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

Sequence VG Information Letter 01-1
Sequence No. 7

January 16, 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. Change in Test Method for Determining Water in Fuel
2. Deletion of Section 7.1.1
3. Changes to Footnotes
4. Enhancement of Bore Wear Measurement, Follower Pin Wear, Oil Screen Clogging and Ring Gap Increase Measurement Techniques
5. Change in Stage III to I Rocker Cover Inlet Temperature Transition
6. Removal of Ring Groove Chamfer Measurement Requirement
7. Change in Pressure and Temperature Calibration Frequency
8. Standardization of Dipstick Correlation Table
9. Elimination of Stage I Blowby Measurements
10. Revision to Fuel Injector Flow Rate Specification
11. Revision to Calibration Gas, O_2 Span
12. Number of Decimal Places to be Used for Data in QI Calculations
13. Change in Name of Fuel Supplier

At the November 16, 2000 Sequence VE Surveillance Panel Meeting, the panel approved the following changes to the Sequence VG Test Procedure:

1. The panel agreed to change the test method for determining the amount of water in the fuel in storage at a laboratory. Test Method D1744 has been rescinded and D6304 has been found to be a suitable replacement. Section 2.1 and Table 2 have been revised.

2. Section 7.1.1 references *Subcommittee D02.B Standard Guide for Test Hardware Control in ASTM D02.B Test Methods and Practices*, which has not been successfully balloted through Subcommittee D02.B. Section 7.1.1 has been deleted and Section 7.1.2 has been renumbered as 7.1.1.

3. As a result of items No. 1 and No. 2 above, Footnote 7 has been added and Footnote 13 has been deleted. Footnotes previously numbered 7 through 12 have been renumbered 8 through 13.

4. The panel approved a number of enhancements to the methods and techniques for determining cylinder bore wear, oil screen clogging, follower pin wear and top ring gap increase. Sections 7.5.5, 13.4.1.2, 13.7.2 and 13.7.3 have been revised and Sections 7.5.6 and 13.7.1.1 through 13.7.1.12 have been added to further clarify these measurements.

5. The panel agreed to change the Rocker Cover Inlet Temperature ramp for Stage III to I from within 15±2 minutes to within 17 minutes. Table 4 has been revised.

6. The panel agreed to the remove ring groove chamfer specification and the requirement that the second ring gap must be larger than the top ring gap. Table 1 has been revised and Section 7.8.5.3 (c) has been deleted.

7. The panel agreed to decrease the calibration frequency for temperature and pressure channels from every 90 days to prior to a reference oil test. Sections 9.1.8 and 9.2.10 have been revised.

8. The panel agreed to standardize on a common table for determining oil level and to delete the requirement to calibrate the dipstick and tube each reference oil test. Section 12.1.1 has been deleted and Section 12.1.2 has been renumbered as 12.1.1. Sections 7.4.4, 12.1.1.1 and Annex A8 have been revised.

9. The panel agreed to no longer take blowby measurements during Stage I. Section 12.3.1 and Annex A7 and A12 have been revised.

10. The panel agreed to increase the upper limit for fuel injector flow from 198 to 203 mL. Annex A13 has been revised.

11. A motion to no longer require spanning the O_2 meters at 0.5% O_2 was approved. Figures 8 and A3.19 have been revised.

12. The panel agreed to include a table, which specifies the precision of the data values to be used in calculating a Quality Index value. Table A2.3 has been added to Annex A2.

13. The name of the fuel supplier has changed. Section X2.1.5 has been revised and X2.1.6 has been deleted. Sections X2.1.7 through X2.1.24 have been renumbered as X2.1.6 through X2.1.23. The references to X2.1 in 7.4.9, 7.5.2, 7.8.5.1, 8.7.4, 8.3.2.2, 8.3.3, 8.4.3.3, 9.3.2, and 9.3.4.3 have also been revised due to the renumbering of Appendix X2.

Revised sections of the test procedure are attached. These changes are effective for all tests completing on or after February 6, 2001.

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ftp://www.tmc.astm.cmri.cmu.edu/documents/gas/sequencev/procedure_and_ils/vgil01-1-7

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]
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[6]
D4175	Terminology Relating to Petroleum, Petroleum Products, and Lubricants[6]
D4294	Test Method for Sulfur in Petroleum Products by Non-dispersive X-Ray Fluorescence Spectroscopy[6]
D4485	Specification for Performance of Engine Oils[6]
D4739	Test Method for Base Number Determination by Potentiometric Titration[6]
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 J183	Engine Oil Performance and Engine Service Classification[10]
SAE J254	Instrumentation and Techniques for Exhaust Gas Emissions Measurement[10]

2.3. *API Standard:*

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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.

API 1509 Engine Service Classification and Guide to Crankcase Oil Selection[11]

2.4. *ANSI Standard:*

ANSI MC96.1 Temperature Measurement-Thermocouples[12]

3. Terminology

3.1. *Definitions:*

3.1.1. *air-fuel ratio, n--in internal combustion engines*, the mass ratio of air-to-fuel in the mixture being inducted into the combustion chambers. (D 5302)

3.1.1.1. *Discussion*--In this test method, air-fuel ratio (AFR) is controlled by the EEC IV engine control module.

3.1.2. *blowby, n--in internal combustion engines*, the combustion products and unburned air and fuel mixture that enter the crankcase. (D 5302)

3.1.3. *cold-stuck piston ring, n--in internal combustion engines*, a piston ring that is stuck when the piston and ring are at room temperature, but inspection shows that it was free during engine operation.

3.1.3.1. *Discussion*--A cold-stuck piston ring cannot be moved with moderate finger pressure. It is characterized by a polished face over its entire circumference, indicating essentially no blowby passed over the ring face during engine operation. (D 5302)

3.1.4. *debris, n--in internal combustion engines*, solid contaminant materials unintentionally introduced into the engine or resulting from wear. (D 5862)

3.1.4.1. *Discussion*--Examples include such things as gasket material, silicone sealer, towel threads, and metal particles.

