Test Monitoring Center
6555 Penn Avenue
Pittsburgh, PA 15206-4489
(412) 365-1000

APPROVED BY ASTM D02.B June 20, 2001
(DATE)

Sequence VG Information Letter 01-2
Sequence No. 8

March 20, 2001

ASTM consensus has not been obtained on this information letter. An appropriate ASTM ballot will be issued in order to achieve such consensus.

TO: Sequence VG Mailing List

SUBJECT: 1. Incorporation of Information Letters 00-2 through 01-1
2. Corrections to Precision Statement

1. The following sections of Test Method D6593 have been revised to incorporate Information Letters 00-2 through 01-1: Table of Contents, 2.1, 2.2, 2.3, 6.1, 7.1.1, 7.4.9, 7.5, 7.5.2, 7.5.5, 7.5.6, 7.6.3.2, 7.7.1, 7.7.2, 7.7.3, 7.8.5.1, 7.8.5.2, 7.8.5.3, 7.8.6, 7.9.4, Tables 1, 3, and 4, 8.2.4, 8.3.2.2, 8.4.1, 8.4.3.3, 9.1.8, 9.2.1, 9.2.10, 9.3.2, 9.3.4.3, 12.1 (entire), 12.3.1, 12.3.4.1, 13.4 (entire), 13.7 (entire), 15 (entire), Figure 8, Figure A3.19, Annexes A2, A7, A8 and A12, and Appendix X2.

2. Recently, the chairman of Section D02.B0.9 informed the Test Monitoring Center that the oil screen intermediate precision and reproducibility estimates had been reversed in Table 8. In addition, several editorial changes to the precision statement were needed. Sections 16.1.1, 16.1.2 and Table 8 have been revised and Sections 16.1.1.1 and 16.1.2.1 have been added.

The attached changes to Test Method D6593 are effective the date of this letter.

Peter Misangyi
Product Engineering
Ford Motor Company

John Zalar
Administrator
ASTM Test Monitoring Center

Attachment

c: ftp://www.tmc.astm.cmri.cmu.edu/documents/gas/sequencev/procedures_and_ils/vgil01-2-8

1.3. A Table of Contents follows:

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X1 Suggested Engine Measurement Sheets
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2. Referenced Documents

2.1. *ASTM Standards:*

D86 Test Method for Distillation of Petroleum Products[4]
D287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)[4]
D323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)[4]
D381 Test Method for Existent Gum in Fuels by Jet Evaporation[4]

[4] Annual Book of ASTM Standards, Vol. 05.01.

D445	Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)[4]
D525	Test Method for Oxidation Stability of Gasoline (Induction Period Method)[4]
D873	Test Method for Oxidation Stability of Gasoline (Potential Residue Method)[4]
D893	Test Method for Insolubles in Used Lubricating Oils[4]
D1266	Test Method for Sulfur in Petroleum Products (Lamp Method)[4]
D1298	Practice for Density, Relative Density (Specific Gravity) or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[4]
D2622	Test Method For Sulfur in Petroleum Products by X-Ray Spectrometry[5]
D2789	Test Method for Hydrocarbon Types in Low Olefinic Gasoline By Mass Spectrometry[5]
D3237	Test Method for Lead in Gasoline by Atomic Absorption Spectrometry[5]
D3525	Test Method for Gasoline Diluent in Used Gasoline Engine Oils by Gas Chromatography[5]
D3606	Test Method for the Determination of Benzene and Toluene in Finished Motor and Aviation Gasoline by Gas Chromatography[5]
D4057	Practice of Manual Sampling of Petroleum and Petroleum Products[5]
D4175	Terminology Relating to Petroleum, Petroleum Products, and Lubricants[5]
D4294	Test Method for Sulfur in Petroleum Products by Non-dispersive X-Ray Fluorescence Spectroscopy[5]
D4485	Specification for Performance of Engine Oils[5]
D4739	Test Method for Base Number Determination by Potentiometric Titration[5]
D5059	Test method for Lead in Gasoline by X-Ray Spectroscopy[6]
D5185	Test Method for Determination of Additive Elements, Wear Metals and Contaminants in Used Lubricating Oils by Inductively Coupled Plasma Atomic Emissions Spectrometry[6]
D6304	Test Method for Determination of Water in Petroleum Products, Lubricating Oils and Additives by Coulometric Karl Fischer Titration[7]
E29	Practice for Using Significant Digits in Test Data to Determine Conformance With Specifications[8]
G40	Terminology Relating to Erosion and Wear[9]

2.2. *SAE Standards:*

SAE J254 Instrumentation and Techniques for Exhaust Gas Emissions Measurement[10]

2.3. *ANSI Standard:*

ANSI MC96.1 Temperature Measurement-Thermocouples[11]

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[5] Annual Book of ASTM Standards, Vol. 05.02.

[6] Annual Book of ASTM Standards, Vol. 05.03

[7] Annual Book of ASTM Standards, Vol. 05.04

[8] Annual Book of ASTM Standards, Vol. 03.02.

[9] Annual Book of ASTM Standards, Vol. 14.02

[10] Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096

[11] Available from American National Standards Institute, 11 W. 42nd St. 13th Floor, New York, NY 10036.

6.1. The test engine is a Ford 4.6L, spark ignition, four stroke, eight-cylinder "V" configuration engine. Features of this engine include an overhead camshaft, a cross-flow fast-burn cylinder head design, two valves per cylinder and electronic port fuel injection. It is based on the Ford Motor Company's 4.6L EFI Crown Victoria[12] passenger car engine.

7.1. *Sequence VG Test Engine*--The test engine kit is available from the Ford Motor Company (Annex A9.1). A detailed listing of all parts included in the kit is given in Annex A5. Orders for test engine hardware will be solicited yearly.

