATHER TUBE COOLANT FLOW MEASUREMENT SYSTEM RESPONSE
5140	13	IIIE	AFRSENS	10	0	C		AFR MEASUREMENT SENSING DEVICE
5150	13	IIIE	AFRCALF	10	0	C		AFR MEASUREMENT CALIBRATION FREQUENCY
5160	13	IIIE	AFRRECD	3	0	C		AFR MEASUREMENT RECORD DEVICE
5170	13	IIIE	AFROBSF	10	0	C		AFR MEASUREMENT OBSERVATION FREQUENCY
5180	13	IIIE	AFRRECF	10	0	C		AFR MEASUREMENT RECORD FREQUENCY
5190	13	IIIE	AFRLOGF	9	0	C		AFR MEASUREMENT LOG FREQUENCY
5200	13	IIIE	AFRSYSR	8	0	C		AFR MEASUREMENT SYSTEM RESPONSE
5210	13	IIIE	BLWGSENS	10	0	C		BLOWBY GAS SENSING DEVICE
5220	13	IIIE	BLWGCALF	10	0	C		BLOWBY GAS CALIBRATION FREQUENCY
5230	13	IIIE	BLWGRECD	3	0	C		BLOWBY GAS RECORD DEVICE
5240	13	IIIE	BLWGOBSF	10	0	C		BLOWBY GAS OBSERVATION FREQUENCY
5250	13	IIIE	BLWGRECF	10	0	C		BLOWBY GAS RECORD FREQUENCY
5260	13	IIIE	BLWGLOGF	9	0	C		BLOWBY GAS LOG FREQUENCY
5270	13	IIIE	BLWGSYSR	8	0	C		BLOWBY GAS SYSTEM RESPONSE
5280	13	IIIE	IAHMSENS	10	0	C		INTAKE AIR HUMIDITY SENSING DEVICE
5290	13	IIIE	IAHMCALF	10	0	C		INTAKE AIR HUMIDITY CALIBRATION FREQUENCY
5300	13	IIIE	IAHMRECD	3	0	C		INTAKE AIR HUMIDITY RECORD DEVICE
5310	13	IIIE	IAHMOBSF	10	0	C		INTAKE AIR HUMIDITY OBSERVATION FREQUENCY
5320	13	IIIE	IAHMRECF	10	0	C		INTAKE AIR HUMIDITY RECORD FREQUENCY
5330	13	IIIE	IAHMLOGF	9	0	C		INTAKE AIR HUMIDITY LOG FREQUENCY
5340	13	IIIE	IAHMSYSR	8	0	C		INTAKE AIR HUMIDITY SYSTEM RESPONSE
5350	13	IIIE	LOADSENS	10	0	C		LOAD SENSING DEVICE
5360	13	IIIE	LOADCALF	10	0	C		LOAD CALIBRATION FREQUENCY
5370	13	IIIE	LOADRECD	3	0	C		LOAD RECORD DEVICE
5380	13	IIIE	LOADOBSF	10	0	C		LOAD OBSERVATION FREQUENCY
5390	13	IIIE	LOADRECF	10	0	C		LOAD RECORD FREQUENCY

FIG. A6.23 Data Dictionary

3-apr-1998 Report: ASTM Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
5400	13	IIIE	LOADLOGF	9	0	C		LOAD LOG FREQUENCY
5410	13	IIIE	LOADSYSR	8	0	C		LOAD SYSTEM RESPONSE

FIG. A6.24 Data Dictionary

```
##########################################################################
#                                                                        #
#           D a t a  D i c t i o n a r y  R e p e a t i n g              #
#               F i e l d  S p e c i f i c a t i o n s                   #
#                                                                        #
##########################################################################
# The following contains specifications and field groupings for fields in the
# Data Dictionary that are REPEATING Fields.  These fields can be identified
# in the Data Dictionary by the Hxxx or Rxxx in the last four positions of the
# field name.
#
# Repeating fields are used to specify repeating measurements.
#
# The format for a repeating field name is 4 descriptive characters followed
# by the letter H or R followed by 3 characters for the actual interval
# the measurement was taken. The field will always be a total of 8 characters.
#
# Example ABCDHxxx.
#
# The following is the format of this specification:
#
# Column 1 - 8:   Repeating Field Name
# Column 10 - 17: The Parent Field Name of the Group
# Column 19 - 80: Comments about the Repeating Field Group.
#
# The lines following the Repeating Field Name Record will contain the required
# measurements for the particular field.  Multiple 80 characters lines
# can be specified.  A blank line marks the end of each specification.
#
# The Field Name in Column 10-17 designates the the Group in which the field
# belongs.  The First field name in a group is the Parent of the grouping
# and can be used to determine how fields should be grouped.
# The changing of the Parent Field marks the end of a repeating group
# specification.
#
# Example:
#
# VIS_Hxxx, DVISHxxx and PVISHxxx expanded for transmission (8 and 16 hours):
#
#          VIS_H008
#          DVISH008
#          PVISH008
#          VIS_H016
#          DVISH016
#          PVISH016
#
# Note:  During electronic transmission, repeating field groups must be kept
#        together with in the specified group but the order with in the group
#        does not have to be maintained.
#
##########################################################################
#                Start of Field Grouping Specifications                  #
##########################################################################
#
IIIE VERSION 19980403
VIS_Hxxx VIS_Hxxx   VISCOSITY AT 40 DEG C AT XXX TEST HOURS (CST)
008 016 024 032 040 048 056 064

DVISHxxx VIS_Hxxx   VISCOSITY INCREASE AT XXX HOURS (CST)
008 016 024 032 040 048 056 064
```

FIG. A6.25 Repeating Field Specifications

```
PVISHxxx VIS_Hxxx   % VISCOSITY INCREASE @ XXX HOURS (%)
008 016 024 032 040 048 056 064

OILLHxxx OILLHxxx   OIL LEVEL LOW AT XXX HOURS (ML)
008 016 024 032 040 048 056 064 BRK

GLYCHxxx GLYCHxxx   GLYCOL CONTAMINATION HOURS POSITIVE/NEGATIVE
040 EOT INI

DOWNHxxx DOWNHxxx   DOWNTIME TEST HOURS (HH:MM)

DDATHxxx DOWNHxxx   DOWNTIME DATE (YYYYMMDD)

DTIMHxxx DOWNHxxx   DOWNTIME TIME (HH:MM)

DREAHxxx DOWNHxxx   DOWNTIME REASON

OCOMHxxx OCOMHxxx   OTHER DOWNTIME COMMENT XXX

BLWBHxxx BLWBHxxx   TEST BLOWBY AT HOURS XXX (L/MIN)
001 005 009 013 017 021 025 029 033 037 041 045 049 053 057 061 064
```

FIG. A6.26 Repeating Field Specifications

A7. SEQUENCE IIIE TEST AIR-TO-FUEL RATIO

A7.1 See Table A7.1 and Fig. A7.1.

