



Standard Test Method for Determination of the Tendency of Lubricants to Promote Preignition in Two-Stroke-Cycle Gasoline Engines¹

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

¹ This ~~specification~~ test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.B0 on Automotive Lubricants.

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1. Scope

1.1 This test method² evaluates the performance of lubricants intended for use in two-stroke-cycle spark-ignition gasoline engines which are prone to preignition.

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

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

2. Referenced Documents

2.1 ASTM Standards:

B 152 Specification for Copper Sheet, Strip, Plate, and Rolled Bar³

D 439 Specification for Automotive Gasoline⁴

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

D 664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration⁴

D 874 Test Method for Sulfated Ash from Lubricating Oils and Additives⁴

D 910 Specification for Aviation Gasolines⁴

D 2270 Practice for Calculating Viscosity Index from Kinematic Viscosity at 40° and 100°C⁴

D 2699 Test Method for ~~Knock Characteristics of Motor Fuels by the Research Method~~ Octane Number of Spark-Ignition Engine Fuel⁴

D 2700 Test Method for ~~Knock Characteristics of Motor and Aviation Fuels by the Motor Method~~ Octane Number of Spark-Ignition Engine Fuel⁴

D 2885 Test Method for Research and Motor Method Octane Ratings Using On-Line Analyzers⁴

D 2896 Test Method for Base Number of Petroleum Products by Potentiometric Perchloric Acid Titration⁴

D 4857 Test Method for Determination of the Ability of Lubricants to Minimize Ring Sticking and Piston Deposits in Two-Stroke-Cycle Gasoline Engines Other than Outboards⁵

D 4863 Test Method for Determination of Lubricity of Two-Stroke-Cycle Gasoline Engine Lubricants⁵

E 230 Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples⁶

2.2 ~~American National Standards Institute (ANSI)~~ ANSI Standard:

ANSI MC 96.1 American National Standard for Temperature Measurement Thermocouples⁷

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. ~~00-1-01-3~~.

³ *Annual Book of ASTM Standards*, Vol 02.01.

⁴ *Annual Book of ASTM Standards*, Vol 05.01.

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

⁶ *Annual Book of ASTM Standards*, Vol 14.03.

⁷ Available from American National Standards Institute, 11 West 42nd Street, 13th Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

3. Terminology

3.1 Definitions:

3.1.1 *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.

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

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

3.1.4 *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. **D 4857**

3.1.5 *spark plug whiskering, also spark plug bridging*—a deposit of conductive material on the spark plug electrodes which tends to form a bridge between them, thus shorting out the plug. **D 4857**

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *major preignition*—preignition that causes a temperature increase of 10°C (18°F) or more measured at the inner surface of the cylinder head.

3.2.2 *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 inner surface of the cylinder head.

4. Summary of Test Method

4.1 The test is run in a 49 cm³ single-cylinder air-cooled engine operated under the conditions required by the specification against which it is being run. These are typically 4000 r/min wide open throttle (WOT) using a 20:1 ratio of gasoline to oil by volume for a minimum of 50 h. The number of incidences of preignition, as indicated by a rapid increase in combustion chamber temperature, is recorded.

NOTE 1—*Pass-Fail Criterion*—The number of occurrences of preignition during the test of a candidate oil shall not exceed that permitted by the specification against which it is run.

5. Significance and Use

5.1 Two-stroke-cycle gasoline engines are generally more prone to preignition than are four-stroke-cycle engines due to the absence of the internal cooling that takes place during the induction stroke of the four-stroke-cycle engines. Preignition can lead to major piston damage, either directly due to localized overheating or as the result of preignition-induced detonation. Some lubricant additives that are widely used in four-stroke-cycle gasoline engine oils are known to increase the probability of preignition in gasoline two-stroke-cycle engines. This procedure is used to determine the tendency of an oil to induce preignition in both water-cooled and air-cooled two-stroke-cycle gasoline engines.

6. Apparatus

6.1 Test Engine and Stand:

6.1.1 *Test Engine Configuration*—A Yamaha CE-50 49 cm³ loop-scavenged air-cooled two-stroke-cycle engine is used.⁸ This has 40 mm (1.57 in.) bore, 39.2 mm (1.54 in.) stroke, with an aluminum piston operating in a cast iron cylinder bore. The cylinder head is removable, with a hemispherical combustion chamber. For the purposes of this test the head shall be modified as specified in 6.3.1.1. Further details are given in Annex A1.

NOTE 2—The engine designation normally includes a final letter indicating the model, such as CE-50S, the model on which this test was developed. If this model is not available check the suitability for this test of available models with the manufacturer.⁸

6.1.2 *Test Stand*—The dynamometer shall be able to absorb 2.5 kW (3.4 hp) at 4000 to 6000 r/min with an inherent torque measurement accuracy of ±0.5 % or better, and be capable of maintaining 4000 ± 30 r/min with varying power input. A direct shaft drive or a belt drive from the engine crankshaft may be used. A complete test stand assembly, as shown in Fig. 1, is available.⁹

6.1.3 *Cooling Blower*—The original internal engine fan shall be removed or have its blades machined off. A variable delivery blower with a free flow capacity of about 34 m³/min (1200 ft³/min) of air is recommended. The flow from the blower shall be directed toward the intake side of the engine. A suitable arrangement is shown in Fig. 1.

