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Designation: D 5844 – 98

An American National Standard

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Test Method for Evaluation of Automotive Engine Oils for Inhibition of Rusting (Sequence IID)[1]

This standard is issued under the fixed designation D 5844; 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.

1. Scope

1.1 This test method covers a laboratory engine test procedure, utilizing a 1977 350 in.[3] displacement (5.7 L) Oldsmobile V-8 engine. The procedure, using leaded gasoline, evaluates the rust inhibition characteristics of engine oils. The test method was designed to relate particularly to short-trip service under typical winter conditions in the upper midwestern United States. The procedure has been correlated with vehicles, using leaded gasoline, in that type of service and prior to 1978,[2] particularly with regard to rusting. It is one of the test methods required to evaluate oils intended to satisfy the API SJ category.[3]

1.2 Information Letters are published occasionally by the ASTM Test Monitoring Center[4] (see Appendix X1) to update the test method. Copies of these letters can be obtained by writing the Center.

1.3 The method may not be applicable for the evaluation of engine oils if unleaded gasoline is used.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.5 *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.* See Note 1, Note 2, Note 3, Note 6, Note 7, Note 8, Note 9, Note 10, Note 11, Note 14, and Note 15.

1.6 A Table of Contents 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.

Current edition approved April 10, 1998. Published November 1998.

. Originally published as D 5844 – 95. Last previous edition D 5844 – 97.

[2] Available from ASTM in Special Technical Publication (STP) 3151 (Part 1). Also available from the Society of Automotive Engineers (SAE) as Technical Paper No. 780931. The SAE address is 400 Commonwealth Drive, Warrendale, PA 15096.

[3] Information available from the American Petroleum Institute (API) in its publication API1509 Engine Oil Licensing and Certification System. The API address is 1220 L Street, NW, Washington, DC 20005.

[4] Until the next revision of this test method, the ASTM Test Monitoring Center will update changes in the test method by means of Information Letters; these can be obtained from the ASTM Test Monitoring Center, 6555 Penn Ave., Pittsburgh, PA 15206-4489. Attention: Administrator. This edition incorporates revisions in all Information Letters through No. 97–1.

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2. Referenced Documents

2.1 *ASTM Standards:*

D 2982 Test Methods for Detecting Glycol-Base Antifreeze in Used Lubricating Oils[5]

D 4175 Terminology Relating to Petroleum, Petroleum Products, and Lubricants[5]

D 4863 Test Method for Determination of Lubricity of Two-Stroke-Cycle Gasoline Engine Lubricants[6]

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[6]

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications[7]

E 1119 Specification for Industrial Grade Ethylene Glycol[8]

G 40 Terminology Relating to Wear and Erosion[9]

2.2 *Coordinating Research Council:*

CRC Rust Rating Manual No. 7[10]

3. Terminology

3.1 *Definitions:*

3.1.1 *blind reference oil*, *n*—a reference oil, the identity of which is unknown by the test facility.

3.1.1.1 *Discussion*—This is a coded reference oil which is submitted by a source independent from the test facility. **(Sub. B Glossary)**[11]

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

3.1.3 *candidate oil*, *n*—an oil which is intended to have the performance characteristics necessary to satisfy a specification and is to be tested against that specification. **(Sub. B Glossary)**

3.1.4 *clogging*, *n*—the restriction of a flow path due to the accumulation of material along the flow path boundaries. **(Sub. B Glossary)**

3.1.5 *corrosion*, *n*—the chemical or electrochemical reaction between a material, usually a metal surface, and its environment that can produce a deterioration of the material and its properties. **(Sub. B Glossary)**

3.1.6 *non-reference oil*, *n*—any oil other than a reference oil; such as a research formulation, commercial oil or candidate oil. **(Sub. B Glossary)**

3.1.7 *nonstandard test*, *n*—a test that is not conducted in conformance with the requirements in the standard test method; such as running on an uncalibrated test stand, using different test equipment, applying different equipment assembly procedures, or using modified operating conditions. **(Sub. B Glossary)**

3.1.8 *operationally valid standard test*, *n*—*in automotive lubricant testing*, a standard test that meets operational validity requirements, where specified.

3.1.8.1 *Discussion*—Operational validity is determined after a test is completed. Requirements can include (*1*) mid-limit ranges for the average values of primary and secondary parameters that are narrower than the specified control ranges, (*2*) allowable deviations for primary and secondary parameters from the specified control ranges, (*3*) downtime limitations, and (*4*) special parameter limitations.

[5] *Annual Book of ASTM Standards*, Vol 05.02.

[6] *Annual Book of ASTM Standards*, Vol 05.03.

[7] *Annual Book of ASTM Standards*, Vol 14.02.

[8] *Annual Book of ASTM Standards*, Vol 15.05.

[9] *Annual Book of ASTM Standards*, Vol 03.02.

[10] Available from the Coordinating Research Council, Inc., Perimeter Center Pkwy., Atlanta, GA 30346.

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

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

3.1.9.1 *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. **(Sub. B Glossary)**

3.1.10 *rust, n—of ferrous alloys*, a corrosion product consisting primarily of hydrated iron oxides. **(Sub. B Glossary)**

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

3.1.12 *scuff, scuffing, n— in lubrication*, damage caused by instantaneous localized welding between surfaces in relative motion which does not result in immobilization of the parts. **(Test Method D 4863)**

3.1.13 *sludge, n—in internal combustion engines*, a deposit, principally composed of insoluble resins and oxidation products from fuel combustion and the lubricant, that does not drain from engine parts but can be removed by wiping with a cloth. **(Test Method D 5302)**

3.1.14 *standard test, n*—a test on a calibrated test stand, using the prescribed equipment that is assembled according to the requirements in the test method, and conducted according to the specified operating conditions. **(Sub. B Glossary)**

3.1.15 *stuck lifter, n— in internal combustion engines*, a lifter plunger that does not return to its original position by its own force upon removal from the engine.

3.1.16 *varnish, n—in internal combustion engines*, a hard, dry, generally lustrous deposit that can be removed by solvents but not by wiping with a cloth. **(Test Method D 5302)**

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

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *test start, n*—the phrase denoting the installation of test oil into the engine.

4. Summary of Test Method

4.1 *Test Oil and Fuel Requirements*:

4.1.1 Approximately 2 gal (7.6 L) of test oil are required.

4.1.2 Approximately 120 gal (454 L) of test fuel are required.

4.2 *Test Stand Calibration*—Calibration is required and is achieved by the laboratory running reference oils supplied by the ASTM Test Monitoring Center (see Annex A1 for details).

4.3 *General Procedure*:

4.3.1 Prior to each test, the engine is completely disassembled, solvent cleaned, measured, and rebuilt in strict accordance with all furnished specifications.

4.3.2 Following this preparation, the engine is installed on a dynamometer test stand equipped with the appropriate accessories for controlling speed, load, and various other engine operating conditions.

4.3.3 The engine is operated continuously for 28 h under conditions of moderate engine speed, partially warmed-up jacket coolant temperature, and rich air-to-fuel ratio. The engine is then operated an additional 2 h at a slightly elevated jacket coolant temperature, with all other conditions unchanged.

4.3.4 After the 30 h of operation, the engine is shutdown for 25 min. During this period, spark plugs are changed, and adjustments made to the cooling system controls.

4.3.5 The engine is then operated for an additional 2 h under conditions of relatively high speed and jacket coolant temperature, and lean air-to-fuel ratio.

4.3.6 The engine is then disassembled, and specified parts visually rated to determine the extent of corrosion formed.

5. Significance and Use

5.1 Rust ratings from this test method indicate the tendency of an oil to permit the formation of corrosion products that can interfere with hydraulic valve lifter operation, or any other close tolerance engine parts, as well as contribute to general wear problems.

5.2 The test method is used in various engine oil specifications.

5.3 The test results are significant only when all details of the procedure are followed, and operationally valid criteria are documented.

6. Apparatus

6.1 The test engine is a 350-in.^{3} (5.7-L displacement) Oldsmobile V-8 engine with an 8.5:1 compression ratio and equipped with a two-barrel carburetor.[12]

6.2 The engine is mounted on a test stand and connected to a dynamometer capable of absorbing 100 hp (74.6 kW) at a speed of 3600 r/min.

6.3 An external cooling system is required for the engine, with a pumping system capable of delivering 60 gal/min (3.79 L/s) (see Annex A2 for details).

6.4 An external cooling system is required for the jacketed rocker cover, intake manifold crossover, and breather tubes. This system controls coolant flow, pressure, and temperature in these engine parts (see Annex A3 for details).

6.5 An external oil cooling system is required which includes a positive displacement pump and a heat exchanger (see Annex A4 for details).

6.6 Suitable air treatment equipment is required to maintain the carburetor intake air at constant moisture content and temperature (see 9.3).

6.7 A flushing tank is required to premix and circulate the cleaning agents (see Annex A5 for details).

6.8 A mixing tank is required to premix the glycol and water coolant (see Annex A6 for details).

6.9 A suitable pressurized fuel delivery system is required (see Annex A7 for details).

7. Reagents and Materials

7.1 *General Cleaning Agents*—The following have been found satisfactory:

7.1.1 Aliphatic naphtha with a 300 to 400°F (149 to 204°C) boiling point.

[12] Test engines and various other parts available from the Central Parts Distributor, Bowden Manufacturing Corp., 4590 Beidler, Willoughby, OH 44094.