3.1.5. *free piston ring, n--in internal combustion engines*, a piston ring that will fall in its groove under its own weight when the piston with the ring in a horizontal plane, is turned 90 degrees (putting the ring in a vertical plane). (D 5862)

3.1.5.1. *Discussion*--A slight touch to overcome static friction is permissible.

3.1.6. *hot-stuck piston ring, n--in internal combustion engines*, a piston ring that is stuck when the piston and ring are at room temperature, and inspection shows that it was stuck during engine operation. (D 5302)

3.1.6.1. *Discussion*--The portion of the ring that is stuck cannot be moved with moderate finger pressure. A hot-stuck piston ring is characterized by varnish or carbon across some portion of its face, indicating that portion of the ring was not contacting the cylinder wall during engine operation.

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[11] Available from American Petroleum Institute, 2101 L St., NW, Washington, DC 20037.

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

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

3.1.8. *knock, n--in a spark ignition engine*, abnormal combustion, often producing audible sound, caused by autoignition of the air/fuel mixture (D 4175).

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.

3.1.10. *out of specification data, n--in data acquisition*, Sampled value of a monitored test parameter that has deviated beyond the procedural limits

3.1.11. *scoring, n--in tribology*, a severe form of wear characterized by the formation of extensive grooves and scratches in the direction of sliding (G 40).

3.1.12. *scuffing, n--in lubrication*, damage caused by instantaneous localized welding between surfaces in relative motion that does not result in immobilization of the parts (D 4863).

3.1.13. *sludge, n--in internal combustion engines*, a deposit, principally composed of insoluble resins and oxidation products from fuel combustion and the lubricant, that does not drain from engine parts but can be removed by wiping with a cloth. (D 5302)

3.1.14. *tight piston ring, n--in internal combustion engines*, a piston ring that will not fall in its groove under the force of its own weight when the piston, with the ring in a horizontal plane, is turned 90 degrees (putting the ring in a vertical plane); by subsequent application of moderate finger pressure, the ring will be displaced. (D 5862)

3.1.15. *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.

3.1.16. *varnish, n--in internal combustion engines*, a hard, dry, generally lustrous deposit that can be removed by solvents but not by wiping with a cloth. (D 5302)

3.1.17. *wear, n*--loss of material from, or relocation of material on, a surface. (D 5302)

3.1.17.1. *Discussion*--Wear generally occurs between two surfaces moving relative to each other, and is the result of mechanical or chemical action or by a combination of mechanical and chemical actions.

3.2. *Definitions of Terms Specific to This Standard:*

3.2.1. *clogging, n*--the restriction of a flow path due to the accumulation of material along the flow path boundaries.

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

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

3.2.3. *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.

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

4. Summary of Test Method

4.1. Each test engine is assembled with many new parts and essentially all aspects of assembly are specified in detail.

4.2. The test stand is equipped to control speed, load, AFR, and various other operating parameters.

4.3. The test is run for a total of 216 h, consisting of 54 cycles of 4 h each. Each cycle consists of three stages.

4.4. While the operating conditions are varied within each cycle, overall they can be characterized as a mixture of low-temperature and moderate-temperature, light and medium duty operating conditions.

4.5. To accelerate deposit formation, the level of oxides of nitrogen in the blowby and the rate of blowby into the crankcase are significantly increased. The fresh air breathing of the crankcase is eliminated and the oil and coolant temperatures are lowered to induce condensation of water and fuel.

4.6. The performance of the test engine oil is evaluated at the end of the test by dismantling the engine and measuring the level of deposit formation.

5. Significance and Use

5.1. This test method is used to evaluate an automotive engine oil's control of engine deposits under operating conditions deliberately selected to accelerate deposit formation. This test method was correlated with field service data, determined from side-by-side comparisons of two or more oils in police, taxi fleets and delivery van services. The same field service oils were then used in developing the operating conditions of this test procedure.

5.2. This test method, along with other test methods, defines the minimum performance level of the API Category SL (detailed information about this category is included in Specification D4485). This test method is also incorporated in automobile manufacturers' factory-fill specifications.

5.3. The basic engine used in this test method is representative of many that are in modern automobiles. This factor, along with the accelerated operating conditions, should be considered when interpreting test results.

6. Apparatus-General Description

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[13] passenger car engine.

6.2. Configure the test stand to accept a Ford 4.6L two valves per cylinder engine. All special equipment necessary for conducting this test is listed herein.

6.3. Use the appropriate air conditioning apparatus to control the temperature, pressure, and humidity of the intake air.

6.4. Use an appropriate fuel supply system (Fig 1).

6.5. The control and data acquisition system shall meet the requirements listed in Annex A2.

7. Apparatus-The Test 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 was not oil related.

7.4.4 *Dipstick and Dipstick Tube (Annex 3.6)*—The dipstick tube has been modified for accurate oil level measurements. Use the dipstick and tube available from the supplier listed in Annex 9.2.

7.4.9 *Oil Filter*—Use a 60μm screen type oil filter with a bypass (see Annex A3.8) available from the supplier listed in Appendix X2.1.21.

7.5.2 *Piston Ring Grinder*—A ring grinder is required for adjusting ring gaps. A suitable ring grinder is available from the supplier shown in Appendix X2.1.16.

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 cylinders 1 and 8. This 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 a device designed 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. Use the device available from the supplier listed in Annex A9.3.

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 ring grinder listed in Appendix X2.1.16. Record the new ring gap(s) and ring side clearance(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 retained (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

7.8.5.2. *Piston Ring Cutting Procedure:*

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

(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[18] 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[19] and wipe with a dry towel.

(d) Measure the gap with the ring in the its respective bore positioned with the ring positioner. For cylinders 1 and 8, measure the ring in the master bore (7.5.5)

(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.

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.)

