



# Standard Test Method for Determination of the Ability of Lubricants to Minimize Ring Sticking and Piston Deposits in Two-Stroke-Cycle Gasoline Engines Other Than Outboards<sup>1</sup>

This standard is issued under the fixed designation D 4857; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope

1.1 This test method<sup>2</sup> evaluates the performance of lubricants intended for use in two-stroke-cycle spark-ignition gasoline engines that are particularly prone to ring sticking. Piston varnish and spark plug fouling are also evaluated.

~~1.2 The values stated in SI units are the standard. The values given in parentheses are provided for information only.~~

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>3</sup>

B152 152/B 152M Specification for Copper Sheet, Strip, Plate, and Rolled Bar

D 93 Test Methods for Flash- Point by Pensky-Martens Closed Cup Tester

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

~~D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids~~ Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

D 874 Test Method for Sulfated Ash from Lubricating Oils and Additives

D 2270 Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 and ~~100~~100°C

D 2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry

D 4052 Test Method for Density and Relative Density of Liquids by Digital Density Meter

D 4629 Test Method for Trace Nitrogen in Liquid Petroleum Hydrocarbons by Syringe/Inlet Oxidative Combustion and Chemiluminescence Detection

D 4858 Test Method for Determination of the Tendency of Lubricants to Promote Preignition in Two-Stroke-Cycle Gasoline Engines

D 4859 Specification for Lubricants for Two-Stroke-Cycle Spark-Ignition Gasoline Engines-TC

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

D 4951 Test Method for Determination of Additive Elements in Lubricating Oils by Inductively Coupled Plasma Atomic Emission Spectrometry

E 230 Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples

G 40 Terminology Relating to Wear and Erosion

### 2.2 ANSI Standard:

ANSI MC 96.1 American National Standard for Temperature Measurement Thermocouples<sup>4</sup>

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.B0.06 on Automotive Lubricants—Two-Stroke Cycle Gasoline.

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<sup>2</sup> Until the next revision of this test method, the ASTM Test Monitoring Center will update changes in this 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. 02-2.

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>4</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

### 3. Terminology

#### 3.1 Definitions:

3.1.1 *cold sticking*—of piston rings, a condition in which the ring is free in its groove while the engine is running but stuck when the piston is cold, normally indicated by the absence of varnish or other deposits on the outer face of the ring and of signs of blowby on the piston skirt.

3.1.2 *combustion chamber*—in reciprocating internal combustion engines, the volume bounded by the piston crown and any portion of the cylinder walls extending above the piston crown when in the top dead center position, and the inner surface of the cylinder head including any spark plugs and other inserted components. **D 4858**

3.1.3 *hot sticking*—of piston rings, a condition in which the ring is stuck in its groove while the engine is running, normally indicated by varnish or other deposits on the outer face of the ring, by signs of blowby on the piston skirt, or both.

3.1.4 *lubricity*—a qualitative term describing the ability of a lubricant to minimize friction between and damage to surfaces in relative motion under load. **D 4863**

3.1.5 *preignition*—in a spark-ignition engine, ignition of the mixture of fuel and air in the combustion chamber before the passage of the spark. **D 4858**

3.1.6 *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**

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

3.1.8 *seizure*—in lubrication, welding between surfaces in relative motion that results in immobilization of the parts. **D4863**

3.1.9 *spark plug fouling*—deposition of essentially nonconducting material onto the electrodes of a spark plug that may, but will not necessarily, prevent the plug from operating.

3.1.10 *spark plug whiskering, or spark plug bridging*—a deposit of conductive material on the spark plug electrodes that tends to form a bridge between them, thus shorting out the plug.

#### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *benchmark reference oil*—an oil whose performance in this test method is compared with the performance of the non-reference oil.

3.2.2 *major preignition*—preignition that causes a temperature increase of 10°C (18°F) or more measured at the spark plug gasket.

3.2.3 *minor preignition*—preignition that causes a temperature increase of more than 7°C (13°F) and less than 10°C (18°F) measured at the spark plug gasket.

### 4. Summary of Test Method

4.1 The test is run in a 347 cm<sup>3</sup> Yamaha RD-350B twin-cylinder air-cooled motorcycle engine.<sup>5</sup> It is intended primarily to evaluate ring sticking and piston skirt deposits. Spark plug fouling, combustion chamber deposits, and exhaust port blockage are also evaluated. The engine is set up with one cylinder supplied with a fuel and oil mixture made using the non-reference oil and the other with a fuel and oil mixture using the benchmark reference oil. The test is normally run twice, exchanging the oils between cylinders for the second run. Each run is performed on a 25-min part throttle 5-min idle cycle, with a 60-min shutdown after each 150 min of running time. Total running time per single test is normally 20 h.

