Designation: ~~D8279 – 22a~~ D8279 – 23

Standard Test Method for Determination of Timing-Chain Wear in a Turbocharged, Direct-Injection, Spark-Ignition, Four-Cylinder Engine[1]

This standard is issued under the fixed designation D8279; 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.

INTRODUCTION

Portions of this test method are written for use by laboratories that make use of ASTM Test Monitoring Center (TMC)[2] services (see Annex A1 to Annex A4).

The TMC provides reference oils, and engineering and statistical services to laboratories that desire to produce test results that are statistically similar to those produced by laboratories previously calibrated by the TMC.

In general, the Test Purchaser decides if a calibrated test stand is to be used. Organizations such as the American Chemistry Council require that a laboratory utilize the TMC services as part of their test registration process. In addition, the American Petroleum Institute and the Gear Lubricant Review Committee of the Lubricant Review Institute (SAE International) require that a laboratory use the TMC services in seeking qualification of oils against their specifications.

The advantage of using the TMC services to calibrate test stands is that the test laboratory (and hence the Test Purchaser) has an assurance that the test stand was operating at the proper level of test severity. It should also be borne in mind that results obtained in a non-calibrated test stand may not be the same as those obtained in a test stand participating in the ASTM TMC services process.

Laboratories that choose not to use the TMC services may simply disregard these portions.

ASTM International policy is to encourage the development of test procedures based on generic equipment. It is recognized that there are occasions where critical/sole-source equipment has been approved by the technical committee (surveillance panel/task force) and is required by the test procedure. The technical committee that oversees the test procedure is encouraged to clearly identify if the part is considered critical in the test procedure. If a part is deemed to be critical, ASTM encourages alternative suppliers to be given the opportunity for consideration of supplying the critical part/component providing they meet the approval process set forth by the technical committee.

An alternative supplier can start the process by initiating contact with the technical committee (current chairs shown on ASTM TMC website). The supplier should advise on the details of the part that is intended to be supplied. The technical committee will review the request and determine feasibility of an alternative supplier for the requested replacement critical part. In the event that a replacement critical part has been identified and proven equivalent, the sole-source supplier footnote shall be removed from the test procedure.

[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 on Automotive Lubricants.

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[2] Until the next revision of this test method, the ASTM Test Monitoring Center will update changes in the test method by means of information letters. Information letters may be obtained from the ASTM Test Monitoring Center, 203 Armstrong Drive, Freeport, PA 16229. Attention: Director. This edition incorporates revisions in all Information Letters through No. ~~22-1.~~23-1.

1. Scope*

1.1 Undesirable timing-chain wear has been observed with gasoline, turbocharged, direct-injection (GTDI) engines in field service, and data from correlating laboratory engine tests have shown that chain wear can be affected by appropriately formulated engine lubricating. A laboratory engine test has been developed to provide a means for screening lubricating oils for that specific purpose. The laboratory engine test is 216 h in length, conducted under varying conditions, and the increase in timing-chain length determined at the end of test is the primary result. This test method is commonly known as the Sequence X, Chain Wear (CW) Test.

1.2 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.2.1 *Exception*—Where there is no direct SI equivalent such as screw threads, national pipe threads/diameters, tubing size, or specified single source equipment.

1.3 *Table of Contents:*

1.4 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

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)
D664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration
D4485 Specification for Performance of Active API Service Category Engine Oils
D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants
D4739 Test Method for Base Number Determination by Potentiometric Hydrochloric Acid Titration
D5185 Test Method for Multielement Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)
D5967 Test Method for Evaluation of Diesel Engine Oils in T-8 Diesel Engine
D6304 Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration
D6593 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Deposit Formation in a Spark-Ignition Internal Combustion Engine Fueled with Gasoline and Operated Under Low-Temperature, Light-Duty Conditions
D8047 Test Method for Evaluation of Engine Oil Aeration Resistance in a Caterpillar C13 Direct-Injected Turbocharged Automotive Diesel Engine
D8291 Test Method for Evaluation of Performance of Automotive Engine Oils in the Mitigation of Low-Speed, Preignition in the Sequence IX Gasoline Turbocharged Direct-Injection, Spark-Ignition Engine

2.2 *American National Standards Institute Standard:*

ANSI MC96.1 Temperature Measurement – Thermocouples[4]

2.3 *Other Document:*

2012 Ford Explorer 2.0 L-4V TiVCT GTDi Build Manual[5]

3. Terminology

3.1 *Definitions:*

3.1.1 *blowby, n—in internal combustion engines*, the combustion products and unburned air-and-fuel mixture that enter the crankcase. **D4175**

3.1.2 *engine oil, n*—a liquid that reduces friction or wear, or both, between the moving parts within an engine; removes heat, particularly from the underside of pistons; and serves as a combustion gas sealant for piston rings.

