



# Standard Test Method for Determination of Lubricity of Two-Stroke-Cycle Gasoline Engine Lubricants<sup>1</sup>

This standard is issued under the fixed designation D 4863; 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 ability of lubricants to minimize piston and bore scuffing in two-stroke-cycle spark-ignition gasoline engines.

1.2

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.*

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

## 2. Referenced Documents

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

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

D 439 Specification for Automotive Gasoline<sup>4</sup>

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

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

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

D 2270 Practice for Calculating Viscosity Index from Kinematic Viscosity at 40°C<sup>40</sup> and 100°C<sup>5</sup>100C

D 2700 Test Method for Motor Octane Number of Spark-Ignition Engine Fuel

D 2885 Test Method for ~~Research and Motor Determination of Octane Ratings Using~~ Number of Spark-Ignition Engine Fuels by On-Line Analyzers<sup>5</sup>Direct Comparison Technique

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

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 Outboards

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

E 178 Practice for Dealing with Outlying Observations

2.2 *Coordinating European Council (CEC) Standard*<sup>5</sup>

CEC L-19-T-77 The Evaluation of the Lubricity of Two-Stroke Engine Oils

<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. ATT: Administrator. This edition incorporates revisions in all Information Letters through No. 01-4.

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards*, Vol 02.01, volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>4</sup> Discontinued; see 1990 Annual Book of ASTM Standards, Vol 05.01.

<sup>4</sup> Withdrawn. The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

<sup>5</sup> Annual Book of ASTM Standards, Vol 05.01.

<sup>5</sup> Order from the Coordinating European Council, 61 New Cavendish Street, London W1M 8AR, England.

### 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. **D 4858**

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

3.1.3 *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**

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

3.1.5 *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**

3.1.6 *spark plug whiskering, or 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 *benchmark reference oil*—a reference oil that represents an acceptable level of performance with regard to the property evaluated in an engine test and whose performance in the test is equaled, within the tolerance allowed, or exceeded by that of the non-reference oil.

### 4. Summary of Test Method

4.1 The test has been developed to replace the CEC L-19-T-77 Lubricity Test, for which test engines are no longer available. It is run in a 49 cm<sup>3</sup> single-cylinder air-cooled two-stroke-cycle engine operated at 4000 r/min wide open throttle (WOT) using a 150:1 mixture of gasoline and oil by volume. After conditions have stabilized, the cooling air is cut off. The output torque is measured when the spark plug gasket temperature reaches 200°C (392°F) and again when it reaches 350°C (662°F), 350°C, at which point the cooling air is restored. The smaller the reduction in torque output during this period, the better the ability of the oil to lubricate the piston. This test is not normally damaging to the engine. Sets of five such tightenings are normally run, using alternately a benchmark reference oil and the non-reference oil for each set.

NOTE 1—*Pass-fail Criterion*—The ~~Obtain the~~ mean torque drop ~~obtained~~ with a candidate non-reference oil shall be that is the same or less than that with the reference oil as calculated by the procedures of Annex A4.

### 5. Significance and Use

5.1 The oil in a two-stroke-cycle gasoline engine is either mixed with the fuel prior to use or is metered into the fuel supply at, or at some point prior to, its passage into the engine crankcase. The possibility of the amount of oil actually present in the engine being less than optimum always exists. Also, with some oil metering systems short periods of operation with less oil than desirable can occur when the power is increased suddenly. It has also been found that the incidence of piston scuff early in the life of the engine may be related to the lubricity of the oil used as defined by test procedures of this type.

### 6. Apparatus

#### 6.1 Test Engine and Stand:

6.1.1 *Test Engine Configuration*—A Yamaha CE-50 49 cm<sup>3</sup> loop-scavenged air-cooled two-stroke-cycle engine is used. 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. Further details are given in Annex A1. For the purposes of this test the standard piston-to-bore clearance is increased as specified in 6.1.2. The engine is no longer produced. Small quantities of parts can be obtained through Yamaha dealers. Special arrangements must be made through Yamaha for the production of large quantities of test parts.

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.<sup>6</sup>

6.1.2 *Adjustment of Piston Clearance*—For the purposes of this test method, the cylinder bore shall be honed to give a 0.10 to 0.13 mm (0.004 to 0.005 in.) piston skirt diametral clearance with a 0.45 to 0.7 μm (18 to 28 μin.) arithmetic mean roughness finish, as specified in A3.4. It is recommended that a number of cylinders be honed out as it is normally necessary to use a new piston for each test and a new cylinder after every three tests. The modified cylinders shall be clearly marked as such.