### 5. Significance and Use

5.1 This test method is primarily intended for the evaluation of lubricants for use in two-stroke-cycle engines of high specific output.

NOTE 1—If the test method is being used to satisfy a portion of Specification D 4859, refer to the specification for the pass-fail criteria.

### 6. Apparatus

#### 6.1 Test Engine and Stand:

6.1.1 *Test Engine*—A Yamaha RD-350B 347 cm<sup>3</sup> twin cylinder motorcycle engine with attached standard transmission (gearbox) is used.<sup>5</sup> The engine is described more fully in Annex A1. It is set up on a dynamometer test stand with a modified fuel system so that each of the cylinders is supplied independently through its associated carburetor. A typical test stand is shown in Fig. 1. The dynamometer is located to the left of the engine behind the instrument cabinet, and is driven by the motorcycle transmission output shaft.

6.1.2 *Lubrication System*—The test engine, as manufactured, is provided with an oil injection system by which oil is metered to the carburetor bowls from a common source. Because the test is run using a different fuel and oil mixture in each carburetor, the oil pump and its connections shall be removed and the oil connections to the carburetors plugged.

<sup>5</sup> Order from Engineering and Service Dept., Yamaha International Corp., P.O. Box 6555, Cypress, CA 90630. Complete RD-350B engines are no longer available from the manufacturer, but all parts are still available and are expected to remain so. It is suggested that a used RD-350 series motorcycle be purchased for familiarization purposes.

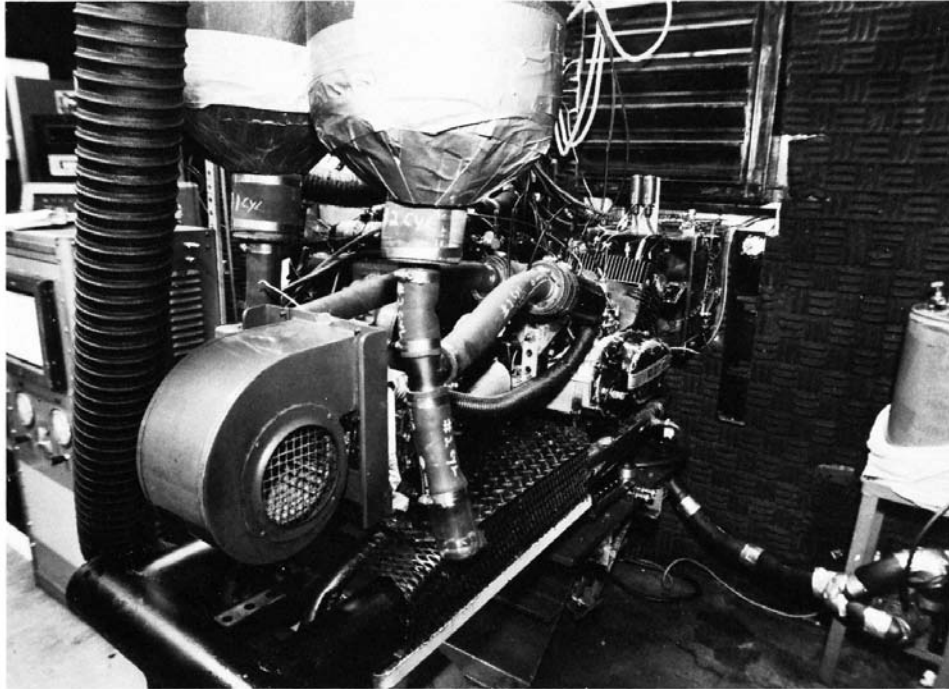


FIG. 1 Test Stand

6.1.3 *Dynamometer*— The dynamometer shall be capable of absorbing at least 8 kW (10 hp). The engine crankshaft speed is 6000 ~~r/min, rpm~~, and the motorcycle transmission may be used to provide speed reduction. No correction is required for the power loss in the transmission.

6.1.4 *Cooling Air*— A variable delivery blower with a free flow capacity of about 300 m<sup>3</sup>/min (10 000 ft<sup>3</sup>/min) of air is required. The flow from the blower shall be directed toward the exhaust side of the engine so as to deliver an approximately equal stream to each cylinder, and is varied as required to maintain the spark plug gasket temperature within the limits specified in Section 9. It is advised that the blower be set up to draw its air from outside the building. Where this is not practicable, or in hot climates, coolers may be required.