7.1.1. Non-rated parts can be replaced during the test, provided the reason for replacement is not oil related.

7.4.9 *Oil Filter*—Use a 60µm screen type oil filter with a bypass (see Fig A3.8) available from the supplier listed in X2.1.20

7.5. *Special Engine Measurement and Assembly Equipment*--Items routinely used in the laboratory and workshop are not included. Use any special tools or equipment shown in the 1994 Ford Crown Victoria Service Manual[13] for assembly. A list of these tools is shown in Annex A4. Complete any assembly instructions not detailed in Section 7 according to the instructions in the 1994 Ford Crown Victoria Service Manual.

7.5.5. *Master Bore*—Use a cylinder bore of 90.70±0.03 mm as a master bore for determining top ring gap increase for the rings in cylinders 1 and 8. Using a master bore allows for consistent measurement of top ring gap increase at end-of-test. Maintain the master bore in a temperature controlled room.

7.5.6. *Oil Screen Blowdown Device*—Use the device available from the supplier listed in Annex A9.3 to blow a controlled amount of compressed air across the oil screen to remove any oil that is retained on the oil screen after allowing it to drain.

7.6.3.2. Submerge the RAC in agitated organic solvent (see 7.7.2) until clean (approximately 1 h). Rinse the parts thoroughly with hot water (> 60 °C). Rinse the RAC with aliphatic naphtha (7.7.1) and allow to air-dry. Inspect the appearance of the interior surface of the RAC. If the before-test rating is less than ten on the CRC varnish rating scale (Manual 14)[14], polish the interior surface lightly with Number 0 fine steel wool to achieve a dull finish. Rinse the cover with aliphatic naphtha (7.7.1) and allow to air-dry before use.

7.7.1. *Aliphatic Naphtha*, Stoddard solvent[15] or equivalent is satisfactory.

7.7.2. *Organic solvent, Penmul L460*[16]

7.7.3. *Dearsol 134 Acidic Cleaner*[17] *with Inhibitor,* RAC cooling jacket internal cleaner.

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[12] Ford Crown Victoria is a product of the Ford Motor Company., Dearborn, MI 48121

[13] Ford Crown Victoria/Grand Marquis 1994 Service Manual

[14] Available from Coordinating Research Council, Inc., 219 Perimeter Ctr. Parkway, Atlanta, GA 30346

[15] Stoddard Solvent is a product of UNOCAL Chemicals Division. 7010 Mykawa St., Houston, TX 77033.

[16] Penmul L460 is a product of Penetone Corp., P.O. Box 22006, Los Angeles, CA 90022

[17] Dearsol 134 Acidic Cleaner is a product of Dearbom Division, subsidiary of W. R. Grace and Co., 300 Genesee St., Lake Zurich, IL 60047.

7.8.5.1. *Ring Gap Adjustment*:

(a) Cut the top and second compression ring gaps as required to obtain the specified blowby flow rate, using the Sanford Piston Ring Grinder[18]. Record the ring side clearance(s) and new ring gap(s) on any ring(s) adjusted. Enter the new dimension(s) on the Supplemental Operational Data sheets. Typical forms for recording these dimensions are shown in Appendix X1. Ensure that the required ring gap delta and ring side clearance are attained (Table 1). Replace rings if smaller ring gaps are required. Measure the rings for cylinders 1 and 8 in the master bore. These measurements are required to determine the ring gap increase.

(b) Using the master bore, measure the ring gaps for the top rings in cylinders 1 and 8 prior to the start of the test.

7.8.5.2. *Piston Ring Cutting Procedure:*

(a) With the block in a free state, position the ring in the cylinder bore with the ring positioning tool (see Annex A3.9) and measure the ring gap.

(b) Cut the ring to the required gap using the ring cutting burr[19] rotated at a rated speed of 3450 r/min. Remove equal amounts from both sides of the gap. Make final cuts on the down stroke only. The ring is cut with a maximum increment of 0.125 mm until the desired ring gap is achieved.

(c) After the rings are cut remove the ring from the cutting tool, debur using a Sunnen soft stone[20] and wipe with a dry towel.

(d) Measure the gap with the ring in its respective bore positioned with the ring positioner.

(e) Repeat steps (b) through (d) until the desired ring gap is achieved, then wash the ring with aliphatic naphtha (7.7.1) and wipe clean with a dry towel.

7.8.5.3. *Installation:*

(a) Install the oil control rings and the compression rings on the pistons with the gaps located over the piston pin. Position the gaps at approximately 180° intervals, with the top compression ring gap toward the rear. Install the rings using a ring spreader tool, keeping the rings' surfaces parallel to the ring groove in the piston.

(b) If any rings require replacement, then measure and record the new ring gap(s) and ring side clearance(s). Calculate ring side clearance by determining the difference between the ring groove width and the associated ring width.

7.8.6 Cylinder Bore Measurements: Measure cylinder 1 and 8 cylinder bores with the bearing caps in place. Clean bores with a dry rag. The bores shall be clean and dry when measured. Use a bore gage micrometer to determine the diameter of cylinders 1 and 8 at the top, middle and bottom of the second ring travel in the transverse direction.

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[18] Available from Sanford Manufacturing Co., 300 Cox Street, P.O. Box 318, Roselle, NJ 07203.

[19] 3/16 in carbide ring cutting burr, No. 74010020, made by M. A. Ford,

[20] Sunnen soft stone No. JHU-820

Table 1. Required piston and piston ring dimensions

Ring side clearance, Average	0.0508 - 0.1016 mm (0.0020 - 0.0040 in.)
Ring gap delta	0.045 - 0.055 mm (0.0018 - 0.0022 in.)

7.9.4. *Cylinder Head*--Prior to the installation of the cylinder heads, clock the crankshaft keyway at 270° of crankshaft angle (45° BTDC for piston No.1). Install the cylinder head on the cylinder block. Oil the head bolt threads lightly with EF-411[21] oil, and torque the head bolts according to the sequence described in the service manual. Do not use any sealing or anti-seizure compounds on the cylinder head gasket.