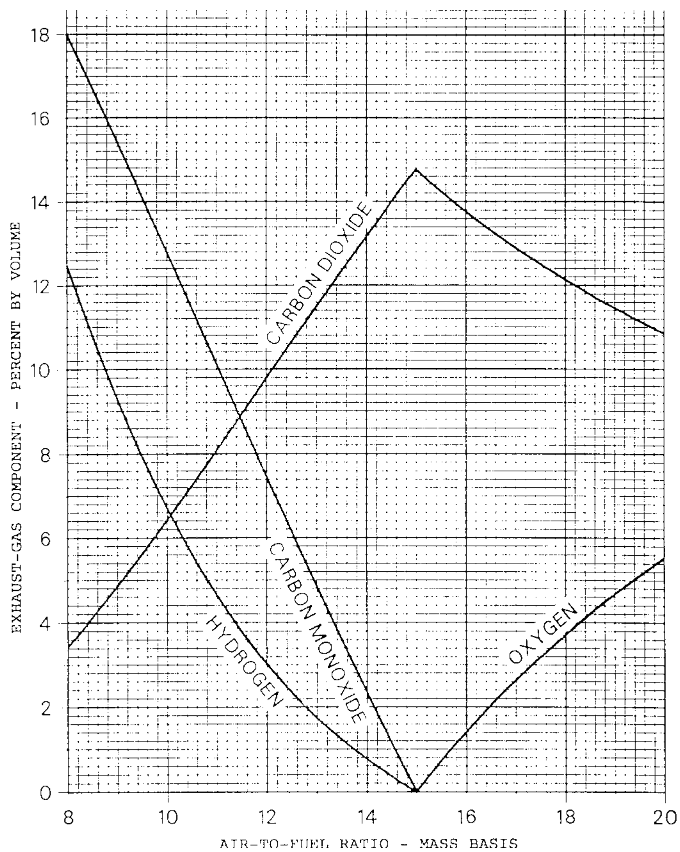
A8. SEQUENCE IIIE TEST BLOWBY FLOW RATE CORRECTION FACTOR

A8.1 See Table A8.1 and Table A8.2.

TABLE A7.1 Sequence IIIE Test Air-to-Fuel Ratio for Specified Fuel (CH_2.10)*x*

Air-to-Fuel Ratio	Vol % CO_2[A]	Vol % O_2[A]	Air-to-Fuel Ratio	Vol % CO_2[A]	Vol % O_2[A]
15.0	14.76	0.01	16.6	13.24	2.17
15.1	14.65	0.16	16.7	13.16	2.29
15.2	14.55	0.31	16.8	13.07	2.41
15.3	14.44	0.46	16.9	12.98	2.52
15.4	14.34	0.60	17.0	12.90	2.64
15.5	14.24	0.74	17.1	12.82	2.75
15.6	14.15	0.88	17.2	12.74	2.86
15.7	14.05	1.02	17.3	12.66	2.98
15.8	13.95	1.15	17.4	12.59	3.09
15.9	13.86	1.28	17.5	12.51	3.20
16.0	13.77	1.41	17.6	12.43	3.30
16.1	13.68	1.54	17.7	12.36	3.40
16.2	13.59	1.67	17.8	12.29	3.51
16.3	13.50	1.80	17.9	12.22	3.62
16.4	13.41	1.92	18.0	12.14	3.72
16.5	13.32	2.04			

[A]Corrected values; see text.



NOTE 1—Use corrected values for oxygen and carbon dioxide volumes; see text.

FIG. A7.1 Sequence IIIE Test Air-to-Fuel Ratio for Specified Fuel ($CH_{2.10}$)*x*

TABLE A8.1 Sequence IIIE Test Blowby Flow Rate Correction Factor (SI Units)

Pressure, kPa	Temperature, °C															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
105.0	1.064	1.062	1.061	1.059	1.057	1.055	1.053	1.052	1.050	1.048	1.046	1.045	1.043	1.041	1.039	1.038
104.5	1.062	1.060	1.058	1.056	1.054	1.053	1.051	1.049	1.047	1.046	1.044	1.042	1.040	1.039	1.037	1.035
104.0	1.059	1.057	1.056	1.054	1.052	1.050	1.048	1.047	1.045	1.043	1.041	1.040	1.038	1.036	1.034	1.033
103.5	1.057	1.055	1.053	1.051	1.049	1.048	1.046	1.044	1.042	1.041	1.039	1.037	1.035	1.034	1.032	1.030

Pressure, kPa	Temperature, °C															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
103.0	1.054	1.052	1.050	1.049	1.047	1.045	1.043	1.042	1.040	1.038	1.036	1.035	1.033	1.031	1.029	1.028
102.5	1.052	1.050	1.048	1.046	1.044	1.043	1.041	1.039	1.037	1.035	1.034	1.032	1.030	1.029	1.027	1.025
102.0	1.049	1.047	1.045	1.044	1.042	1.040	1.038	1.036	1.035	1.033	1.031	1.030	1.028	1.026	1.024	1.023
101.5	1.046	1.045	1.043	1.041	1.039	1.037	1.036	1.034	1.032	1.030	1.029	1.027	1.025	1.024	1.022	1.020
101.0	1.044	1.042	1.040	1.038	1.037	1.035	1.033	1.031	1.030	1.028	1.026	1.024	1.023	1.021	1.019	1.018
100.5	1.041	1.039	1.038	1.036	1.034	1.032	1.031	1.029	1.027	1.025	1.024	1.022	1.020	1.019	1.017	1.015
100.0	1.039	1.037	1.035	1.033	1.031	1.030	1.028	1.026	1.025	1.023	1.021	1.019	1.018	1.016	1.014	1.013
99.5	1.036	1.034	1.032	1.031	1.029	1.027	1.025	1.024	1.022	1.020	1.019	1.017	1.015	1.013	1.012	1.010
99.0	1.033	1.032	1.030	1.028	1.026	1.025	1.023	1.021	1.019	1.018	1.016	1.014	1.013	1.011	1.009	1.008
98.5	1.031	1.029	1.027	1.025	1.024	1.022	1.020	1.019	1.017	1.015	1.013	1.012	1.010	1.008	1.007	1.005
98.0	1.028	1.026	1.025	1.023	1.021	1.019	1.018	1.016	1.014	1.013	1.011	1.009	1.007	1.006	1.004	1.002
97.5	1.026	1.024	1.022	1.020	1.019	1.017	1.015	1.013	1.012	1.010	1.008	1.007	1.005	1.003	1.002	1.000
97.0	1.023	1.021	1.019	1.018	1.016	1.014	1.012	1.011	1.009	1.007	1.006	1.004	1.002	1.001	0.999	0.997
96.5	1.020	1.019	1.017	1.015	1.013	1.012	1.010	1.008	1.006	1.005	1.003	1.001	1.000	0.998	0.996	0.995
96.0	1.018	1.016	1.014	1.012	1.011	1.009	1.007	1.006	1.004	1.002	1.000	0.999	0.997	0.995	0.994	0.992
95.5	1.015	1.013	1.011	1.010	1.008	1.006	1.005	1.003	1.001	1.000	0.998	0.996	0.994	0.993	0.991	0.990
95.0	1.012	1.011	1.009	1.007	1.005	1.004	1.002	1.000	0.999	0.997	0.995	0.994	0.992	0.990	0.989	0.987
94.5	1.010	1.008	1.006	1.004	1.003	1.001	0.999	0.998	0.996	0.994	0.993	0.991	0.989	0.988	0.986	0.984
94.0	1.007	1.005	1.004	1.002	1.000	0.998	0.997	0.995	0.993	0.992	0.990	0.988	0.987	0.985	0.983	0.982