6.1.5 *Combustion Air*— The air supply to the engine may be taken from the ambient air in the test cell, but if a controlled air source is used, it is recommended that it be set to 25 to 27°C (77 to 81°F) with a moisture content of 11 to 12 g/kg (77 to 83 grains/lb) of dry air and a maximum pressure at the carburetor inlet of 3.7 kPa (1.5 in. water) kPa. Supply to each carburetor shall be through a separate flowmeter each with a capacity of 30 kg/h (65 lb/h) minimum. A plenum chamber is provided at the intake of each carburetor to damp out pulsations. These are shown in Fig. 1.

#### 6.1.6 *Fuel System:*

6.1.6.1 Fuel is supplied to each of the carburetors by an individual electric fuel pump with a capacity of at least 2.5 L/h (0.7 gal/h) taking the fuel mix from separate tanks through a paper or ceramic filter and a flowmeter as specified in 6.1.6.2. The fuel shall enter the carburetors at a maximum temperature of 25°C (77°F) and cooling may be required in a hot climate.

6.1.6.2 Two flowmeters, one for each carburetor, are required. Any type accurate to ±0.01 kg/h (±0.02 lb/h) at the flow rate specified in 6.1.6.1 may be used, but those measuring weight directly rather than volume are preferred. If a volume measuring device is used, the relationship of density to temperature over the range of fuel temperature experienced shall be determined for the actual test gasoline and test oil mixtures used, and the appropriate value used for conversion of volume to mass.

6.1.6.3 When permitted by local regulations, the use of portable containers with a capacity of at least 60 L (15 U.S. gal) is recommended to facilitate changing of fuels. If the fuel lines to the carburetors cannot be replaced when the fuel and oil mixture is changed, it is necessary to be able to purge the fuel system between the tanks and the carburetors.

6.1.7 *Exhaust System*— The standard motorcycle exhaust system shall be used, discharging into a pipe of at least 200-mm (8-in.) internal diameter leading out of the test cell. No modification other than axial rotation may be made to the exhaust system as supplied by Yamaha except the installation of thermocouples as specified in 6.2.4. Any rotation of the exhaust system shall be the same for both cylinders and shall not place the exhaust in the cooling air stream.

#### 6.2 *Instrumentation:*

6.2.1 *Tachometer*—An electronic or vibration tachometer accurate to ±25 ~~r/min, rpm~~.

6.2.2 *Measurement of Ambient Conditions* —If the air supply to the engine is taken from a controlled source, references to ambient pressure, temperature and humidity apply to the air from the controlled source.

6.2.2.1 *Temperature*— A thermocouple or thermometer shall be provided to measure air temperature in the range from 10 to

50°C (50 to 120°F), 50°C. The overall accuracy of temperature measurement, including that of recorders, if used, shall be within  $\pm 1^\circ\text{C}$  ( $2^\circ\text{F}$ ),  $\pm 1^\circ\text{C}$ .

6.2.2.2 *Barometric Pressure*—A barometer measuring the pressure in the test room is required. Its overall accuracy, including recorder, if used, shall be within  $\pm 0.1$  kPa (0.75 mm Hg), kPa.

6.2.2.3 *Humidity*—A hygrometer accurate to  $\pm 3\%$  or a wet and dry bulb thermometer accurate to  $\pm 1^\circ\text{C}$  ( $2^\circ\text{F}$ ) is also required.

6.2.2.4 *Recorder*—Continuous recording of the ambient conditions is recommended.

6.2.3 *Spark Plug Gasket Temperature Measurement:*

6.2.3.1 *Thermocouples*—The composite gasket normally supplied with the spark plug is not satisfactory for the attachment of thermocouple wires. A design that has been found satisfactory is given in Appendix X1.<sup>6,7</sup> Provision shall be made for shutdown of the engine in the case of a spark plug gasket temperature increase of  $10^\circ\text{C}$  ( $18^\circ\text{F}$ ) or more. An automatic shutdown that operates if such an increase occurs is preferred. As a minimum, an alarm shall be provided to operate after a temperature increase of 6 to  $7^\circ\text{C}$  ( $11$  to  $13^\circ\text{F}$ ) to allow manual shut down by the operator if the  $10^\circ$  limit is exceeded. If the alarm or shutdown is a separate instrument from the temperature recorder, it is usually necessary to provide two thermocouples as shown in Appendix X1, but if it is incorporated into the recorder, only one thermocouple is required. Glass or silica double and constantan thermocouple wires meeting the requirements of Type J of ANSI Specification MC 96.1 (summarized very briefly in Specification E 230) are normally satisfactory. Constantan is an alloy of approximately 40 % nickel (Ni) 60 % copper (Cu) by mass.

