Designation: D4857 – 12

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[1]

This standard is issued under the fixed designation D4857; 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.

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

1. Scope*

1.1 This test method[2] 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 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:*[3]

B152/B152M Specification for Copper Sheet, Strip, Plate, and Rolled Bar

D93 Test Methods for Flash Point by Pensky-Martens Closed Cup Tester

D235 Specification for Mineral Spirits (Petroleum Spirits) (Hydrocarbon Dry Cleaning Solvent)

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

D874 Test Method for Sulfated Ash from Lubricating Oils and Additives

D2270 Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 and 100°C

D2622 Test Method for Sulfur in Petroleum Products by Wavelength Dispersive X-ray Fluorescence Spectrometry

D4052 Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter

D4629 Test Method for Trace Nitrogen in Liquid Petroleum Hydrocarbons by Syringe/Inlet Oxidative Combustion and Chemiluminescence Detection

D4858 Test Method for Determination of the Tendency of Lubricants to Promote Preignition in Two-Stroke-Cycle Gasoline Engines

D4859 Specification for Lubricants for Two-Stroke-Cycle Spark-Ignition Gasoline Engines-TC

D4863 Test Method for Determination of Lubricity of Two-Stroke-Cycle Gasoline Engine Lubricants

D4951 Test Method for Determination of Additive Elements in Lubricating Oils by Inductively Coupled Plasma Atomic Emission Spectrometry

E230 Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples

G40 Terminology Relating to Wear and Erosion

2.2 *ANSI Standard:*

ANSI MC 96.1 American National Standard for Temperature Measurement Thermocouples[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *cold sticking, adj—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, n—in reciprocating internal combustion engines*, the volume bounded by the piston crown

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.B0.06 on Two-Stroke Cycle Gasoline.

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[2] 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. 12-1.

[3] 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.

[4] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

***A Summary of Changes section appears at the end of this standard**

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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. **D4858**

3.1.3 *hot sticking, adj—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, n*—a qualitative term describing the ability of a lubricant to minimize friction between and damage to surfaces in relative motion under load. **D4863**

3.1.5 *preignition, n—in a spark-ignition engine*, ignition of the mixture of fuel and air in the combustion chamber before the passage of the spark. **D4858**

3.1.6 *scoring, v—in tribology* , a severe form of wear characterized by the formation of extensive grooves and scratches in the direction of sliding. **G40**

3.1.7 *scuff, scuffing, v—in lubrication* , damage caused by instantaneous localized welding between surfaces in relative motion which does not result in immobilization of the parts. **D4863**

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

3.1.9 *spark plug fouling, v*—deposition of essentially non-conducting 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, v*—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, n*—an oil whose performance in this test method is compared with the performance of the non-reference oil.

3.2.2 *major preignition, n*—preignition that causes a temperature increase of 10°C or more measured at the spark plug gasket.

3.2.3 *minor preignition, n*—preignition that causes a temperature increase of more than 7°C and less than 10°C measured at the spark plug gasket.

4. Summary of Test Method

4.1 The test is run in a 347 cm^3 Yamaha RD-350B twin-cylinder air-cooled motorcycle engine.[5] 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 D4859, 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^3 twin cylinder motorcycle engine with attached standard transmission (gearbox) is used.[5] 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, remove the oil pump and its connections and plug the oil connections to the carburetors.

6.1.3 *Dynamometer*—The dynamometer shall be capable of absorbing at least 8 kW. The engine crankshaft speed is 6000 rpm, and the motorcycle transmission can 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^3 /min of air is required. Direct the flow from the blower toward the exhaust side of the engine so as to deliver an approximately equal stream to each cylinder, and vary the flow 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 with a moisture content of (11 to 12) g/kg of dry air and a maximum pressure at the carburetor inlet of 3.7 kPa. Supply air to each carburetor through a separate flowmeter each having a capacity of 30 kg/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 Supply the fuel to each of the carburetors by individual electric fuel pumps, each with a capacity of at least 2.5 L/h, taking the fuel mix from separate tanks through paper or ceramic filters and flowmeters as specified in 6.1.6.2. The

[5] 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.