3.1.2.1 *Discussion—*

It may contain additives to enhance certain properties. Inhibition of engine rusting, deposit formation, valve train wear, oil oxidation, and foaming are examples. **D4175**

3.1.3 *enrichment, n—in internal combustion engine operation*, a fuel consumption rate in excess of that which would achieve a stoichiometric air-to-fuel ratio.

3.1.3.1 *Discussion—*

Enrichment is usually indicated by elevated CO levels and can also be detected with an extended range air/fuel ratio sensor. **D6593**

3.1.4 *filtering, n—in data acquisition*, a means of attenuating signals in a given frequency range. They can be mechanical (volume tank, spring, mass) or electrical (capacitance, inductance) or digital (mathematical formulas), or a combination thereof. Typically, a low-pass filter attenuates the unwanted high frequency noise. **D4175**

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[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, http://www.ansi.org.

[5] Available from Helminc, https://www.helminc.com/helm/homepage.asp.

3.1.5 *lambda, n*—the ratio of actual air mass induced, during engine operation, divided by the theoretical air mass requirement at the stoichiometric air-fuel ratio for the given fuel.

3.1.5.1 *Discussion*—

A lambda value of 1.0 denotes a stoichiometric air-fuel ratio. **D6593**

3.1.6 *out of specification data, n—in data acquisition*, sampled value of a monitored test parameter that has deviated beyond the procedural limits. **D4175**

3.1.7 *PCM, n*—an engine control unit, most commonly called the powertrain control module (PCM), is an electronic device that instantaneously controls a series of actuators on an internal combustion engine to ensure optimal engine performance.

3.1.8 *quantity, n—in the SI*, a measurable property of a body or substance where the property has a magnitude expressed as the product of a number and a unit; there are seven, well-defined base quantities (length, time, mass, temperature, amount of substance, electric current and luminous intensity) from which all other quantities are derived (for example, volume whose SI unit is the cubic metre).

3.1.8.1 *Discussion*—

symbols for quantities must be carefully defined; are written in italic font, can be upper or lower case, and can be qualified by adding further information in subscripts, or superscripts, or in parentheses (for example, t_{fuel} = 40 °C, where t is used as the symbol for the quantity Celsius temperature and t_{fuel} is the symbol for the specific quantity fuel temperature). **D8047**

3.1.9 *reading, n—in data acquisition*, the reduction of data points that represent the operating conditions observed in the time period as defined in the test procedure. **D4175**

3.1.10 *time constant, n—in data acquisition*, a value which represents a measure of the time response of a system. For a first order system responding to a step change input, it is the time required for the output to reach 63.2 % of its final value. **D4175**

3.1.11 *wear, n*—the loss of material from a surface, generally occurring between two surfaces in relative motion, and resulting from mechanical or chemical action or a combination of both. **D4175**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *low-temperature, light-duty conditions, n*—indicative of engine oil and coolant temperatures that average below normal warmed-up temperatures, and engine speeds and power outputs that average below those encountered in typical highway driving.

3.2.2 *ramping, n*—the prescribed rate of change of a variable when one set of operating conditions is changed to another set of operating conditions.

3.2.3 *timing chain, n*—the part of an internal combustion engine that synchronizes the rotation of the crankshaft and the camshaft(s) so that the engine's valves open and close at the proper times during each cylinder's intake and exhaust strokes; in this engine, the timing chain is an inverted tooth configuration.

3.3 *Acronyms and Abbreviations:*

3.3.1 AFR—air fuel ratio

3.3.2 ANSI—American National Standards Institute

3.3.3 CCV—characterized control valve

3.3.4 *CE*—chain elongation (that is, change in timing chain length); see Eq 2

3.3.5 CW—chain wear

3.3.6 EEC—electronic engine control

3.3.7 EOT—end of test

3.3.8 fps—frames per second

3.3.9 GTDI—gasoline turbocharged direct injection

3.3.10 ID—internal diameter

3.3.11 *ip*—intermediate precision

3.3.12 ILSAC—International Lubricants Standardization and Approval Committee

3.3.13 *KV*—kinematic viscosity

3.3.14 L_f—final average chain length

3.3.15 L_i—initial average chain length

3.3.16 L_{nom}—the nominal chain length (1095.375 mm)

3.3.17 MAF—mass air flow

3.3.18 MAPT—manifold absolute pressure and temperature

3.3.19 NIST—National Institute of Standards and Technology

3.3.20 OHT—OH Technologies

3.3.21 OEM—original equipment manufacturer

3.3.22 PCM—powertrain control module

3.3.23 PCV—positive crankcase ventilation

3.3.24 P/N—part number

3.3.25 *R*—reproducibility

3.3.26 *Ra*—average surface roughness

3.3.27 RTV—room-temperature-vulcanizing

3.3.28 SAE—Society of Automotive Engineers

3.3.29 *S*—standard deviation

3.3.30 S_{ip}—standard deviation for intermediate precision

3.3.31 S_R—standard deviation for reproducibility

3.3.32 *TAN*—total acid number

3.3.33 *TBN*—total base number

3.3.34 TDC—top dead center

3.3.35 TGA—thermogravimetric analysis

3.3.36 VCT—variable valve timing

4. Summary of Test Method

4.1 The test engine is completely rebuilt before each test and essentially all aspects of assembly are specified in detail. The piston-ring gaps are increased to increase the level of blowby, and crankcase ventilation is modified to exacerbate chain wear.