6.2.4 *Exhaust Temperature*—A thermocouple is required in each exhaust elbow within 75 mm (3 in.) of the cylinder exhaust port to monitor exhaust temperature.<sup>7,8</sup> The junction of the thermocouple shall be at the center of the pipe within  $\pm 3$  mm (0.12 in.), mm.

6.2.5 *Temperature Recorder:*

6.2.5.1 *Plug Gasket and Exhaust Temperatures*—These temperatures shall be recorded continuously. Maximum interval between successive recordings of the spark plug gasket temperature should not exceed 2 s, and 10 s for the exhaust temperature. A recorder with a range from 40 to  $750^\circ\text{C}$  ( $100$  to  $1400^\circ\text{F}$ ) accurate to  $\pm 2^\circ\text{C}$  ( $4^\circ\text{F}$ ) is suitable.

6.2.5.2 *Temperature of the Air Supplied to the Engine*—This is preferably recorded continuously. In any case it shall be logged at intervals of not more than 30 min.

6.2.6 *Pressure and Humidity of the Air Supplied to the Engine*—The air pressure and humidity shall be logged at intervals of not more than 30 min.

## 7. Materials and Reagents

7.1 *Test Fuel:*

7.1.1 *Phillips J* is the preferred test fuel.<sup>7,9</sup>

7.1.2 About 225 L (60 gal) of test fuel are required for a complete test following the standard procedure of two runs with interchange of oils between cylinders.

7.2 *Reference Oils:*

7.2.1 *Benchmark Reference Oil*—ASTM Reference Oil 606 is the benchmark reference oil for this test. About 6 L (1.6 gal) are required for a complete test (two evaluation runs), mixed with the fuel at the specified ratio.

7.2.2 *Cylinder Calibration Oil*—A calibration run is required on a new or fully rebuilt engine and at intervals as specified in 9.1. Use ASTM Reference Oil 606<sup>10</sup> in both cylinders. Six litres (1.6 gal) are required for the run. This oil's properties are summarized in Annex A2.

7.3 *Stoddard Solvent*—Hydrocarbon solvent meeting the requirements of Specification D 235, Type I.

7.4 *Thread Lubricant*—Use an antiseize compound.

7.5 *Gasket Sealer*—Use a non-setting type to facilitate disassembly.

7.6 *Cleaning Pads and Brushes*—For cleaning engine parts for re-use, when this is permitted, scouring pads and brushes have been found to be satisfactory.

## 8. Procedure

8.1 *Assembly of the Engine*—For information on the dismantling, inspection, and reassembly of the engine, see Annex A3 and the Yamaha RD-350B Engine Service Manual.<sup>5</sup>

8.1.1 The following new parts are used for each test:

Two piston and ring assemblies, complete.

Two cylinder head gaskets.

Two cylinder base gaskets.

<sup>6</sup> The sole source of supply of the thermostat washer known to the committee at this time is Lewis Engineering, 238-T Water St., Naugatuck, CT 06770.

<sup>7</sup> If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

<sup>8</sup> The sole source of supply of a suitable instrument known to the committee at this time is Omega Engineering Inc., P.O. Box 4047, One Omega Dr., Stamford, CT 06907.

<sup>9</sup> The sole source of supply of the test fuel known to the committee at this time is Phillips Chemical Co. Specialty Chemicals, P.O. Box 968, Borger, TX 79008.

<sup>10</sup> Available from ASTM Test Monitoring Center, 6555 Penn Ave., Pittsburgh, PA 15206-4489.

- Two exhaust gaskets.
- Two NGK B9HS spark plugs (or equivalent).
- Two sets of breaker points.

8.1.1.1 It is desirable to fit breakerless ignition, in which case, the points are not required.

8.1.2 Cylinders may be used for two engine builds. Install Yamaha manufactured oversize pistons and ring sets for the second build. Hone cylinders and obtain piston clearances in accordance with A3.2.3 and A3.2.4. Use oversize pistons and rings in both cylinders of the second build.