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NOTE 1—**Warning:** Combustible. Health hazard.

7.1.2 *Oakite 811*. [13]

NOTE 2—**Warning:** Combustible. Health hazard.

7.1.3 *Oakite 77*. [13]

7.1.4 *Oakite Rust Stripper—O.F*. [13]

NOTE 3—**Warning:** Health hazard.

NOTE 4—**Caution:** Some of the Oakite products listed in 7.1.2 to 7.1.4 are alkaline agents used to clean the engine coolant jacket and necessitate that all aluminum or galvanized materials be removed from contact with the cleaning agent.

7.2 *Organic Solvent*—Organic cleaning solution having a composition of:

ethyl acetate	37.5 % volume
denatured alcohol (No. 30)	27.5 % volume
butyl alcohol	5.0 % volume
tetrahydrofuran (THF)	30.0 % volume

7.2.1 The THF used shall meet the following specifications: 99.5 + % THF, inhibited with 0.025 % butylated hydroxy toluene (BHT), and less than 0.03 % water. Aldrich Chemical Co. THF,[14] catalog number 14722-2, has been found satisfactory. The BHT inhibitor limits the potential explosive hazard of THF upon drying.

NOTE 5—**Warning:** Flammable (alcohols). Denatured alcohol cannot be made nontoxic. Health hazard.

NOTE 6—**Warning:** Combustible (THF). Health hazard.

7.3 *Engine Coolant*—The engine coolant and the rocker cover and breather tube coolant (see Annex A9) consist of a mixture of 40 ± 1 % volume ethylene glycol meeting Specification E 1119 for industrial grade ethylene glycol,[15] and 60 ± 1 % volume distilled water, to which is added 0.25 pt/gal (31.25 mL/L) Pencool 2000 coolant additive.[16]

NOTE 7—**Warning:** Combustible (ethylene glycol). Health hazard.

7.3.1 Only the materials from the stated supply sources have been found satisfactory.

7.4 *Test Fuel*—The test fuel is certified GMR 995 gasoline.[17]

NOTE 8—**Warning:** Flammable. Health hazard.

7.4.1 Care shall be taken by purchasers of GMR 995 gasoline that all tanks used for transportation and storage are adequately cleaned before being filled with the test fuel.

7.5 *Sealing Compounds*:

7.5.1 *Perfect Seal No. 4 Sealing Compound*, [18] (Part No. 1050026).

7.5.2 No. 2 Non-Hardening Permatex.[19]

7.5.3 3M Super Weatherstrip Adhesive[20] (Part No. 051135-08001).

7.5.4 *Anti-Seizure Compound*, such as Fel-Pro C-100[21] or EM Lubricants Inc. CP-29 Spray or can.[22]

7.6 *Engine Assembly Oil*—Engine Test Assembly Fluid, EF 411[23] (Part No. 47503-8).

7.7 *Reference Oils*—Can be purchased from the ASTM Test Monitoring Center.[4] Send inquiries to the attention of the operations manager (see Annex A1).

7.8 *Rust Remover*—The composition of the rust remover is as follows:

Phosphoric acid (85 % concentrate)	20 % by volume
Denatured alcohol	40 % by volume
Distilled water	40 % by volume

NOTE 9—**Warning:** Corrosive (phosphoric acid). Health hazard.

8. Preparation of Apparatus

8.1 *Laboratory Ambient Condition*:

8.1.1 Air from fans or a ventilation system should not be permitted to blow directly on the test engine.

8.1.2 Do not use heat lamps or insulation for temperature control.

8.1.3 The ambient laboratory atmosphere should be relatively free of contaminants.

8.1.4 It is recommended that the atmosphere in the engine buildup areas be filtered and controlled for temperature and humidity to minimize accumulation of dirt or rust on engine parts.

8.1.4.1 Uniform temperature control also aids in measuring and selecting parts for assembly.

8.1.5 Engines assembled in a controlled environment area and moved to a non-controlled storage area, should be protected so moist air cannot enter the engine and promote pretest corrosion.

8.2 *Assembling the Test Engine*:

8.2.1 *General Information*:

8.2.1.1 Use standard General Motors service parts and buildup procedures as outlined in the 1977 Oldsmobile Parts Book and the Service Manual[23] unless special or modified parts or procedures are specified. Make pertinent measurements of the cylinders, pistons, journals, bearings, and valve train to ensure conformance to the test method's specifications.

[13] Oakite materials are available from Oakite Products, Inc., 50 Valley Rd., Berkeley Heights, NJ 07922. However, when ordering Oakite Rust Stripper, specify Oakite Rust Stripper O.F., and order from Wrico Corp., 4835 Whirlwind, San Antonio, TX 78217.

[14] THF is available from Aldrich Chemical Co., 1001 W. St. Paul Ave., Milwaukee, WI 53233.

[15] Available from Chemcentral, 1107 E. Southcross, San Antonio, TX 78223.

[16] The sole source of supply of Pencool 2000 known to the committee at this time is The Penray Companies, Inc., 1801 Estes Ave., Elk Grove, IL 60007. If you are aware of alternative suppliers, please provide this information to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

[17] Direct purchase orders to Phillips 66 Oil Co., Philter Marketing Service, P.O. Box 968, Borger, TX 79008.

[18] Order part No. 1050026 (available in 40 oz, pt, or gal containers) from Allied Technology, Inc., P.O.B. Sealants Division, 11102 Kenwood Rd., Cincinnati, OH 45242.

[19] Available from local distributors of Permatex products. Contact Permatex Co., Inc., (Loctite Corp.), 18731-T Cranwood Pkwy., P.O. Box 7183, Cleveland, OH 44128, for distributor names in your locality.

[20] Order part No. 051135-08001 from Minnesota Mining and Manufacturing Co., AC & S Division, Dept. TR, 3M Center 223-6 N.E., St. Paul, MN 55101.

[21] Available from Fel-Pro, Inc., 7450 N. McCormick Blvd., Skokie, IL 60076. Also available from E/M Lubricants, Inc., 6940 Farmdale, N. Hollywood, CA 91605.

[22] Refer to Engine Test Assembly Fluid, EF 411 No. PN 47503-8 when ordering from Mobil Oil Corp., Illinois Order Board, P.O. Box 66940, AMF-O'Hare, IL 60666.

[23] Available from local General Motors Corp. dealers.

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8.2.1.2 To avoid contamination of rated surfaces (hydraulic valve lifters, oil pump relief valve, and pushrods), handle these engine parts with gloved hands at all times, particularly during assembly as well as at the end of the test.

8.2.1.3 Sealing compound application information is detailed in Annex A9.

8.2.1.4 Fastener torque specifications and torquing procedures are detailed in Annex A10.

8.2.1.5 The classification of engine test parts is provided in A11.1.

8.2.1.6 Procurement and usage of engine test parts are discussed in A11.2.

8.2.1.7 New parts required for each test are shown in Annex A11.3 .

8.2.1.8 Parts replaced as necessary are shown in Annex A11.4 .

8.2.2 *Clean All Engine Parts*:

8.2.2.1 Before using a new block, physically remove all slag and sand deposits contained in the water jacket with a sharp-ended 0.25-in. (6.4-mm) diameter drill rod.

8.2.2.2 Tap the oil filler tube hole with a ¾-in. NPT tap.

8.2.2.3 Whether using a new or used block, remove the crankshaft, main bearings, camshaft bushings, and oil gallery plugs.

8.2.2.4 Clean block by applying Oakite 811 to cylinder walls, and other areas, with a paint brush. **Do not submerge the block in Oakite 811. Do not allow the Oakite 811 to enter the engine jacket cooling areas.**

8.2.2.5 Remove the Oakite 811 by spraying with aliphatic naphtha that has a boiling point between 300 to 400°F (149 to 204°C). Blow dry with air.

8.2.2.6 Care should be taken to prevent the attack of nonferrous materials when using Oakite 811.

8.2.2.7 An alternate method of cleaning the block is to immerse it in a heated chloroethane VG (inhibited 1,1,1, trichloroethane) bath. In this case, the cleaning solution can be circulated through the oil passages to ensure removal of deposits.

8.2.2.8 If a heated bath or approved pressure washing system is used, clean all parts afterwards using Oakite 811 and aliphatic naphtha. Allow block to cool before performing further assembly steps.

8.2.2.9 Degrease all other engine parts in either a heated bath; or brushing with Oakite 811, followed by spraying with aliphatic naphtha.

8.2.2.10 Immediately after cleaning, oil all parts except the block, using EF-411 fluid.

8.2.3 *Cylinder Block Preparation*:

8.2.3.1 Install a solid plug (Part No. 22527020) in the rear oil gallery. Some engines may already have this modification.

8.2.3.2 Replace the freeze plugs. A helpful tool for this purpose is shown in print RX-117622-B.

8.2.3.3 Prestress the block before honing:

(*a*) The honing adapter plate, shown in print RX-117520-D, is required. The RX prints are available through the TMC.

(*b*) Use new head gaskets (Part No. 12355889) with the adapter plate each time an engine block is honed. Since these same head gaskets are to be used for engine assembly, they should be marked *right* and *left* so that they can be installed in exactly the same way they were positioned during honing.