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:

[18] 3/16 in carbide ring cutting burr, No. 74010020, made by M. A. Ford,

[19] Sunnen soft stone No. JHU-820

Table 2. 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 OHT6A-007-1 (Appendix X2.1.11) and oil filter, OHT6A-012-2. Be sure all hoses and fittings on the oil heat exchanger are properly connected and secure. The external oil system components shall not be brass, copper or galvanized, as these metals may influence used oil analysis.

8.3.3. *Heat Exchanger*--The heat exchanger has been chosen to minimize the volume of the external system. The heat exchanger has adequate but not excessive capacity to control the oil temperature. The system requires a high level of maintenance to provide adequate cooling, especially when process water temperature is high. An effective, well-maintained process water control system is necessary to achieve the specified oil temperatures. Use vertically mounted ITT heat exchanger P/N 5-160-02-008-002 Appendix X2.1.9). Configure the system to allow the process water to flow through the vertical tubes and the oil through the shell. This orientation will facilitate cleaning of the tubes.

8.4.3.3. The engine coolant flow rate and outlet temperature are controlled in accordance with the specifications listed in Table 3. Information concerning the coolant flow rate measurement device is detailed in 9.3.2. Cyclic ramping specifications are detailed in Table 4. The coolant flow rate is measured with a venturi flowmeter (Appendix X2.1.6) and controlled with an in-line flow control valve.

Table 4. Test Ramping Requirements

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± .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.

9.2.10. *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 (see 2.7). 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. Test Procedure

12.1. *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. Procedures performed 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 these changes 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.

Note 16: The engine shall normally require approximately 20 min to reach steady-state conditions after a step change.

Note 17: **Caution -** Prolonged operation at a rich air-fuel ratio can cause excessive fuel dilution and alter test severity.

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. *Periodic Measurements and Functions:*

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). New oil is only added to the engine when the level is more than 400 g below the original test full level. Only enough new oil is added to reach the 400 g low mark. No other new oil additions are permitted during the test, except after piston ring gap adjustment (see 12.1.1.8). 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 <u>Oil Sampling, Addition and Leveling Worksheet</u> in Annex A10. This form serves as the oil sampling and oil addition data sheet.

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

(b) Remove a 60 mL analysis sample within 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 g. 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.

13.4. *Clogging:*

13.4.1. *Oil Screen Clogging*--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 (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 procedure detailed in Appendix E of TMC Memorandum 94-200. 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).

13.4.1.1. 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.

13.4.1.2. Use 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 (7.5.6).

(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.

13.7 Additional Measurements

13.7.1 *Follower Pin Wear*—Measure the wear on the pins from the followers from cylinder #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.

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 onto the follower pin and 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. Note: 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 of the four compression rings and record. Determine the maximum ring gap increase of the four compression rings 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.

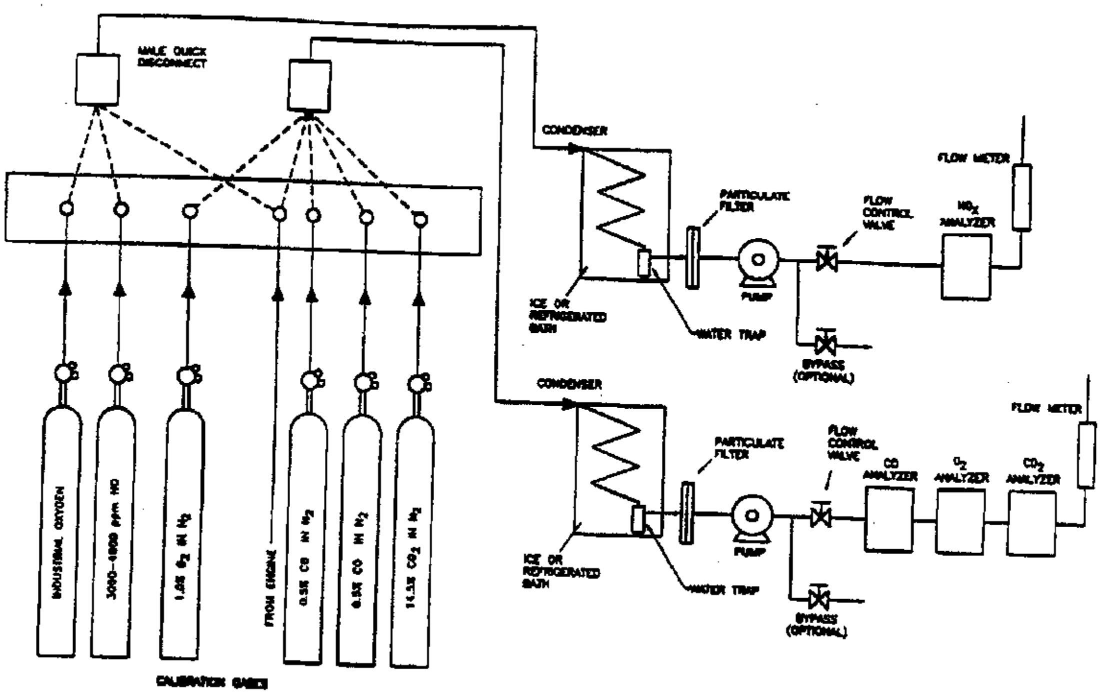


Fig. 8. Exhaust Gas Analysis System

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 (see 2.7) and Data Acquisition Task Force Report (see 2.8) 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 2.3.