4.2 The timing-chain length is measured after engine break in and at the end of test (EOT), 216 h. The test is conducted for 54 cycles, each 4 h cycle consisting of operation at two stages with differing operating conditions for a total test length of 216 h. While the operating conditions are varied within each cycle, overall they can be characterized as a mixture of low- and moderate-temperature, light- and medium-duty operating conditions.

4.3 The increase in timing-chain length, determined at the end of test, is the primary test result.

5. Significance and Use

5.1 This test method evaluates an automotive engine oil's lubricating efficiency in inhibiting timing-chain lengthening under operating conditions selected to accelerate timing-chain wear. Varying quality reference oils of known wear performance were used in developing the operating conditions of the test procedure.

5.2 The test method can be used to screen lubricants for satisfactory lubrication of an engine timing chain and has application in gasoline, automotive, engine-oil specifications. It is expected to be used in specifications and classifications of engine lubricating oils, such as the following:

5.2.1 ILSAC GF-6.

5.2.2 Specification D4485.

5.2.3 SAE Classification J183.

6. Apparatus

6.1 *Test Engine:*

6.1.1 The test engine is a Ford 2.0 L, spark-ignition, four-stroke, four-cylinder, gasoline, turbocharged, direct-injection (GTDI) engine,[6,7] with dual overhead camshafts driven by a timing chain, four valves per cylinder, and electronic fuel injection.

6.1.2 Table A5.1 lists the engine part numbers.

6.1.3 Configure a test stand to accept the test engine. Suggested fixing brackets are shown in Appendix X2.

6.2 *Reusable Engine Parts and Fasteners:*

6.2.1 Tables A5.2 and A5.3 provide the part numbers and descriptions for the reusable engine parts and fasteners, respectively.

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[6] The engine is based on the Ford Motor Co. 2012 Explorer engine, and a completely assembled new test engine is available from Ford Component Sales, Ford Motor Co., 290 Town Center Dr., Dearborn, MI 48126.

[7] If you are aware of alternative suppliers, please provide the information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

6.2.2 All engine parts, other than the 'Required New Engine Parts' (see 6.3), can be used for a maximum of six tests provided they remain serviceable (see Tables A5.2 and A5.3).

6.2.2.1 Crankshaft, connecting rods, pistons, camshafts, cylinder blocks, and cylinder-head assemblies can be used for a maximum of six tests provided they remain serviceable. However, keep these parts together as a set for all six tests.

6.2.3 Test the flowrate of the positive crankcase ventilation (PCV) valve before each test to ensure it meets the required flowrate (see 8.6). The PCV valve stays with the test stand as long as it remains within serviceable test limits.

6.2.4 Correct damaged threads in the block with commercially available thread inserts.

6.3 *Required New Engine Parts for Each Test:*

6.3.1 Part numbers and descriptions for new engine parts (referred to as the "Test Parts") and gaskets are listed in Tables A5.4 and A5.5, respectively.

6.3.2 Use new valve-train drive parts and piston rings for each test.

6.3.3 Do not modify or alter test parts without the approval of the Sequence X Test Surveillance Panel.

6.4 *Additional Related Parts and Tools:*

6.4.1 The part numbers and descriptions of the Test Stand Setup Parts and Special Parts are listed in Tables A5.6 and A5.7, respectively. With a few noted exceptions, they can be reused for numerous tests provided they remain serviceable.

6.4.2 Engine parts other than valve-train and drive parts can be replaced during the test, provided the reason for replacement is not oil related and does not affect the oil.

6.5 *Special Service Tools:*

6.5.1 A list and part numbers of special tools for crankshaft alignment and timing are shown in Table A5.8. The tools are available from a Ford dealership and are designed to aid in performing several service items. The specific service items that require special tools to perform the functions indicated (if not self-explanatory) are listed in relevant sections below.

6.6 *Specially Fabricated Engine Parts:*

6.6.1 The following specially fabricated engine parts are required in this test method:

6.6.1.1 The intake-air system can be fabricated. However, use the stock 2012 Explorer air-cleaner assembly and mass air flow (MAF) sensor listed in Table A5.6 (see also 8.21.13).