Table 3. VG Fuel Analysis

Parameter	Specification Band
API gravity[A]	58.7 - 61.2
RVP[B]	60.7 – 63.4 kPa
Total sulfur[C]	0.01 - 0.04 wt% max
Existent gum[D]	5mg/100 mL, max
Distillation[E]	
IBP	22.2 – 35.0°C
10%	48.9 – 57.2°C
50%	98.9 – 115.2°C
90%	162.8 – 176.7°C
EP	196.1 – 212.8°C
The following parameters are analyzed on an absolute basis:	
Appearance	clear & bright
Water[F]	0.01 vol%, max
Lead[G]	10 mg/L max
Oxidation stability[H]	1440 minutes, min

[A]In accordance with Test Method D1298 or D287.
[B]In accordance with Test Method D323 or Automatic Reid Vapor Pressure.
[C]In accordance with Test Method D4294 or D1266 or D2622.
[D]In accordance with Test Method D381.
[E]In accordance with Method D86.
[F]In accordance with Test Method D6304
[G]In accordance with Test Method D3237 or D5059.
[H]In accordance with Test Method D525.

8.3.2.2 Use oil filter adapter OHTA-0007-1 (Appendix X2.1.11), oil filter OHT6A-012-2 (Appendix X2.1.11). Be sure all hoses and fittings on the oil heat exchanger are properly connected and secure. *The external oil system shall not be brass, copper or galvanized, as these metals may influence used oil analysis.*

[21] Mobil EF-411 oil is a product of Mobil Oil Corp., 3225 Gallows, Fairfax, VA 22037.

8.2.4 *Fuel Batch Approval Process*—Obtain fuel from the supplier listed in Appendix X2.1.5. Each new batch of fuel is approved by the following process:

8.4.1. *Description*--The engine coolant is equal parts of demineralized (less than 0.34 g/kg) or distilled water and a fully formulated ethylene glycol based automotive antifreeze to protect against corrosion of all system components. The RAC coolant is a solution of demineralized (less than 0.34 g/kg) or distilled water and an additive treatment of 475 mL of Pencool 2000[22] per 15 L of water.

8.4.3.3 The engine coolant flow rate and outlet temperature are controlled with the specifications listed in Table 2. Information concerning the cooling flowrate measurement device is detailed in 9.3.2. Cyclic ramping specifications are detailed inTable 4. The coolant flow rateis measured with a venturi fowmeter (Appendix X2.1.6) and controlled with an in-line flow control valve.

Table 4. Test Ramping Requirements[A]

Stage III to I	
Engine Speed	1195 r/min within 5 to 20 s
Manifold Absolute Pressure	68.8 kPa within 20 to 80 s
Oil Inlet Temperature	67.5°C within 8± 2 min
Coolant Outlet Temperature	56.5°C within 6± 2 min
Rocker Arm Cover Inlet Temperature	29°C within 17 min
Stage I to II	
Engine Speed	2895 r/min within 30 to 90 s
Manifold Absolute Pressure	66± 0.2 kPa within 60 to 150 s
Oil Inlet Temperature	99.5°C within 7± 2 min
Coolant Outlet Temperature	84.5°C within 7± 2 min
Rocker Arm Cover Inlet Temperature	84.5°C within 17± 2 min
Stage II to III	
Engine Speed	715 r/min within 5 to 20 s
Engine Power	< 3kW at 5 to 20 s
Oil Inlet Temperature	46°C within 15± 2 min
Coolant Outlet Temperature	46°C within 9± 2 min
Rocker Arm Cover Inlet Temperature	30°C within 10± 2 min

[A] *Test Ramping Requirements Information*--Switch ECT to the fixed resistor at the onset of the Stage II to Stage III ramp. At the onset of Stage III to Stage I ramp, switch from the fixed resistor to the ECT.

9.1.8. *Calibration*--Calibrate all thermocouples prior to a reference oil test. The temperature measurement system shall indicate within ±0.5°C of the laboratory calibration standard. The calibration standard shall be traceable to NIST.

9.2.1. *Equipment*--Pressure measurement for each of the eight required parameters is detailed in the following sections. This allows reasonable opportunity for adaptation of existing test stand instrumentation. However, the accuracy and resolution of the pressure measurement sensors and the complete pressure measurement system shall follow the guidelines detailed in ASTM Research Report RR:D-1218[23] . Replace pressure sensors that are part of the EEC system with only Ford specified equipment.

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[22] Pencool 2000 coolant is a product of Penray Companies, Inc., 1801 Estes Avenue, Elk Grove, IL 60007.

[23] Available from ASTM Headquarters, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959

9.2.10. *Calibration*--Calibrate all pressure measurement sensors prior to a reference oil test. The MAP pressure measurement system shall indicate within 0.1 kPa of the laboratory calibration standard. All other pressure measurement systems shall conform to the guidelines in ASTM Research Report RR: D02-1218 . The calibration standard shall be traceable to NIST.

9.3.2. *Engine Coolant*--Determine the engine coolant flow rate by measuring the differential pressure drop across the specified venturi flowmeter (see Annex A3.18) Flowmeter is available from the supplier in Appendix X2.1.6. Take precautions to prevent air pockets from forming in the lines to the pressure sensor. Transparent lines or bleed lines, or both, are beneficial in this application. Ensure that the manufacturers required straight sections of pipe are installed immediately up and down stream of the flowmeter.

9.3.4.3. The sharp-edged orifice assembly is specifically designed for blowby flow rate measurement and shall be fabricated in strict compliance with the specifications that are available from the TMC. Additional information on the orifice system can be obtained from the source listed in Appendix X2.1.8. The assembly contains five orifices. The 0.375 in. orifice is generally satisfactory for the range of blowby flow rate encountered. The complete orifice assembly can also be purchased from the supplier listed in Appendix X2.1.11.