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 minute. 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. The quality index for each controlled parameter is calculated and reported 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 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

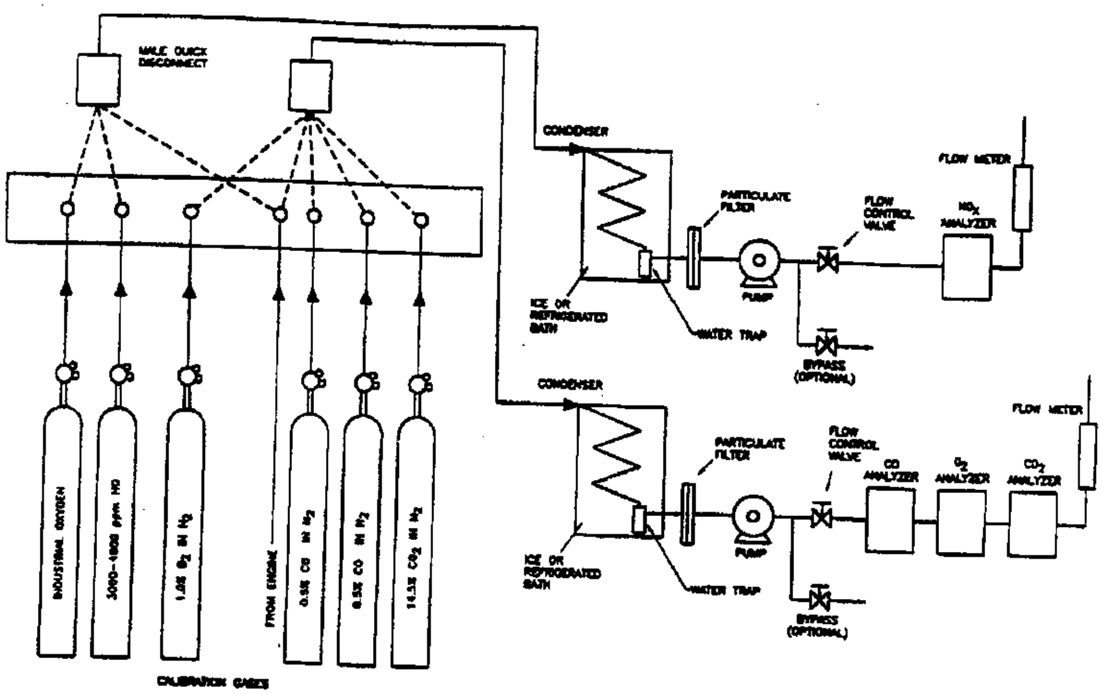
Parameter	Stages	L	U	Over Range	Under Range
Coolflow	1	47.47	48.53	87.0	0
Cooloutt	1	56.71	57.29	113.0	0
	2	84.71	85.29	113.0	0
	3	44.71	45.29	113.0	0
Exhbprs	1	103.92	104.08	115.0	0
	2	106.92	107.08	115.0	0
Humidity	1, 2, 3	10.85	11.95	64.0	0
Intairpr	1, 2, 3	0.04	0.06	1.05	0
Intairt	1, 2, 3	29.80	30.20	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 A2.6.2. This time constant shall pertain to the entire system, running from the sensor to the display and data acquisition.

A2.6.2. 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*

VG REPORT FORMS VERSION *20001214*

REPORT ON SEQUENCE VG EVALUATION

CONDUCTED FOR

TSTSPON1

TSTSPON2

LABVALID	V = VALID
	I = INVALID
	N = RESULTS CAN NOT BE INTERPRETED AS REPRESENTATIVE OF OIL PERFORMANCE (NON-REFERENCE OIL) AND SHALL NOT BE USED IN DETERMINING AN AVERAGE TEST RESULT USING MULTIPLE TEST ACCEPTANCE CRITERIA.

TSTOIL	NR = Non-reference Oil Test
	RO = Reference Oil Test

Test Number			
Test Stand: *STAND*	Runs Between Calibration Tests: *STRUN*	Total Runs on Test Stand: *TOTSRUN*	
Date Completed: *DTCOMP*		End of Test Time: *EOTTIME*	
Oil Code: *OILCODE*			
Formulation/Stand Code: *FORM*			
Alternate Codes:	*ALTCODE1*	*ALTCODE2*	*ALTCODE3*

In my opinion this test *OPVALID* been conducted in a valid manner in accordance with the VG Test Procedure (RR:) and the appropriate amendments through the Information Letter system. The remarks included in the report describe the anomalies associated with this test.

SUBMITTED BY:

SUBLAB
Testing Laboratory

SUBSIGIM
Signature

SUBNAME
Typed Name

SUBTITLE
Title

FIG A7.1 Title Page

Form 2

Sequence VG

Table of Contents

FIG A7.2 Table of Contents

Sequence VG Sludge and Varnish Deposit Test
Form 3

Summary of Test Method

The Sequence VG engine sludge and varnish deposit test is a fired engine-dynamometer test which evaluates the ability of a lubricant to minimize the formation of sludge and varnish deposits. This test method is a cyclic test, with a total running duration of 216 hours.

The test engine is a Ford 4.6L, spark ignition, four stroke, eight cylinder "V" configuration engine. Features of this engine include dual overhead camshafts, a cross-flow fast burn cylinder head design, two valves per cylinder and electronic port fuel injection. A 90 minute break-in schedule is conducted prior to each test, since a new engine build is used for each test.

The Sequence VG test requires a new engine for each test. Each test is run for 216 hours, consisting of 54 cycles of 4 hours each. Each cycle consists of 3 stages. The stages of the test cycle are set at the following conditions:

Condition	Stage I	Stage II	Stage III
Duration, minutes	120	75	45
Engine Speed, r/min	1200	2900	700
Engine Power, kW	Record	Record	1.30
Manifold Abs Press, kPa (abs)	69	66	Record
Engine Oil In, °C	68	100	45
Engine Coolant Out, °C	57	85	45
Engine Coolant Flow, L/min	48	Record	Record
Engine Coolant Pressure, kPa (gauge)	70	70	70
RAC Coolant In, °C	29	85	29
Rocker Cover Flow, L/min	15	15	15
Intake Air, °C	30	30	30
Intake Air Press, kPa (gauge)	0.05	0.05	0.05
Exhaust Gas Analysis			
O_2, Vol. %	1.0 Max	1.0 Max	3.0 Max
CO, Vol. %	1.0 Max	2.0 Max	8.5
CO_2, Vol. %	13.5 - 15.5	13.5 - 15.5	Record
NOx, ppm	-----	Record	-----
Blowby Flow Rate Avg, L/min	Record	60 - 70	-----
Air/Fuel Ratio	Stoich	Stoich	11.5:1
Intake Air Humidity, g/kg	11.4	11.4	11.4
Exhaust Back Pressure, kPa abs	104	107	Record
Fuel Flow, kg/h	Record	Record	Record

Upon test completion, the engine is disassembled and rated for sludge and varnish. Average Engine Sludge and Average Engine Varnish are calculated.