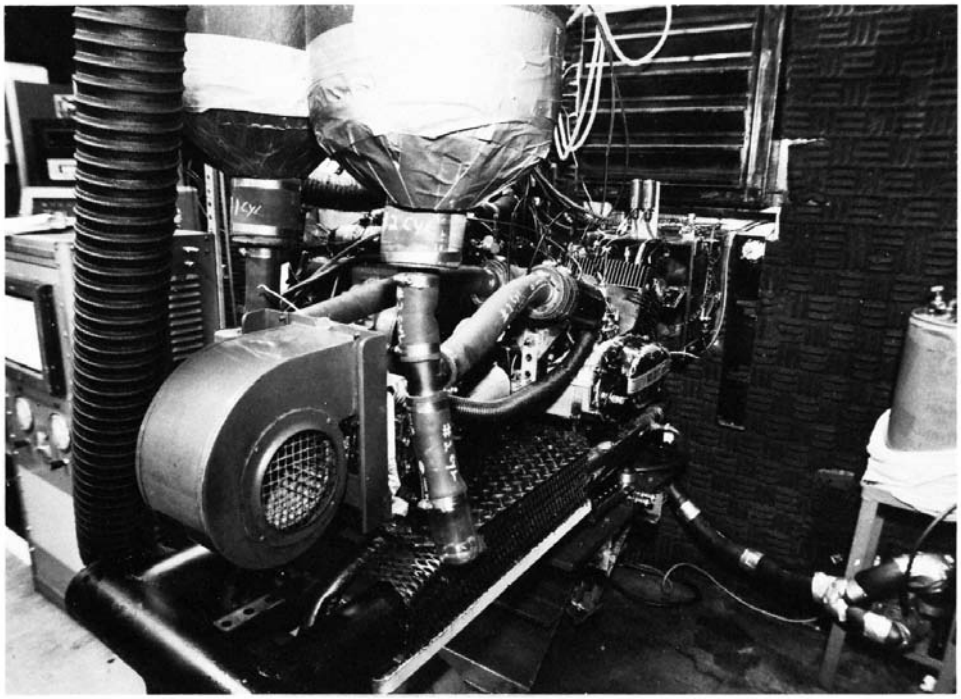


FIG. 1 Test Stand

fuel shall enter the carburetors at a maximum temperature of 25 °C and cooling might 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 at the flow rate specified in 6.1.6.1 may be used, but those measuring mass directly rather than volume are preferred. If a volume measuring device is used, determine the relationship of density to temperature over the range of fuel temperature experienced 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, portable containers with a capacity of at least 60 L are 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*—Use the standard motorcycle exhaust system, discharging into a pipe of at least 200 mm internal diameter leading out of the test cell. No modification other than axial rotation can 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 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*—Provide a thermocouple or thermometer to measure air temperature in the range from (10 to 50) °C. The overall accuracy of temperature measurement, including that of recorders, if used, shall be within ±1°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 ±0.1 kPa.

6.2.2.3 *Humidity*—A hygrometer accurate to ±3 % or a wet and dry bulb thermometer accurate to ±1°C 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.[6,7] Make provision for shutdown of the engine in the case of a spark plug gasket temperature increase of 10 °C or more. An automatic shutdown that operates if such an increase occurs is preferred. As a minimum, provide an alarm to operate after a temperature increase of (6 to 7) °C to allow manual shut down by the operator if the 10° 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

[6] 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.

[7] 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,[1] which you may attend.

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 E230) 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 of the cylinder exhaust port to monitor exhaust temperature.[7,8] The junction of the thermocouple shall be at the center of the pipe within ±3 mm.

6.2.5 *Temperature Recorder:*

6.2.5.1 *Plug Gasket and Exhaust Temperatures* —Record these temperatures 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) °C accurate to ±2 °C is suitable.

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

6.2.6 *Pressure and Humidity of the Air Supplied to the Engine*—Log the air pressure and humidity 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.[7,9]

7.1.2 About 225 L 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 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[10] in both cylinders. Six litres 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 D235, 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] 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., Stanford, CT 06907.

[9] 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.

[10] Available from ASTM Test Monitoring Center, 6555 Penn Ave., Pittsburgh, PA 15206-4489.