6.6.1.2 Use the modified oil pan with dipstick and pick up tube listed in Table A5.7 (see also X1.24 and Fig. A9.6).

NOTE 1—Sources for some materials and information are provided in Appendix X1.

6.7 *Other Special Equipment:*

6.7.1 Use an appropriate air-conditioning system to control the temperature and pressure of the intake air to meet the requirements listed in Table 1 and Table 2.

6.7.2 Use an appropriate fuel-supply system.

6.7.3 Use the control and data acquisition system described in Annex A10.

TABLE 1 Sequence X Break-in Controlled Quantities

Quantity	Value
Coolant-Out Temperature, °C	85 ± 0.5
Oil-Gallery Temperature, °C	100 ± 0.5
Inlet-Air Pressure (gauge), kPa	0.05 ± 0.02
Air-Charge Temperature, °C	37 ± 0.5
Inlet-Air Temperature, °C	30 ± 0.5

6.7.4 Use an appropriate exhaust system to control the pressure and monitor the temperature of the exhaust gases listed in Table 2, Table 3, and Table 4.

6.8 *Driveline:*

6.8.1 Use the flywheel, clutch, pressure plate, bell housing, and clutch spacer listed in Table A5.7 (see also X1.24).

6.8.2 *Driveshaft*—Configure the driveshaft as per the specifications in 8.21.5.1. Grease the driveshaft every test.

6.9 *Special Engine Measurement and Assembly Equipment:*

6.9.1 *General:*

6.9.1.1 Items routinely used in the laboratory and workshop are not included.

6.9.1.2 Use any special tools or equipment shown in the 2012 Explorer Service Manual for assembly.

6.9.1.3 A list of these tools is provided in Table A5.8.

6.9.1.4 Complete any assembly instructions not detailed in Section 8 according to the instructions in the 2012 Explorer Service Manual.

6.9.2 *Piston-Ring Positioner:*

6.9.2.1 Use the piston-ring positioner to locate the piston rings from the cylinder block deck surface by 38 mm (Fig. A7.1). This allows the compression rings to be positioned in a consistent location in the cylinder bore for the ring-gap measurement.

6.9.3 *Piston-Ring Grinder*—A ring grinder is required for adjusting ring gaps. The Sanford piston-ring grinder has been found suitable.[8,7]

7. Reagents and Materials

7.1 *Degreasing Solutions:*

7.1.1 *Stoddard Solvent*—Use only mineral spirits meeting the requirements of Specification D235, Type II, Class C for volume fraction of aromatics (0 % to 2 %), flash point (61 °C minimum) and color (not darker than +25 on Saybolt Scale or 25 on Pt-Co Scale). (**Warning—**Combustible. Health hazard.) Obtain a certificate of analysis for each batch of solvent from the supplier.

7.1.2 *Chemtool B-12*[9,7]—(**Warning—**Combustible. Health hazard.)

7.1.3 *Acqueous Detergent Solution*—Prepare from a commercial laundry detergent. Tide has been found suitable for this purpose.[10,7]

[8] The sole source of supply of this equipment known to the committee at this time is Sanford Manufacturing Co., 300 Cox St., PO Box 318, Roselle, NJ 07203.

[9] The sole source of supply of this product known to the committee at this time is Berryman Products, Inc., 3800 E. Randol Mill Rd, Arlington, TX 76011. Tel: +1 800 433 1704. www.berrymanproducts.com.

[10] The sole source of supply of this detergent known to the committee at this time is Proctor and Gamble Company, 1 P&G Plaza, Cincinnati, OH 45202, USA. Tel. +1-513-983-1100. www.pg.com.

TABLE 2 Test Operational Quantities

Quantity, units	Stage 1	Stage 2
Time, min	120	60
Engine speed, r/min	1550 ± 5	2500 ± 5
Torque, N·m	50 ± 2	128 ± 2
Oil-gallery temperature, °C	50 ± 0.5	100 ± 0.5
Coolant-out temperature, °C	45 ± 0.5	85 ± 0.5
Coolant flowrate, L/min	40 ± 2	70 ± 2
Inlet-air pressure (gauge), kPa	0.05 ± 0.02	
Coolant pressure (gauge), kPa	70 ± 2	
Inlet-air temperature, °C	32 ± 0.5	
Exhaust back pressure (absolute), kPa	104 ± 2	107 ± 2
Air-charge temperature, °C	30 ± 0.5	
Air fuel ratio (AFR), lambda	0.78 ± 0.05	1 ± 0.05
Blowby-outlet temperature, °C	23 ± 2	78 ± 2
Humidity, g/kg	11.4 ± 1.0	
Blowby, L/min	Not measured	65 to 75[A]

[A] Only applicable up to 120 h.