(*c*) Use special bolts (Part No. 9409054) in connection with washers, as shown in print RX-117636-A, to bolt the honing adapter plate to the engine block. Torque these bolts in the same sequence as indicated in the 1977 Oldsmobile Service Manual (Fig. 6A3-29). Torque the bolts three times: first, at 100 lbf·ft (136 N·m), second at 110 lbf·ft (149 N·m), and third a repeat at 110 lbf·ft (149 N·m).

8.2.3.4 Hone The Cylinder Walls:

(*a*) Sunnen CK-10 or Sunnen CV-616[24] honing machines have been found suitable.

(*b*) The appropriate machine setup is as follows:

	CK-10	CV-616
spindle speed	155 r/min	170 r/min
stroke rate	46 strokes/min	57 strokes/min
feed ratchet	3 or 30 tooth gear	2 or 3

(*c*) These speeds and stroke rates provide the required 30 to 40° maximum cross-hatch pattern. Equip the honing machine with a fiber mat, part CV-1100.

(*d*) The flow rate of the honing lubricant (Sunnen CK-50[24]) should be controlled at 2 gal/min (0.13 L/s).

(*e*) 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; clean honing stones or guides only with honing fluid.

(*f*) The cylinders should be honed without main bearings, but with all main bearing caps in place and torqued. Bearing caps Nos. 1 through 4 should be torqued to 80 lbf·ft (108 N·m), and No. 5 should be torqued to 100 lbf·ft (136 N·m).

(*g*) The following stones and resulting finish are recommended:

	Roughening	Finishing
stone	JHU 525[24]	JHU 820[24]
microfinish (AA)	0.51 to 0.76 µm (20 to 30 µin.)	0.23 to 0.28 µm (9 to 11 µin.)

NOTE 10—Once the meter readings have been established which will produce the above micro-inch finishes using a particular honing machine, it is recommended that those same meter readings be used with that machine for future honing jobs.

(*h*) Hone the cylinder walls so that no more than 0.0004 in. (0.010 mm) difference exists at any point of measurement in the piston ring travel area. Essentially zero taper should also exist in this area.

(*i*) *Do not bore cylinder blocks oversize*.

(*j*) After honing, clean the engine block again using Oakite 811 and aliphatic naphtha only.

8.2.4 *Install Main Bearings*:

8.2.4.1 Use production main bearings. Bearings can be reused.

8.2.4.2 Use Plastigage to check bearing clearances. Numbers 1 through 4 main bearing clearances should be 0.0005 to 0.0021 in. (0.0127 to 0.0533 mm), and the rear main bearing clearance should be 0.0015 to 0.0031 in. (0.0381 to 0.0787 mm). Undersize bearings in steps of 0.0005 in. (0.0127 mm) are available to obtain the specified clearances.

[24] Available from Sunnen Products Co., 7910 Manchester Ave., St. Louis, MO 63143.

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8.2.4.3 Crankshaft end play should be between 0.004 and 0.008 in. (0.102 and 0.203 mm).

8.2.4.4 Torque bearings Nos. 1 through 4 to 80 lbf·ft (108 N·m), and bearing No. 5 to 100 lbf·ft (136 N·m).

8.2.5 *Piston Fitting and Numbering*:

8.2.5.1 Fit pistons to cylinders as described in the Oldsmobile Service Manual (page 6A3-24 (Fig. 6A3-53)).

8.2.5.2 The maximum permissible cylinder wall-to-piston clearance is defined as a fit resulting in a 3-lb (13.3-N) pull with a 0.005-in. (0.127-mm) gage.

8.2.5.3 Use only the specified pistons and piston ring set; Central Parts Distributor[12] (CPD) parts BX-214-1 and BX-215-1, respectively.

8.2.5.4 Number 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 at the cylinders).

8.2.5.5 Take extreme care when installing the connecting rods on the piston wrist pins in order to avoid piston pin distortion, to ensure proper connecting rod to piston pin alignment, and to allow the rod to move freely.

8.2.6 *Adjust Piston Ring End Gaps*:

8.2.6.1 For a laboratory setting up this test for the first time, and using a new engine, it is recommended that a top and second end ring gap (suggest using ring gap feeler gage,[25] Part No. X467X) of 0.022 and 0.020 in. (0.56 and 0.51 mm) respectively. The compression ring gaps can be modified in subsequent tests to assist in controlling blowby rates.

8.2.6.2 A Sanford SG-48 Ring Grinder,[26] or a manufactured ring grinder (see prints RX-116728-C through 116733-A, 116933-E through 116949-A, 116951-A through 116957-A, and 117052-C, 117506-B, and 117507-B) is helpful in grinding the ring ends to obtain a square-edged gap.

8.2.6.3 To measure ring end gaps, position rings in the appropriate cylinder bore using a piston ring depth gage (print RX-117329-B). Remove any burrs from the rings with a fine stone prior to installation.

8.2.7 *Install Connecting Rod and Piston Assemblies in the Cylinders*:

8.2.7.1 Oil cylinder walls with EF 411 oil and wipe with a clean, soft cloth. Repeat process until there are no honing or grinding particles left on the cloth. Change cloths frequently. As the final step, re-oil the cylinder walls with EF 411.

8.2.7.2 Use a piston ring expander tool for installing the piston rings. A Perfect Circle 4.0625 ring expander tool[27] (Part No. P401-K) has been found satisfactory for this purpose.

8.2.7.3 Align piston rings as described on print RX-117372-C prior to installing the pistons in the cylinders.

8.2.7.4 Use a Snap-on ring compressor tool (RC-40C or equivalent) to compress the rings, and slide the connecting rod and piston assemblies carefully into the correct cylinders.

8.2.8 *Install Connecting Rod Bearings*:

8.2.8.1 Use connecting rod bearings, Part No. 18008494. Bearings can be reused.

8.2.8.2 The bearing clearance shall be between 0.0004 and 0.0033 in. (0.010 and 0.084 mm).

8.2.8.3 The side clearance shall be between 0.006 and 0.020 in. (0.152 and 0.508 mm).

8.2.8.4 Bolts on Nos. 5 and 6 connecting rods shall be no longer than 2.375 in. (60.33 mm).

8.2.9 *Install Camshaft*:

8.2.9.1 Modify the front camshaft bearing (Part No. 12339842) as shown in print RX-118211-C. The machined groove from the oil hole to the front edge of the bearing provides an oil feed to the thrust washer.

8.2.9.2 When camshaft bearings are replaced, a Burroughs cam bearing installation tool[28] (Part No. BT6409, or equivalent) is recommended.

8.2.9.3 Remove any nicks, burrs, or ridges on the thrust face of the camshaft (Part No. 562299) by light filing. *Do not machine the surface nor remove significant material, as this may alter the thrust face to lifter dimension.*

8.2.9.4 A thrust washer as shown on print RX-118213-A is required between the thrust surfaces of the camshaft and the block. A thrust washer can be used more than once, if in good condition; however, if reused, position the same side of the thrust washer toward the block as previously.

8.2.9.5 Replace the camshaft timing gear (Part No. 381263) at least every second test.

8.2.9.6 Modify the camshaft gear bolt as shown in print RX-117228-A.

8.2.9.7 A timing gear oil deflector and washer are required as shown on prints RX-118306-A and RX-117464-A.

8.2.10 *Install Harmonic Balancer and Oil Slinger*:

8.2.10.1 Deburr the harmonic balancer keyway slot and the slot on the crankshaft with a mill file, and modify as shown in print RX-118317-B. The inside diameter of the bore on the harmonic balancer can be reamed to 1.50 in. (38.1 mm) to facilitate installation and removal. The harmonic balancer should also be checked to ensure that no slippage has occurred between the hub and the outer flange.

8.2.10.2 The production oil slinger (Part No. 382572) may not provide sufficient clearance between the front cover and the harmonic balancer. An additional spacer washer as shown in print RX-117382-A can be used to shim the harmonic balancer out from the front cover.

8.2.11 *Install the Engine Front Cover and Seal*:

8.2.11.1 Replace the front cover and water pump assembly with the front cover shown in print RX-117224-D.

8.2.11.2 Use the production front seal (Part No. 552711), and this can be installed using a seal driver shown in print RX-117370-B.

8.2.11.3 Attach the front cover oil deflector, shown in print RX-117319-B, to the front cover.

8.2.11.4 Use the production front cover gasket (Part No. 22547856).

[25] Part No. X467X, with a range of 0.508 to 1.27 mm (0.020 to 0.050 in.) by 0.0259 mm (0.001 in.) increments, available from Sterling Supply Co., 1220 East Nine Mile Rd., Ferndale, MI 48220.

[26] Sanford SG-48 (with Oldsmobile 350 head) can be ordered from Sanford Manufacturing Co., P.O. Box 318, Roselle, NJ 07203.

[27] The following Perfect Circle tools and seals: 4.0625 in. ring expander tool (Part No. P401-K), valve stem seals (Part No. 55A397), and valve stem seal installation tool (Part No. 55A396) are available from Engine Products Division, Dana Corp., P.O. Box 1166, Richmond, IN 47374.

[28] Available from Burroughs Tool and Equipment Co., 2429 N. Burdick St., Kalamazoo, MI 49002.