Pressure, kPa	Temperature, °C														
	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
105.0	1.036	1.034	1.033	1.031	1.029	1.028	1.026	1.024	1.023	1.021	1.019	1.018	1.016	1.014	1.013
104.5	1.033	1.032	1.030	1.028	1.027	1.025	1.023	1.022	1.020	1.018	1.017	1.015	1.014	1.012	1.010
104.0	1.031	1.029	1.028	1.026	1.024	1.023	1.021	1.019	1.018	1.016	1.014	1.013	1.011	1.010	1.008
103.5	1.028	1.027	1.025	1.023	1.022	1.020	1.018	1.017	1.015	1.014	1.012	1.010	1.009	1.007	1.006
103.0	1.026	1.024	1.023	1.021	1.019	1.018	1.016	1.014	1.013	1.011	1.010	1.008	1.006	1.005	1.003
102.5	1.024	1.022	1.020	1.018	1.017	1.015	1.014	1.012	1.010	1.009	1.007	1.005	1.004	1.002	1.001
102.0	1.021	1.019	1.018	1.016	1.014	1.013	1.011	1.009	1.008	1.006	1.005	1.003	1.001	1.000	0.998
101.5	1.019	1.017	1.015	1.014	1.012	1.010	1.009	1.007	1.005	1.004	1.002	1.001	0.999	0.997	0.996
101.0	1.016	1.014	1.013	1.011	1.009	1.008	1.006	1.005	1.003	1.001	1.000	0.998	0.997	0.995	0.993
100.5	1.013	1.012	1.010	1.009	1.007	1.005	1.004	1.002	1.000	0.999	0.997	0.996	0.994	0.992	0.991
100.0	1.011	1.009	1.008	1.006	1.004	1.003	1.001	1.000	0.998	0.996	0.995	0.993	0.992	0.990	0.988
99.5	1.008	1.007	1.005	1.003	1.002	1.000	0.999	0.997	0.995	0.994	0.992	0.991	0.989	0.988	0.986
99.0	1.006	1.004	1.003	1.001	0.999	0.998	0.996	0.995	0.993	0.991	0.990	0.988	0.987	0.985	0.984
98.5	1.003	1.002	1.000	0.998	0.997	0.995	0.994	0.992	0.990	0.989	0.987	0.986	0.984	0.983	0.981
98.0	1.001	0.999	0.998	0.996	0.994	0.993	0.991	0.989	0.988	0.986	0.985	0.983	0.982	0.980	0.979
97.5	0.998	0.997	0.995	0.993	0.992	0.990	0.989	0.987	0.985	0.984	0.982	0.981	0.979	0.978	0.976
97.0	0.996	0.994	0.992	0.991	0.989	0.988	0.986	0.984	0.983	0.981	0.980	0.978	0.977	0.975	0.974
96.5	0.993	0.991	0.990	0.988	0.987	0.985	0.983	0.982	0.980	0.979	0.977	0.976	0.974	0.973	0.971
96.0	0.991	0.989	0.987	0.986	0.984	0.982	0.981	0.979	0.978	0.976	0.975	0.973	0.972	0.970	0.968
95.5	0.988	0.986	0.985	0.983	0.982	0.980	0.978	0.977	0.975	0.974	0.972	0.971	0.969	0.967	0.966
95.0	0.985	0.984	0.982	0.981	0.979	0.977	0.976	0.974	0.973	0.971	0.970	0.968	0.966	0.965	0.963
94.5	0.983	0.981	0.980	0.978	0.976	0.975	0.973	0.972	0.970	0.969	0.967	0.965	0.964	0.962	0.961
94.0	0.980	0.979	0.977	0.975	0.974	0.972	0.971	0.969	0.968	0.966	0.964	0.963	0.961	0.960	0.958

Pressure, kPa	Temperature, °C														
	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
105.0	1.011	1.010	1.008	1.007	1.005	1.003	1.002	1.000	0.999	0.997	0.996	0.994	0.993	0.991	0.990
104.5	1.009	1.007	1.006	1.004	1.003	1.001	1.000	0.998	0.996	0.995	0.993	0.992	0.990	0.989	0.987
104.0	1.006	1.005	1.003	1.002	1.000	0.999	0.997	0.996	0.994	0.993	0.991	0.990	0.988	0.987	0.985
103.5	1.004	1.002	1.001	0.999	0.998	0.996	0.995	0.993	0.992	0.990	0.989	0.987	0.986	0.984	0.983
103.0	1.002	1.000	0.998	0.997	0.995	0.994	0.992	0.991	0.989	0.988	0.986	0.985	0.983	0.982	0.980
102.5	0.999	0.998	0.996	0.995	0.993	0.991	0.990	0.988	0.987	0.985	0.984	0.982	0.981	0.979	0.978
102.0	0.997	0.995	0.994	0.992	0.991	0.989	0.988	0.986	0.984	0.983	0.981	0.980	0.979	0.977	0.976
101.5	0.994	0.993	0.991	0.990	0.988	0.987	0.985	0.984	0.982	0.981	0.979	0.978	0.976	0.975	0.973
101.0	0.992	0.990	0.989	0.987	0.986	0.984	0.983	0.981	0.980	0.978	0.977	0.975	0.974	0.972	0.971
100.5	0.989	0.988	0.986	0.985	0.983	0.982	0.980	0.979	0.977	0.976	0.974	0.973	0.971	0.970	0.968
100.0	0.987	0.985	0.984	0.982	0.981	0.979	0.978	0.976	0.975	0.973	0.972	0.970	0.969	0.967	0.966
99.5	0.984	0.983	0.981	0.980	0.978	0.977	0.975	0.974	0.972	0.971	0.969	0.968	0.966	0.965	0.964
99.0	0.982	0.980	0.979	0.977	0.976	0.974	0.973	0.971	0.970	0.968	0.967	0.965	0.964	0.963	0.961
98.5	0.979	0.978	0.976	0.975	0.973	0.972	0.970	0.969	0.967	0.966	0.965	0.963	0.962	0.960	0.959
98.0	0.977	0.975	0.974	0.972	0.971	0.969	0.968	0.966	0.965	0.964	0.962	0.961	0.959	0.958	0.956
97.5	0.975	0.973	0.971	0.970	0.968	0.967	0.965	0.964	0.963	0.961	0.960	0.958	0.957	0.955	0.954
97.0	0.972	0.970	0.969	0.967	0.966	0.964	0.963	0.962	0.960	0.959	0.957	0.956	0.954	0.953	0.951
96.5	0.969	0.968	0.966	0.965	0.963	0.962	0.961	0.959	0.958	0.956	0.955	0.953	0.952	0.950	0.949
96.0	0.967	0.965	0.964	0.962	0.961	0.959	0.958	0.957	0.955	0.954	0.952	0.951	0.949	0.948	0.946
95.5	0.964	0.963	0.961	0.960	0.958	0.957	0.956	0.954	0.953	0.951	0.950	0.948	0.947	0.945	0.944
95.0	0.962	0.960	0.959	0.957	0.956	0.954	0.953	0.952	0.950	0.949	0.947	0.946	0.944	0.943	0.942
94.5	0.959	0.958	0.956	0.955	0.953	0.952	0.951	0.949	0.948	0.946	0.945	0.943	0.942	0.940	0.939
94.0	0.957	0.955	0.954	0.952	0.951	0.949	0.948	0.947	0.945	0.944	0.942	0.941	0.939	0.938	0.937