TABLE 1 Break-in Running Procedure

Duration, min	rpm	Power, kW	Spark Plug Gasket Temperature, °C
5	2000-2400	minimum	record
25	4400-4600	3.7	145 max
5	2000-2400	minimum	record
25	4900-5100	4.5	160 max
5	2000-2400	minimum	record
25	5400-5600	5.2	170 max
5	2000-2400	minimum	record
25	5900-6100	6.3	185 max

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.[5]

8.1.1 Use the following new parts for each test:

Two piston and ring assemblies, complete.
Two cylinder head gaskets.
Two cylinder base gaskets.
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. Examine the crankcase, crankshaft, rods, and associated seals and bearings and replace if necessary.

9. Procedure

9.1 *Calibration Run*—Annually, 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*—Break-in a new engine, or one that has been rebuilt as specified in 8.1 or 8.2, over a period of 2 h as specified in Table 1 using the same fuel and oil mixture in each cylinder as is used in the immediately following calibration or test run. The power output specified is approximate and may vary by about ±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

TABLE 2 Test Cycle

Minutes	rpm	Power, kW	Spark Plug Gasket Temperature, °C	Exhaust Temperature, °C	A/F Ratio
25	5950-6050	6.0-6.7	188-193	600-750[A]	11.8-12.2
5	2000-2400	minimum	record	record	n/a

[A] 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.

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 D4859, 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 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 or more from the normal expected reading that cannot be explained by a known change in operating conditions usually indicates a malfunction such as a change in the ventilation of the test cell or obstruction of the exhaust.

9.3.2 *Observations*—Record the temperatures specified in 9.3.1 continuously as specified by 6.2.5.1, log them at least twice per hour, and vary the cooling air stream as necessary to correct any tendency to drift. Log the crankshaft r/min, power output, fuel consumption, air to fuel ratio and ambient conditions at least twice per hour, and preferably recorded continuously.

9.3.3 *Preignition*— A rapid (1 min or less) increase of 10 °C 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 rerunning. Sudden temporary increases of 7 °C or more and less than 10 °C 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. Replace and label the spark plug and report the incident as specified in 9.3.3 for major preignition, after which continue the test.

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*—Perform the inspection and rating within 24 h of the end of the test, and preferably, as soon as possible after completion 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 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.

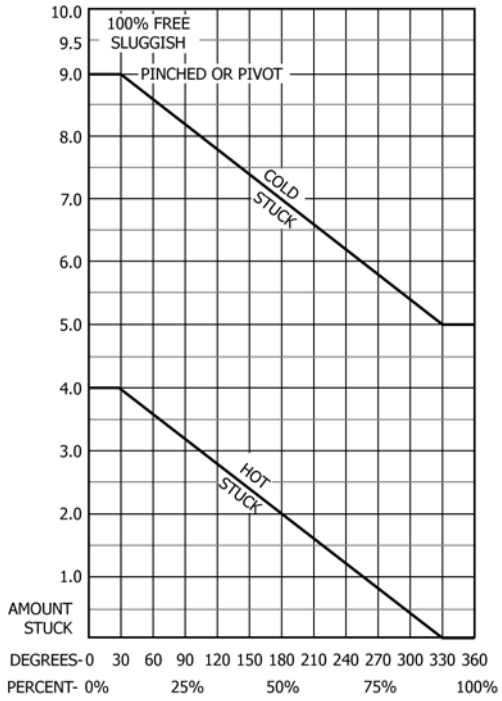


FIG. 2 Ring Sticking Rating Chart

(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)[11] 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.

10.2.4 *Piston Crown*—Describe the deposits by type, thickness, and location. A color photograph, oriented to the ports, may be provided.

10.2.5 *Cylinder Head*—As for the piston crown.

10.2.6 *Exhaust Port Blocking*—Report the percent of the total port area blocked by deposits. If this is greater than 10 %, photographs are required.

10.2.7 *Piston Damage*—Report any occurrence of scuffing or scoring as to extent and location.

10.2.8 *Condition of the Cylinder Bore*—Rate the inlet and exhaust sides separately. Report any varnish deposits by area covered and appearance. If the condition of the bore indicates scuffing or other lubricant-related damage, or is in any other way unusual, report it with appropriate description.