TABLE 3 Parameter Logging

Test Point	Units
Controlled	
Engine speed	r/min
Engine torque	N·m
Coolant-out temperature	°C
Oil-gallery temperature	°C
Coolant flowrate	L/m
Air-charge temperature	°C
Inlet-air temperature	°C
Inlet-air pressure (gauge)	kPa
Coolant pressure (gauge)	kPa
Exhaust back pressure (absolute)	kPa
Air fuel ration (AFR), lambda	unitless
Humidity	g/kg
Monitored	
Fuel flowrate	kg/h
Manifold absolute pressure (MAP)	kPa
Boost pressure (absolute)	kPa
Barometric pressure (absolute)	kPa
Oil-gallery pressure (gauge)	kPa
Oil-head pressure (gauge)	kPa
Oil-filter-in temperature	°C
Exhaust temperature	°C
Crankcase pressure (gauge)	kPa
Fuel pressure (gauge)	kPa
Pre-intercooler air pressure (absolute)	kPa
Ambient temperature	°C
Coolant-in temperature	°C
Fuel temperature	°C
PCM CAN BUS Channels	
Ignition timing advance for #1 cylinder	° CA
Absolute throttle position	%
Engine-coolant temperature	°C
Inlet-air temperature	°C
Equivalence ratio (lambda)	unitless
Absolute torque value	%
Intake-manifold absolute pressure	kPa
Fuel-rail pressure (gauge)	kPa
Accelerator pedal position	%
Boost absolute pressure – raw value	kPa
Turbocharger wastegate duty cycle	%
Actual Intake (A) camshaft position	°
Actual exhaust (B) camshaft position	°
Intake (A) camshaft position actuator duty cycle	%
Exhaust (B) camshaft position actuator duty cycle	%
Charge air cooler temperature	°C

7.1.4 *n-Heptane*—(**Warning—**Flammable. Health hazard. Harmful if inhaled.)

TABLE 4 Typical Uncontrolled Ranges for Fuel Flowrate and Exhaust Temperature

Quantity, unit	Stage 1	Stage 2
Fuel flowrate, kg/h	3.2 to 3.5	8.0 to 8.5
Exhaust temperature, °C	400 to 430	640 to 680

7.2 *Test Fuel*—Use only Haltermann HF2021 EPA Tier 3 EEE Lube Certificate test fuel.[11,7] Approximately 1600 L is required for each test. (**Warning—**Flammable. Health Hazard.)

7.3 *Test Oil*—A minimum of 23 L (6 gal) of test oil is required.

7.4 *Engine Coolant*—Use only Dex-Cool[12] concentrate mixed 50/50 with deionized water or pre mixed 50/50.

7.5 *Ultrasonic Cleaner*—Use only Brulin AquaVantage 815 GD and 815 QR-DF or 815 QR-NF.[13,14,7]

7.6 *Sealing Compounds:*

7.6.1 *Silicon-based Sealer*—Use as needed on the contact surfaces between the rear-seal housing and the oil pan and the front cover and cylinder block, cylinder head, and oil pan.

7.6.1.1 Use silicon-based sealer sparingly because it can elevate the indicated silicon content of the used oil.

7.6.2 *Motorcraft Gasket Maker TA-16 or equivalent*—Use between the 6th intake and exhaust camshaft cap and the cylinder head.

7.6.3 *Non-silicon Liquid or Tape Thread Sealers*—Use as needed on bolts and plugs.

7.6.4 *Thread Sealant*—Use Loctite 565.[15,16,7]

7.7 *Engine Build Up Oil—Use EF-411*[17,7]—as engine assembly oil.

8. Preparation of Apparatus

8.1 *Engine Parts Cleaning:*

8.1.1 *Ultrasonic Cleaner Preparation:*

8.1.1.1 The TierraTech model MOT-400 N[18,7] (capacity 400 L) has been found suitable.

8.1.1.2 Add solution once that in the ultrasonic cleaner reaches a minimum of 60 °C (140 °F).

(1) Use Brulin AquaVantage 815 GD and 815 QR-NF solutions with a volume fraction of 12.5 %.

(2) Mix these solutions to give a volume fraction of 50 %. For the TierraTech Model 400N, the quantities involved are 25 L of each solution. Quantities will be different for a different capacity unit.

(3) Change the soap and water solution at least after every 25 h of use.

[11] The sole source of supply of this product known to the committee at this time is Haltermann Solutions, P.O. Box 0429, Channelview, TX 777530-0429, USA. Tel: +1 800 969 2542; www.haltermansolutions.com.

[12] Available from retailers and autoparts stores. See also X1.34.

[13] The sole source of supply of this product known to the committee at this time is Brulin Holding Company, 2920 Dr Andrew J Brown Ave., Indianapolis, IN 46205. Tel: +1 317 923 3211; www.bhcinc.com.