TABLE A8.2 Sequence IIIE Test Blowby Flow Rate Correction Factor (in.-lb units)

Pressure, in. Hg	Temperature,° F													
	58	60	62	64	66	68	70	72	74	76	78	80	82	84
31.0	1.062	1.060	1.058	1.056	1.054	1.052	1.050	1.048	1.046	1.044	1.042	1.040	1.038	1.037
30.8	1.059	1.057	1.055	1.053	1.051	1.049	1.047	1.045	1.043	1.041	1.039	1.037	1.035	1.033
30.6	1.055	1.053	1.051	1.049	1.047	1.045	1.043	1.041	1.039	1.038	1.036	1.034	1.032	1.030
30.4	1.052	1.050	1.048	1.046	1.044	1.042	1.040	1.038	1.036	1.034	1.032	1.030	1.028	1.026
30.2	1.048	1.046	1.044	1.042	1.040	1.039	1.037	1.035	1.033	1.031	1.029	1.027	1.025	1.023
30.0	1.045	1.043	1.041	1.039	1.037	1.035	1.033	1.031	1.029	1.027	1.025	1.023	1.022	1.020
29.8	1.042	1.040	1.038	1.036	1.034	1.032	1.030	1.028	1.026	1.024	1.022	1.020	1.018	1.016
29.6	1.038	1.036	1.034	1.032	1.030	1.028	1.026	1.024	1.022	1.020	1.019	1.017	1.015	1.013
29.4	1.035	1.033	1.031	1.029	1.027	1.025	1.023	1.021	1.019	1.017	1.015	1.013	1.011	1.009
29.2	1.031	1.029	1.027	1.025	1.023	1.021	1.019	1.017	1.015	1.014	1.012	1.010	1.008	1.006
29.0	1.027	1.025	1.023	1.022	1.020	1.018	1.016	1.014	1.012	1.010	1.008	1.006	1.004	1.003
28.8	1.024	1.022	1.020	1.018	1.016	1.014	1.012	1.010	1.008	1.007	1.005	1.003	1.001	0.999
28.6	1.020	1.018	1.016	1.014	1.013	1.011	1.009	1.007	1.005	1.003	1.001	0.999	0.997	0.996
28.4	1.017	1.015	1.013	1.011	1.009	1.007	1.005	1.003	1.001	1.000	0.998	0.996	0.994	0.992
28.2	1.013	1.011	1.009	1.007	1.005	1.004	1.002	1.000	0.998	0.996	0.994	0.992	0.990	0.989
28.0	1.010	1.008	1.006	1.004	1.002	1.000	0.998	0.996	0.994	0.992	0.991	0.989	0.987	0.985

Pressure, in. Hg	Temperature,° F													
	86	88	90	92	94	96	98	100	102	104	106	108	110	112
31.0	1.035	1.033	1.031	1.029	1.027	1.025	1.023	1.022	1.020	1.018	1.016	1.014	1.013	1.011
30.8	1.031	1.029	1.028	1.026	1.024	1.022	1.020	1.018	1.017	1.015	1.013	1.011	1.009	1.008
30.6	1.028	1.026	1.024	1.022	1.021	1.019	1.017	1.015	1.013	1.011	1.010	1.008	1.006	1.004
30.4	1.025	1.023	1.021	1.019	1.017	1.015	1.014	1.012	1.010	1.008	1.006	1.005	1.003	1.001
30.2	1.021	1.019	1.018	1.016	1.014	1.012	1.010	1.008	1.007	1.005	1.003	1.001	0.999	0.998
30.0	1.018	1.016	1.014	1.012	1.010	1.009	1.007	1.005	1.003	1.001	1.000	0.998	0.996	0.994
29.8	1.014	1.013	1.011	1.009	1.007	1.005	1.003	1.002	1.000	0.998	0.996	0.995	0.993	0.991
29.6	1.011	1.009	1.007	1.006	1.004	1.002	1.000	0.998	0.997	0.995	0.993	0.991	0.990	0.988
29.4	1.008	1.006	1.004	1.002	1.000	0.999	0.997	0.995	0.993	0.991	0.990	0.988	0.986	0.984
29.2	1.004	1.002	1.001	0.999	0.997	0.995	0.993	0.992	0.990	0.988	0.986	0.985	0.983	0.981
29.0	1.001	0.999	0.997	0.995	0.993	0.992	0.990	0.988	0.986	0.985	0.983	0.981	0.979	0.978
28.8	0.997	0.995	0.994	0.992	0.990	0.988	0.986	0.985	0.983	0.981	0.979	0.978	0.976	0.974
28.6	0.994	0.992	0.990	0.988	0.987	0.985	0.983	0.981	0.980	0.978	0.976	0.974	0.973	0.971
28.4	0.990	0.989	0.987	0.985	0.983	0.981	0.980	0.978	0.976	0.974	0.973	0.971	0.969	0.968
28.2	0.987	0.985	0.983	0.981	0.980	0.978	0.976	0.974	0.973	0.971	0.969	0.968	0.966	0.964
28.0	0.983	0.982	0.980	0.978	0.976	0.974	0.973	0.971	0.969	0.968	0.966	0.964	0.962	0.961