(1) The power and specific fuel consumption curves at 500 r/min intervals over the range from 3000 to 6000 r/min.

<sup>6</sup> Annual Book of ASTM Standards, Vol 05.02.

<sup>6</sup> Obtainable from Engineering and Service Dept., Yamaha Motor Corp., 6555 Katella Ave Cypress, CA 90630. Parts, but not complete engines, are obtainable from Yamaha motorcycle dealers.

(2) The spark plug gasket temperatures for each point of the power curve.

(3) Modified piston clearance, with measurements of the piston and cylinder bore dimensions. Additional modified piston and cylinder assemblies can also be supplied.

(4) Measurements of the piston rings, ring grooves, ring clearances, and ring gaps.

6.2 *Test Stand*—The dynamometer shall be able to absorb 2.5 kW (3.3 hp) at 4000 r/min rpm with an inherent torque measurement accuracy of  $\pm 0.5\%$  or better, and be capable of maintaining  $4000 \pm 30$  r/min rpm 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.<sup>7</sup>

6.3 *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 m<sup>3</sup>/min (1200 ft<sup>3</sup>/min) of air is recommended. The flow from the blower shall be directed toward the intake side of the engine, as may be seen in Fig. 1.

6.4 *Fuel System*—Quick disconnects or other means to facilitate rapid interchange of fuel supply shall be provided as near to the carburetor as practicable. When local regulations permit their use, outboard portable fuel tanks of about 20 to 25 L (5 to 6 gal) capacity and flexible fuel hoses are suitable. In any case three fuel sources will be needed for a test, one for the non-reference oil fuel mix, one for the reference oil fuel mix, and one supplying test gasoline only with no oil. The temperature of the fuel entering the carburetor shall not exceed 25°C (77°F), 25°C, and this may require cooling in hot climates.

6.5 *Instrumentation:*

6.5.1 *Tachometer*—An electronic or vibration tachometer accurate to  $\pm 25$  r/min rpm.

6.5.2 *Measurement of Ambient Conditions*—It is assumed in this section 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.

6.5.2.1 *Temperature*—A thermocouple or thermometer shall be provided to read air temperature in the range 10 to 50°C (50 to 120°F), 50°C. The overall accuracy of temperature measurement, including that of recorders, shall be within  $\pm 1^\circ\text{C}$  (2°F),  $\pm 1^\circ\text{C}$ .

<sup>7</sup> Annual Book of ASTM Standards, Vol 14.02.

<sup>7</sup> A thermocouple gasket that has been found satisfactory may be obtained from The Lewis Engineering Company, 238 Water St., Naugatuck, CT 06770.

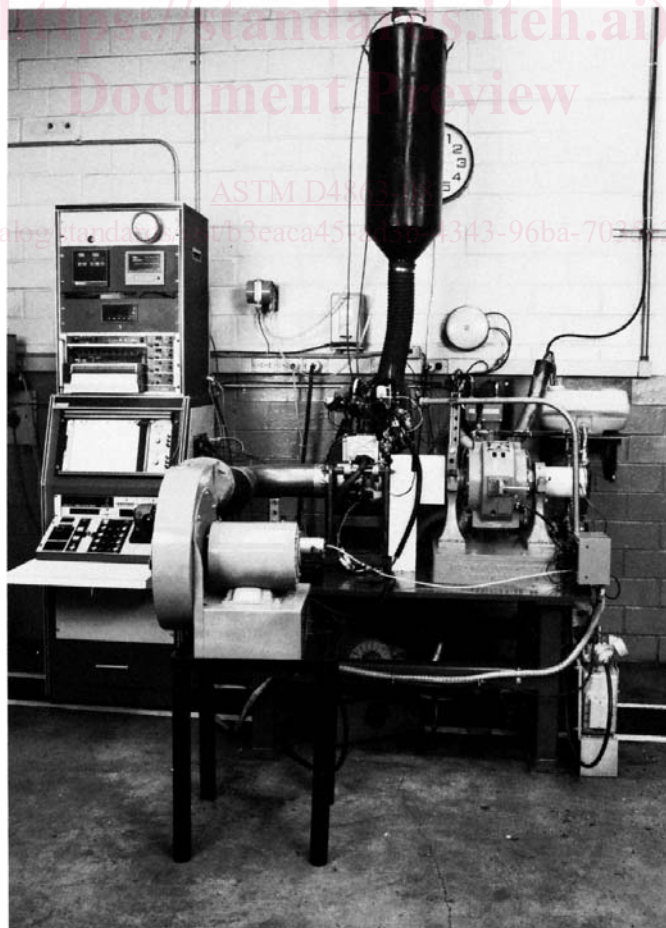


FIG. 1 Test Stand

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

6.5.2.3 *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.