6.1.4 *Fuel System*—Fuel delivery pressure shall be maintained at 19 to 21 kPa (2.7 to 3.0 lb/in.²). The temperature of the fuel entering the carburetor shall not exceed 25°C (77°F), and this may require cooling in hot climates.

6.2 Instrumentation:

^{*}Obtainable from

⁸ The sole source of supply of the apparatus known to the committee at this time is Engineering and Service Dept., Yamaha International Corp., P.O. Box 6555, Cypress, CA 90630. Parts, but not complete engines, may be obtained from Yamaha motorcycle dealers. 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 committee¹, which you may attend.

⁹ Order from Southwest Research Institute, Automotive Products and Emissions Research Division, 6220 Culebra Rd., San Antonio, TX 78238.

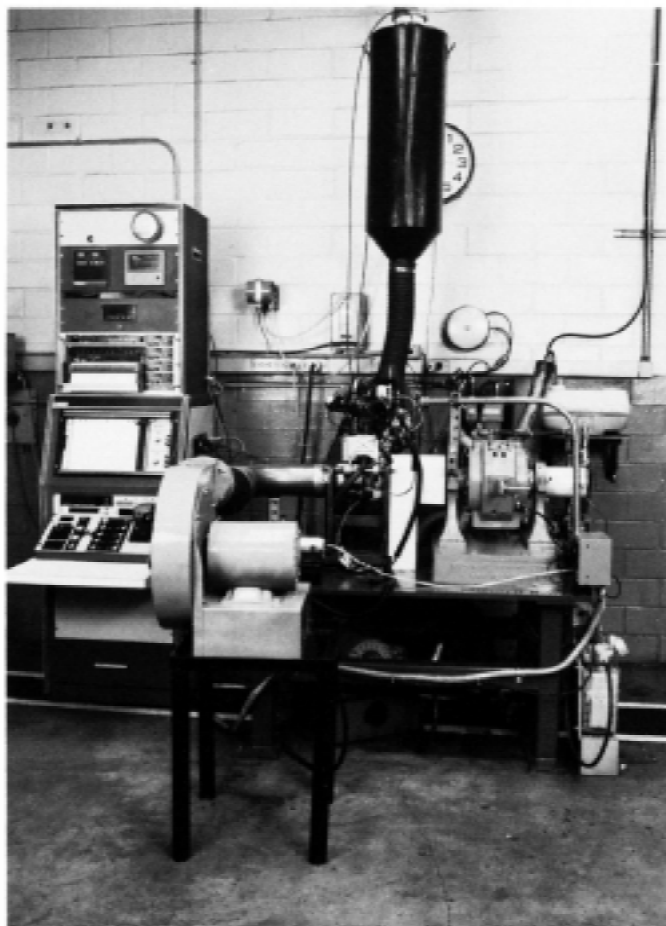


FIG. 1 Test Stand

6.2.1 *Tachometer*—An electronic tachometer accurate to ± 25 r/min.

6.2.2 *Measurement of Ambient Conditions*—6.2.2 is written on the assumption that the engine draws ambient air from the test room. If it is supplied with air from a controlled source, references to ambient temperature, pressure and humidity apply to the air from the controlled source.

6.2.2.1 *Temperature*—A thermocouple or thermometer shall be provided to read air temperature in the range 10 to 50°C (50 to 120°F).

6.2.2.2 *Barometric Pressure*—A barometer recording the pressure in the test room is required.

6.2.2.3 *Humidity*—A hygrometer or a wet and dry bulb thermometer is also required.

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

6.2.3 *Calibration*— Calibrate the tachometer, ambient temperature, and pressure measurement devices every 90 days. The calibration standard shall be traceable to NIST.

6.3 *Engine and System Temperatures :*

6.3.1 *Combustion Chamber Temperature :*

6.3.1.1 *Modification of Cylinder Head*— The cylinder head shall be fitted with a shielded thermocouple. A thermocouple of the iron-constantan type meeting the requirements of ANSI 91.6 Type J (summarized very briefly in ASTM Tables Specification E 230) is recommended, but any thermocouple capable of performing satisfactorily under the conditions of the test can be used.¹⁰ The general dimensions and machining requirements are shown in Fig. 2. The through hole, in which the thermocouple is required to fit closely, is about 3-mm (0.12-in.) diameter, and the counterbore shall not extend closer than 4 mm (0.16 in.) to the combustion chamber surface. The dimensions of the counterbore and thread are not critical, being suitable to available thermocouples, but the thread diameter shall be less than 14 mm (0.55 in.). A 1/8 27-NPTF thread is recommended. The thermocouple shall be made so that the last 3 to 4 mm (0.12 to 0.16 in.) of its tip is a snug fit into the 3-mm diameter portion of the hole, and be mounted in the head so that its tip protrudes sufficiently to allow it to be ground flush with the internal surface of the head without penetrating

¹⁰ A suitable instrument is available from Omega Engineering Inc., P.O. Box 4047, One Omega Dr., Stamford, CT 06907.