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8.2.12 *Timing Mark Indicator*:

8.2.12.1 Modify the timing mark indicator in accordance with print RX-118318-A.

8.2.12.2 Dowel the indicator to the front cover to ensure proper alignment.

8.2.13 *Install Oil Pump*:

8.2.13.1 Use a new oil pump for each test. Pumps are available (Part No. BX-211-1 or BX-211-2) through the Central Parts Distributor,[12] and are supplied with all necessary hardware, excluding the relief valve. *Use no abrasive materials during cleaning, and do not make modifications to any part of the assembly*.

8.2.13.2 The oil pump relief valve is available from the CPD (Part No. BX-201-1). *Use the valve as received with no modifications to the surface finish.*

8.2.13.3 Wash the valve with aliphatic naphtha and oil with EF 411 prior to installation.

8.2.13.4 The cleaned valve should have a numerical rating of 9.7 using the Coordinating Research Council (CRC) Rating Manual No. 7.

8.2.13.5 The oil pump relief valve spring can be stretched or trimmed to vary oil pressure. Up to three coils can extend beyond the housing with the relief valve seated.

8.2.14 *Install Dipstick Tube*:

8.2.14.1 Install a dipstick tube using a driver conforming to print RX-117348-B. Check the position of the tube with a gage shown in print RX-117326-B. Note position at cylinder head for manifold clearance.

8.2.14.2 No dipstick is used for the test. Use a dipstick tube cap, shown in print RX-117349-A, during the test.

8.2.15 *Oil Pan*—Modify the oil pan (Part No. 555137) as shown on print RX-118305-D.

8.2.15.1 Install the special oil pan baffle shown on print RX-118332-B.

8.2.16 *Cylinder Head Preparation*:

8.2.16.1 Deburr all mating surfaces of the cylinder heads to the block and manifolds with a 12-in. (30.5-cm) smooth file to ensure gasket seating.

8.2.16.2 Machine the outside diameter of all valve guides to 0.531 ± 0.007 in. (13.49 ± 0.18 mm) using a valve guide cutter.[29]

(*a*) Machine the guides until the cutter touches the top of the guides (approximately 0.38 in. [9.53 mm]). *Do not machine the top of the guide*.

(*b*) Be sure that the guides are machined all around (360°) and have no nicks or grooves.

(*c*) Use an 11⁄32-in. (8.73-mm) pilot with the cutting tool. *Check the pilot periodically for wear*. No excessive clearance should exist between the pilot and the valve bores.

8.2.16.3 Thoroughly clean cylinder heads with Oakite 811 solvent, followed by spraying with aliphatic naphtha, and air-blow dry.

8.2.16.4 Install the cup-type freeze plugs (Part No. 380254) on the cylinder heads. A driver that facilitates the installation is shown on print RX-117377-A.

8.2.16.5 All valves should be lightly lapped with fine grit lapping compound to improve seating (before seals are installed).

8.2.16.6 Use new valve stem seals (Part No. BX-216-1)[12] for 11⁄32-in. (8.73-mm) diameter valve stems on both intake and exhaust valves.

8.2.16.7 Install the seals using the plastic shields, to protect the seals from damage, and an installation tool (Part No. 53A396),[27] to ensure proper seating.

8.2.16.8 Use Part No. BX-213-1[12] valve springs. These springs are protected with red oxide primer by the manufacturer.

8.2.17 *Valve Lifters*:

8.2.17.1 Do not remove the oil in the hydraulic valve lifters[12] (Part No. BX-202-1).

8.2.17.2 Oil the lifter bodies with EF-411 oil prior to installation.

8.2.17.3 Number the left bank lifters with odd numbers from front to rear, and the right bank with even numbers from front to rear.

8.2.18 *Pushrods*:

8.2.18.1 Use the pushrods[12] (Part No. BX-210-1) as received from the CPD.

8.2.18.2 Clean the pushrods with aliphatic naphtha, air-dry, and oil with EF-411 oil prior to installation.

8.2.19 *Rocker Arm Pivots*:

8.2.19.1 Use rocker pivots (Part No. 391208) for cylinder numbers 1, 2, 7, and 8.

8.2.19.2 Use rocker pivots (Part No. BX-221-1) for cylinders 3, 4, 5, and 6.

8.2.20 *Rocker Cover Deflectors*:

8.2.20.1 Use four stud-type bolts (Part No. 556931) for mounting the rocker cover deflector stanchions shown on print RX-117288-A.

8.2.20.2 Attach the rocker cover deflectors shown on print RX-117289-B, (modified) to the stanchions using the specified bolts (Part No. 388708).

8.2.21 *Intake Manifold*:

8.2.21.1 Modify the intake manifold crossover, as shown on prints RX-118315-D, RX-117813-A and RX-118316-A, to permit the circulation of coolant per print RX-117928-C.

8.2.21.2 Plug the heater water outlet hole located at the right rear corner and the temperature sensor hole on the left front corner.

8.2.21.3 Remove the choke stove from the manifold, and install a plate conforming to print RX-117813-A using a gasket (Part No. 382709).

8.2.21.4 Deburr all mating surfaces of the intake manifolds to cylinder heads with a 12-in. (30.5-cm) smooth file to ensure gasket seating.

8.2.21.5 Use special intake manifold gaskets[12] (Part Nos. BX-204-1 [left] and BX-205-1 [right]).

8.2.22 *Rocker Cover, Spacers and Gaskets*:

8.2.22.1 Install rocker cover spacer-to-head gaskets[30] (Part No. 393573) on the cylinder heads using Perfect Seal No. 4 Sealing Compound.

[29] TRW No. VP-503 for 11⁄32 in. can be ordered from TRW Valve Division, 8001 E. Pleasant Valley, Cleveland, OH 44131. Also available as Crane No. 97017 for 11⁄32 in. from Crane Cams, Inc., 100 N.W. 9th Terrance, Hallandale, FL 33009.

[30] These gaskets are manufactured semiannually (order cut-off dates are January 1 and July 1). Order from Crotty Corp., 848 W. Chicago, Quincy, MI 49082.

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8.2.22.2 Attach rocker cover spacers conforming to print RX-118304-D to the head using 0.875 in. (22.2 mm) ¼ by 20 socket head cap screws coated with 3M Super Weatherstrip Adhesive.

8.2.22.3 Install the cork rocker cover gasket (Part No. 573396) on the rocker cover side of the spacer with 3M Super Weatherstrip Adhesive.

8.2.23 *Water Inlet Adapter*:

8.2.23.1 Use a water inlet adapter conforming to that shown on print RX-118315-D and in conjunction with a gasket (Part No. 382927).

8.2.23.2 Quick disconnect full-opening fittings[31] such as shown on prints RX-118137-C and RX-118136-A can also be used.

8.2.24 *Breather Tube*—Attach a breather tube (Part No. BX-212-1), available from the CPD, to the front cover using a gasket (Part No. 555765).

8.2.25 *Thermostat Housing*—Replace the thermostat housing with a coolant outlet adapter (fabricated from copper or black iron), using a gasket (Part No. 22547855), and with a suitable connection as on print RX-117261-A.

8.2.26 *Fuel Pump and Eccentric*:

8.2.26.1 Remove and replace the fuel pump with a plate conforming to print RX-117262-A, and use a gasket (Part No. 22505998).

8.2.26.2 Remove and replace the eccentric with a deflector and washer as on prints RX-118306-A and RX-117464-A, respectively.

8.2.27 *Oil Filter Housing*:

8.2.27.1 Separate the oil filter housing from the engine by an oil filter block conforming to print RX-117227-A.

8.2.27.2 Use gaskets (Part No. 382455, two required), and Perfect Seal No. 4 Sealing Compound.

8.2.28 *Oil Sample Line*—Remove the oil pressure sensing element located in the front-left corner of the cylinder block, and add suitable plumbing to permit the removal of oil samples. *The oil sample line length should be held to a minimum.*

8.2.29 *Ignition System*:

8.2.29.1 High energy ignition wire capable of withstanding moisture and high temperature is required. Delco part 378E, or equivalent, is satisfactory.

(*a*) Use an acceptable spark plug boot removal tool[32] (Part Nos. OTC 7078 or BT 7604) to remove the ignition wires from the spark plugs.

8.2.29.2 Check the distributor (Part No. 1103259) on a distributor tester before installing in the engine.

(*a*) Disable the mechanical advance mechanism by tack welding the advance weights so that no motion is possible.

8.2.29.3 Disconnect the vacuum advance unit by removing the vacuum hose and plugging the vacuum source at the carburetor, shown on print RX-118319-D.

8.2.29.4 Use AC spark plugs (Part No. R46SZ).

(*a*) Install new spark plugs prior to test startup and at the 30 h shutdown.

(*b*) Gap spark plugs with a wire gage to 0.060 in. (1.52 mm).

8.2.30 *Carburetor*—Use a duty cycle controlled carburetor (Part No. 17111526) to control air to fuel ratio.

8.2.30.1 Obtain a carburetor adapter plate (Part No. BX-260-1) and model 555 timer (Part No. BX-150-1) from the CPD.

8.2.30.2 Carburetor settings and build guidelines can be obtained from GM NAO Research and Development Center.[33]

8.2.30.3 Disassemble, clean and rebuild carburetors prior to each sixth test, or more often if air to fuel ratio control becomes a problem.