12.1.1 *Engine Break-In Procedure*--Run break-in schedule listed in Table 6. Conduct the break-in before each test using the test oil.

12.1.1.1. Charge the engine with 3000 g of test oil before the break-in run . Run the engine at 1500±25 r/min and 37.6 kPa MAP until the oil temperature reaches 80±2°C or for at least two min. Record the dipstick level 20 min ± 2 min after shutdown. This shall be the Test Full mark for this test. Use the table in Annex A8 to determine the oil level.

12.1.1.2. The laboratory ambient atmosphere shall be reasonably free of contaminants. The temperature and humidity levels of the operating area are not specified. Divert air from fans or ventilation systems away from the test engine.

12.1.1.3. The break-in allows an opportunity to check EEC system operation, blowby levels, air/fuel ratio for Stage II and III, check for leaks in the various systems and purge air from the cooling systems. Specifications concerning the break-in procedure are shown in Table 6. The engine start-up and shutdown procedures are detailed in 12.2.1 and 12.2.2 respectively.

12.1.1.4. During Step 1, bleed the air from the engine and RAC coolant systems and check all fluid systems for leaks.

12.1.1.5. During Step 2, check blowby level for the Stage II conditions. A high or low blowby flow rate at this time could be indicative of the blowby flow rate during the test. A ring gap adjustment can be performed at this time or after the break-in, but before the start of cycle 1, to achieve an adequate blowby flow rate. Testing has shown that a blowby range of 65-75 L/min during the break-in typically produces acceptable blowby during the test. However, it is the laboratory's discretion as to the need for a ring gap adjustment, noting that an adjustment cannot be made at any other time during the test.

12.1.1.6. During Step 3 (see Table 6) check Stage III air/fuel ratio, the operation of the idle load control system and EEC system operation. Allow the oil and coolant temperatures to reach 45±0.5°C. Exhaust gas analysis shall indicate 8.5±1.5% CO and

3.0% O_2 max for both banks. If the exhaust gas analysis is not within the specified limits check the idle load circuit and the EEC system operation with a STAR tester.

12.1.1.7. Record all normal parameters in Steps 2 and 3 after operation at each step for 35 min. **Warning** - Prolonged operation at a rich air-fuel ratio can cause excessive fuel dilution and alter test severity.

> Note 6: The engine normally requires approximately 20 min to reach steady-state conditions after a step change.

12.1.1.8. Check and record oil level after break-in. If piston rings are regapped or replaced during or after the break-in, ensure that the oil level is brought back to the Test Full mark by adding new oil or removing oil.

12.3.1. *Blowby Flow Rate Measurement*--Every sixth cycle, measure and record the blowby flow rate at 30±5 min into Stage II. The engine shall be stable and operating at normal Stage II operating conditions. Measure blowby when the gas temperature is at least 32°C. Blowby gas temperature shall not differ from the laboratory average by more than ±5°C. The installation of the blowby flow rate measurement apparatus is shown in Fig 7. The procedure for measuring blowby flow rate is detailed in 12.3.1.1. Complete only one set (Stage II) of blowby flow rate measurement during each six cycles. Under special circumstances additional blowby flow rate measurements can be performed to determine or verify a problem with the flow rate measurement apparatus or the engine. Record additional blowby flow rate measurements and an explanation of the reason for the additional measurements. Include these data in the supplemental operational data in the final test report.

12.3.4.1 *Oil Leveling and Sampling Procedure*--Make up oil additions for leveling and oil sampling occur at 24 h intervals. Annex A10 shows the cycle when this is to occur. Used oil additions are permitted only during engine reassembly for maintenance (see 12.4.2.2). Add new oil to the engine only when the level is more than 400 g below the original test full level. Add only enough new oil to reach the 400 g low mark. No other new oil additions are permitted during the test, except after piston ring gap adjustment (see 12.1.2.8). In the event that the oil level is above the test full mark do not remove oil until the level is greater than 200 g above the test full mark. Drain off a sufficient amount of oil so that the level is at the 200 g above test full mark. Record the amount drained on the oil leveling sheet. The procedure is shown on the Oil Sampling, Addition and Leveling Worksheet in Annex A10. This form serves as the oil sampling and oil addition data sheet.

(a) Remove a 150 mL purge sample within the first 10 min of Stage III.

(b) Remove a 60 mL analysis sample within the first 10 min of Stage III.

(c) Return the purge sample to the engine.

(d) Shut-down the engine 10 min after the start of Stage III. Do not shut off the RAC coolant pump.

(e) Record the dipstick level in mm 20±2 min after the engine is shutdown.

(f) Compute the oil level in grams. The difference between the oil level and the Test Full mark is oil consumed or gained. Use the chart in A8 to determine the level. Do not add oil at 216 h. This allows the final drain to be used as a backup to the 216 h sample.

(g) If the level is more than 400 g below the Test Full mark, record the amount of new oil added to bring the level to the -400 g mark. However, never add more than 400 g during an oil addition.

(h) If the level is more than 200 g above the Test Full mark, record the amount of oil drained to bring the level to the +200 g mark.

(I) Restart the engine 30±1 min after shutdown (step d). Allow the engine to run at Stage III conditions for 5±1 min then resume normal operation.

13.4. *Clogging:*

13.4.1 Oil Screen Clogging

13.4.1.1Use the following procedure to determine the percentage of the oil screen clogged by sludge:

(a) Use a device to blow air across the screen to remove any retained oil on the screen. A suitable device can be obtained from the supplier listed in X2.1.21.

(b) Regulate the air pressure to 130±10 kPa (18.85±1.45 psig).

(c) Connect the device to the screen.

(d) Allow air to flow for 5-10s.

(e) Remove the device and rate.