Pressure, in. Hg	Temperature,° F													
	114	116	118	120	122	124	126	128	130	132	134	136	138	140
31.0	1.009	1.007	1.006	1.004	1.002	1.000	0.999	0.997	0.995	0.994	0.992	0.990	0.989	0.987
30.8	1.006	1.004	1.002	1.001	0.999	0.997	0.995	0.994	0.992	0.990	0.989	0.987	0.985	0.984
30.6	1.003	1.001	0.999	0.997	0.996	0.994	0.992	0.991	0.989	0.987	0.986	0.984	0.982	0.981
30.4	0.999	0.998	0.996	0.994	0.992	0.991	0.989	0.987	0.986	0.984	0.982	0.981	0.979	0.977
30.2	0.996	0.994	0.993	0.991	0.989	0.987	0.986	0.984	0.982	0.981	0.979	0.977	0.976	0.974
30.0	0.993	0.991	0.989	0.988	0.986	0.984	0.982	0.981	0.979	0.977	0.976	0.974	0.973	0.971
29.8	0.989	0.988	0.986	0.984	0.983	0.981	0.979	0.978	0.976	0.974	0.973	0.971	0.969	0.968
29.6	0.986	0.984	0.983	0.981	0.979	0.978	0.976	0.974	0.973	0.971	0.969	0.968	0.966	0.964
29.4	0.983	0.981	0.979	0.978	0.976	0.974	0.973	0.971	0.969	0.968	0.966	0.964	0.963	0.961
29.2	0.979	0.978	0.976	0.974	0.973	0.971	0.969	0.968	0.966	0.964	0.963	0.961	0.960	0.958
29.0	0.976	0.974	0.973	0.971	0.969	0.968	0.966	0.964	0.963	0.961	0.959	0.958	0.956	0.955
28.8	0.973	0.971	0.969	0.968	0.966	0.964	0.963	0.961	0.959	0.958	0.956	0.955	0.953	0.951
28.6	0.969	0.968	0.966	0.964	0.963	0.961	0.959	0.958	0.956	0.954	0.953	0.951	0.950	0.948
28.4	0.966	0.964	0.963	0.961	0.959	0.958	0.956	0.954	0.953	0.951	0.949	0.948	0.946	0.945
28.2	0.962	0.961	0.959	0.957	0.956	0.954	0.953	0.951	0.949	0.948	0.946	0.945	0.943	0.941
28.0	0.959	0.957	0.956	0.954	0.952	0.951	0.949	0.948	0.946	0.944	0.943	0.941	0.940	0.938

A9. SEQUENCE IIIE SERIES FLOW CHECK PROCEDURE FOR BLOWBY FLOW MEASUREMENT SYSTEMS

A9.1 Perform a correlation check of two blowby meters by flowing the two meters in series as shown in Fig. A9.1.

A9.2 Connect the reference meter and the meter to be checked in series with a clean air supply. Establish a flow rate using a high quality flow controller for some differential pressure (250 to 1500 Pa; 1 to 6 in. H_2O) across the reference meter.

A9.3 Measure the respective differential pressures and the orifice upstream pressures. Measure the upstream pressures using one one of the following two methods:

A9.3.1 Measure the upstream pressure directly with a high quality pressure gage, or

A9.3.2 Measure the differential pressure upstream relative to the ambient room pressure and add to the observed barometric pressure.

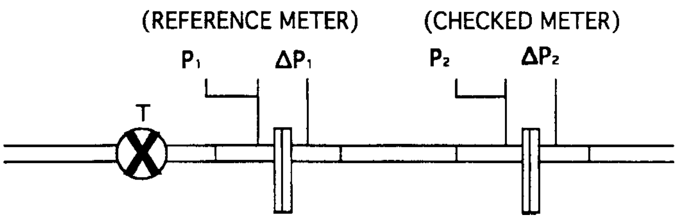


FIG. A9.1 Blowby Flow Meter Series Flow Check Plumbing Schematic

A9.4 All pressure measurements shall be made with quality instrumentation, and accurately read to achieve acceptable results.

A9.5 Calculate a pressure drop for the meter being checked using the equation given in Eq A9.1.

$$(\Delta P_1)\left(\frac{P_1}{P_2}\right) = \Delta P_2 \qquad (A9.1)$$

Subscripts 1 and 2 refer to the respective meters in the test system, where 1 would normally be the reference meter and 2 would be the meter under test.

A9.6 Compare the calculated differential pressure to the measured differential pressure. This procedure should provide acceptable agreement if the meter under test is clean and properly made. An example of the completed calculation is found in Table A9.1.

A9.7 Retain records of all maintenance and cleaning procedures performed on the blowby flow measurement system, as well as the results of this series flow check procedure, with other laboratory calibration documentation.

TABLE A9.1 Blowby Meter Calculation Sample Results

Blowby Meter Series Flow Check Results Example
Pressures of Water, in.

Run	(Reference Meter) DP_1	P_1 P_2	(Checked Meter) DP_2(calculated)	DP_2(measured)
		⅛ in. Diameter Orifice (0.125 in.)		
1	1.000	1.0033	1.003	1.003
2	3.000	1.0098	3.029	3.030
3	5.000	1.0165	5.082	5.090
		3⁄16 in. Diameter Orifice (0.1875 in.)		
1	1.000	1.0035	1.004	1.002
2	3.000	1.0109	3.033	3.030
3	5.000	1.0190	5.095	5.085
		¼ in. Diameter Orifice (0.250 in.)		
1	1.000	1.0036	1.004	1.004
2	3.000	1.0111	3.033	3.045
3	5.040	1.0196	5.139	5.150
		5⁄16″ Diameter Orifice (0.3125″)		
1	1.000	1.0035	1.004	1.000
2	3.000	1.0106	3.032	3.030
3	5.000	1.0177	5.088	5.100
		⅜ in. Diameter Orifice (0.375 in.)		
1	2.000	1.0066	2.013	2.008
2	4.000	1.0129	4.052	4.070

APPENDIXES

(Nonmandatory Information)

X1. SEQUENCE IIIE TEST — ENGINE BUILD MEASUREMENT WORKSHEETS

X1.1 Fig. X1.1, Fig. X1.2 and Fig. X1.3 illustrates the engine build-up calibration sheets respectively.

X2. SEQUENCE IIIE TEST—PRE- AND POST-MEASUREMENTS

X2.1 Cam lobe measurements, rod bearing weight loss and valve lifter dimensions are presented in Figs. X2.1-X2.3.

X3. SEQUENCE IIIE TEST — CAM LOBE OILING WAND

X3.1 Fig. X3.1 is an illustration of the cam lobe oiling wand.

X4. SEQUENCE IIIE TEST — OPERATIONAL LOGS, CHECKLISTS, AND WORKSHEETS

X4.1 The various logs, checklists, and worksheets for the Sequence IIIE test are illustrated in Figs. X4.1-X4.5.