FIG A7.3 Test Method Summary

SEQUENCE VG
FORM 4
TEST RESULT SUMMARY
NON-REFERENCE & REFERENCE OIL TESTS

Laboratory: *LAB*	Stand: *STAND*	Stand Runs: *STRUN*	Oil Code: *OILCODE*
Date Started: *DTSTRT*	Time Started: *STRTTIME*	Date Completed: *DTCOMP*	Time Completed: *EOTTIME*
Formulation/Stand Code: *FORM*			

Lab Engine Number: *ENGINE*	SAE Viscosity: *SAEVISC*
Test Length: *TESTLEN*	Fuel Batch: *FUELBTID*
Industry Oil Code: *IND*	

CRITICAL PARAMETERS						
	Average Engine Sludge, merits	Rocker Cover Sludge, merits	Average Engine Varnish, merits	Average Piston Skirt Varnish, merits	Oil Screen Sludge, % Area	Number of Hot Stuck Rings
Original Result	*AES*	*RACS*	*AEV3*	*APV*	*OSCRNSLG*	*NHSCMPRG*
Transformed Result					*TRANOSCR*	
Industry Correction Factor	*AESCF*	*RACSCF*	*AEV3CF*	*APVCF*	*TOSCRCF*	*NHSRCF*
Corrected Transformed Result					*TOSCRCOR*	
Severity Adjustment	*AESSA*	*RACSSA*	*AEV3SA*	*APVSA*	*TOSCRSA*	*NHSRSA*
Final Transformed Result					*TOSCRFNL*	
Final Original Unit Result	*AESFNL*	*RACSFNL*	*AEV3FNL*	*APVFNL*	*OSCRFNL*	*NHSRFNL*

Clogging Information		Additional Information	
Oil Screen Debris, % Area	*OSCRNDEB*	Number of Cold Stuck Rings	*NCSCMPRG*
Oil Ring Clogging, % Area	*OILRING*	Average Blowby Stage II, L/min	*ACBLWRT2*
PCV Valve @ 25 kPa, %	*PCV25*	Oil Consumption, grams	*TOILCONS*
PCV Valve @ 60 kPa, %	*PCV60*		

Last Reference Oil Test Calibrating Stand Information - Fill Out For Non-reference Oil Tests Only

Stand: *RSTAND*	Total Runs on Test Stand: *RTOTSRUN*	Oilcode: *ROILCODE*	
Industry Oil Code: *RIND*	Engine Number: *RENGINE*	SAE Viscosity: *RSAEVISC*	Date Completed: *RDTCOMP*
Test Length: *RTESTLEN*	Fuel Batch: *RFUELBID*	Calibration Expiration Date: *RDTCALEX*	

Clogging Information		Additional Information	
Oil Screen Debris, % Area	*ROSCRDEB*	Number of Cold Stuck Rings	*RCSCMPRG*
Oil Ring Clogging, % Area	ROILRING	Average Blowby Stage II, L/min	*RACBLWR2*
PCV Valve @ 25 kPa, %	*RPCV25*	Oil Consumption, grams	*RTOILCON*
PCV Valve @ 60 kPa, %	*RPCV60*		

	Average Engine Sludge, merits	Average Rocker Cover Sludge, merits	Average Engine Varnish, merits	Average Piston Skirt Varnish, merits	Oil Screen Sludge, % Area	Number of Hot Stuck Rings
Final Original Unit Result	*RAESFNL*	*RRACSFNL*	*RAEV3FNL*	*RAPVFNL*	*ROSCRSLG*	*RHSCMPRG*

FIG A7.4 Test Result Summary

SEQUENCE VG
FORM 5
TEST RESULT SUMMARY
NON-REFERENCE & REFERENCE OIL TESTS

Laboratory: *LAB*	Stand: *STAND*	Stand Runs: *STRUN*	Oil Code: *OILCODE*
Date Started: *DTSTRT*	Time Started: *STRTTIME*	Date Completed: *DTCOMP*	Time Completed: *EOTTIME*
Formulation/Stand Code: *FORM*			

Hardware Identification	Production Number *PRODNUM*		Serial Number *SERNUM*
Casting Numbers	Block *BLKCAST*	Cam, Left *CAMCASTL*	Cam, Right *CAMCASTR*
Piston Part Number *PISTPART*		Piston Ring Casting Number *PRINGNUM*	
Cylinder Head Casting Number	Left *CYLHCSTL*		Right *CYLHCSTR*

Sludge Deposits	
Area	**Merit**
Rocker Arm Cover, Left	*RACLSRT*
Rocker Arm Cover, Right	*RACRSRT*
Camshaft Baffle, Left	*CAMBLSRT*
Camshaft Baffle, Right	*CAMBRSRT*
Timing Chain Cover	*TCCSRT*
Oil Pan Baffle	*OILPBSRT*
Oil Pan	*OILPNSRT*
Valve Deck Area, Left	*VLVDLSRT*
Valve Deck Area, Right	*VLVDRSRT*
Average Engine Sludge	*AES*

Varnish Deposits	
Area	**Merit**
Piston Skirt, Thrust	*APV*
Rocker Arm Cover, Left	*RACLVRT*
Rocker Arm Cover, Right	*RACRVRT*
Average Engine Varnish	*AEV3*