10.2.9 *Spark Plugs*—Report the condition of any spark plug removed during the test and the operating time as specified in 9.3.3.

10.2.10 *Other Discrepancies*—Report any unusual wear or damage in any part of the engine.

11. Report and Records

11.1 *Report Forms*— The required report forms and data dictionary are available from the ASTM Test Monitoring Center.

11.1.1 Include inspection results and ratings for both the non-reference and the benchmark reference oils, with photographs where appropriate.

11.1.2 Include a statement that the non-reference oil was or was not equal to or better than the benchmark reference oil within the tolerances allowed.

11.2 Make available upon request, to ASTM Subcommittee D02.B0.06, the detailed results obtained from tests on any of the reference oils, including the results obtained from the benchmark reference oil cylinder, so that statistical analysis of test consistency can be made as considered appropriate.

11.3 *Retention of Parts and Records:*

11.3.1 The testing laboratory shall retain for a minimum of 3 years the piston assemblies and all test spark plugs, the log sheets, recordings, and other test records from both non-reference and benchmark reference cylinders, and the original of the report. Protect the parts from atmospheric attack by means of vapor wrapping or other means that permit re-inspection to be made. A 1 L retain sample from each batch of reference oil and from each batch of test gasoline shall also be similarly retained, recording the amount and type of inhibitors added to the gasoline if such addition is considered to be advisable. Retain rated test parts by the laboratory for a minimum of 1 year.

12. Precision and Bias

12.1 Although the results of the deposit and ring sticking tests of this procedure are expressed numerically, the performance of a non-reference oil is based solely on whether or not it has equalled or surpassed the performance of a reference oil *tested simultaneously in the same laboratory.* Therefore, no statement can be made at this time about either precision or bias as the result merely states whether there is or is not conformance to the criteria for success specified in the procedure.

13. Keywords

13.1 air-cooled; engine deposits; lubricant; two-cycle gasoline engine

[11] Order from Coordinating Research Council, 219 Perimeter Center Parkway, Suite 400, Atlanta, GA 30346.

ANNEXES

(Mandatory Information)

A1. SPECIFICATION OF THE TEST ENGINE

A1.1 Specification of the Yamaha RD-350B Test Engine

A1.1.1 *General:*

Twin-cylinder, loop scavenge
Aluminum piston, slightly domed
Two pegged rings, 2 mm thick
Cast iron bore in aluminum
Removable hemispherical head
Built-up crank, solid connecting rod
Antifriction bearings throughout
Two Mikuni P/N 25504101 carburetors setting 514-4 #140 main jet
Idle setting (2000 to 2400) r/min

A1.1.2 *Dimensions:*

Cylinder bore 64 mm
Stroke 54 mm
Compression ratio 5.9:1 to 6.0:1
Exhaust port (32 by 27) mm
Transfer ports (2) (27 by 12) mm
(11 by 12) mm

A1.1.3 *Ignition Settings:*

Timing (1.9 to 2.1) mm BTDC
Breaker gap 0.4 mm max.

A1.1.4 *Spark Plug:*

NGK B9HS, or equivalent.
Plug gap setting (0.6 to 0.7) mm
Plug torque (19 to 20) N·m

A2. CALIBRATION REFERENCE OIL

A2.1 Calibration Oil

Designation (ASTM)	606
Oil properties (Typical):	
Viscosity mm^2/s, D445	
40 °C	53.7
100 °C	7.95
Viscosity index, D2270	115
Specific gravity, D4052	0.879
Flash point, °C, D93	600
Sulfated ash mass %, D874	0.10
Calcium mass %, D4951	0.035
Nitrogen mass %, D4629	0.049
Sulfur mass %, D2622	0.344
Approximate oil composition, volume %:	
Bright stock	11.82
150 Neutral	9.10
600 Neutral	59.56
Kerosine	15.79
Additives	3.73

A3. YAMAHA RD-350 B ENGINE BUILD PROCEDURE

A3.1 Rebuild Procedure

A3.1.1 This procedure summarizes the inspection and part replacement of the test engine required between tests. For greater detail and for operations other than those summarized here, refer to the RD-350B Service Manual.[5]

A3.2 Inspection

A3.2.1 *Piston*—Measure and record the piston diameter along the crankshaft axis and at right angles to it (9 to 11) mm above the bottom of the skirt.