8.2.31 *Accessory Drive Units—Use no external drive units*, including alternators, generators, fuel pumps, power steering units, air pumps, etc.

8.2.32 *Exhaust Manifolds*:

8.2.32.1 Use the left exhaust manifold (Part No. BX-209-1) on both banks.

8.2.32.2 Deburr all mating surfaces of the exhaust manifolds to cylinder heads with a 12-in. (30.5-mm) smooth file to ensure gasket seating.

8.2.32.3 The recommended method for connecting the exhaust pipes to the manifolds is shown on print RX-117284-A.

8.2.32.4 Locate pressure taps for exhaust back pressure and exhaust gas analysis in each manifold as shown on print RX-117286-C.

8.2.32.5 Stainless steel bolts, ⅜ by 16 and 1.25-in. (31.8-mm) long, can be used to fasten the exhaust manifolds to the engine.

NOTE 11—**Caution:** Exhaust manifolds can warp during engine operation. The sealing surfaces may be reground flat several times to increase utilization of the manifolds.

8.2.33 *Engine Flywheel and Guards*:

8.2.33.1 Modify the flywheel (Part No. 399071) as shown on print RX-117225-C.

8.2.33.2 The engine flywheel guard shown on print RX-117167-E and the safety housing shown on print RX-117168-D, facilitate the installation and removal of the engine.

8.2.34 *Special Parts*—In Section 8 there have been references to several prints where part fabrication is described. These parts can be ordered from GM[33] or made by any machine shop capable of fabricating the parts exactly according to the prints.

8.2.35 *Pressure Checking the Engine Coolant System*:

8.2.35.1 It has been found advantageous to pressure check the coolant system before installing the assembled engine on the test stand.

8.2.35.2 Block and pressurize the coolant passages to 30 in. Hg (101 kPa) and monitor any change in pressure for 10 min.

(*a*) Changes in pressure of less than 1 in. Hg (3.4 kPa) in 10 min are considered satisfactory.

(*b*) Larger changes in pressure necessitate re-torquing or replacing the cylinder heads, or both; or replacing the intake manifold gaskets or seals, or both.

[31] Available from Aeroquip Corp., Industrial Division, 1225 W. Main St., Van Wert, OH 45891.

[32] Tool OTC 7078 is available from Owatonna Tool Co., 376 North St., Owatonna, MN 55060. Tool BT 7604 is available from Burroughs Tool and Equipment Co., 2429 N. Burdick St., Kalamazoo, MI 49007.

[33] Available from GM NAO Research and Development Center, Warren, MI 48090. Attention: Sequence Test Coordinator.

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8.3 *Install Assembled Engine on Test Stand*:

8.3.1 *Lifting Engine*—Lift the assembled engine as described in the 1977 Oldsmobile Service Manual (Fig. 6A3-6). *Do not lift the engine by the manifold. Glycol coolant leaks may occur*.

8.3.2 *Engine Mounts*—In conjunction with prints RX-117379-D, RX-117529-D and RX-117990-B, the following engine mounts are recommended:

8.3.2.1 Rear right-hand (Part Nos. 568980 or 31-2138),

8.3.2.2 Rear left-hand (Part Nos. 568981 or 31-2139), and

8.3.2.3 Front (Part Nos. 572945 or 31-2137).

8.3.3 *Drive Shaft*—A flywheel to driveshaft coupling adapter shown on print RX-117157-B, can be used in conjunction with a Dana shaft[34] (Part No. 1601-1608), and a rubber joint set (part 206881-20).

8.4 *Engine-Dynamometer Installation*:

8.4.1 A typical engine-dynamometer installation is shown on print RX-117529-D.

8.4.2 Mount the engine on the test stand so that the carburetor mounting flange to intake manifold interface is horizontal.

9. Measurement and Control of Operating Conditions

9.1 *Temperature Measurements*:

9.1.1 *General Considerations*:

9.1.1.1 Accurate temperature measurement of several operating conditions is required. Temperature measurement is of extreme importance and assurance of temperature measurement accuracy is mandatory.

9.1.1.2 Suitable temperature readout instrumentation with premium type, sheathed, grounded thermocouples, and premium grade wire shall be used.

9.1.1.3 Check all thermocouples for accuracy at the temperature levels at which they are used.

(*a*) This is particularly important for the thermocouples used in the oil filter block and water jacket.

9.1.1.4 Iron-Constantan (Type J) thermocouples are recommended. Conax[35] part numbers are as follows:

(*a*) For the oil filter block and breather tube gas—Conax J-SS-12-G-PJ 1.5 in. (38 mm).

(*b*) For fuel, the coolant outlet and inlet, breather tube coolant outlet, carburetor air, and intake manifold—Conax J-SS-12-G-PJ 2 in. (51 mm).

(*c*) For the rocker cover coolant outlet, and intake manifold exhaust crossover—Conax J-SS-12-G-PJ 3 in. (76 mm).

(*d*) For the oil pan—Conax J-SS-G-PJ 4 in. (102 mm).

9.1.1.5 The recommended thermocouple packing gland for the above thermocouples is the Conax MPG-125-A-T[35] packing gland.

9.1.1.6 Accurate location of thermocouples is essential for acceptable test operation.

9.1.2 *Specific Thermocouple Locations*:

9.1.2.1 *Oil Filter Block*—Locate the thermocouple in the center of the stream of flow (see print RX-117227-A).

9.1.2.2 *Oil Pan (Sump)*—Locate the thermocouple in the right rear corner of the oil sump as shown on print RX-118305-D; it should extend 1.5 in. (38 mm) into the oil pan.

9.1.2.3 *Engine Coolant Out*—Locate the thermocouple in the thermostat housing within 3 in. (76 mm) of the intake manifold in the center of the stream of flow.

9.1.2.4 *Engine Coolant In*—Locate the thermocouple in the coolant inlet adapter 9 in. (22.9 cm) from the front cover to the inlet adapter interface, as shown on print RX-118135-D. The thermocouple should be located in the center of the stream of flow.

9.1.2.5 *Rocker Cover Coolant Out*—Locate the thermocouple within 3 in. (76 mm) of the fitting in the cover. The thermocouple should be located in the center of the stream of flow.

9.1.2.6 *Breather Tube Coolant Out*—Locate the thermocouple within 3 in. (76 mm) of the fitting in the breather tube. The thermocouple should be located in the center of the stream of flow.

9.1.2.7 *Blowby Gas*—Extend the thermocouple 0.5 in. (12.7 mm) into the stream from the wall, as shown on print RX-117729-C.

9.1.2.8 *Intake Manifold Exhaust Crossover Coolant Outlet*—Install the thermocouple in a tee fitting in the coolant outlet close to the intake manifold. The thermocouple should be located in the center of the stream of flow.

9.1.2.9 *Carburetor Air*—Locate the thermocouple in the intake air horn (Part No. BX-395-1). The thermocouple should be located in the center of the stream of flow.

9.1.2.10 *Intake Manifold Mixture*—Install the thermocouple in the threaded ¼in. NPT hole located to the front of the carburetor and in the center of the Nos. 1 and 4 cylinder legs of the intake manifold. Locate the thermocouple in the center of the intake mixture stream (approximately 0.75 in. (19.1 mm)).

9.1.2.11 *Fuel*—Install the thermocouple in a tee fitting in the fuel line within 2 in. (51 mm) of the carburetor fuel inlet. The thermocouple should be located in the center of the stream of flow.

9.2 *Air to Fuel Ratio (AFR) Measurement and Control*:

9.2.1 Determine engine AFR by Orsat analysis or by electronic gas analysis equipment of the exhaust gases, and comparing the analyzed values with theoretical values plotted on a chart of exhaust gas component volumes versus AFR (see Fig. 1).

9.2.2 Suitable electrical AFR indicating equipment may be used to provide continuous AFR indications, as long as it is properly calibrated using appropriate span gases.

9.2.3 The electronic fuel mixture control unit (BX-150-1) can be used to control air-to-fuel ratios.

9.2.4 The theoretical relationship between engine exhaust gas CO_2, CO, and O_2 contents and AFR is shown on Fig. 1 for fuel with an H to C ratio of 2:1.

9.2.4.1 Since the theoretical chart was constructed assuming complete combustion, it is necessary to correct exhaust gas analyses that contain either oxygen or carbon monoxide (indicating *rich* and *lean* combustion, respectively) before using the figure. The corrections can be made as follows:

[34] Available from Dana Corp., Spicer Universal Joint Division, P.O. Box 986, Toledo, OH 43696.

[35] Available from Conax Corp., 2302 Walden Ave., Buffalo, NY 14225. Attention: Sales Dept.