13.4.1.2. Flexible, transparent rating aids can be made for different surface areas so that when compared to the test screen's surface, a more accurate determination of surface clogging is possible.

13.4.1.3 Determine the percentage of the total screen opening that is obstructed with sludge and debris. Transform the oil screen results by taking the natural log (ln) of the oil screen rating plus 1; i.e. ln(oil screen clogging+1). Round this value to four decimal places. Report both transformed and original result on the appropriate form(s). Where laboratory bias is determined to be significant, adjust the results for severity in accordance with the Lubricant Test Monitoring System[24]. Round this adjusted result to 4 decimal places and convert to original units by subtracting 1 from the antilog (e^x) of the adjusted result in transformed units. Record this value as the final result in original units on the appropriate form(s).

13.7 *Additional Measurements*

13.7.1 *Follower Pin Wear*—Measure the wear on the pins from the followers from cylinder No. 8 intake and exhaust, using the following procedure.

13.7.1.1 Label one end of the follower with the position in the engine; 8I, 8E.

13.7.1.2 Label the opposite end of the roller pin with an arrow indicating the top of the rocker and the position of the measurement.

[24] Available from ASTM Test Monitoring Center, 6555 Penn Avenue, Pittsburgh, PA 15206.

13.7.1.3 Using a vice to hold the rocker, punch the pins with a 5mm (3/16 in.) diameter punch from the rockers.

13.7.1.4 Measure the wear step on the follower pins using a surface finish analyzer.

13.7.1.5 Set the machine up following the manufacturer's instructions for measuring the depth of the wear.

13.7.1.6 Place the follower pin in a V-block with the arrow up (13.7.1.2).

13.7.1.7 Lower the stylus on to the follower pin an center the pin horizontally.

13.7.1.8 Set the travel points on the machine so the stylus will transverse the length of the worn surface, starting on an unworn surface at one end and completing its trace on the unworn surface at the opposite end. Position stylus to start and finish on an area between the worn surface and the area that was pressed into the rocker body.

13.7.1.9 Take a trace.

13.7.1.10 Position the evaluation length lines to bracket the displayed wear step so the measurement will only evaluate the wear step maximum depth.

13.7.1.11 Perform the above steps for both pins.

13.7.2 Ring Gap Increase—Using the top rings from cylinders 1 and 8, clean the rings thoroughly and measure the ring gap after the rings have been installed in the master bore (7.5.5). Calculate the ring gap increase. Compensate for any ring gap adjustments made during the test. Average the results and record. Determine the maximum ring gap increase and record.

13.7.3 *Bore Wear*—Measure cylinder 1 and 8 cylinder bores with the bearing caps in place. Clean the bores with a dry rag. The bores shall be clean and dry when measured. Use a bore gage micrometer to determine the diameter of cylinders 1 and 8 at the top, middle and bottom of the second ring travel in the transverse direction. Subtract these values from the initial measurement. Average the results and record. Determine the maximum bore wear result and record.

15. Final Test Report

15.1. *Report Forms*—Use the standardized report form set and data dictionary for reporting the test results and for summarizing the operational data. The photographs can be omitted for the reference oil test reports sent to the TMC.

15.2. *Photographs*--The required photographs are listed in this section. All photographs shall be 5 by 7 in., and in full color.

15.2.1. RAC and camshaft baffles

15.2.2. Oil pan and baffle

15.2.3. Oil pick-up screen

15.2.4. Cylinder head valve decks

15.2.5. Timing chain cover

15.2.6. Average and worst piston skirts, thrust sides

16. Precision and Bias

16.1 Test Precision—Reference Oils

16.1.1 *Intermediate Precision (formerly called repeatability) conditions*—conditions where test results are obtained with the same test method using the same test oil, with changing conditions such as operators, measuring equipment, test stands, test engines, and time.

16.1.1.1 Intermediate Precision limit (i.p.)--the difference between two results obtained under intermediate precision conditions that would, in the long run, in the normal and correct conduct of the test method, exceed the values shown in Table 8 in only one case in twenty.

16.1.2 *Reproducibility conditions*—conditions where test results are obtained with the same test method using the same test oil in different laboratories with different operators using different equipment.

16.1.2.1 *Reproducibility limit (R)*--the difference between results obtained under reproducibility conditions that would, in the long run, in the normal and correct conduct of the test method, exceed the values in Table 8 in only one case in twenty.

16.2 *Bias*—will be determined by applying an accepted statistical technique to reference oil test results, and when a significant bias is determined, a severity adjustment will be permitted for non-reference oil test results

Table 8 Reference Oil Statistics[A]

Variable, Merits	Intermediate Precision		Reproducibility	
	$S_{i.p.}$	i.p.	S_R	R
Average Engine Sludge	0.63	1.76	0.64	1.79
Rocker Cover Sludge	0.32	0.90	0.35	0.98
Average Engine Varnish	0.10	0.28	0.10	0.28
Oil Screen Clogging, Sludge	17.26	48.33	17.32	48.50
Average Piston Varnish	0.27	0.76	0.30	0.84

$S_{i.p.}$ – intermediate precision standard deviation
i.p. - intermediate precision limit[B]
S_R – reproducibility standard deviation
R – reproducibility limit[B]

[A] These statistics are based on results obtained on Test Monitoring Center Reference Oils 925-2, 926-1, 930, 1006 and 1007 over the period from June 1, 1999 through August 26, 1999.
[B] This value is obtained by multiplying the standard deviation by 2.8.

A2. *Control and Data Acquisition Requirements*

A2.1. *General Description*

A2.1.1. The data acquisition system shall be capable of logging the operational data in digital format. It is to the advantage of the laboratory that the system be capable of real time plotting of controlled parameters to help assess test validity. The systems shall be capable of calculating real time quality index as this will be monitored throughout the test as designated in A2.5.