Wear Measurements		
Ring Wear	**Units**	**Value**
Follower Pin Wear, cyl #8, Intake.	μm	*CFPIN8I*
Follower Pin Wear, cyl #8, Exhaust.	μm	*CFPIN8E*
Cylinder Bore Wear, cyl #1 & #8 Max.	μm	*MXCYLB18*
Cylinder Bore Wear, cyl #1 & #8 Avg.	μm	*ACYLBW18*
Ring Gap Increase, cyl #1 & #8, Max	μm	*MXRGINC*
Ring Gap Increase, cyl #1 & #8, Avg	μm	*ARGINC*

Piston Varnish Deposits, Thrust Side	
Piston Number	**Merit**
1	*PSVTH1*
2	*PSVTH2*
3	*PSVTH3*
4	*PSVTH4*
5	*PSVTH5*
6	*PSVTH6*
7	*PSVTH7*
8	*PSVTH8*
Average	*APV*

FIG A7.5 Deposit Breakdown

SEQUENCE VG
FORM 6
OPERATIONAL SUMMARY

Laboratory: *LAB*		Date Completed: *DTCOMP*	Time Completed: *EOTTIME*
Stand: *STAND*	Stand Runs: *STRUN*	Total Runs on Stand: *TOTSRUN*	Oil Code: *OILCODE*
Formulation/Stand Code: *FORM*			

	Parameter	Units	QI Threshold	EOT QI	Target			Average			Samples	BQD	Over/Under Range
					Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3			
Controlled Parameters	Speed	r/min	0.000	*QRPM*	1200	2900	700	*ARPM1*	*ARPM2*	*ARPM3*	*NRPM*	*BRPM*	*ORPM*
	Power	kW	0.000	*QPOWER*	Record	Record	1.3	*APOWER1*	*APOWER2*	*APOWER3*	*NPWR*	*BPWR*	*OPWR*
	Manifold Abs Press	kPa	0.000	*QMANABP*	69	66	Record	*AMANABP1*	*AMANABP2*	*AMANABP3*	*NMAP*	*BMAP*	*OMAP*
	Engine Oil, In	°C	0.000	*QENGOIN*	68	100	45	*AENGOIN1*	*AENGOIN2*	*AENGOIN3*	*NEOIN*	*BEOIN*	*OEOIN*
	Engine Coolant,Out	°C	0.000	*QCOLOUT*	57	85	45	*ACOLOUT1*	*ACOLOUT2*	*ACOLOUT3*	*NCOUT*	*BCOUT*	*OCOUT*
	Engine Coolant Flow	L/min	0.000	*QCOLFRT*	48	Record	Record	*ACOLFRT1*	*ACOLFRT2*	*ACOLFRT3*	*NCFRT*	*BCFRT*	*OCFRT*
	Engine Coolant Pressure	kPa	0.000	*QCOLPRE*	70	70	70	*ACOLPRE1*	*ACOLPRE2*	*ACOLPRE3*	*NCPRE*	*BCPRE*	*OCPRE*
	RAC Coolant, In	°C	0.000	*QRACCTP*	29	85	29	*ARACCTP1*	*ARACCTP2*	*ARACCTP3*	*NRACC*	*BRACC*	*ORACC*
	RAC Flow	L/min	0.000	*QRACCFR*	15	15	15	*ARACCFR1*	*ARACCFR2*	*ARACCFR3*	*NRACF*	*BRACF*	*ORACF*
	Intake Air	°C	0.000	*QINAIRT*	30	30	30	*AINAIRT1*	*AINAIRT2*	*AINAIRT3*	*NINAT*	*BINAT*	*OINAT*
	Intake Air Pressure	kPa	0.000	*QINAIRP*	0.05	0.05	0.05	*AINAIRP1*	*AINAIRP2*	*AINAIRP3*	*NINAP*	*BINAP*	*OINAP*
	Intake Air Humidity	g/kg	0.000	*QAIRHUM*	11.4	11.4	11.4	*AAIRHUM1*	*AAIRHUM2*	*AAIRHUM3*	*NAHUM*	*BAHUM*	*OAHUM*
	Exhaust Backpressure	kPa	0.000	*QEXBKPR*	104	107	Record	*AEXBKPR1*	*AEXBKPR2*	*AEXBKPR3*	*NEXBP*	*BEXBP*	*OEXBP*

	Parameter	Units		Specifications					
Non-controlled Parameters	Fuel Flow	kg/h		Record	Record	Record	*AFUELRT1*	*AFUELRT2*	*AFUELRT3*
	Blowby	L/min		Record	60-70		*ACBLWRT1*	*ACBLWRT2*	
	Exhaust Gas								
	Left Manifold O_2	% Vol		1.0 Max	1.0 Max	3.0 Max	*ALEXGO1*	*ALEXGO2*	*ALEXGO3*
	Right Manifold O_2	% Vol		1.0 Max	1.0 Max	3.0 Max	*AREXGO1*	*AREXGO2*	*AREXGO3*
	Left Manifold CO	% Vol		1.0 Max	2.0 Max	8.5 ± 1.5	*ALEXGCO1*	*ALEXGCO2*	*ALEXGCO3*
	Right Manifold CO	% Vol		1.0 Max	2.0 Max	8.5 ± 1.5	*AREXGCO1*	*AREXGCO2*	*AREXGCO3*
	Left Manifold CO_2	% Vol		13.5-15.5	13.5-15.5	Record	*ALEXCO21*	*ALEXCO22*	*ALEXCO23*
	Right Manifold CO_2	% Vol		13.5-15.5	13.5-15.5	Record	*AREXCO21*	*AREXCO22*	*AREXCO23*
	Left Manifold NO_x	ppm			Record			*ALEXGNO2*	
	Right Manifold NO_x	ppm			Record			*AREXGNO2*	
	Average NO_x	ppm			± 600 [A]			*AEXGNO2*	
	Cumulative Ref Oil Test Avg, NO_x	ppm						*CUMEXNO2*	

[A] Until 10 operationally valid reference oil tests are obtained at lab, the specification 3000 - 3900 ppm. Otherwise, average NO_x is to be within 600 ppm of cumulative reference oil test average.