8.2 *Expected Life*— It is recommended that the engine be rebuilt after ten complete tests (normally twenty evaluation runs) plus when the calibration run specified in 9.1 has been completed. The crankcase, crankshaft, rods, and associated seals and bearings shall be examined and replaced if necessary.

## 9. Procedure

9.1 *Calibration Run*— Every six months, run as specified in 9.3 with Reference Oil 606 in both cylinders. The ratings for both piston skirt varnish and second ring sticking shall be within 1.0 merit numbers in both cylinders. Invalidate tests where hot ring sticking or scuffing on the second ring in either cylinder is noted. Find and correct the reasons for test failure or invalidation, or both, before further testing.

9.2 *Break-In*—A new engine, or one that has been rebuilt as specified in 8.1 or 8.2, shall be broken in over a period of 2 h as specified in Table 1 using the same fuel and oil mixture in each cylinder as will be used in the immediately following calibration or test run. The power output specified is approximate and may vary by about  $\pm 5\%$ .

9.3 *Test Procedure*— Initially, run the benchmark reference oil in number one cylinder of the engine, and the non-reference oil in number two cylinder (the cylinder on your right when facing the intake side of the engine). Normally, run the test twice, exchanging the non-reference and reference oils between the cylinders. If hot ring sticking or scuff is observed on the reference oil piston, determine and correct the cause of the malfunction and rerun the test. If this occurs during the second run of a test, it is not necessary to repeat the first run.

NOTE 2—If the test method is being used to satisfy a portion of Specification D 4859, refer to the specification for possible exception to the above conditions.

9.3.1 *Procedure*—Before starting each running cycle, initially and after any shutdown, idle for 5 to 6 min at 2000 to 2400 ~~r/min~~rpm to warm up. Run the test on the cycle of Table 2, varying the cooling air flow to maintain the specified plug gasket temperature.

NOTE 3—The exhaust temperature is not in itself a test parameter, but any change of 30°C (55°F) or more from the normal expected reading that cannot be explained by a known change in operating conditions will usually indicate a malfunction such as a change in the ventilation of the test cell or obstruction of the exhaust.

9.3.2 *Observations*— The temperatures specified in 9.3.1 shall be recorded continuously as specified by 6.2.5.1 and be logged at least twice per hour, and the cooling air stream varied as necessary to correct any tendency to drift. The crankshaft ~~r/min~~rpm, power output, fuel consumption, air to fuel ratio and ambient conditions is preferably recorded continuously and shall be logged at least twice per hour.

9.3.3 *Preignition*— A rapid (1 min or less) increase of 10°C (18°F) in the spark plug gasket temperature over the steady state level may constitute an incident of *major preignition*. Normally an increase in spark plug temperature and a decrease in engine power output accompany a preignition. If it is determined that a major preignition has occurred, remove the spark plug and retain it, labeled with the run number, the oil used, the cylinder number, the total test hours, and the hours on that plug to the nearest 0.1 h. Replace with a new plug. If major preignition occurs again with the non-reference oil, terminate the test and record a failure. If more than one major preignition occurs with the reference oil, stop the test to investigate and correct the problem before

**TABLE 1 Break-in Running Procedure**

Duration min	r/min	Power kW (hp)	Spark Plug Gasket Temperature °C (°F)
Duration, min	rpm	Power, kW	Spark Plug Gasket Temperature, °C
5	2000-2400	minimum	record
<del>25</del>	<del>4400-4600</del>	<del>3.7 (5.0)</del>	<del>145 (290) max</del>
<del>25</del>	<del>4400-4600</del>	3.7	145 max
5	2000-2400	minimum	record
<del>25</del>	<del>4900-5100</del>	<del>4.5 (6.0)</del>	<del>160 (320) max</del>
<del>25</del>	<del>4900-5100</del>	4.5	160 max
5	2000-2400	minimum	record
<del>25</del>	<del>5400-5600</del>	<del>5.2 (7.0)</del>	<del>170 (340) max</del>
<del>25</del>	<del>5400-5600</del>	5.2	170 max
5	2000-2400	minimum	record
<del>25</del>	<del>5900-6100</del>	<del>6.3 (8.5)</del>	<del>185 (365) max</del>
<del>25</del>	<del>5900-6100</del>	6.3	185 max

**TABLE 2 Test Cycle**

Minutes	r/min	Power kW (hp)	Spark Plug Gasket Temperature °C (°F)	Exhaust Temperature °C (°F)	A/F Ratio
Minutes	rpm	Power, kW	Spark Plug Gasket Temperature, °C	Exhaust Temperature, °C	A/F Ratio
25	5950-6050	6.0-6.7 (8-9)	188-193 (370-380)	600-750 (1100-1380) <sup>A</sup>	11.8-12.2
25	5950-6050	6.0-6.7	188-193	600-750 <sup>A</sup>	11.8-12.2
5	2000-2400	minimum	record	record	n/a

<sup>A</sup> If the temperature has not stabilized within 6 min max, shut down and ascertain the cause.