DATE: ________ ENGINE NO: ________ BLOCK RUN NO: ________

Cylinder Bore Measurements After Honing

Cylinder	1				3				5			
Location	Top	Mid.	Bot.	Taper	Top	Mid.	Bot.	Taper	Top	Mid.	Bot.	Taper
Trans. Dia.												
Long. Dia.												
Δ												
Micro Finish												
Piston Pull	Gauge		N		Gauge		N		Gauge		N	

Cylinder	2				4				6			
Location	Top	Mid.	Bot.	Taper	Top	Mid.	Bot.	Taper	Top	Mid.	Bot.	Taper
Trans. Dia.												
Long. Dia.												
Δ												
Micro Finish												
Piston Pull	Gauge		N		Gauge		N		Gauge		N	

Piston and Piston Fit

Cylinder	1	2	3	4	5	6
Piston Batch Code						
Piston Size Grade						
Clearance						

Ring Gap

Top: ________

Second: ________

Mechanic: ________

Honing

	Rough	Smooth
Strokes:		
Load:		
Mechanic:		

Ring Set Batch Code: ________ ________ ________ ________

Ring Set Receive Date: ________

Engine Front Cover No: ________ Run ________

Oil Pan No: ________

Intake No: ________

FIG. X1.1 Sequence IIIE Engine Build-up Sheet

TRAVEL = 8.9 + 0.25 mm @ 104.3 kg SPRING LOAD

TRAVEL = 0.350 + 0.010 in. @ 230 lbs SPRING LOAD

BUILT BY ____________________

DATE ____________________

LEFT	TRAVEL	SHIM
1		
3		
5		
7		
9		
11		

RIGHT	TRAVEL	SHIM
2		
4		
6		
8		
10		
12		

Head Serial No: ____________________

Head Serial No: ____________________

SPRING BATCH CODE ____________________

SEAL BATCH CODE ____________________

FIG. X1.2 Sequence IIIE Head Calibration Sheet

Sequence IIIE Camshaft Bearing Clearance		
Engine Number		
Date		
Position	High Limit Ball	Low Limit Ball
1		
2		
3		
4		
Record "Y" if ball passes through position, record "N" if not.		

FIG. X1.3 Comshaft Bearing Clearance

DATE: ___________ ENGINE NO.:_________

CAMSHAFT SERIAL NO.:_________________

LABORATORY ID NO.:__________________

LOBE	FRONT OR REAR	BEFORE TEST MEASUREMENT	AFTER TEST		DECREASE
			VISUAL	MEAS.	
NO. 1	FRONT				
NO. 2	REAR				
NO. 3	FRONT				
NO. 4	REAR				
NO. 5	REAR				
NO. 6	REAR				
NO. 7	FRONT				
NO. 8	REAR				
NO. 9	FRONT				
NO. 10	REAR				
NO. 11	FRONT				
NO. 12	REAR				
					WEAR
				AVG.	
				MAX.	
				MIN.	

FIG. X2.1 Sequence IIIE Cam Lobe Measurements

DATE: ___________ ENGINE NO.:_________

BEARING KIT SERIAL NO.: ____________________

Rod No.		Weight Before Test	Weight After Test	Wear
1	T			
	B			
2	T			
	B			
3*	T			
	B			
4	T			
	B			
5	T			
	B			
6	T			
	B			

* Mandatory

Measured by: ____________________

FIG. X2.2 Sequence IIIE Rod Bearing Weight Loss

DATE: ________ ENGINE NO.: ________

LIFTER BATCH CODE: ________ BOX CONTROL NO: ________

	INITIAL	FINAL VISUAL	FINAL MEAS.	DIFFERENCE	CAM + LIFTER
NO. 1					
NO. 2					
NO. 3					
NO. 4					
NO. 5					
NO. 6					
NO. 7					
NO. 8					
NO. 9					
NO. 10					
NO. 11					
NO. 12					
			AVERAGE		
			MAXIMUM		
			MINIMUM		

MEASURED BY ________

FIG. X2.3 Sequence IIIE Valve Lifter Dimensions

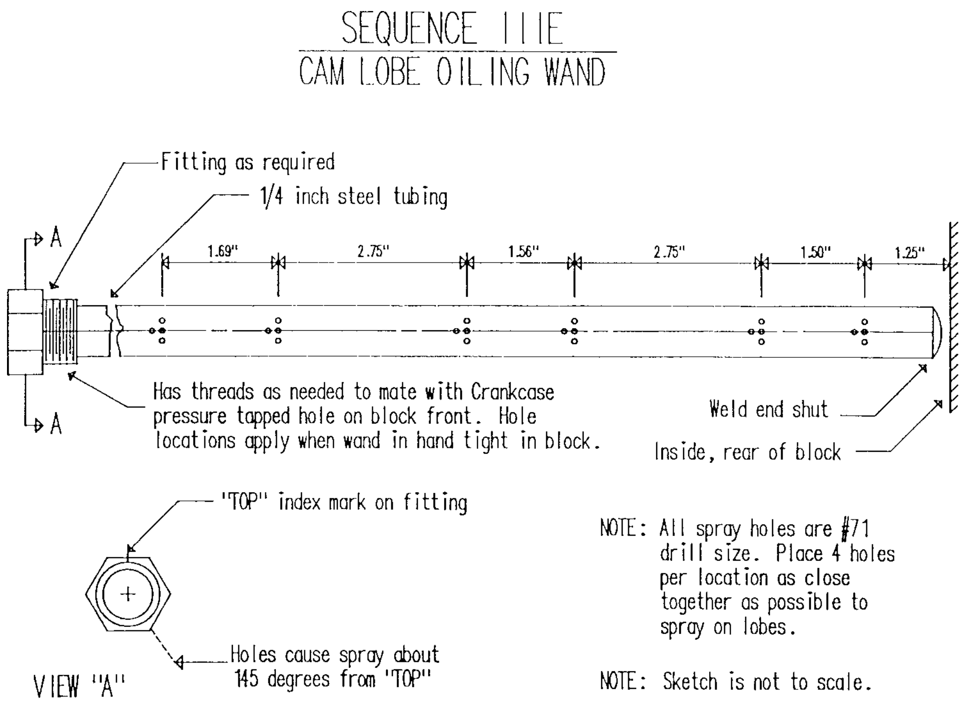


FIG. X3.1 Sequence IIIE Test Cam Lobe Oiling Wand

Test No.: ____________ Oil Code: ____________ Lab Oil Code: ____________ Dyno. Const.: ____________ Fuel Batch: ____________ Engine No.: ____________