A3.2.2 *Cylinder*—Measure and record to an accuracy of ±0.01 mm the cylinder bore along the crankshaft axis and at right angles to it in the following locations:

(18 to 20) mm below the top of the bore.
Just above the exhaust ports.
Just below the exhaust ports.
Just above the cutaway at the bottom of the bore.

A3.2.2.1 Record the maximum out-of round and the taper, which shall not exceed 0.025 mm total indicated runout (TIR).

A3.2.3 *Clearances*—Calculate the following for diameters measured in the same direction:

Minimum clearance
= smallest bore diameter minus largest skirt diameter
Maximum clearance
= largest bore diameter minus smallest skirt diameter

These clearances shall be in the range from (0.09 to 0.22) mm. If these limits are exceeded, use selective assembly to make up pairs of pistons and cylinders that are within limits or hone as specified in A3.2.4. Record the clearances and letter or number of the matching piston and cylinder pairs. Conduct

non-reference oil tests with piston-to-cylinder clearance within ±0.013 mm of the piston-to-cylinder clearance used for the acceptable reference oil test.

A3.2.4 *Honing*—Use a 150 grit stone for the initial hone and a 280 grit stone for the finish hone.

A3.2.5 *Cylinder Surface Finish*—Cylinder surface finish shall be in the range of (0.45 to 0.70) µm Ra.

A3.2.6 *Ports*—Inspect the ports for sharp edges or burrs. When found, file by hand to remove the sharp edge. Do not enlarge the ports.

A3.2.7 *Cylinder Gasket Surface*—Place the cylinder head gasket surface on a surface plate and try to wobble it. When it is possible to insert a 0.05 mm feeler gage between the surface plate and the gasket surface, it shall be corrected or the cylinder rejected.

A3.2.8 *Cylinder Head*— Check its gasket surface for flatness as for the cylinder gasket surface, and correct or discard if necessary.

A3.2.9 *Piston Rings*— Install standard size rings with standard size pistons and first oversize rings with first oversize pistons. Measure ring gaps as follows. With the rings removed from the piston, consecutively compress each ring into the respective cylinder (5 to 10) mm below the top of the cylinder bore. The gaps shall be (0.20 to 0.71) mm. If a gap is less than the minimum, increase the gap to 0.20 mm using a ring grinder. Record the final gaps. Assemble the piston rings onto the pistons. Check that the rings are free, with (0.03 to 0.07) mm side clearances, after positioning over the pins. Face the markings on the rings upward.

A3.2.10 *Other Components*—Make a general inspection of the engine, including the ignition system, cleaning, repairing, or replacing as necessary.

A3.3 *Determination and Adjustment of Compression Ratio*:

A3.3.1 Perform and record all procedures of this section, as required, for each set of engine test parts (cylinder head, cylinder and piston assembly) checked. Mark these in some permanent manner and keep them together. More than one set of test parts may be checked at a time; but if the crankcase and crankshaft assembly are changed after a particular set of test parts have been checked, recheck at least one set on the new crankcase assembly. If the difference does not put any of the prechecked sets of parts out of specification, these need not be rechecked.

A3.3.2 *Initial Assembly*—Wash all parts with hydrocarbon solvent and allow to air dry. Mount each piston on the rod *so that the arrow on the piston crown points to the exhaust port.* Apply gasket sealer to the cylinder base gasket and mount it on the cylinder. Oil the cylinder bore and the piston assembly lightly with Reference Oil 606 and mount the cylinder over the piston assembly. Using spacers on the studs to make up the thickness of the cylinder head flange, torque the nuts to (20 to 21) N·m (177 to 186 lbf·in.).