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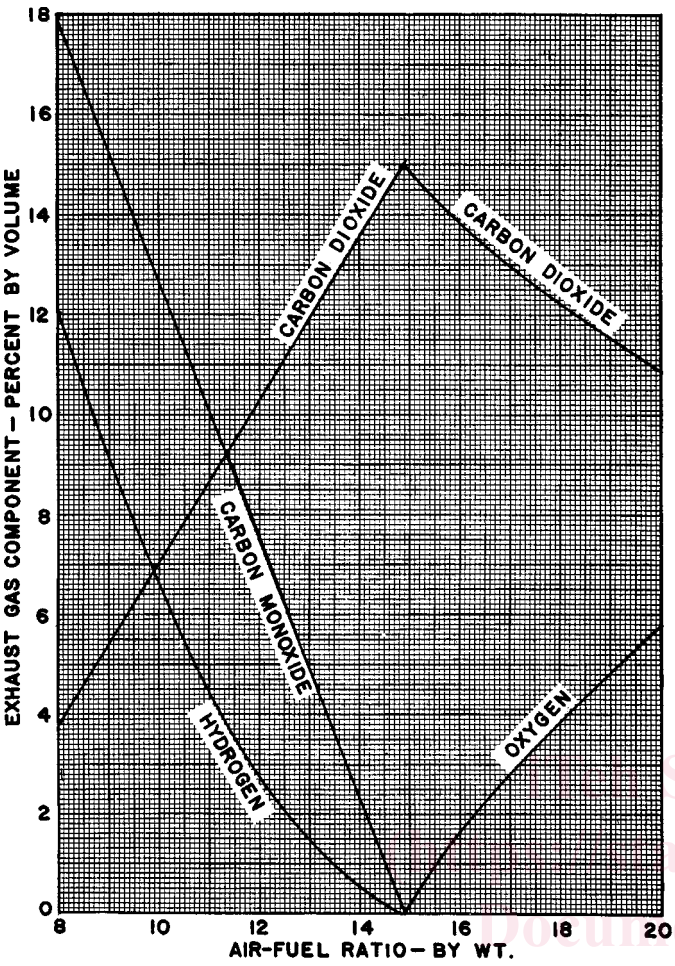

FIG. 1 Air-to-Fuel Ratio Chart

(*a*) *Rich Samples:*

$$\frac{\text{observed \% } CO_2 \times 100}{100 - 5\ (\text{observed \% } O_2)} = \text{corrected } CO_2 \quad (1)$$

$$\frac{\text{observed \% CO} \times 100}{100 - 5\ (\text{observed \% } O_2)} = \text{corrected CO} \quad (2)$$

(*b*) *Lean Samples:*

$$\text{observed \% } O_2 - 0.5\ (\text{observed \% } CO) = \text{ corrected } O_2 \quad (3)$$

$$\text{observed \% } CO_2 + \text{observed \% } CO = \text{corrected } CO_2 \quad (4)$$

9.2.4.2 Air to fuel ratios obtained from Fig. 1 using the corrected CO, CO_2, and O_2 values shall agree within 0.5 ratio.

9.3 *Carburetor Air Supply Humidity Measurement and Control*:

9.3.1 An instrument such as the Alnor 7300 Dewpointer[36] can be used to determine the moisture content of the carburetor air.

9.3.2 Determination of the dew point should be made at the test stand.

9.3.3 Suitable equipment is needed to maintain the carburetor intake air at a moisture content of 80 ± 5 grains/lb of dry air (11.4± 0.7 g/kg of dry air), a dry bulb temperature of 80 ± 2°F (26.7 ± 1.1°C), and a static pressure of 0.1 to 0.3 in. water (24.9 to 74.6 Pa) measured at the carburetor inlet.

9.3.3.1 A system, such as shown in prints RX-179649-D through RX-179653-D, RX-117375-C and RX-117376-C, can be used to control the moisture content and temperature of the carburetor air.

9.3.4 Maintain the duct surface temperature above the dew point to prevent condensation (loss of humidity level).

9.3.5 A method of controlling the flow of air to the carburetor is shown on print RX-117162-C.

9.3.5.1 Use the intake air horn, Part No. BX-395-1; the carburetor intake air adapter shown on print RX-118616-E and corresponding gasket, Part No. BX-361-1; and the carburetor adapter plate, Part No. BX-260-1. Alternatively, the air intake horn can be fabricated from a print available from the CPD.

9.3.5.2 Position the adapter so that the air enters the adapter from the rear of the engine.

9.3.5.3 *Remove the carburetor intake air horn anytime the engine is not running and during the timing run.*

9.3.5.4 Carburetors shall be disassembled, cleaned, and rebuilt prior to each test, or more often if air-to-fuel ratio control becomes a problem.

9.4 *Exhaust and Exhaust Back Pressure Measurement and Control*:

9.4.1 The use of 4-in. (102-mm) stainless steel exhaust pipe, Part No. RT10E (Flexonic Corp.)[37] has proven satisfactory.

9.4.2 Do not add cooling water or spray directly into the exhaust streams or onto the exhaust pipes.

9.4.3 Do not use water-jacketed exhaust pipes on the sections of the exhaust pipes extending from the exhaust manifold to the test bed or floor level.

9.4.4 Jacketed exhaust pipes or external water spray can be used on the portions of the exhaust systems extending below the test bed or floor level.

9.4.5 Measure the exhaust back pressure at the exhaust sample line location as shown on print RX-117286-C.

9.4.6 The back pressure and exhaust sample lines from the exhaust manifold, their location shown on print RX-117286-C, shall run downhill from the manifolds to traps before the connection to manometers.

9.4.6.1 It is recommended that about 0.75 in (19 mm) of water (19 mm) be left in the traps to ascertain that a closed system exists.

9.4.7 Pressure taps are required in each manifold in order to permit reading the back pressure separately on each bank.

9.4.8 Do not connect the sample lines together, in order that separate samples can be taken from each bank for air-to-fuel ratio determinations.

9.4.9 The readout device for exhaust back pressure can be either a manometer or a suitable pressure gage with scale graduations of 0.1 in. of water (24.9 Pa), and a suggested range of zero to 36 in. of water (8.96 kPa).

9.4.10 The control system can be either a manual system for controlling the exhaust back pressure from each bank, or an automatic system such as shown on print RX-117462-C. A

[36] Available through local distributors, or Alnor Instrument Co., 97301 N. Caldwell Ave., Niles, IL 60648.

[37] Available from local distributors, or Flexonic Division UOP, Inc., 300 E. Devon Ave., Bartlett, IL 60123.

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restriction in one side may be required to permit automatic differential pressure control.

9.5 *Blowby Measurement and Control*:

9.5.1 Measure blowby at the breather tube outlet with the crankcase oil filler tube and the dipstick guide tube plugged and while maintaining the crankcase pressure at 0.05 in. of water (0.0 ± 12.4 Pa).

9.5.1.1 Crankcase pressure should be stabilized in 6 min or less. If not, record the blowby rate obtained and include a note on the Supplemental Operational Data sheet that the crankcase pressure had not stabilized within the 6 min.

9.5.2 Use a sharp-edged orifice meter such as shown on print RX-116169-C[33] to measure engine blowby rates.

9.5.3 The blowby meter to breather tube connection shall exist only during the blowby rate determinations. At all other times, the blowby gas shall be emitted directly out of the breather tube top, as shown on print RX-117729-C, into the surrounding air.

9.5.4 This system includes the required surge tank shown on print RX-117431-C, means to measure blowby gas temperature, and means to maintain crankcase pressure at 0.00 ± 0.05 in. of water (0.00 ± 12.4 Pa).

9.5.5 A system, such as shown on prints RX-117726-C, RX-117727-C, RX-117294-A, RX-117730-C and RX-117731-C can be used as an aid in making blowby measurements.

9.5.6 Report observed data in cfm (L/min) after correcting for meter calibrations and adjusting these results to 100°F (37.8°C) and 29.7 in. Hg (100 kPa).

9.5.7 Refer to 8.2.6.1 for information about controlling blowby.

9.6 *Crankcase Pressure Measurement*:

9.6.1 Measure the pressure with a gage or manometer that has a range of − 0.5 to 0.5 in. of water (−124 to 124 Pa), in graduations of no greater than 0.02 in. of water (5.0 Pa).

9.6.2 For manual systems, Magnehelic Gage Model No. 2301[38] is suitable.

9.6.3 If a manometer is used in this application, a condensation trap shall be employed to eliminate the possibility of manometer fluid accidentally entering the crankcase.

9.6.4 For automated blowby systems, a Honeywell Controller 714P2B-31K1[39] shown on print RX-117727-C has been found satisfactory for measuring crankcase pressure. This controller can be used for pressure measurements up to 0.5 in. of water (124 Pa).

9.6.5 For either manual or automated systems, two additional indicators such as Magnehelic Model No. 2310 and Model No. 2020 (see print RX-117727-C for location) can be used for pressure measurements from 0.5 to 5.0 in. of water (0.124 to 1.24 kPa), and 0 to 20 in. of water (0 to 4.98 kPa), respectively.

9.6.5.1 The first indicator shall have a zero center scale and measure from−0.5 to + 5.0 in. of water (−1.24 to +1.24 kPa), with graduations no greater than 0.5 in. of water (0.124 kPa).

9.6.6 The accuracy of both the low range (0 ± 0.5 in. of water (0 ± 0.124 kPa)) and the mid range (0 ± 5.0 in. of water (0 ± 1.24 kPa)) pressure indicating devices used by a laboratory shall not be affected by pressure excursions of about 5.0 in. of water (1.24 kPa).

9.6.7 Pressures exceeding 5.0 in. of water (1.24 kPa) should be measured and recorded on the 0 to 20 in. of water (0 to 4.98 kPa) gage. Record pressures exceeding 20 in. of water (4.98 kPa) as + 20.0 in. of water (+ 4.98 kPa).