	Date	BREAK-IN SPECIFICATIONS									TEST									
	Time	1	2	3	4						SPECS.									
	Engine Hours					On Test	1	2	3	4		On Test	1	2	3	4	5	6	7	8
ENGINE	Speed	1500 ± 20	2500 ± 20	3000 ± 20	3000 ± 20						3000 ± 20									
	Power, BHP	8.5 ± 2	28.4 ± 2	42.6 ± 2	67.8 ± 2						67.8 ± 2									
	Timing	36	40	40	40						40									
TEMPERATURES °C	Oil Filter Block	95 ± 1.1	95 ± 1.1	95 ± 1.1	149 ± 1.1						149 ± 1.1									
	Oil Sump	R	R	R	R						R									
	Coolant In	R	R	R	R						110 ± 1.1									
	Coolant Out	95 ± 3.0	95 ± 3.0	95 ± 3.0	115 ± 1.1						115 ± 1.1									
	Intake Manifold	R	R	R	R						R									
	Right Rocker Cover	R	R	R	113 ± 2.8						113 ± 2.8									
	Left Rocker Cover	R	R	R	113 ± 2.8						113 ± 2.8									
	Crossover	R	R	R	R						R									
	Breather Tube Out	40 ± 2.0	40 ± 2.0	40 ± 2.0	40 ± 1.1						40 ± 1.1									
	Blowby Gas	R	R	R	R						R									
	Fuel	R	R	R	R						R									
	Carburetor Air Drybulb	27 ± 1.5	27 ± 1.5	27 ± 1.5	27 ± 1.5						27 ± 1.5									
	Carburetor Air Dewpoint	16.1 ± 1.1	16.1 ± 1.1	16.1 ± 1.1	16.1 ± 1.1						16.1 ± 1.1									
	Ambient Air	R	R	R	R						R									
	Exhaust Manifold Coolant Out Right	R	R	R	R						R									
	Exhaust Manifold Coolant Out Left	R	R	R	R						R									
PRESSURES	Intake Vacuum, kPa	R	R	R	27 ± 7						27 ± 7									
	Oil Galley, kPa	R	R	R	R						R									
	Oil Pump, kPa	R	R	R	30 Min.						30 Min.									
	Rocker Cover Out Right, kPa	27.5 ± 6.9	27.5 ± 6.9	27.5 ± 6.9	27.5 ± 6.9						27.5 ± 6.9									
	Rocker Cover Out Left, kPa	27.5 ± 6.9	27.5 ± 6.9	27.5 ± 6.9	27.5 ± 6.9						27.5 ± 6.9									
	Breather Tube Out, kPa	27.5 ± 6.9	27.5 ± 6.9	27.5 ± 6.9	27.5 ± 6.9						27.5 ± 6.9									
	Exhaust Manifold Coolant Out, kPa	76 ± 62	76 ± 62	76 ± 62	76 ± 62						76 ± 62									
	Exhaust Back Pressure Right, kPa	0.25 ± 0.19	1.24 ± 0.38	2.49 ± 0.50	4.98 ± 0.75						4.98 ± 0.75									
	Exhaust Back Pressure Left, kPa	0.25 ± 0.19	1.24 ± 0.38	2.49 ± 0.50	4.98 ± 0.75						4.98 ± 0.75									
	Carburetor, kPa	0.05 ± .025	0.05 ± .025	0.05 ± .025	0.05 ± .025						0.05 ± .025									
	Crankcase, kPa	R	R	R	R						R									
FLOWS	Coolant ΔP, In.		151 ± 3.8	Cal. Pnt	L/m						151 ± 3.8									
	Rocker Cover/Crossover, L/m	11.4 ± 3.8	11.4 ± 3.8	11.4 ± 3.8	11.4 ± 3.8						11.4 ± 3.8									
	Breather Tube, L/m	11.4 ± 3.8	11.4 ± 3.8	11.4 ± 3.8	11.4 ± 3.8						11.4 ± 3.8									
	Exhaust Manifold Coolant Right, L/m	7.6 ± 1.9	7.6 ± 1.9	7.6 ± 1.9	7.6 ± 1.9						7.6 ± 1.9									
	Exhaust Manifold Coolant Left, L/m	7.6 ± 1.9	7.6 ± 1.9	7.6 ± 1.9	7.6 ± 1.9						7.6 ± 1.9									
	Operator Initials																			

Reduced Speed and Load at ____, S/D at ____, ____ Minute Oil Adjustment, Start at ____, On Test ____.

Reduced Speed and Load at ____, S/D at ____, ____ Minute Oil Adjustment, Start at ____, On Test ____.

FIG. X4.1 (a) Sequence IIIE Data Log

Test No.: ____________ Oil Code: ____________ Lab Oil Code: ____________ Dyno. Const.: ____________ Fuel Batch: ____________ Engine No.: ____________

	Date	TEST SPECS.																				
	Time																					
	Engine Hours		On Test										On Test									
ENGINE	Speed	3000 ± 20																				
	Power, BHP	67.8 ± 2																				
	Timing	40																				
TEMPERATURES °C	Oil Filter Block	149 ± 1.1																				
	Oil Sump	R																				
	Coolant In	110 ± 1.1																				
	Coolant Out	115 ± 1.1																				
	Intake Manifold	R																				
	Right Rocker Cover	113 ± 2.8																				
	Left Rocker Cover	113 ± 2.8																				
	Crossover	R																				
	Breather Tube Out, kPa	40 ± 1.1																				
	Blowby Gas	R																				
	Fuel	R																				
	Carburetor Air Drybulb	27 ± 1.55																				
	Carburetor Air Dewpoint	14.1 ± 1.1																				
	Ambient Air	R																				
	Exhaust Manifold Coolant Out Right	R																				
	Exhaust Manifold Coolant Out Left	R																				
	Intake Vacuum, kPa	27 ± 7																				
PRESSURES	Oil Galley, kPa	R																				
	Oil Pump, kPa	30 Min.																				
	Rocker Cover Out Right, kPa	27.5 ± 6.9																				
	Rocker Cover Out Left, kPa	27.5 ± 6.9																				
	Breather Tube Out, kPa	27.5 ± 6.9																				
	Exhaust Manifold Coolant Out, kPa	76 ± 62																				
	Exhaust Back Pressure Right, kPa	4.98 ± 0.75																				
	Exhaust Back Pressure Left, kPa	4.98 ± 0.75																				
	Carburetor Air, kPa	0.05 ± .025																				
	Crankcase, kPa	R																				
FLOWS	Coolant ΔP, In.	151 ± 3.8																				
	Rocker Cover/Crossover, L/m	11.4 ± 3.8																				
	Breather Tube, L/m	11.4 ± 3.8																				
	Exhaust Manifold Coolant Right, L/m	7.6 ± 1.9																				
	Exhaust Manifold Coolant Left, L/m	7.6 ± 1.9																				

Reduced Speed and Load at ____, S/D at ____, ____ Minute Oil Adjustment, Start at ____, On Test ____.

Reduced Speed and Load at ____, S/D at ____, ____ Minute Oil Adjustment, Start at ____, On Test ____.