Repeat 5 times for a total of 150 min.

Shut down for a minimum of 60 min.

Repeat the full cycle for the total running time specified in the test method.

rerunning. Sudden temporary increases of 7°C (13°F) or more and less than 10°C (18°F) constitute *minor preignition*. These are logged and reported, but the test is not interrupted.

9.3.4 *Other Spark Plug Malfunction*—Spark plug problems of fouling or bridging are normally indicated by a loss of power accompanied by a decrease in the gasket temperature of the affected spark plug. The spark plug shall be replaced and labeled and the incident reported as specified in 9.3.3 for major preignition, after which the test is continued.

9.3.5 *End of Test*—Remove the cylinders and cylinder heads. Remove the pistons from the rods, but do not remove the rings from the grooves. Rate the following according to the procedures of Section 10:

Piston ring sticking.

Piston skirt varnish.

Piston crown deposits.

Cylinder head deposits.

Exhaust port blockage.

## 10. Inspection and Rating of Engine Parts

10.1 *Inspection*—Inspection and rating should be performed as soon as possible after completion of the test, and shall be performed within 24 h of the end of the test. Do not leave the engine disassembled for more than two hours prior to inspection, as exposure to the atmosphere may change the condition of rings and deposits. Do not begin the disassembly until the engine has cooled to within 5°C (40°F) of ambient temperature.

10.1.1 *Disassembly*—Remove the exhaust system, cylinder heads, cylinders, and pistons from the engine. Do not remove the rings from the piston. Engine parts may be washed in hydrocarbon solvent or wiped with a soft cloth, but shall not otherwise be cleaned. Deposits that are removed by washing in hydrocarbon solvent or by wiping gently with a dry or hydrocarbon-solvent-wetted cloth are not considered for rating purposes.

### 10.2 Rating:

10.2.1 Piston ring sticking and piston skirt and land deposits are given in numerical rating from 10 (best) to 0 (worst). The condition of the cylinder bore is stated qualitatively, as is that of the combustion chamber surfaces (piston crown and cylinder head). Port plugging is rated as the mean percentage of exhaust port area blocked by carbon deposits. Preignition and spark plug fouling and whiskering are rated by the number of occurrences. These procedures are discussed in more detail in the balance of this section.

10.2.2 *Piston Rings*—Rating numbers are given according to the tightness of the ring in its groove and the number of circumferential degrees over which it is stuck. Each ring is rated and reported separately. The criteria are given as follows, and are shown graphically in Fig. 2.

10.2.2.1 Apply a correction of -2.45 to the reference oil second ring sticking result before comparing the non-reference oil second ring sticking result.

(1) 10 *free*—a ring that will move under gravity if the piston is turned with its axis horizontal. A slight touch to overcome static friction is permissible.

(2) 9.5 *sluggish*—the ring will not fall under its own weight, but yields to pressure from a finger or pencil point up to the amount required to compress the ring by half its width.

(3) 9.0–5.0 *cold stuck*—will not move under pressure but shows no evidence of blowby across its face, indicating that it is free when running. The ratings range from 9 for a ring that is cold stuck over 30° or less of its circumference to 5 for a ring cold stuck over 330 to 360°, as indicated by Fig. 2.

(4) 4.0–0.0 *hot stuck*—firmly stuck in its groove with evidence of blowby or scuff across its face. Any hot stuck ring is a failure for the oil, but a numerical rating is normally assigned, from 4 for a ring hot stuck over 30° or less to zero from a ring hot stuck over 330 to 360°.

10.2.3 *Piston Skirt Varnish*—Follow the CRC Manual No. 14 (Varnish Rating)<sup>11</sup> in allocating numbers from 10 (clean) to 0 (completely black). Rate the inlet and exhaust side of the piston separately, looking in the direction at right angles to the axis of the wrist pin.

<sup>11</sup> This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.B0.06 on Two-Stroke Cycle Gasoline.