A2.1.2. Control capability is not dictated by this procedure. The control system shall be capable of keeping the controlled parameters within the limits specified in Table 3 (see 8.3.5) and maintain the quality index shown in A2.5.

A2.1.3. Design the control and data acquisition system to meet the requirements listed below. Use the recommendations laid out in the Instrumentation Task Force Report and Data Acquisition Task Force Report for any items not addressed in Annex A2.

A2.2. *Digital Recording Frequency*

A2.2.1. The maximum allowable time period over which data can be accumulated is one second. This data can be filtered, as described in section A2.6, and will be considered a reading.

A2.3. *Steady state operation:*

A2.3.1. This portion of the test will start, at most, 20 min after the beginning of a transition and continue until the beginning of the next stage. By 20 min into a stage all parameters shall be in the steady state condition listed in Table 3. The start of the transition is considered the start of the stage. Calculate the quality index using values reported to the accuracy levels in Table A2.3.

Table A2.3 Accuracy Levels of Data Points to be Used in QI Calculations

Parameter	Field Length
Speed	5.0
Power	6.2
Humidity	5.1
Temperature	5.1
Manifold Absolute Pressure	5.1
Intake Air Pressure	6.3
Exhaust Backpressure	6.1
Coolant Outlet Pressure	6.1
Coolant Flow	6.1

A2.3.2. The time intervals between recorded readings shall not exceed 1 min. Data shall be recorded throughout the length of the steady state portion of each stage.

A2.4. *Transitions:*

A2.4.1. This portion of the test shall be, at most, the first 20 min of each stage. Ramping requirements are listed in Table 4.

A2.4.2. During the transition, the time intervals between recorded readings shall not exceed 1 min.

A2.5. *Quality index:*

A2.5.1. Calculate and report the quality index for each controlled parameter for the steady state portions of each test stage throughout the entire test.

A2.5.2. Update the quality index periodically throughout the test to determine the operational validity while the test is in progress. This could indicate if the test operational validity is in question before the test has completed.

A2.5.3 Use the following equation and the values listed in Table A2.5 to calculate the Qi.

$$1-\frac{1}{n}\sum_{i=1}^{n}\left(\frac{U+L-2Xi}{U-L}\right)^{2} = \text{Quality Index}$$

X_i = values of the parameter measured
U = Allowable upper limit of X
L = allowable lower limit of X
n = number of measurements taken

A2.5.4 Reset data that is greater than the over range values listed in Table A2.5 with the over range value listed in Table A2.5.

A2.5.5 Reset data that is lower than the under range values listed in Table A2.5 with the under range value listed in Table A2.5.

A2.5.5 Round the Qi values to the nearest 0.001.

A2.5.6 Report the Qi values on Form 6 of the test report.

A2.5.7 If the end of test quality index value is below 0.000 for reference oil tests, review the test operations with the TMC. The TMC will issue a letter to the laboratory and the test sponsor on its opinion. The laboratory will document its comments regarding the end of test quality index values less than 0.000 for non-reference oil tests. The laboratory or test sponsor may request TMC review of test operations for non-reference oil tests. The TMC will issue a letter to document its opinion.

Table A2.5 L & U CONSTANTS and OVER and UNDER RANGE VALUES

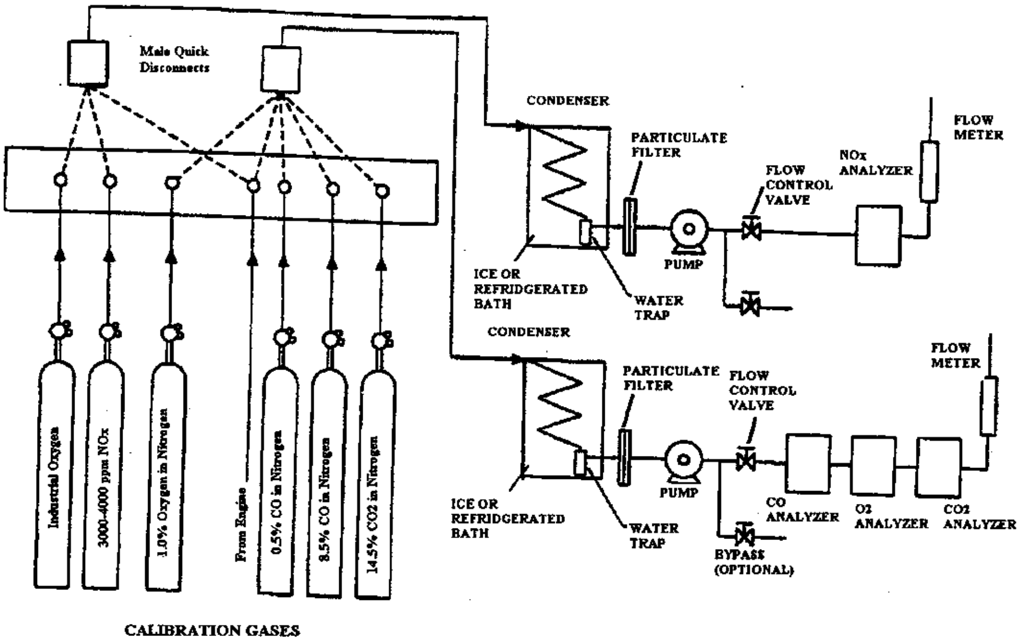
Parameter	Stages	L	U	Over Range	Under Range
Coolflow	1	47.47	48.53	87.0	0
Cooloutt	1	56.71	57.29	113.0	0
	2	84.71	85.29	113.0	0
	3	44.71	45.29	113.0	0
Exhbprs	1	103.92	104.08	115.0	0
	2	106.92	107.08	115.0	0
Humidity	1, 2, 3	10.85	11.95	64.0	0
Intairpr	1, 2, 3	0.04	0.06	1.05	0
Intairt	1, 2, 3	29.80	30.20	49.0	0
Oilint	1	67.79	68.21	120.0	0
	2	99.79	100.21	120.0	0
	3	44.79	45.21	120.0	0
Speed	1	1198.1	1201.9	3156.0	0
	2	2898.1	2901.9	3156.0	0
	3	698.1	701.9	3156.0	0
Power	3	1.25	1.35	2.92	0
Map	1	68.92	69.08	76.0	0
	2	65.92	66.08	76.0	0
Cooloutp	1, 2, 3	69.35	70.65	159.0	0
Raccint	1, 3	28.63	29.37	120.0	0
	2	84.63	85.37	120.0	0
Raccfl	1, 2, 3	14.85	15.15	29.0	0