[14] Available from Haltermann (P.O. Box 0429, Channelview, TX 777530-0429, USA. Tel: +1 800 969 2542; www.haltermansolutions.com.

[15] Loctite is a registered trade mark of Henkel Corporation.

[16] Available from Henkel corporation, One Henkel Way, Rocky Hill, CT 06067. www.henkelna.com.

[17] The sole source of supply of this product known to the committee at this time is Exxon-Mobil Oil Corp., Attention Illinois Order Board, PO Box 66940, AMF O'Hare, IL 60666.

[18] The sole manufacturer of this equipment known to the committee at this time is TierraTech, 701 N Bryan Rd., 78572 Mission, TX. Tel: +1 956 519 4545; sales@tierratech.com.

8.1.2 *Engine Parts for Ultrasonic Cleaning*—The following engine parts are subjected to ultrasonic cleaning:

8.1.2.1 *Cylinder Block*—Remove oil jets and main bearings.

8.1.2.2 *Bare Pistons without Wristpins*—Remove the piston compression and oil rings. A new set of piston rings is used for every test.

8.1.2.3 *Bare Cylinder Head*—Remove valve-train components.

8.1.2.4 *OHT Oil Pan*—This pan is available from OH Technologies[19,7] (see Table A5.7).

8.1.2.5 *Front Cover*.

8.1.3 *Procedure for Ultrasonic Cleaning:*

8.1.3.1 *Bare Pistons without Wristpins:*

NOTE 2—Leaving the pistons in the ultrasonic cleaner longer than 30 min can remove the skirt coating on the piston sides.

(1) Place the bare pistons without wristpins into the ultrasonic cleaner for 30 min maximum. A nylon brush may be used to scrub the pistons and remove heavy deposits. Do not leave the pistons in the ultrasonic cleaner longer than 30 min.

(2) After 30 min, remove the pistons and immediately spray with hot water, then with solvent and leave to air-dry.

(3) Repeat steps (a) and (b) until all the piston deposits have been removed.

8.1.3.2 *Other Parts*—Clean all the other parts listed in 8.1.2 as follows:

(a) First rinse the parts with aqueous detergent solution (see 7.1.3) followed by a hot-water rinse.

(b) Then place the parts in the ultrasonic parts cleaner apparatus for 30 min.

(c) After 30 min, remove the parts and immediately spray with hot water, then with solvent and leave to air-dry.

8.1.4 *Degreasing*—Spray clean the following components with Stoddard solvent, then blow out with pressurized air, and leave to air-dry:

8.1.4.1 Camshafts and all valve-train components;

8.1.4.2 Intake manifold/throttle body (not being separated);

8.1.4.3 Fuel-pump housing with piston;

8.1.4.4 Vacuum pump and oil screen;

8.1.4.5 The oil screen (do not clean the inside of the turbocharger);

8.1.4.6 Oil pump;

8.1.4.7 Valve cover;

8.1.4.8 Turbocharger oil lines;

8.1.4.9 Oil separator (PCV housing on the cylinder block);

8.1.4.10 Oil pick up tube;

8.1.4.11 Oil squirters/jets;

8.1.4.12 Crankshaft;

[19] The sole source of this equipment known to the committee at this time is OH Technologies, 9300 Progress Pkwy., Mentor, OH 44060.

8.1.4.13 Rods and pins;

8.1.4.14 The test batch camshaft sprockets and crankshaft gear.

8.1.5 *Cleaning of Other Components:*

8.1.5.1 *VCT Solenoids*—Spray with solvent, then blow out with pressurized air, and leave to air-dry.

8.1.5.2 *Turbocharger Intake and Outlet*—Lightly wipe down with solvent.

8.1.5.3 *Injectors*—Wipe off carbon build up.

8.1.5.4 *Test Batch Timing Chain*—Clean as described 8.20.1.

8.2 *Cylinder Deglazing:*

8.2.1 Use a silicon carbide, grit flexible cylinder hone Flex Hone Model GB31232[20,7] and Pneumatic Honing Drill, Westward ½ in. Reversible Air Drill, 500 r/min, 600 kPa (90 psig) max, Model 5ZL26G[20,7] to deglaze the cylinder walls (see 8.13 and Figs. A9.3 and A9.4).

8.3 *PCV Valve Flowrate Device:*

8.3.1 Use this device to verify the flowrate of the PCV valve before the test and to measure the degree of clogging after the test.

8.3.2 Fabricate the device according to the details shown in Fig. A9.1.

8.3.2.1 The device shall have a full-scale accuracy of 5 % and a resolution of 0.05 L/s.

8.3.2.2 The inlet-flowrate meter shall calibrate to within 5 % of the standard (pre-calibrated) orifices at the pressure differentials stamped on the orifices.