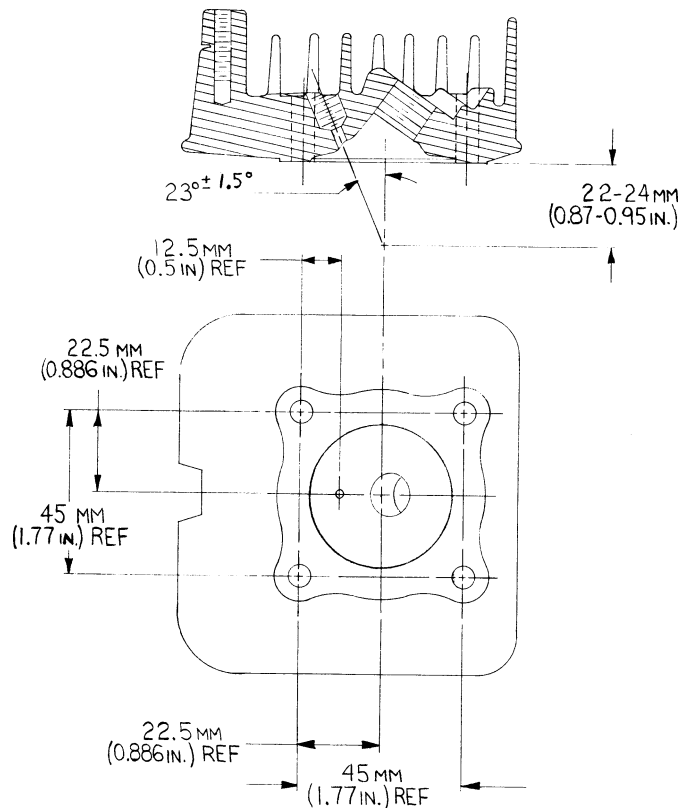


FIG. 2 Machining of Cylinder Head

the shield. When a head has been newly fitted with a thermocouple, run a break-in in accordance with 10.2 and Table 1. The thermocouple reading normally requires about 90 min to stabilize.

6.3.1.2 *Shutdown Provision*—Provision shall be made for shutdown of the engine in the case of a rapid (1 min or less) combustion chamber temperature increase of 10°C (18°F) or more. This normally indicates an incidence of *major preignition*, and is required to minimize the risk of damage to the engine. An automatic shut down when such an increase is experienced is recommended. At the least an alarm shall be provided to operate after a temperature increase of 6 to 7°C (11 to 13°F) to allow manual shut down by the operator if the 10°C limit is exceeded.

6.3.2 *Exhaust Temperature*—A thermocouple is required in the exhaust elbow within about 65 mm (2.5 in.) of the cylinder exhaust port to monitor exhaust temperature.⁹ The thermocouple junction shall be located within ±3 mm (0.12 in.) of the center of the pipe.

6.3.3 *Spark Plug Gasket Temperature*—The spark plug gasket may be fitted with one or two thermocouples, the number depending on the instrumentation used. A design that has been found satisfactory is described in Appendix X1.¹¹

6.3.4 *Combustion Chamber and Spark Plug Gasket Temperature Recorders*—These temperatures shall be recorded using a system capable of storing the data for later retrieval. Maximum interval between successive recordings of the combustion chamber temperature is 2 s. A system with a range from 40 to 750°C (100 to 1400°F) and an overall accuracy of ±2°C (4°F) is suitable.

6.3.5 *Calibration*—Calibrate the combustion chamber, exhaust and spark plug gasket temperature measurement devices every 90 days. The calibration standard shall be traceable to NIST.

6.4 Fuel System:

6.4.1 *Flow Meter*—Any type accurate to ±0.01 kg/h (±0.02 lb/h) at about 1 kg/h (2 lb/h) flow rate may be used. Instruments measuring mass directly are preferred. If a volumetric measurement meter is used the temperature-density relationship shall be determined over the operating range for the actual fuel-non-reference oil mixture used for use in volume-mass conversion.

6.4.2 A temperature measuring device reading to at least 40°C (100°F) to an accuracy of ±1°C (2°F) and a pressure gage or transducer reading up to about 35 kPa (5 lbf/in.²) to an accuracy of ±2% are required to monitor the temperature and pressure of the fuel entering the carburetor.

7. Materials and Reagents

7.1 *Test Fuel*—The test fuel shall be a leaded gasoline consisting essentially of hydrocarbons, except for conventional lead

¹¹ 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 on Automotive Lubricants.