A2.6. *Time constants:*

A2.6.1. Filtering can be applied to all control parameters. The amount of filtering applied shall not allow time constants to exceed the values listed in Table A2.6. This time constant shall pertain to the entire system, running from the sensor to the display and data acquisition.

Table A2.6. Maximum allowable system time constants for the controlled parameters

Control Parameter	Time Constant, seconds
Engine Speed, r/min	1.9
Engine Power, kW	2.0
Manifold Abs Press, kPa	1.8
Engine Oil, In, °C	2.4
Engine Coolant Out, °C	2.4
Engine Coolant Flow, L/min	17.0
RAC Coolant, In, °C	2.4
Rocker Cover Flow, L/min	2.0
Intake, Air, °C	2.4
Intake Air Press, kPa	2.6
Exhaust Back Pressure, kPa	1.7
Engine Coolant Pressure	2.0



A3.19.1 A typical exhaust gas analysis system is shown above. The condenser may use an ice bath or mechanical refrigeration. Ice bath condensers should use a coil fabricated from 0.25 in. (0.64 cm) stainless steel tubing and provide sufficient cooling to condense moisture at a dew point of 34 °F (1 °C). Mechanical refrigeration should provide control of the bath temperature to 34 ± 2 °F (1 ± 1 °C). The flow rate of engine exhaust and calibration gases should be identical and within the specifications of the instrumentation. An air conditioned chamber for instrumentation is required if ambient temperatures are above the maximum recommended for the particular instrumentation used.

Stainless steel fittings are preferred throughout the analysis system. Aluminum fittings may cause erroneous NO, and ultimately NO_x readings. Brass fittings should not be used in the analysis system. The porosity of the particulate filter should be between 2 and 10 microns. A diaphragm type pump is recommended to reduce pump "hang up."

Note A2 - Warning Safety precautions are necessary concerning venting CO, NO, and ozone gases from the analyzer instruments.

A3.19.2 Require Calibration Gases

Nominal 3500 ppm NO_x, balance N_2
Nominal 8.5% CO, balance N_2
Nominal 0.5% CO, balance N_2
Nominal 1.0% O_2, balance N_2
Nominal 14.5% CO_2, balance N_2

Optional Zero Standard Gas
N_2 for NO_x, O_2, CO, and CO_2 analyzers

A3.19.3 If the optional zero standard gases are not used to "zero" the analyzers, the CO calibration gases may be used to "zero" the O_2 analyzer, the O_2 calibration gases may be used to "zero" the CO and CO_2 analyzers, and bottled air may be used to "zero" the NO_x analyzer.

Fig. A3.19 *Exhaust Gas Analysis System*

Annex A7
Sequence VG Report Forms and Data Dictionary

Download the actual report forms and data dictionary seperately from the ASTM Test Monitoring Center Web Page at http://www.tmc.astm.cmri.cmu.edu/ or can be obtained in hardcopy format from the TMC.

Table of Contents

1. Title / Validity Declaration Page — Form 1
2. Table of Contents — Form 2
3. Summary of Test Method — Form 3
4. Test Result Summary — Form 4
5. Test Results Summary — Form 5
6. Operational Summary — Form 6
7. Oil Addition Record and Blowby Rates — Form 7
8. Analysis of Oil — Form 8
9. Downtime Occurrences and Other Comments — Form 9

Sequence VG Dipstick Correlation
Slope = 21 gm/mm
Offset =1953 mm

mm	grams	mm	grams
0	1953	30	2583
1	1974	31	2604
2	1995	32	2625
3	2016	33	2646
4	2037	34	2667
5	2058	35	2688
6	2079	36	2709
7	2100	37	2730
8	2121	38	2751
9	2142	39	2772
10	2163	40	2793
11	2184	41	2814
12	2205	42	2835
13	2226	43	2856
14	2247	44	2877
15	2268	45	2898
16	2289	46	2919
17	2310	47	2940
18	2331	48	2961
19	2352	49	2982
20	2373	50	3003
21	2394	51	3024
22	2415	52	3045
23	2436	53	3066
24	2457	54	3087
25	2478	55	3108
26	2499	56	3129
27	2520	57	3150
28	2541	58	3171
29	2562	59	3192
		60	3213

A8. *Typical Dipstick Calibration*

A12. Fuel Injector Flow Measurements

A12.1 Fuel Injector Test Rig—A suitable device capable of accurate, repeatable flow measurement of port fuel injectors is required. This device shall be capable of performing necessary port fuel injector evaluations as outlined below. Since no suitable commercially available apparatus has been identified, design of the test rig is up to the laboratory, Use Stoddard solvent as the fluid for flow testing injectors.

A12.2 Fuel Injectors—Prior to installations, evaluate all injectors (new and used) for spray patterns and flow rate using a suitable apparatus as identified above. The evaluation procedure is outlined in this section. Injectors may be cleaned and reused if the criteria outlined in this section are satisfied.

A12.3 Perform a visual inspection of each injector. Ensure that they have been cleaned of all oily deposits. Check O ring for cracking or tearing and replace as required.

A12.4 Flush new injectors for 30s to remove any assembly residue before flow-testing.