9.7 *Oil Pressure at the Oil Pump Outlet—Measurement and Control*:

9.7.1 Measure the oil pressure at the location shown on print RX-117227-A.

9.7.2 Measurement of the oil pressure at the oil pump outlet pressure requires the use of a pressure gage having a scale range of 0 to 100 psi (0 to 689 kPa), with scale graduations of 1 psi (6.9 kPa).

9.7.3 Refer to 8.2.13.5 for information about the control of oil pressure.

9.8 *Oil Pressure at the Engine Oil Filter—Measurement*—Measurement of the oil pressure at the engine oil filter requires the use of a gage having a scale range of 0 to 100 psi (0 to 689 kPa), with scale graduations of 1 psi (6.9 kPa).

9.9 *Carburetor Inlet Air Pressure Measurement and Control*:

9.9.1 Measure the air pressure at the carburetor intake air horn (BX-395-1).

9.9.2 The measurement of carburetor inlet air pressure can be made by either a manometer or a pressure gage. A range of 0 to 0.5 in. of water (0 to 124 Pa), and scale graduations of 0.02 in. of water (4.98 Pa) are required.

9.9.2.1 When using a manometer, a condensate trap should be installed between the manometer and the air horn to protect against the possibility of a momentary interruption of air flow or any other transient condition that might result in manometer fluid entering the engine intake system.

9.9.2.2 Measure the pressure at the location provided on the carburetor intake air horn, Part No. BX-395-1.

9.9.3 Refer to 9.3.5 for information about controlling the inlet air pressure.

9.10 *Intake Manifold Vacuum Measurement*:

9.10.1 Install a fitting for the measurement of intake manifold vacuum in the existing ¼in. NPT hole located in the center of the No. 6 and 7 cylinder leg of the intake manifold (to the rear of the carburetor).

9.10.2 Suitable readout instrumentation with a range of 0.0 to 20 in. Hg (0.0 to 68 kPa) and approximate scale graduations of 0.1 in. Hg (0.34 kPa) is required.

9.11 *Rocker Cover Coolant Pressure Measurement and Control*:

9.11.1 Measure the pressure at the top front fitting of each rocker cover as described on print RX-117928-C.

9.11.2 A pressure gage with scale graduations of approximately 1 psi (6.9 kPa) and a range of 0.0 to approximately 15 psi (103.5 kPa) is required.

9.11.3 Refer to Annex A3 for information about controlling the rocker cover coolant pressure.

9.12 *Breather Tube Coolant Pressure Measurement*:

[38] Available from Dwyer Instrument Co., P.O. Box 373-T, Michigan City, IN 46360.

[39] Available from Honeywell Inc., Industrial and Automation Div., 1100 Virginia Dr., Ft. Washington, PA 19034.

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9.12.1 Measure the pressure at the coolant outlet fitting of the breather tube as shown on print RX-117731-C.

9.12.2 A pressure gage with scale graduations of approximately 1 psi (6.9 kPa) and a range of 0.0 to approximately (15 psi) (103.5 kPa) is required.

9.13 *Intake Manifold Crossover Coolant Outlet Pressure Measurement*:

9.13.1 Measure the pressure at the tee installed in the choke stove adapter plate as shown on print RX-117813-A.

9.13.2 A pressure gage with a range of 0 to 15 psi (0 to 6.9 kPa) and scale graduations 1 psi (6.9 kPa) is suggested.

9.14 *Engine Speed and Load Measurement and Control*:

9.14.1 Engine speed and load are important test parameters, and particular attention should be given to achieving and maintaining accurate calibration of the related instrument systems.

9.14.2 A typical closed loop control system maintains speed by dynamometer control, and load by engine throttle control.

10. Procedure (Start of the Test)

10.1 *External Cooling System Cleaning*:

10.1.1 Clean the external cooling system of a new test stand or new flushing tank assembly, or both, prior to flushing an engine the first time.

10.1.2 Remove all aluminum and galvanized materials from the system.

10.1.3 A solution of 5 oz/gal (37.4 g/L) of Oakite 77 in water heated to 160 ± 5°F (71.1 ± 2°C) and circulated at the maximum obtainable flow rate for 60 min will clean the external system satisfactorily. Follow this cleaning with a thorough water flush of all system components.

10.1.4 Recleaning of the external cooling system is periodically required.

10.2 *Engine Coolant Jacket and Intake Manifold Coolant Crossover Cleaning (Flushing)*:

10.2.1 After the engine has been installed on the test stand, chemically clean the engine coolant jacket and intake manifold coolant crossover simultaneously.

10.2.1.1 Make the connection of the cleaning flushing tank to the engine so that the cleaning solutions enter at the coolant outlet adapter and exit at the front of the block (reverse flow direction only for flushing) though the water inlet adapters shown on print RX-118135-D.

10.2.1.2 Attach the coolant crossover fitting for the dual rocker cover system (prints RX-117814-C or RX-117815-C) to the intake manifold coolant crossover as shown on the schematic.

10.2.1.3 Plumb the output of the intake manifold coolant crossover into the jacket flush return line at the front of the block.

10.2.1.4 Print RX-118138-B describes a charging adapter useful when charging the system with the specified coolant.

10.2.2 Care should be taken to reduce the elapsed time between each step of the cleaning procedure to minimize rusting of the water jacket.

10.2.3 Use new flushing agents for each test.

10.2.4 Use the following jacket cleaning procedure:

10.2.4.1 Pass 120 ± 5°F (48.9 ± 2.8°C) water once through the engine with block petcocks open for 2 min.

10.2.4.2 Remove the oil pan drain plug. If no water comes out, that indicates that there are no coolant leaks. Replace plug.

10.2.4.3 Add 120 ± 2°F (48.9 ± 1.1°C) water to the flushing tank to provide a total volume of 10 to 12 gal (37.8 to 45.4 L) in the tank and water jackets.

10.2.4.4 Close valves to isolate the engine block from the flushing tank. The engine should remain full of water.

10.2.4.5 Begin circulating the water in the tank and add sufficient Oakite 77 to provide a concentration of 5 oz/gal (37.4 g/L) in water.

10.2.4.6 Premix for 15 min at 160 ± 5°F (71.1± 2.8°C). The fifteen minute time period should start when the mixture reaches 160 ± 5°F (71.1 ± 2.8°C).

10.2.4.7 After the premixing period, open the valves to the engine and circulate the mixture for 30 min at 160 ± 5°F (71.1 ± 2.8°C) at a flow rate of 30 to 35 gal/min (1.89 to 2.21 L/s). Start timing when the mixture temperature (leaving the engine) reaches 160 ± 5°F (71.1 ± 2.8°C).

10.2.4.8 Drain the Oakite 77/water mixture from the flushing tank leaving the water jacket full.

10.2.4.9 Flush the engine with water for 2 to 3 min at 120± 5°F (48.9 ± 2.8°C) and at a flow rate of 20 to 25 gal/min (1.26 to 1.58 L/s). *Discard the flushing water after passing it through the engine once*. The pH of the flushing water should be neutral after about 2 min. The engine exit water shall be checked with litmus paper or other suitable pH measuring equipment.

10.2.4.10 Shut drain lines. Do not drain the engine water jacket.

10.2.4.11 Add 120 ± 5°F (48.9 ± 2.8°C) water to the flushing tank to provide a total volume of 10 to 12 gal (37.8 to 45.4 L) in the tank and water jacket. Close valves to isolate the engine block from the flushing tank. The engine should remain full of water.

10.2.4.12 Begin circulating the water in the tank and very slowly add sufficient Oakite Rust Stripper (RS) to provide a concentration of 1 lb/gal (119.8 g/L) in water. The rate of addition should be adjusted to keep mixture temperature below 165°F (73.8°C).

NOTE 12—**Precaution:** In addition to other precautions, face masks, dust breathers, and gloves should be worn when handling RS. Also, use extra care during the addition of RS to water since this causes an exothermic reaction.

10.2.4.13 Premix the rust stripper and water for about 2 min at 160 ± 5°F (71.1 ± 2.8°C). The 2-min premix time starts when the solution reaches 160 ± 5°F (71.1 ± 2.8°C). After premixing, open the valves to the engine and circulate the mixture for 1 h at 30 to 35 gal/min (1.89 to 2.21 L/s), and at 160± 5°F (71.1 ± 2.8°C). The 1 h time starts when the temperature of the mixture (leaving the engine) reaches 160 ± 5°F (71.1 ± 2.8°C).

10.2.4.14 Drain the rust stripper mixture from the tank and engine, and retain for proper disposal.

10.2.4.15 Flush the engine with water at 120 ± 5°F (48.9 ± 2.8°C), and at a flow rate of 20 to 25 gal/min (1.26 to 1.58 L/s) for 2 to 3 min with the petcocks open. *Discard the flushing water after one pass through the engine*. The pH of the engine exit water should be neutral after about 2 min when checked

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with litmus paper or other pH measuring device.

10.2.4.16 Remove one or more freeze plugs and immediately inspect the water jacket. The cylinder walls should be clean and free of deposit when wiped with a finger. *Inspection speed is essential so that the water jacket does not air dry and start to rust.*

10.2.4.17 Quickly install new freeze plugs (cup type) and connect the engine to the external engine cooling system.

10.2.4.18 The engine jacket, rocker cover, and breather tube cooling systems shall be immediately charged with coolant. (See 10.3 for details.)