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TABLE 1 Break-In

Duration, min	RPM	Throttle Position	Plug Temperature, °C (°F)
2	2000 ± 100	Closed (idle)	Record
2	4000 ± 50	1/3open	125 (257) max
2	5500 ± 50	1/3open	125 (257) max
2	3500 ± 50	1/3open	125 (257) max
2	4500 ± 50	1/3open	125 (257) max
Repeat for a total of 2 cycles, or 20 min running time.			
Duration, min	RPM	Throttle Position	Plug Temperature, °C (°F)
2	2000 ± 100	Closed (idle)	Record
2	4000 ± 50	1/2open	140 (284) max
2	5500 ± 50	1/2open	140 (284) max
2	3500 ± 50	1/2open	140 (284) max
2	4500 ± 50	1/2open	140 (284) max
Repeat for a total of 4 cycles, or 40 min running time.			
Duration, min	RPM	Throttle Position	Plug Temperature, °C (°F)
2	2000 ± 100	Closed (idle)	Record
2	4000 ± 50	3/4open	155 (311) max
2	5500 ± 50	3/4open	155 (311) max
2	3500 ± 50	3/4open	155 (311) max
2	4500 ± 50	3/4open	155 (311) max
Repeat for a total of 4 cycles, or 40 min running time.			
Duration, min	RPM	Throttle Position	Plug Temperature, °C (°F)
2	2000 ± 100	Closed (idle)	Record
2	4000 ± 50	WOT	170 (338) max
2	5500 ± 50	WOT	170 (338) max
2	3500 ± 50	WOT	170 (338) max
2	4500 ± 50	WOT	170 (338) max
Repeat for a total of 2 cycles, or 20 min running time.			

antiknock, anticorrosion, anti-icing, etc. additives in normal concentration, and containing no non-lead metallic antiknock compounds or oxygenated blending compounds such as alcohols or ethers. It shall contain 0.4 to 0.6 g/L (1.5 to 2.2 g/gal) of lead as lead alkyls with conventional motor mix or aviation mix scavengers, and shall have a minimum motor octane number of 83, a maximum sensitivity (research octane number minus motor number) of 12 as determined by Test Methods D 2699, D 2700, or D 2885, as applicable, and shall otherwise meet the requirements of Specification D 439 volatility grade A or B. Aviation gasoline meeting these requirements and otherwise conforming to Specification D 910 Grade 100 or 100LL may be used. Fuel from the same batch shall be used for calibration running and for any other tests referenced to that calibration. About 40 L (10 gal) of fuel are required for a test, plus 12 L (3 gal) for the break-in.

7.2 *Reference Oils*—ASTM 601 and 605 reference oils are used for calibration purposes.¹² ASTM 600 reference oil is used for break-in and as an assembly lubricant.¹² About 4 L (1 gal) of reference oil is required to run a calibration test, and 0.4 L (0.1 gal) of 600 for a break-in. The properties of these oils are summarized in Annex A2.

7.3 *Non-Reference Oil*—About 4 L (1 gal) are required for a 50 h test, varying according to the number of test hours specified. It is recommended that at least twice this amount be provided in case the test is rerun.

7.4 *Grease*—OMC needle bearing grease or petroleum jelly.

8. Calibration

8.1 After 30 tests or 180 days, whichever occurs first, or at any time a new or completely rebuilt engine or test bed is put in service, conduct calibration tests. Run a test for 50 h using reference oil 605. There shall be a minimum of four and a maximum of ten major preignitions during this test. If reference oil 605 fails to provide a minimum of four and a maximum of ten preignitions, investigate the cause and repeat the test. Run a test for 50 h using reference oil 601 as if it were a non-reference oil. When not more than one major preignition is obtained, no further action is required. If more than one preignition is obtained, investigate the cause and repeat the test.

8.2 In order for a test stand to be accepted for non-reference oil qualification, it shall be calibrated by the procedure of 8.1.

¹² Available from ASTM Test Monitoring Center, 6555 Penn Ave., Pittsburgh, PA 15206-4489.

9. Procedure

9.1 Assembly of the Engine:

9.1.1 *Initial Build*—Use a new piston, rings, cylinder, and cylinder base and head gaskets (see Annex A3). The cylinder head is fitted with a thermocouple (see 6.3.1.1), and the compression ratio shall be checked as indicated in A3.6 through A3.8 after the thermocouple has been mounted, and corrected if necessary. This is done if possible by interchange of parts, but if necessary by modification as described in A3.9.

9.1.2 *Rebuild After Test*—It is not necessary to use new parts other than gaskets, a new piston and rings assembly and a new muffler, provided that all parts are clean and within specification with no sign of damage.

9.2 *Expected Life*—The cylinder will usually require replacement after 100 to 150 running hours. After about 1000 to 1500 running hours the entire engine will normally require replacement or a complete rebuild.

10. Operating Instructions

10.1 *Fuel Temperature and Pressure*—The temperature of the fuel entering the carburetor shall not exceed 25°C (77°F), which may require cooling in hot climates, and fuel delivery pressure shall be maintained at 19 to 21 mPa (2.7 to 3.0 lb/in.³) for all test operation.