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

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

6.5.3 *Engine and System Temperatures* :

6.5.3.1 *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.<sup>7</sup>

6.5.3.2 *Exhaust Temperature*—A thermocouple is required in the exhaust elbow within approximately 65 mm (~~2.5 in.~~) from the cylinder exhaust port to monitor exhaust temperature.<sup>8</sup> The thermocouple junction shall be located within  $\pm 3$  mm (~~0.12 in.~~) of the center of the pipe.

6.5.3.3 *Spark Plug Gasket and Exhaust 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 spark plug gasket temperature shall not exceed 1 s, those of the exhaust temperature should not exceed 10 s. A recorder with a range of 40 to 750°C (~~100 to 1400~~°F) and an overall accuracy of  $\pm 1^\circ\text{C}$  ( $2^\circ\text{F}$ ) is suitable. An alarm or automatic shut-down device may be provided.

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

## 7. Materials and Reagents

7.1 *Test Fuel*:

7.1.1 Phillips J is the preferred test fuel.<sup>9</sup> It consists essentially of hydrocarbons and contains trace amounts only of lead.

7.1.2 If Phillips J is not available, use gasoline containing 0.013 g/L (~~0.05 g/gal~~) maximum of lead, free of non-lead metallic antiknock additives and oxygenated blending components such as alcohols or ethers, with a minimum Motor Octane number of 82 as determined by Test Method D 2700 ~~or D 2885~~ or D 2885 and otherwise conforming to the requirements of Specification D 439 Class A or Class B. It may contain conventional anticorrosion, anti-icing, and so forth, additives and oxidation inhibitors in normal concentration. Any such alternative gasoline shall be tested by the procedure of 9.6 before it is adopted as a test fuel as it has been found that adequate differentiation between reference oils cannot be obtained with some fuels, some as *isooctane*, that otherwise meet the requirements of this section.

7.1.3 About 72 L (~~19 gal~~) of fuel are required for a complete test, including 15 L (~~4 gal~~) for the break-in.

7.2 *Reference Oils*—ASTM 604 and 602 reference oils are used for calibration purposes.<sup>10</sup> ASTM 600 reference oil is used for break-in and as an assembly lubricant, and can be specified as the benchmark reference oil. About 0.4 L (~~0.1 gal~~) of each 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 0.4 L (~~0.1 gal~~) is required for a test. At least twice this amount should be provided in case the test is rerun.

## 8. Procedure

8.1 *Assembly of Engine*:

8.1.1 *Initial Build*—The test engine is initially built up using a new piston, rings, cylinder (modified as specified in 6.1.2), and cylinder base and head gaskets (see Annex A3). The test is not sensitive to compression ratio and this need not be determined.

8.1.2 *Rebuild After Test*—It is not necessary to use new parts after each test other than gaskets, a new piston, new piston rings and a new or reconditioned muffler, provided that all parts are clean and within specification with no sign of damage. The cylinder will usually require replacement after 3 to 5 complete tests (approximately 60 tightenings). After 125 to 175 complete tests (about 1000 to 1500 running hours) the entire engine will normally require replacement or a complete rebuild.

## 9. Operating Instructions

9.1 *Fuel Temperature and Pressure*— The temperature of the fuel entering the carburetor shall not exceed 25°C ( $77^\circ\text{F}$ ) and fuel delivery pressure shall be maintained at 19 to 21 mPa (~~2.7 to 3.0 lb/in.<sup>2</sup>~~)-kPa.

9.2 *Break-In*—Each time that the cylinder is replaced the engine shall be broken in for 2 h using a 20:1 (5 % oil) by volume mixture of test gasoline and ASTM 600 reference oil under the conditions of Table 1. After break-in the piston and cylinder shall

<sup>7</sup> Order from the Coordinating European Council, 61 New Cavendish Street, London W1M 8AR, England.

<sup>8</sup> A suitable instrument is available from Omega Engineering Inc., P.O. Box 4047, One Omega Dr., Stamford, CT 06907.