10.3 *Coolant Charging*:

10.3.1 After cleaning the engine coolant passages, 22.5± 2.5 gal (85 ± 9 L) of inhibited coolant (see 7.3.1) should immediately be charged to the jacket, rocker cover, and breather tube coolant circulating systems.

10.3.2 Use a new glycol/water/additive mixture in both the engine and rocker cover cooling systems for each test.

10.3.3 Fill the engine water jacket with the inhibited coolant prior to filling the other associated piping and equipment. Charge the rocker cover and breather tube cooling system immediately after charging the engine cooling system.

10.3.4 Check the coolant glycol percentages in both cooling systems after charging and at the test times specified in Fig. 2.

10.3.4.1 See Annex A12 for details of making coolant calibration standards that are used for checking glycol percentages.

10.3.5 Intermittently operate the coolant circulating pump (on 15 s and off 45 s) for a 10-min period after adding the inhibited coolant. This aids in the removal of air and consequently decreases the time to coolant clarity. Any proportioning valves in the coolant systems should be operated during this 10-min period.

10.3.6 Circulate the inhibited coolant at 120 ± 5°F (48.9 ± 2.8°C) , and at a flow rate of 60 gal/min (3.78 L/s) until the test is started. *No more than 6 h can elapse between filling the cooling system and starting the test.*

10.3.7 Check the glycol concentration during this period (prior to the engine timing run).

10.3.8 Maintain the glycol concentration in the cooling systems at 40± 1 %.

10.3.9 Record the addition of any glycol or water or both to the coolants for concentration adjustments on the data sheets.

10.3.9.1 When an adjustment has been made, check the resulting new glycol percentage after the coolant has been circulated for approximately 1 h.

NOTE 13—**Precaution:** In addition to other precautions, the ethylene glycol type coolant used represents a special fire hazard. Coolant hoses and clamps should be selected and installed with special care to prevent leaks and spills since ethylene glycol may ignite when it contacts hot exhaust system components. A dry chemical fire extinguisher should be available at the test stand to extinguish any coolant fires. The use of water is not recommended for this type of fires.

10.4 *The following operations shall be performed in the order listed in 10.4.1 through 10.4.3.*

10.4.1 *Test Oil Charging*:

10.4.1.1 Air-dry the heat exchanger prior to charging the engine with test oil.

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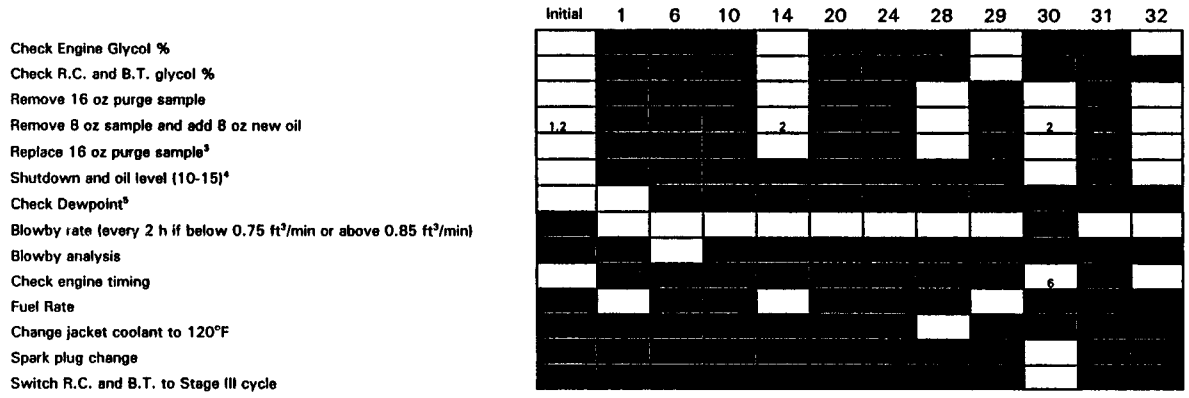
Laboratory:	EOT Date:
Test Number:	EOT Time:
Oil Code:	
Formulation/Stand Code:	



[1] Do not replace oil sample.
[2] Samples to be checked for glycol contamination.
[3] At 32 h use 16 oz purge sample for engine oil leveling.
[4] Pump on 10 min, off 15 min.
[5] Alnor Dewpointer or other suitable apparatus shall be used.
[6] Check timing at end of Stage II and start of Stage III cycles (30 test hours).

NOTE 1—Operator should sign open block after completing specified function.

FIG. 2 Operational Check List

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10.4.1.2 Use a single, clean, well-calibrated and accurate container to install the initial filling of test oil.

(*a*) Add 5 qt, 28 oz (5.56 L) of test oil to the engine through the oil fill tube.

(*b*) Add 4 oz (118 mL) of test oil to the rocker arm pivots (approximately 2 oz (59 mL) per side).

10.4.2 *Installation of Rocker Covers*:

10.4.2.1 Use special rocker arm covers available from the CPD.

10.4.2.2 Install the rocker covers on the engine after pre-oiling the rocker arm pivots. (*Note that the coolant lines shall have been installed on the rocker covers prior to coolant charging.*)

10.4.3 *Timing Run*:

10.4.3.1 After the engine is filled with oil, start the external oil pump and start the engine (see 10.5) for a 10-min timing run. *The carburetor intake air horn is not to be connected during the timing run.*

10.4.3.2 Initially, establish the engine speed at 1500 r/min for 2 min and set the spark timing at 27° before top dead center (btdc).

10.4.3.3 For the remainder of the 10 min, operate the engine at 1500 r/min and 25 bhp (18.6 kW).

10.4.3.4 Control the oil sump temperature, and the coolant temperatures in the jacket, rocker covers, breather tube, and intake manifold crossover at 120 ± 5°F (48.9 ± 2.8°C)

10.4.3.5 Draw the initial oil sample at 10 min after starting, but prior to stopping the engine (see Fig. 3).

10.4.3.6 During the timing run, check that the ignition voltage is at least 13 V. *Be sure that the ignition voltage is at least 13 V throughout the test.*

10.4.3.7 At the end of the 10-min timing run, shutdown the engine (see 10.7.2).

10.4.3.8 Re-torque the exhaust manifold bolts after the timing run.

10.4.3.9 Fifteen minutes after the shutdown at the end of the timing run, switch the rocker covers and breather tube cooling system to chilled glycol at 60°F (15.6°C). See A4.1.

10.5 *Engine Startup Procedure*—Use the following procedure to start the engine where motor generator dynamometers are not used:

10.5.1 Back the idle screw off the lowest cam position.

10.5.2 Close throttle completely.

10.5.3 Crank engine for no more than 3 s.

10.5.4 During cranking, crack throttle at high intake manifold vacuum. This procedure normally provides sufficient fuel for starting. *Do not pour fuel directly into the carburetor or intake manifold.*

10.5.5 Repeat steps (*c*) and (*d*) if engine fails to start.

10.5.6 When engine has been started, bring to 1500 r/min and 25 bhp (18.6 kW) as soon as possible (*except for timing run*).

10.5.7 After 2 min of operation, set the specified speed and load conditions.

NOTE 14—**Precaution:** In addition to other precautions, guards should be installed around all moving parts. When the engine is operating at high speed, heavy duty guards should be placed on both sides of the engine and personnel should be cautioned against working alongside the engine and coupling shaft. All fuel lines, oil lines and electrical wiring should be properly routed, guarded, and kept in good condition. Safety masks or glasses should always be worn by personnel working on and around the engine, and no loose or flowing clothing should be worn near a running engine.

The external parts of the engine and the floor area around the engine should be kept free of oil or fuel spills. Do not allow containers of fuel or oil to accumulate in the testing area.

Personnel should be alert for leaking fuel or exhaust gas. Leaking fuel represents a fire hazard and exhaust gas fumes are noxious.

11. Procedure—During the Test

11.1 *Engine Shutdown Procedure*:

11.1.1 Use the following procedure in stopping the engine:

11.1.1.1 Reduce engine speed and load to 1500 r/min and 25 bhp (18.6 kW).

11.1.1.2 Disconnect the fuel line or shut off fuel.

Test Stand:_____ Test No:_____

Engine No:_____ Oil Code:_____

Date:_____

SEQUENCE IID OIL SAMPLE, LEVEL, AND CONSUMPTION RECORDS

Initial Oil Level[1]:_____ in[2]:_____ oz. Below Factory Stamped Dipstick Full Mark[3]

IID Test Hours

	Initial[1]	14	28	30	32
1. Remove 16 oz. Purge Sample					
2. Remove 8 oz. Analysis Sample					
3. Replace 16 oz. Purge Sample					
4. Add 8 oz. to Replace Sample					
5. Oil Level (in.) After Draindown					
6. Computer Oil Level[4] (oz.)					
7. Performed by (initials)					

NOTE 1—Oil consumption for test is calculated as follows:
[Initial oil level oz—oil level at 32 h (oz, Item 6)] ÷ 32 = qt.

[1] Initial oil level is to be determined at the end of the 10 min timing run and is used in all computations of oil consumption.

[2] Should be 5⁄16 to 9⁄16 in. below factory stamped full mark.

[3] Determined prior to startup of each test.

[4] Difference from initial oil level.[1]

FIG. 3 Oil Sampling, Leveling, and Consumption