10.2 *Break-In*—Before each test the engine shall be broken in for 2 h as specified in Table 1, using a 20:1 (5 % oil) by volume mixture of test gasoline and the (non-reference) or reference oil that is to be used in the test. After break-in the piston and cylinder shall be removed and examined. If there is any sign of piston scuff, ring sticking, or other malfunction the parts involved shall be replaced and the break-in repeated.

10.3 Test Procedure:

10.3.1 *Conditioning Run*—Following the break in, run the engine under the conditions of Table 2.

10.3.2 *Warmup*—When restarting after any shutdown run an 8 min warmup under the conditions of Table 3. This time is not counted toward the total test time.

10.3.3 *Test*—As soon as the warmup is completed, run the test for the time specified under the conditions of Table 4. The combustion chamber temperature shall be recorded continuously, the interval between successive readings not exceeding 2 s. This, together with the fuel pressure, fuel flow rate, and intake air temperature shall be logged every 30 min. The barometric pressure and the relative humidity in the test cell shall be recorded at least every 2 h. Set the automatic shut-down or alarm in accordance with 6.3.1.2, taking care to compensate for any gradual change in the temperature level that may occur. The exhaust temperature, while not a test parameter, shall be monitored as any change from the normal level for the installation and conditions of more than about 20°C (36°F) that cannot be accounted for by a known change in the ambient conditions requires investigation. Such a change may indicate either a change in the air supply to the cell or an obstruction of the exhaust.

10.3.4 *Major Preignition*—If at any time the cylinder head thermocouple temperature rises rapidly by 10°C (18°F) or more above its stable temperature at 4000 r/min at WOT, a *major preignition* is assumed and the engine stopped immediately. Log the occurrence to the nearest 0.1 h. Usually the spark plug temperature increases and the torque decreases during a major preignition.

10.3.5 *Inspection and Restart after Major Preignition*—Do not remove the spark plug immediately. Remove the exhaust assembly and the cylinder head. Inspect the cylinder bore. If there is no mechanical damage, clean the deposits from the combustion chamber and replace the cylinder head using a new gasket and spark plug. Label the plug with total running hours, hours on the plug and reason for removal. If scuff or seizure is visible, remove the cylinder also and inspect the piston. If necessary, fit a new piston and cylinder and break in accordance with 10.2 before continuing the test.

10.3.6 *Minor Preignition*—If a rapid temperature rise of less than 10°C (18°F) and more than 7°C (13°F) is noted on the recorder, log this as a minor preignition, with the total engine hours and the hours since the last plug change to the nearest 0.1 h, the combustion chamber and cylinder head temperature increases, and the accompanying torque reduction. Do not stop the engine.

10.3.7 *Other Spark Plug Malfunction*—If the engine slows by more than 100 r/min and does not return to its previous speed within a further 2 min, with a reduction of combustion chamber temperature, remove and replace the plug. Note the time as in 10.3.6, and whether the plug is whiskered (bridged) or fouled. If it is found that the problem is not related to the spark plug, replace the plug in use at the time of the failure when restarting after repairs are complete. If the plug is removed label it as in 10.3.5.

10.3.8 *Exhaust System Plugging*—If at any time the torque falls to 90 % of its initial steady value, remove any exhaust port deposits and replace the exhaust system with a clean unit. If this does not restore the power, investigate and repair as appropriate. Any such event shall be recorded as called for in 10.3.6.

TABLE 2 Conditioning Run

Duration, min	Engine, rpm	Load	Plug Temperature, °C (°F)
30	4000 ± 30	0.746 ± .07 kw (1 ± 1 bhp)	174 ± 3°C (345 ± ° F)
<u>30</u>	<u>4000 ± 30</u>	<u>0.746 ± .07 kw (1 ± 1 bhp)</u>	<u>174 ± 3°C (345 ± ° F)</u>

TABLE 3 Warm Up

Duration, min	Engine, rpm	Throttle Position	Load	Plug Temperature, °C (°F)
2	2000 ± 200	Closed (idle)	0	Record
2	3000 ± 50	1/3 Open	Record	125 (257)
2	3500 ± 50	2/3 Open	Record	185 (365)
2	4000 ± 50	WOT	Record	200 (392)

TABLE 4 Test Running

Engine, rpm	Throttle Position	Load	Plug Temperature, °C (°F)
4000 ± 30	WOT	Record	200 ± 3 (392 ± 5)

11. Report

11.1 *Report Forms*—The required report shall include the following:

11.1.1 The name of the testing laboratory forms and the run number.

11.1.2 Identification of the non-reference oil by the name of the submitting organization and its code. If the testing laboratory also allocates an identification code to non-reference oils, this also shall be given.

11.1.3 Dates on which the test was begun and ended and total test hours run.

11.1.4 Test results and any comments necessary to their full understanding.

11.2 The detailed results obtained data dictionary are available from tests on any of the reference oils shall be made available to ASTM Subcommittee D02.B0.06 upon request so that statistical analysis of test consistency may be made as considered appropriate. Test Monitoring Center.