FIG A7.6 Operational Summary

SEQUENCE VG
FORM 7
OIL ADDITION RECORD & BLOWBY RATES
NON-REFERENCE & REFERENCE OIL TESTS

Laboratory: *LAB*	Stand: *STAND*	Stand Runs: *STRUN*	Oil Code: *OILCODE*
Date Started: *DTSTRT*	Time Started: *STRTTIME*	Date Completed: *DTCOMP*	Time Completed: *EOTTIME*
Formulation/Stand Code: *FORM*			

Cycle	Test Hour	Oil Added, g	Oil Consumed, g
6	23 h, 25 min	*OILAR006*	*OILCR006*
12	47 h, 25 min	*OILAR012*	*OILCR012*
18	71 h, 25 min	*OILAR018*	*OILCR018*
24	95 h, 25 min	*OILAR024*	*OILCR024*
30	119 h, 25 min	*OILAR030*	*OILCR030*
36	143 h, 25 min	*OILAR036*	*OILCR036*
42	167 h, 25 min	*OILAR042*	*OILCR042*
48	191 h, 25 min	*OILAR048*	*OILCR048*
54	215 h, 25 min		*OILCR054*
Total, g		*TOILADD*	*TOILCONS*

Stage II	
Test Hours	Blowby, L/min
Break-in	*BLBYH001*
23	*BLBYH023*
47	*BLBYH047*
71	*BLBYH071*
95	*BLBYH095*
119	*BLBYH119*
143	*BLBYH143*
167	*BLBYH167*
191	*BLBYH191*
215	*BLBYH215*
Maximum	*XCBLWRT2*
Minimum	*MCBLWRT2*
Average Blowby, Hours 23 - 119	*ABLW2120*
Average	*ACBLWRT2*

FIG A7.7 Blowby and Oil Additions

SEQUENCE VG
FORM 8
ANALYSIS OF OIL

Laboratory: *LAB*	Stand: *STAND*	Stand Runs: *STRUN*	Oil Code: *OILCODE*
Date Started: *DTSTRT*	Time Started: *STRTTIME*	Date Completed: *DTCOMP*	Time Completed: *EOTTIME*
Formulation/Stand Code: *FORM*			

Test Hours	Ag, ppm	Al, ppm	Cr, ppm	Cu, ppm	Fe, ppm	Pb, ppm	Si, ppm	Sn, ppm	Fuel Dilution by GC, Wt. % D3525	Pentane Insolubles, Wt. % D893B	TBN D4739	Vis. @ 40°C, cSt D445	Vis. @ 100°C, cSt D445
TST_HN	*EWGWMHNE*	*ALWMHNE*	*CRWMHNE*	*CUWMHNE*	*FEWMHNE*	*PBWMHNE*	*SIWMHNE*	*SNWMHNE*	*W*		*TBN_HNEW*	*V40_HNEW*	*V100HNEW*
TST_H0	*24GWMH02*	*4LWMH02*	*4CRWMH02*	*4CUWMH02*	*4FEWMH02*	*4PBWMH02*	*4SIWMH024*	*SNWMH02*	*4FUELH024*		*TBN_H024*	*V40_H024*	*V100H024*
TST_H0	*48GWMH04*	*8LWMH04*	*8CRWMH04*	*8CUWMH04*	*8FEWMH04*	*8PBWMH04*	*8SIWMH048*	*SNWMH04*	*8FUELH048*	*PEN_H048*	*TBN_H048*	*V40_H048*	*V100H048*
TST_H0	*72GWMH07*	*2LWMH07*	*2CRWMH07*	*2CUWMH07*	*2FEWMH07*	*2PBWMH07*	*2SIWMH072*	*SNWMH07*	*2FUELH072*		*TBN_H072*	*V40_H072*	*V100H072*
TST_H0	*96GWMH09*	*6LWMH09*	*6CRWMH09*	*6CUWMH09*	*6FEWMH09*	*6PBWMH09*	*6SIWMH096*	*SNWMH09*	*6FUELH096*	*PEN_H096*	*TBN_H096*	*V40_H096*	*V100H096*
TST_H1	*20GWMH12*	*0LWMH12*	*0CRWMH12*	*0CUWMH12*	*0FEWMH12*	*0PBWMH12*	*0SIWMH120*	*SNWMH12*	*0FUELH120*		*TBN_H120*	*V40_H120*	*V100H120*
TST_H1	*44GWMH14*	*4LWMH14*	*4CRWMH14*	*4CUWMH14*	*4FEWMH14*	*4PBWMH14*	*4SIWMH144*	*SNWMH14*	*4FUELH144*	*PEN_H144*	*TBN_H144*	*V40_H144*	*V100H144*
TST_H1	*68GWMH16*	*8LWMH16*	*8CRWMH16*	*8CUWMH16*	*8FEWMH16*	*8PBWMH16*	*8SIWMH168*	*SNWMH16*	*8FUELH168*		*TBN_H168*	*V40_H168*	*V100H168*
TST_H1	*92GWMH19*	*2LWMH19*	*2CRWMH19*	*2CUWMH19*	*2FEWMH19*	*2PBWMH19*	*2SIWMH192*	*SNWMH19*	*2FUELH192*	*PEN_H192*	*TBN_H192*	*V40_H192*	*V100H192*
TST_H2	*16GWMH21*	*6LWMH21*	*6CRWMH21*	*6CUWMH21*	*6FEWMH21*	*6PBWMH21*	*6SIWMH216*	*SNWMH21*	*6FUELH216*	*PEN_H216*	*TBN_H216*	*V40_H216*	*V100H216*