A12.5 Using a rig as described, place the injector(s) in the rig and turn on the pressure source to the injector(s). After the pressure source is turned on, the test fluid will start to flow through the injector(s). Maintain the test fluid pressure supplied to the injector(s) at 290 ± 3.4 kPa during the entire test. Maintaining this pressure is critical because a small change in pressure will have a dramatic effect on the flow rate and spray pattern. Once pressure is set, zero the volume-measuring device.

A12.6 Flow-test each injector for a 60s period. While the injector is flowing, make a visual observation of the spray pattern quality. The spray pattern should be typical for the make and model of the injector. At the completion of the 60s period leave pressure on closed injector(s) for at least 30s. Discard any injector that leaks or drips.

A12.7 The acceptable total flow for each injector after the 60s test shall be 188 to 203 mL at 290±3.4 kPa of test fluid pressure. Discard any injector that flows above or below this range.

X2. *Sources of Materials and Information*

X2.1. The following sources are provided for convenience only. This does not represent an exclusive or complete listing of required materials or information sources.

X2.1.1. *ASTM Sequence VG Test Parts*--ASTM Sequence VG Test Parts Kits can be purchased through Ford Power Products distributors and Ford or Lincoln-Mercury dealers.

X2.1.2. *ASTM Test Monitoring Center*--All communications with the TMC should be directed as follows:

ASTM Test Monitoring Center
6555 Penn Ave
Pittsburgh, PA 15206

X2.1.3. *Test Sponsor*--All communications with the test sponsor (Ford Motor Company) should be directed as follows:

Ford Motor Co.
21500 Oakwood Blvd.
POEE Bldg., MD 44 (D-145)
P. O. Box 2053
Dearborn, MI 48121

X2.1.4. *Aeroquip Hose and Fittings*--Aeroquip hose and fittings can be obtained from the following supplier:

Aeroquip Corp.
1225 W. Main
Van Wert, OH 45891

X2.1.5. *Fuel Information and Availability*—General information concerning the VG fuel, including availability, is available from the following supplier:

Haltermann Products
1201 S. Sheldon Rd.
P.O. Box 249
Channelview, TX 79530-0429

X2.1.6. *Engine Coolant Flowmeter*--Barco flowmeters for the engine coolant system (PN BR 12705-16-310) can be obtained from the following supplier:

Aeroquip Corp.
1225 W. Main
Van Wert, OH 45891

X2.1.7. *Intake-Air Humidity Instruments*--The Alnor Dewpointer, EG & G, Foxboro, Hy-Cal, General Eastern and Protimeter dewpoint meters are suitable for measurement of the intake-air specific humidity.

X2.1.8. *Blowby Flow Rate Orifice*--Information concerning the blowby flow rate orifice meter is available from the following:

General Motors Research Laboratories Fuels and Lubricants Dept.
30500 Mound Road
Warren, MI 48090-9055

X2.1.9 *Heat Exchangers*--ITT Standard Heat Exchangers can be obtained from the following supplier:

Kinetics Engineering Corp.
2055 Silber Road, Suite 101
Houston, TX 77055

X2.1.10. *Fuel Flow Measurement*--Mass fuel flowmeters are available from the following supplier:

Micro Motion Corp.
7070 Winchester Circle
Boulder, CO 80301

X2.1.11. *Various Materials*--RAC kits, camshaft baffles, oil filter adapters and various other test stand parts and component calibration devices utilized in this test method are available from the following supplier:

OH Technologies
9300 Progress Parkway
Mentor, OH 44060

X2.1.12. *Exhaust Gas Analysis Calibration Gases*--Calibration gases for exhaust gas analysis equipment can be obtained from the following supplier:

Scott Environmental Technology, Inc.
Route 611
Plumbsteadville, PA 18949

X2.1.13. *Crankcase and Intake--Air Pressure Gages*- Gages are available from the following supplier:

Dwyer Instrument Co.
Junction of Indiana State Highway 212 and U.S. Highway 12
P.O. Box 373
Michigan City, IN 46360

X2.1.14. *RAC Coolant*--Nacool 2000 Engine Cooling System Treatment is available from the following supplier:

Nalco Chemical Co. Functional Chemicals Group
One Nalco Center
Naperville, IL 60566-1024

X2.1.15. *Lubricants*--EF-411 and Vacmul 3-D are available from local distributors of Mobil products.

X2.1.16. *Connecting Rod Heater*--The Sunnen Model CRH-50 connecting rod heater is available from the following supplier:

Sunnen Inc.
7910 Manchester
St. Louis, MO 63143

X2.1.17. *Tygon Hose*--Tygon hose is available through local Cadillac Plastic Company distributors or the following supplier:

The Norton Co.
12 East Avenue
Tallmadge, OH 44278

X2.1.18. *Rating Lamps*--Suitable rating lamps are available from the following supplier:

Dazor Manufacturing Corp.
4455 Duncan Ave.
St. Louis, MO 63110

X2.1.19. *Special Tools for the Test Engine*--Special tools to facilitate assembly and disassembly of the engine are available from the following supplier:

Owatonna Tool Co.
2013 4th St.
NW Owatonna, MN 55060

X2.1.20. *Oil Filter*- Oberg oil filter, LFS-55, and oil screen, LFS-5528WCF, are available from the following supplier:

Oberg Enterprises, Inc.		OH Technologies, Inc
12429 Highway 99 South, Unit 80	or	9300 Progress Parkway
Everett, WA 98204		Mentor, OH 44061

X2.1.21. *Inspected Engine Parts*-Pre-measured and calibrated Sequence VG engine parts and various components calibration devises are available form the supplier listed below:

Test Engineering, Inc.
12758 Cimarron Path, Suite 102
San Antonio, TX 78249-3417
Attn: John Knight
Phone: (210)690-1958
Fax: (210)690-1959