<sup>9</sup> Obtainable from Engineering and Service Dept., Yamaha International Corp., P.O. Box 6555, Cypress, CA 90630. Parts, but not complete engines, are obtainable from Yamaha motorcycle dealers.

<sup>9</sup> Available from Phillips Chemical Co., Specialty Chemicals, P.O. Box 968, Borger, TX 79008-0968.

<sup>10</sup> A thermocouple gasket that has been found satisfactory may be obtained from Lewis Engineering, 238-T Water St., Naugatuck, CT 06770.

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



**TABLE 1 Break-In**

Duration Minutes	r/min	Throttle Position	Spark Plug Gasket Temperature, °C (°F)
2	1900–2100	closed	record
2	3900–4100	1/2 open	125 (257) max
2	3900–4100	1/3 open	125 max
2	5400–5600	1/2 open	125 (257) max
2	5400–5600	1/3 open	125 max
2	3400–3600	1/2 open	125 (257) max
2	3400–3600	1/3 open	125 max
2	4400–4600	1/2 open	125 (257) max
2	4400–4600	1/3 open	125 max
Repeat for a total of 2 cycles, or 20 min running time.			
Duration Minutes	r/min	Throttle Position	Spark Plug Gasket Temperature, °C (°F)
Duration Minutes	rpm	Throttle Position	Spark Plug Gasket Temperature, °C
2	1900–2100	closed	record
2	3900–4100	1/2 open	140 (284) max
2	3900–4100	1/2 open	140 max
2	5400–5600	1/2 open	140 (284) max
2	5400–5600	1/2 open	140 max
2	3400–3600	1/2 open	140 (284) max
2	3400–3600	1/2 open	140 max
2	4400–4600	1/2 open	140 (284) max
2	4400–4600	1/2 open	140 max
Repeat for a total of 4 cycles, or 40 min running time.			
Duration Minutes	r/min	Throttle Position	Spark Plug Gasket Temperature, °C (°F)
Duration Minutes	rpm	Throttle Position	Spark Plug Gasket Temperature, °C
2	1900–2100	closed	record
2	3900–4100	3/4 open	155 (311) max
2	3900–4100	3/4 open	155 max
2	5400–5600	3/4 open	155 (311) max
2	5400–5600	3/4 open	155 max
2	3400–3600	3/4 open	155 (311) max
2	3400–3600	3/4 open	155 max
2	4400–4600	3/4 open	155 (311) max
2	4400–4600	3/4 open	155 max
Repeat for a total of 4 cycles, or 40 min running time.			
Duration Minutes	r/min	Throttle Position	Spark Plug Gasket Temperature, °C (°F)
Duration Minutes	rpm	Throttle Position	Spark Plug Gasket Temperature, °C
2	1900–2100	closed	record
2	3900–4100	WOT	170 (338) max
2	3900–4100	WOT	170 max
2	5400–5600	WOT	170 (338) max
2	5400–5600	WOT	170 max
2	3400–3600	WOT	170 (338) max
2	3400–3600	WOT	170 max
2	4400–4600	WOT	170 (338) max
2	4400–4600	WOT	170 max
Repeat for a total of 2 cycles, or 20 min running time.			

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. On completion of break-in and before the engine is opened for inspection, run for 5 min at 4000 r/minrpm at no load using oil-free test gasoline.

**9.3 Test:**

9.3.1 All testing is performed using a 150:1 (0.67 % oil) fuel to oil volumetric mixture. The temperature of the fuel entering the carburetor shall not exceed 25°C (77°F). 25°C. Run at 4000 r/minrpm and WOT for 25 to 30 min to establish thermal equilibrium, delivering about 1.4 kW (1.9 hp). kW. Regulate the cooling air to give a spark plug gasket temperature of 169 to 171°C (336 to 340°F). 171°C. The cooling air is then shut off. As soon as the spark plug gasket temperature reaches 200°C (392°F) 200°C, record the output torque, and when it reaches 350°C (662°F) 350°C, record the torque again and restore the cooling air. The torque drop between 200°C (392°F) and 350°C (662°F) spark plug gasket temperature is determined. It is recommended that the torque and the corresponding spark plug gasket temperature be recorded simultaneously on a X-Y plotter and the torque drop determined from this record. After the cooling air has been restored, stabilize the plug gasket temperature again at 169 to 171°C (336 to 340°F).