12. Retention of Parts and Records

12.1 The testing laboratory shall retain for a minimum of 3 years the log sheets, recordings, and other test records from both non-reference and reference tests, the original of the report.

13. Precision and Bias

13.1 The precision of this procedure has not yet been determined.

13.2 No statement can be made regarding bias, as the preignition tendency of an oil is defined only in terms of the test method.

14. Keywords

14.1 air-cooled; lubricant; preignition; two-cycle gasoline engine

ANNEXES

(Mandatory Information)

A1. SPECIFICATION OF THE TEST ENGINE

A1.1 Specification of the Yamaha Ce-50S Test Engine

A1.1.1 General:

Single-cylinder, loop scavenge

Aluminum piston, slightly concave head

Two pegged rings, 1.1 mm (0.045 in.) thick

Cast iron bore in aluminum

Removable hemispherical head

Built-up crank, solid connecting rod

Antifriction bearings throughout

Tikai Kikaki Y12P carburetor

Idle setting 1500 to 2100 r/min

A1.1.2 Dimensions:

Cylinder 40 mm (1.57 in.)

Stroke 39.2 mm (1.54 in.)
 Compression ratio 7.01:1 to 8.0:1
 A1.1.3 *Ignition Settings:*
 Timing 18° BTDC (not adjustable)

Breakerless CDI ignition

A1.1.4 *Spark Plug:*

NGK BP6HS, or equivalent.

Plug gap setting 0.9 mm (0.035 in.)

Plug torque 19 to 20 N·m (14 to 15 ft·lbf)

A1.2 *Compression Ratio*—The specification for this test procedure is 7.0:1 to 8.0:1. The average compression ratio as determined by the procedure of Annex A3 on a random sample of 10 engines was 7.53:1. The range was 7.01:1 to 8.10:1.

A2. REFERENCE OILS

A2.1 Oil Properties (Typical):

Designation (ASTM)	600	601	605
Viscosity mm ² /s (cSt) D 445:			
40°C (104°F)	34.2–38.2	121.0	107.9
100°C (212°F)	6.1–6.6	12.2	12.4
Viscosity index D 2270	128 (typical)	90	106
TAN mg KOH/g D 664	1.7	n/a	n/a
	(typical)		
TBN mg KOH/g D 2896	6.5	n/a	n/a
	(typical)		
Sulfated ash mass % D 874	<0.005	0.16	1.28
Calcium mass %	0	0.045	0.21
Barium mass %	0	0	0.26
Zinc mass %	0	0	0.08
Nitrogen mass %	0.58	0.17	0.02
<i>Approximate oil composition,</i>			
<i>vol %:</i>			
Bright stock	9.00	n/a	n/a
650 Neutral	61.65	—	—
Hydrocarbon solvent	20.00	—	—
Additives	9.35 ^A	n/a ^B	4.0 ^C

^A Principally an ashless dispersant.

^B Principally a metallic-based detergent.

^C Contains both ashless and metallic-based additives.

A2.2 The applications of the reference oils used in this test method are described in 7.2.

A3. YAMAHA CE-50S ENGINE BUILD PROCEDURE

~~(Engine Build Procedure:)~~

~~A3.1—General:~~ (ENGINE BUILD PROCEDURE)

A3.1 General

A3.1.1 This annex summarizes the inspection of a new Yamaha CE-50S test engine prior to test and the inspection and part replacement required between tests. For greater detail and for operations other than those summarized here, refer to the Yamaha CE-50S Service Manual.⁷

A3.2 Disassembly:

A3.2.1 *Cylinder and Piston*—Remove the engine cowling and spark plug. Using a cross-over pattern, loosen the cylinder head nuts ¼turn at a time until free, then remove the nuts and cylinder head. Remove the intake manifold and reed valve assembly. Remove the cylinder. Place a clean shop towel into the crankcase opening around the connecting rod. Remove the piston pin locks using suitable pliers. Gently tap or, preferably, press out the piston pin using a piloted driver. If it will not come out readily, heat the piston as the use of force can damage both the piston and the connecting rod. Remove the piston and ring assembly. If this is a new unit, proceed as specified by A3.3. If the engine has been run on test, replace the piston and rings assembly and the cylinder; and install a cleaned cylinder head.

A3.2.2 *Crankcase*—If it is necessary to disassemble the crankcase, refer to the Yamaha CE-50SS Service Manual. This is not

normally required in the useful life of the engine.

A3.3 Inspection and Rework of New Engine Parts—The checks specified in A3.3.1-A3.3.5 shall be performed on all engines.

A3.3.1 Piston Clearance—The diametral piston to bore clearance shall be 0.045 to 0.13 mm (0.0018 to 0.005 in.). This tolerance will normally be met by an as-received assembly. The piston and ring clearances shall be recorded, and the engine, and in particular the piston assembly and the cylinder, shall be visually inspected before running.

A3.3.2 Cylinder Bore—Measure and record the cylinder bore along the crank axis and at 90° to it to the nearest 0.01 mm (0.004 in.) in the following locations.