8.4 *Preparation of Miscellaneous Engine Components:*

8.4.1 *Area Environment of Engine Build-Up and Measurement:*

8.4.1.1 The ambient atmosphere of the engine build-up and measurement areas shall be reasonably free of contaminants.

8.4.1.2 Maintain a relatively constant temperature (within ±3 °C) to ensure acceptable repeatability in the measurement of parts dimensions.

8.4.1.3 Maintain the relative humidity at a nominal maximum of 50 % to prevent moisture forming on cold engine parts that are brought into the build-up or measurement areas.

8.5 *Throttle Body:*

8.5.1 Clean the butterfly and bore of the throttle body with carburetor cleaner Chemtool B12 (see 7.1.2) and air-dry before each test.

8.5.1.1 Do not disassemble the throttle body as this will cause excessive wear on the components.

8.5.1.2 There is no specific life for the throttle body. The clearance between the bore and the butterfly will, however, eventually increase and render the body unserviceable.

8.5.1.3 Discard the throttle body when the clearance becomes too great to allow control of speed, torque, and air-fuel ratio.

[20] The sole source of supply of this equipment known to the committee at this time is W.W.Grainger, Inc., www.grainger.com.

8.6 *PCV Valve Cleaning and Measurement:*

8.6.1 Clean the PCV valve by spraying the inside of the valve with Chemtool B12 until the solvent comes out clear.

8.6.2 Measure and record the flowrates of the PCV valve with the calibrated flow device described in Fig. A9.1.

8.6.2.1 Measure the flowrate at 27 kPa and 60 kPa vacuum.

8.6.2.2 Because of the hysteresis in the PCV valve spring, make the vacuum adjustments in one direction only.

8.6.2.3 Correct the actual flow measurements to 65.5 °C and 100.7 kPa using the formula:

$$F_C = 1.8338*F_A[(P_{baro})/(T_{AIR} + 273)]^{0.5} \quad (1)$$

where:

F_C = the corrected flow rate, L/min,
F_A = the actual flow rate, L/min,
P_{baro} = the barometric pressure in the measurement area, kPa (absolute), and
T_{AIR} = the air temperature in the measurement area, °C.

When using a float type flow meter for the PCV valve measurement, correct the converted flow value from meter's standard-condition scale to actual flow (using actual temperature and pre-PCV outlet pressure), before applying correction formula Eq 1.

8.6.2.4 Measure the flowrate twice and average the readings.

8.6.2.5 Reject any PCV valve that does not exhibit an average corrected flowrate of 36 L⁄min to 54 L⁄min at 27 kPa and 19 L⁄min to 21 L⁄min at 60 kPa.

8.7 *Drive System for Water Pump*—The water-pump drive is shown in Fig. A9.2. Use only the pulleys and belt provided in the test stand set-up parts list (Table A5.6) for the crankshaft pulley, water-pump pulley, tensioner, and six-groove belt shown in Fig. A9.2.

8.8 *Oil Separators*—Clean with Stoddard solvent and allow to air-dry.

8.9 *Assembling the Test Engine:*

8.9.1 *General*—Use the long block obtained from the supplier.[21,7]

8.9.1.1 Disassemble the long block in accordance with the 2012 Explorer workshop manual.

8.9.1.2 Required new parts and reusable parts are listed in Tables A5.4 and A5.5.

8.10 *Parts Selection*—Instructions concerning the use of new or used parts are detailed in 6.2 to 6.6.

8.11 *Gaskets and Seals*—Install new gaskets and seals during engine assembly.

8.12 *Block Preparations*—Inspect block, including oil galleries for debris and rust.

8.12.1 Remove any debris or rust that is found.

8.12.2 Remove oil gallery plugs.

8.12.3 Removal of coolant jacket plugs is left to the discretion of the laboratory.

[21] The sole source of supply of this block known to the committee at this time is Ford Component Sales, Ford Motor Co., 290 Town Center Dr., Dearborn, MI 48126.

8.13 *Deglazing Procedure:*

8.13.1 *General*—Carry out deglazing after ultrasonic cleaning for both new and used engines under the following conditions to achieve a per cylinder average surface roughness (*Ra*) of 0.178 µm to 0.330 µm (7 µin. to 13 µin.) using a Mitutoyo SJ-410 profilometer.

8.13.1.1 Mount the engine block on an engine stand or suitable fixture so it is secure and will not move during the deglazing operation.

8.13.1.2 Rinse cylinder bores with Stoddard solvent.

8.13.1.3 Deglaze cylinder bores using the drill[20,7] and hone[20,7] shown in Figs. A9.3 and A9.4 (see also 8.2).

8.13.1.4 Run the drill at 500 r/min horizontal drill speed for 25 vertical strokes to 35 vertical strokes over an elapsed time of 20 s to 25 s. Ensure a steady supply of lubricant is supplied during each stroke.