171°C. Run for 3 to 4 min and again shut off the cooling air to repeat the test. To obtain good repeatability it is advisable to run at an ambient temperature of about 23 to 27°C (75 to 80°F), 27°C, and it is very important to protect the engine from drafts, especially during the period that the cooling air is cut off. A typical recording of torque against spark plug gasket temperature is shown as Fig. 2. Repeat to give a set of at least five tightenings. Under the conditions of 9.3.3, a set may consist of up to seven tightenings.

9.3.2 Alternate the non-reference oil and reference oil sets, running a series of two non-reference and two reference sets as indicated in Table 2. Each set shall be run without interruption, and the interval between sets shall not exceed 1 h. If the test is interrupted for any longer period the entire test shall be rerun as set-to-set comparisons are then not reliable.

9.3.3 *Range of Torque Drops*—For each set of tightenings, keep a running record of the range (difference between the highest and lowest values). If this exceeds 0.085 N·m (0.75 lbf·in.) N·m, run an additional tightening in case one is rejected. If, after replacing the most deviant value in the set, the range is still greater than 0.085 N·m, run one more tightening. No more than seven tightenings per set may be run. If an acceptable range cannot be obtained by discarding two out of seven tightenings terminate the test, rebuild the engine, and rerun.

9.3.4 *Change-Over Engine Flush*—After completing each set run the carburetor dry and change or flush out the fuel supply lines. Then restart and run for 5 min at 4000 r/min rpm at no load on oil-free test fuel before beginning the next set.

9.3.5 *Spark Plug Malfunction*—Malfunctioning plugs are replaced and the test continued, repeating any set of tightenings during which this occurs (see Note 4).

9.4 *Calculation*—The mean (average) value and standard deviation of the torque drop are calculated separately for the reference and the non-reference oil. These values are used to determine whether there is a significant difference between the results obtained with the two oils. A sample calculation is found in Annex A4.

9.5 *Anomalous Results*—Check for apparent outliers, especially if the range of the results in any set of tightenings exceeds the value specified in 9.3.3. If these are suspected but are not obvious the procedures of Practice E 178 are used to test their validity. See Annex A4.

NOTE 3—*Pass-Fail Criterion*—If the average torque drop obtained with a candidate oil is equal to or less than that obtained with the benchmark reference oil, as calculated by the procedures specified in Annex A4, the candidate passes.

9.6 *Calibration:*

9.6.1 After 30 tests or 180 days, whichever comes first, or any time a new or completely rebuilt engine is put in service, evaluate reference oils 604 and 602 oils as if they were a non-reference oil, using the 600 reference oil as the benchmark oil. For an acceptable calibration, the performance of the 602 reference oil, as determined by the procedures called for in 9.5 and 9.6, shall be rated as a pass, equal to or better than that of the 600 reference oil, and the performance of the 604 oil shall be rated as a fail.

9.6.2 In order for a test stand to be acceptable for non-reference oil evaluation it shall have been calibrated by the procedure of 9.6.1.

10. Report

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

10.2 The detailed results obtained from tests on any of the reference oils shall be made available to ASTM Test Monitoring Center upon request so that statistical analysis of test consistency may be made.

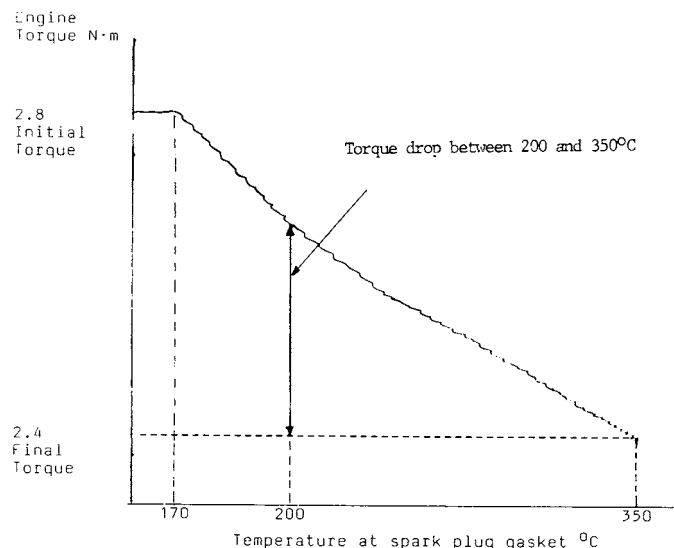


FIG. 2 Torque/Temperature Trace