7 mm (0.28 in.) below the top of the bore.
12 mm (0.47 in.) below the top of the bore.
32 mm (1.26 in.) below the top of the bore.

Record the maximum out-of-round and the taper.

A3.3.3 Piston—Measure and record the piston diameter along the crank axis and at 90° to it to the nearest 0.01 mm (0.0004 in.) in the following locations.

The middle of the top land.
12 mm (0.47 in.) from the top of the piston.
32 mm (1.26 in.) from the top of the piston.

A3.3.4 Piston Rings—Insert each ring separately into the bore 15 mm (0.6 in.) from the top, using the piston or a positioning plug to ensure that it is square with the bore. Measure and record the end gap. End gaps shall be 0.15 to 0.4 mm (0.006 to 0.016 in.). Assemble the rings onto the piston. Ring side clearance shall be 0.03 to 0.05 mm (0.0012 to 0.0020 in.). If these limits are not met, exchange or select other parts as necessary.

A3.3.5 Piston Ports—Inspect the piston ports for sharp edges or burrs. When found, file by hand to remove the sharp edge. Do not enlarge the ports.

A3.3.6 Piston Clearance—Calculate the following for diameters measured in the same direction for each location of measurement:

$$\begin{aligned} & \text{Minimum clearance} && \text{(A3.1)} \\ & = \text{smallest bore diameter} - \text{maximum piston diameter} \\ & \text{Maximum clearance} \\ & = \text{maximum bore diameter} - \text{minimum piston diameter} \end{aligned}$$

A3.4 Inspection of New Units and Between-Tests: Tests

A3.4.1 Cylinder Gasket Surface—Place the cylinder head gasket surface of the cylinder on a surface plate and try to wobble it. If it is possible to insert a 0.05 mm (0.002 in.) feeler gage between the surface plate and the gasket surface it shall be corrected or the cylinder rejected.

A3.4.2 Cylinder Head—Check its gasket surface for flatness as for the cylinder gasket surface, and correct or discard if necessary.

A3.4.3 Connecting Rod and Crankpin Bearing—Remove the towel from the crankcase opening and wash out the crankcase assembly with hydrocarbon solvent. Inspect the crankpin bearing for signs of discoloration. Measure and record the side clearance between the connecting rod and the crankthrow face. If this exceeds 0.5 mm (0.02 in.) or there is any sign of bearing distress, either replace the crankshaft, rod, and associated bearings and seals or discard and replace the entire engine. Lubricate thoroughly with ASTM 600 reference oil after inspection to prevent rust.

A3.4.4 Induction System—Inspect the intake manifold for cracks or warpage. Check the reed petals for cracks or chipping. Hold the reed valve assembly against a light source to check for leakage. Replace any defective parts.

A3.4.5 Other Components—Make a general inspection of the air filter, carburetor and ignition wiring; cleaning, repairing, or replacing as necessary.

A3.5 Assembly:

A3.5.1 Power Section—Lubricate all bearings with ASTM 600 reference oil. Install the piston on the rod *with the arrow on the crown facing the exhaust side* of the engine. Apply gasket sealer to both sides of the cylinder base gasket and mount it on the crankcase. Locate the ring gaps over the locating pins in the ring grooves. Lubricate the piston assembly and bore with ASTM 600 reference oil and mount the cylinder over the piston assembly. The compression ratio of the engine shall be determined when building up the engine to ensure that the compression ratio is between 7.0:1 and 8.0:1 after insertion of the cylinder head thermocouple (see 6.3.1.1).

A3.6 Determination and Adjustment of Compression-Ratio: Ratio

A3.6.1 All procedures of A3.6, as required, shall be performed and recorded for each set of engine test parts (cylinder head and cylinder) checked. A cylinder head may be checked against a number of cylinders. These shall be marked in a permanent manner and kept together. More than one set of test parts may be checked at a time; but if the crankcase and crank assembly are changed

after a particular set of test parts have been checked, at least one set shall be rechecked on the new crankcase assembly. If the difference is such as will not put any of the prechecked sets of parts out of specification, these need not be rechecked.

A3.6.2 Initial Assembly—Wash all parts with hydrocarbon solvent and 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 install it on the cylinder. Oil the cylinder bore and the piston assembly lightly with ASTM 600 reference oil and install the cylinder over the piston assembly. Using spacers on the studs to make up the thickness of the cylinder head flange, tighten the nuts to 10.5 to 11.5 N·m (8 lbf·ft).

A3.6.3 Determination of Effective Swept Volume:

A3.6.3.1 Set the piston at bottom dead center (BDC), using a dial indicator, and measure the distance from the piston crown surface adjacent to the cylinder wall to the cylinder head mounting surface.

A3.6.3.2 Measure the distance from the top edge of the exhaust port to the cylinder head mounting surface. The difference between this and A3.6.3.1 plus the depth of any piston chamfer is the effective port height.