A3.3.3 *Determination of Effective Swept Volume:*

A3.3.3.1 Set the piston at bottom dead center (BDC) and measure the distance from the piston crown surface adjacent to the cylinder wall to the top of the exhaust port (the effective port height), using the procedure of A3.3.3.2 or A3.3.3.3

A3.3.3.2 Using a dial indicator, locate the piston at BDC. Measure the distance from the edge of the piston crown at BDC to the top edge of the exhaust port and add the vertical length of any chamfer. Without moving the piston, measure the distance from the same point on the piston crown to the cylinder head mounting surface.

A3.3.3.3 Locate the piston at top dead center (TDC) and measure from the same point on the piston crown to the piston head mounting surface. The difference between the BDC and TDC measurements minus the effective port height equals the effective stroke.

A3.3.3.4 Multiply the effective stroke by the area corresponding to the cylinder bore diameter ($bore^2 \times 0.7854$) to obtain the effective volume. The cross-sectional area of the cylinder bore of the Yamaha RD-350B engine is 32.17 cm^2 and the effective volume is approximately 87 cm^3. The volume is obtained in cubic centimetres or in numerically identical millilitres, as all commercially available burets are so calibrated.

A3.4 *Determination of Compressed Volume*:

A3.4.1 Position the engine so that the spark plug gasket mounting surface is up and horizontal when the cylinder head is in place.

A3.4.2 Position the piston at TDC.

A3.4.3 Using the finger tips, press heavy petrolatum[7,12] (not a lubricating grease or petroleum jelly) into the space between the piston and the cylinder wall so that no gap appears around the piston circumference. Wipe off any excess from the piston crown and from the cylinder head gasket surface. Be careful not to move the piston during this operation.

A3.4.4 Mount the cylinder head and gasket, torquing to (20 to 21) N·m.

A3.4.5 Using the Reference Oil 600 diluted with about 20 % volume of hydrocarbon solvent, which gives about (4.0 to 5.5) mm^2/s viscosity at 100 °C, fill the combustion chamber just to the top of the spark plug hole, measuring the amount of oil to ±0.1 mL (cm^3). Tap gently to dislodge any air bubbles and make sure that the oil level has stabilized before recording the amount used. This will normally be (18 to 22) mL. This is most easily done using a 50 mL buret set in a stand over the engine.

A3.4.6 Subtract 1.1 mL from the volume of oil to allow for the volume of the spark plug. This is the compressed volume, which will normally be (17 to 18) cm^3.

A3.5 *Calculation of Compression Ratio*:

A3.5.1 The compression ratio is as follows:

$$(ESV + CV)/CV \qquad \text{(A3.1)}$$

[12] OMC Needle Bearing Grease has been found satisfactory. The sole source of supply of the material known to the committee at this time is Outboard Marine Corp., Parts and Accessories Dept., P.O. Box 88 (3225 Prairie Ave.), Beloit, WI 53511, or from OMC's subsidiaries Evinrude or Johnson Outboard.

where:

ESV = effective swept volume, mL or cm^3, and
CV = compressed volume, mL or cm^3

A3.6 *Adjustment of Compression Ratio*:

A3.6.1 The compression ratio shall fall into the range of 5.75 to 5.90 to 1. For the Yamaha RD-350B this is 5.9 to 6.0 to 1. If the compression ratio is too low, it will be necessary to grind the cylinder head gasket surface to remove metal. There is at present insufficient experience with the procedure to make any recommendation as to how much metal to remove to obtain a specific compression ratio increase.

A3.6.2 If the compression ratio is too high, try to correct by interchange of heads. If this is not possible, remove small quantities of metal from the inside of the cylinder head using a high-speed hand grinder evenly over the surface.

A3.6.3 After correction, repeat Sections A3.4 and A3.5. Record final values.

A3.7 *Final Assembly* :

A3.7.1 Empty out the oil used for volume determination. Remove the cylinder heads and cylinders. Wash with hydrocarbon solvent to remove the grease, and lubricate lightly with Reference Oil 600.

A3.7.2 Replace the cylinders, cylinder heads, and gaskets. The gaskets may normally be reused after the volume determination procedure.

A3.7.3 Complete the rebuilding of the engine as specified in the Service Manual.

A3.7.4 Before inserting the spark plugs, turn the engine over by hand to ensure that it is free.