8.13.1.5 Use a 50/50 ratio of Stoddard solvent and EF411 as the hone lubricant.

8.13.1.6 Clean cylinders after honing deglazing with warm/hot water or hot water and detergent (Tide[22,7] has been found suitable) using a brush, then oil cylinders with EF411.

8.13.1.7 Replace ball hone after deglazing 24 engine blocks.

8.14 *Crosshatch Measurement Procedure:*

8.14.1 *Apparatus*—Use the following:

8.14.1.1 *HatchView Software*.

8.14.1.2 *USB Microscope*.

8.14.1.3 *Computer System*—Minimum requirements: Windows XP, Vista or Windows 7 (32 or 64 bit), an available USB 2.0 port is required for live "video" viewing.

8.14.2 *Preparation:*

8.14.2.1 Clean the cylinder of any oil or residue from honing to maintain consistency of measurements.

8.14.2.2 Adjust the focus of the camera while the face of the camera is placed against the cylinder wall.

8.14.2.3 Set camera resolution to 640 ~~x~~× 480 and 30 frames per second (fps).

8.14.2.4 Use the identification feature available in the program to title the image with cylinder number and test number.

8.14.3 *Measurement:*

8.14.3.1 Take the measurement at the rear-most longitudinal position of each cylinder.

8.14.3.2 Using a ruler, take the measurement 38.1 mm (1.5 in.) down from the top of the cylinder deck.

8.14.3.3 The measurement shall be between 25° to 35° with a target of 30°.

8.15 *Crankshaft Preparation:*

[22] The sole source of supply of this product known to the committee at this time is Procter & Gamble Co., 1 P&G Plaza, Cincinnati, OH 45202. Tel: +1 513 983 1100.

8.15.1 Clean the crankshaft as described in 8.1.4.

8.15.2 Measure the horizontal and vertical diameters of the main and connecting rod journals, the bearing inside diameter and clearance, and verify that they meet the service limits.

8.15.3 Polish the crankshaft with 400 grit aluminum oxide utility cloth while it is still lightly coated in Stoddard solvent. 3M utility cloth 314D[23] has been found to be suitable.

8.15.4 Give a final finish with 600 grit crocus cloth.

8.15.5 Clean with Stoddard solvent as described in 8.1.4 for the final time.

8.16 *Piston and Rod Assembly:*

8.16.1 Clean the pistons as described in 8.1.3.1.

8.16.2 Measure piston, piston pin, and pin-rod-hole diameters to ensure they meet service limits.

8.16.3 Install the pistons on the connecting rods following the procedure in the 2012 Explorer workshop manual.

8.17 *Piston Rings:*

8.17.1 *Ring Gap Adjustment:*

8.17.1.1 Clean the piston rings by spraying them with Chemtool B12 carburetor cleaner to remove the factory coating. Wipe the piston rings with EF411.

8.17.1.2 Typically a gap of 1.651 mm (0.065 in.) for the top ring and 1.778 mm (0.070 in.) for the second ring have been shown to produce acceptable blowby levels with the surface finish and crosshatch pattern achieved in See 8.14. However, ensure that the delta between the top and second ring gaps is 0.127 mm (0.005 in.).

8.17.1.3 To achieve an average blowby of 65 L/min to 75 L/min, an adjustment may be necessary immediately before or after the 24 h measurement.

8.17.1.4 A 24 h blowby value of at least 70 L/min is recommended. The 24 h to 120 h blowby average shall fall within 65 L/min to 75 L/min.

8.17.1.5 Ring gap adjustments are not allowed once the test has resumed after the 24 h blowby reading.

8.17.1.6 Place the ring 38 mm (1.5 in.) from the deck, using the piston-ring setter (see Fig. A7.1).

8.17.2 *Piston-Ring Cutting Procedure:*

8.17.2.1 Cut the top and second compression-ring gaps to the required gap using a ring grinder. The Sanford Piston Ring Grinder[24,7] has been found suitable with a 3⁄16 in. (4.76 mm) ring cutting burr (P/N 74010020[25,7]) rotated at a rated speed of 3450 r/min.

8.17.2.2 Remove equal amounts from both sides of the gap. Make final cuts on the down stroke only.

8.17.2.3 Cut the ring with a maximum increment of 0.125 mm until the desired ring gap is achieved.

[23] The sole source of supply of this product known to the committee at this time is 3M United States, 3M Center, St. Paul, MN.

[24] The sole source of supply of this equipment known to the committee at this time is Sanford Mfg. Co., 300 Cox St., PO Box 318, Roselle, NJ 07203.

[25] The sole source of supply of this equipment known to the committee at this time is M.A.Ford Mfg. Co., Inc., 7737 Northwest Blvd., Davenport, IA 52806. www.maford.com.