FIG. X4.2 (b) Sequence IIIE Data Log

Test Cell____________ Test No.____________
Engine No.____________ Oil Code ____________

Blowby (at Zero Crankcase Pressure)

Test Hours											
r/min											
KW (HP)											
Orifice Diameter											
ΔP kPa											
Temp. °C											
Barometer											
Observed L/min											
Correct Factor											
Corrected L/min											

Blowby (at Zero Crankcase Pressure)

Test Hours											
r/min											
KW (HP)											
Orifice Diameter											
ΔP kPa											
Temp. °C											
Barometer											
Observed L/min											
Correct Factor											
Corrected L/min											

Air to Fuel Ratio, Exhaust NOx (Exhaust or Blowby)

Test Hours											
Bank (R or L)											
Elect/Orsat											
Duty Cycle											
%CO_2(Uncorrected)											
% O2 (Uncorrected)											
%CO(Uncorrected)											
AFR CO_2											
AFR O_2											
Delta AFR											
Avg AFR											
NO_x											

Air to Fuel Ratio, Exhaust NOx (Exhaust or Blowby)

Test Hours											
Bank (R or L)											
Elect/Orsat											
Duty Cycle											
%CO_2(Uncorrected)											
% O2 (Uncorrected)											
%CO(Uncorrected)											
AFR CO_2											
AFR O_2											
Delta AFR											
Avg AFR											
NO_x											

FIG. X4.3 Supplemental Sequence IIIE Daily Log

Test Cell ________________ Test No. ________________

Engine No. ________________ Oil Code ________________

ENGINE HOURS	BREAK-IN	1	5	9	13	17	21	25	29	32	33	37	41	45	49	53	57	61	64
Blowby Rate																			
Air to Fuel Ratio Right & Left Bank	1*	1				1					1				1				1
Spark Plug Change																			
Engine Timing Check	2	2				2					2				2				2
Re-Torque Exhaust Manifold Bolts																			
NOx		1									1								
Dew Point		1									1								

1. Check during the last 30 minutes of the hour. For break-in samples, take measurement during the fourth hour break-in.

2. Check at the start of hour.

* Optional reading not to be used in maximum, minimum, and average computation.

FIG. X4.4 Sequence IIIE Operational Checklist

Laboratory:	EOT Date:
Test Number:	EOT Time:
Oil Code:	

OIL LEVEL AT END OF TIMING RUN: ________ mm, ________ ml

INITIAL FILL = 4 320 ml	END OF		TEST TIME								E.O.T.
	TMNG	BRKIN	8	16	24	32	40	48	56	64	TOTAL
1. Remove 472 ml Purge Sample	XXX										
2. Remove 472 ml Leveling Sample		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	
3. Remove 236 ml Analysis Sample	XXX									XXX	
4. Remove 59 ml Analysis Sample			XXX	XXX	XXX	XXX	XXX	XXX	XXX		
5. Replace 472 ml Purge Sample	XXX										
6. Add 236 ml to Replace Sample										XXX	
7. Add 59 ml to Replace Sample			XXX	XXX	XXX	XXX	XXX	XXX	XXX		
8. Add 472 ml New Oil		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
9. Oil Level After Draindown (mm)	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	
10. Leveling Sample Added (ml)		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	
11. Leveling Sample Discarded (ml)		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
12. Resulting Dipstick Level (mm)		XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	
13. Computed Oil Level* (ml)	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX
14. Performed By											

*Difference From Oil Level at End of Timing Run

Oil Consumption:

Total new oil added during Test Time (Item 8) - total discarded (Item 11) + level at E.O.T. (Item 13) = total amount of oil consumed during test ________ ml.

FIG. X4.5 Sequence IIIE Oil Sample, Level, and Consumption Worksheet

X5. SEQUENCE IIIE TEST RATING WORKSHEETS

X5.1 Rating worksheets are illustrated in Figs. X5.1-X5.4.

Sample No.: ______________ Test No.: ______________

Engine No.: ______________ Date Rated: ______________

Rater: ______________

Depth Scale	SITE 1	2	3	4	5	6	7	8	9	10	Total	Area %	Volume
Clean													
1/4													
1/2													
3/4													
A													
AB													
B													
BC													
C													
D													
E													
F													
G													
Grand Total													

Sludge Merit Rating ______________

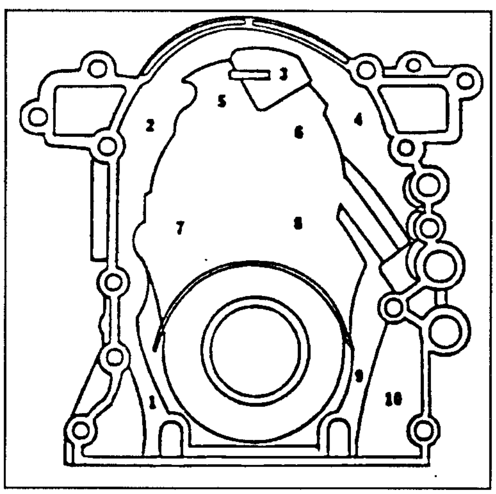


FIG. X5.1 Sequence IIIE Front Cover Rating Worksheet

Test Number:	EOT Date:
Rater:	Rating Date:

DEPTH	ROCKER COVER LEFT																				TOTAL	AREA	VOLUME
SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		%	
Clean																							
1/4																							
1/2																							
3/4																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
																				Grand Total			

Area = Total times 5

Sludge Merit Rating ____________________

DEPTH	ROCKER COVER RIGHT																				TOTAL	AREA	VOLUME
SCALE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		%	
Clean																							
1/4																							
1/2																							
3/4																							
A																							
AB																							
B																							
BC																							
C																							
D																							
E																							
F																							
G																							
																				Grand Total			

Area = Total times 5

Sludge Merit Rating ____________________

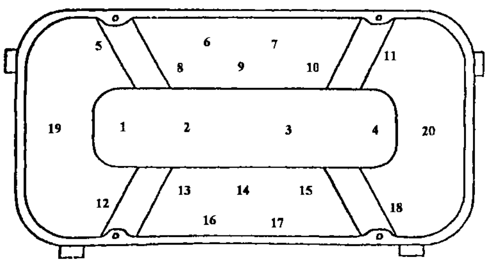


FIG. X5.2 Sequence IIIE Rocker Cover Sludge Worksheet

Engine No. ________

Depth Scale	Left										Total	Area %	Volume
	1	2	3	4	5	6	7	8	9	10			
Clean													
1/4													
1/2													
3/4													
A													
AB													
B													
BC													
C													
D													
E													
F													
G													
										Grand Total			

Sludge Merit Rating ________

Depth Scale	Right										Total	Area %	Volume
	1	2	3	4	5	6	7	8	9	10			
Clean													
1/4													
1/2													
3/4													
A													
AB													
B													
BC													
C													
D													
E													
F													
G													
										Grand Total			

Sludge Merit Rating ________

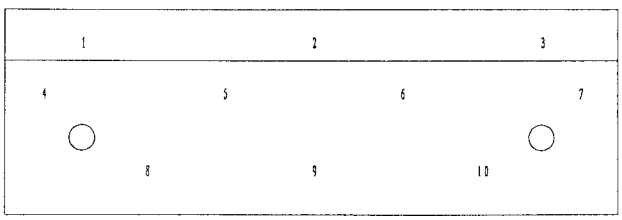


FIG. X5.3 Sequence IIIE Rocker Arm Cover Raffle Sludge Rating Worksheet

RATED BY: ______________ DATE: ____________

ENGINE: ______________ TEST NO.: ________

OIL CODE: ________

OIL LAND

Part	Area	Rate	Merit
1			
2			
3			
4			
5			
6			

FIG. X5.4 Sequence IIIE Oil Land Rating Worksheet