A3.7.5 Gap two new NGK B9HS (or equivalent) spark plugs to (0.70 to 0.75) mm. Install a thermocouple washer under each plug (see 6.2.3.1) and tighten to (19 to 20) N·m.

APPENDIX

(Nonmandatory Information)

X1. PREPARATION OF SPARK PLUG GASKET THERMOCOUPLES

X1.1 *Material* :

X1.1.1 *Gasket*—Use nominally pure (99.9 %) copper such as Specification B152/B152M. The use of quarter hard material (Grade H01 or 081) is recommended to facilitate machining. The method by which the gaskets are produced, turning, stampling from sheet, and so forth is not critical.

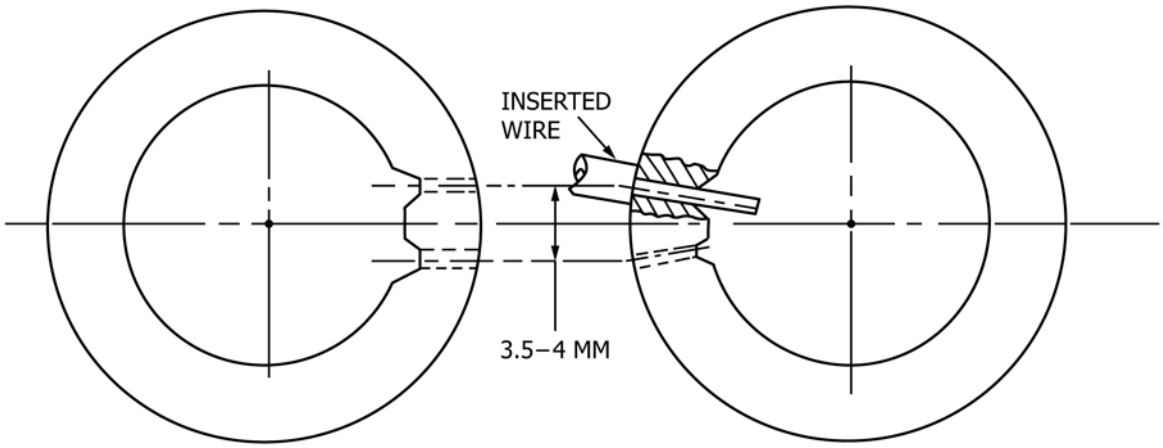
X1.1.2 *Thermocouple Wires*—One iron and one constantan Type J solid core glass or silica double-insulated thermocouple wire of (0.8 to 1) mm diameter and of any convenient length are required for each thermocouple. Up to four thermocouples can be installed in a single gasket.

X1.2 *Manufacture* :

X1.2.1 Make gaskets (rings), drilled and notched as shown in Fig. X1.1, as necessary to supply each sparkplug of the unit to be tested. The notches in the inner diameter of the gasket at the ends of the radial holes are only required if the wires are soldered in place and, if used, are not critical as to size or finish. The drilled holes may be parallel or drilled radially, and their diameter such as to allow easy insertion of the thermocouple wires with minimum clearance.

X1.2.2 Remove insulation from the ends of the thermocouple wires so that the bare ends of the wires protrude beyond the inner diameter of the gasket when they are inserted into the holes from the outer diameter. Insert the wires as shown, and either apply silver solder to the inside ends or secure them with a crush fit. When the wires have been secured restore the inner diameter of the gasket by filing or grinding. If necessary, use shrink tubing to repair damaged insulation. Remove any silver solder that is on the faces of the gasket.

X1.3 Check the completed thermocouple gasket against a known standard. A reading within ±1°C of the standard is acceptable.



NOTE 1—The inserted wire is shown prior to silver soldering.
NOTE 2—Material copper—¼ hard.
NOTE 3—Outside diameter (20.8 to 21.0) mm
Inside diameter (14.3 to 14.6) mm
Thickness (1.8 to 2.2) mm
For other dimensions, see the text.

FIG. X1.1 Spark Plug Thermocouple Gasket

SUMMARY OF CHANGES

Subcommittee D02.B0 has identified the location of selected changes to this standard since the last issue (D4857–08) that may impact the use of this standard.

(1) Changed reference oil test frequency from six months to one year in 9.1.

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