A3.6.3.3 After determining the effective port height, locate the piston at top dead center (TDC) and measure from the same point on the crown to the cylinder head mounting surface. The difference between the measurements A3.6.3.1 and A3.6.3.3 minus the port height equals the effective stroke.

A3.6.3.4 Multiply the effective stroke in centimetres (1 in. = 2.54 cm) by the area corresponding to the cylinder bore diameter, which is 12.57 cm² for this engine, to obtain the effective volume, which is approximately 35.3 to 35.4 cm³. The volume is to be obtained in cubic centimetres or in numerically identical millilitres, as all commercially available burets are so calibrated.

A3.6.4 Determination of Compressed Volume:

A3.6.4.1 Position the engine so that the spark plug gasket mounting surface will be up and horizontal when the cylinder head is in place.

A3.6.4.2 Position the piston at top dead center.

A3.6.4.3 Using the finger tips, press heavy petrolatum into the space between the piston and the cylinder wall so that no gap appears around the piston circumference. OMC needle bearing grease or petroleum jelly has been found satisfactory.¹³ 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.

A3.6.4.4 Mount the cylinder head and gasket, tightening to 10.5 to 11.5 N·m (8 lbf·ft).

A3.6.4.5 Using ASTM 600 reference oil diluted with about 20 volume % of hydrocarbon solvent, which gives about 4.0 to 5.5 cSt (m²/s) viscosity at 100°C (212°F), fill the combustion chamber just to the top of the spark plug hole, measuring the amount of oil to ±0.1 mL (cm³). Tap gently to dislodge any air bubbles and make sure that the oil level has stabilized before recording the amount used, which is normally about 6.6 mL. This is most easily done using a 10 mL buret set in a stand over the engine.

A3.6.4.6 Subtract 1.1 mL from the volume of oil to allow for the volume of the spark plug. This is the compressed volume.

A3.6.5 Calculation of Compression Ratio:

A3.6.5.1 The compression ratio is as follows:

$$(ESV + CV)/CV \tag{A3.2}$$

where:

ESV = effective swept volume, mL or cm³, and
CV = compressed volume, mL or cm³.

A3.6.6 Adjustment of Compression Ratio:

A3.6.6.1 The compression ratio shall fall into the range specified for the engine. For the Yamaha CE-50S this is 7.0:1 to 8.0:1. If it is outside this range try to correct by exchange of cylinders. If this is not possible modify as specified in A3.6.6.2 and A3.6.6.3.

A3.6.6.2 If the compression ratio is too low, grind the cylinder head gasket surface to remove metal. At present there is insufficient experience with the procedure to make any recommendation as to how much metal to remove to obtain a specific compression ratio increase.

A3.6.6.3 If the compression ratio is too high, remove small quantities of metal from the inside of the cylinder head using a high speed hand grinder evenly over the surface. Be careful not to remove too much material or to damage the thermocouple.

A3.6.6.4 After correction, repeat the procedure of A3.6. Record final values.

A3.6.6.5 Install the cylinder head, tightening the nuts first to 5 to 6 N·m (4 lbf·ft) and then to 10.5 to 11.5 N·m (8 lbf·ft) using a cross-over pattern.

A3.7 Ignition System—This is electronically controlled and is not mechanically adjustable. Timing shall be 17 to 19° before top center.

A3.8 Induction System—Apply a thin coat of sealant to both sides of the reed block gasket and install it to the cylinder. Install the reed block assembly and the intake manifold. Tighten the bolts to 0.7 N·m (6 lbf·in.). Mount the carburetor, with a new gasket, and tighten also to 0.7 N·m.

¹³ Available from Outboard Marine Corp., Parts and Accessories Dept., P.O. Box 88 (3225 Prairie Ave.), Beloit, WI or from Evinrude or Johnson outboard dealers.

A3.9 Install the air shroud and fan cover. Tighten the bolts to 0.7 N·m (6 lbf·in.).

A3.10 *Spark Plug*—Gap a new NGK BP6HS or equivalent plug to 0.9 mm (0.035 in.). Lubricate the threads with antiseize compound, taking care to keep the electrodes clean. Install the plug, tightening to 1.7 N·m (15 lbf·in.).

A3.11 *Exhaust*—Install the exhaust system, using a new gasket.

APPENDIX

(Nonmandatory Information)

X1. PREPARATION OF SPARK PLUG GASKET THERMOCOUPLES

X1.1 Material:

X1.1.1 *Gasket*—Use nominally pure (99.9 %) copper as described in Specification B 152. The use of quarter hard material (Grade H01 or 081) is recommended to facilitate machining. The method by which the gaskets are produced, turning, stamping from sheet, etc. 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 (0.03 to 0.04 in.) 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 necessary, to supply each spark plug of the unit to be tested. The notches in the inner diameter of the gasket at the ends of the radial holes are required only 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 end 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 face of the gasket.

X1.3 Check the completed thermocouple gasket against a known standard. A reading within $\pm 1^{\circ}\text{C}$ (2°F) of the standard is acceptable.

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