FIG A7.8 Oil Analysis

SEQUENCE VG
FORM 9
DOWNTIME OCCURRENCES AND
OTHER COMMENTS

Laboratory: *LAB*	Stand: *STAND*	Stand Runs: *STRUN*	Oil Code: *OILCODE*	
Date Started: *DTSTRT*	Time Started: *STRTTIME*	Date Completed: *DTCOMP*	Time Completed: *EOTTIME*	
Formulation/Stand Code: *FORM*				

Number of Downtime Occurrences			*DWNOCR*
Test Hours	Date	Downtime	Reasons
DOWNR001	*DDATR001*	*DTIMR001*	*DREAR001*
		TOTLDOWN	Total Downtime

Other Comments	
Number of Comment Lines	*TOTCOM*
OCOMR001	

FIG A7.9 Downtime

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*

14-dec-2000

Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
10	1	VG	VERSION	8	0	C	YYYYMMDD	VG VERSION 20001214
20	1	VG	TSTSPON1	40	0	C		CONDUCTED FOR, FIRST LINE
30	1	VG	TSTSPON2	40	0	C		CONDUCTED FOR, SECOND LINE
40	1	VG	LABVALID	1	0	C	V, I OR N	TEST LAB VALIDATION (V, I OR N)
50	1	VG	TSTOIL	2	0	C	NR or RO	OIL TEST TYPE (NR or RO)
60	1	VG	STAND	5	0	C		STAND
70	1	VG	STRUN	4	0	C		RUNS BETWEEN CALIBRATION TESTS
80	1	VG	TOTSRUN	5	0	C		TOTAL RUNS-TEST STAND
90	1	VG	DTCOMP	8	0	C	YYYYMMDD	DATE COMPLETED (YYYYMMDD)
100	1	VG	EOTTIME	5	0	C	HH:MM	TIME COMPLETED (HH:MM)
110	1	VG	OILCODE	38	0	C		TEST OIL CODE
120	1	VG	FORM	38	0	C		FORMULATION/STAND CODE
130	1	VG	ALTCODE1	10	0	C		ADDITIONAL LABORATORY CODE 1
140	1	VG	ALTCODE2	10	0	C		ADDITIONAL LABORATORY CODE 2
150	1	VG	ALTCODE3	10	0	C		ADDITIONAL LABORATORY CODE 3
160	1	VG	OPVALID	8	0	C	HAS/HAS NOT	OPERATIONAL VALIDITY STATEMENT (HAS/HAS NOT)
170	1	VG	SUBLAB	40	0	C		SUBMITTED BY: TESTING LABORATORY
180	1	VG	SUBSIGIM	40	0	C		SUBMITTED BY: SIGNATURE IMAGE
190	1	VG	SUBNAME	40	0	C		SUBMITTED BY: SIGNATURE TYPED NAME
200	1	VG	SUBTITLE	40	0	C		SUBMITTED BY: TITLE
210	4	VG	LAB	2	0	C		LAB CODE
220	4	VG	DTSTRT	8	0	C	YYYYMMDD	START DATE (YYYYMMDD)
230	4	VG	STRTTIME	5	0	C	HH:MM	START TIME (HH:MM)
240	4	VG	ENGINE	6	0	C		ENGINE
250	4	VG	SAEVISC	7	0	C		SAE VISCOSITY GRADE
260	4	VG	TESTLEN	3	0	Z	HHH	TEST LENGTH (HHH)
270	4	VG	FUELBTID	8	0	C		FUEL BATCH IDENTIFIER
280	4	VG	IND	6	0	C		TMC OIL CODE
290	4	VG	AES	6	2	N	MERITS	AVG ENGINE SLUDGE RATING (MERITS)
300	4	VG	RACS	6	2	N	MERITS	AVG ROCKER COVER SLUDGE RATING (MERITS)
310	4	VG	AEV3	6	2	N	MERITS	AVG ENGINE VARNISH 3-PART RATING (MERITS)
320	4	VG	APV	6	2	N	MERITS	AVG PISTON SKIRT RATING (MERITS)
330	4	VG	OSCRNSLG	4	0	N	% AREA	OIL SCREEN SLUDGE CLOGGING (% AREA)
340	4	VG	NHSCMPRG	2	0	N		NUMBER HOT STUCK COMPRESSION RINGS
350	4	VG	TRANOSCR	7	4	N	Trans Units	TRANSFORMED OIL SCREEN SLUDGE (Trans Units)
360	4	VG	AESCF	6	2	N	MERITS	AVERAGE ENGINE SLUDGE CORRECTION FACTOR (MERITS)
370	4	VG	RACSCF	6	2	N	MERITS	AVERAGE ROCKER COVER SLUDGE CORRECTION FACTOR (MERITS)
380	4	VG	AEV3CF	6	2	N	MERITS	AVERAGE ENGINE VARNISH 3-PART CORRECTION FACTOR (MERITS)
390	4	VG	APVCF	6	2	N	MERITS	AVERAGE PISTON SKIRT VARNISH CORRECTION FACTOR (MERITS)
400	4	VG	TOSCRCF	7	4	N	TRANS UNITS	OIL SCREEN SLUDGE CORRECTION FACTOR (TRANS UNITS)
410	4	VG	NHSRCF	2	0	N		NUMBER OF HOT STUCK RINGS CORRECTION FACTOR
420	4	VG	TOSCRCOR	7	4	N	TRANS UNITS	TRANSFORMED OIL SCREEN SLUDGE CORRECTED RESULT (TRANS UNITS)
430	4	VG	AESSA	6	2	N	MERITS	AVERAGE ENGINE SLUDGE SEVERITY ADJUSTMENT (MERITS)
440	4	VG	RACSSA	6	2	N	MERITS	AVERAGE ROCKER COVER SLUDGE SEVERITY ADJUSTMENT (MERITS)
450	4	VG	AEV3SA	6	2	N	MERITS	AVERAGE ENGINE VARNISH 3-PART SEVERITY ADJUSTMENT (MERITS)
460	4	VG	APVSA	6	2	N	MERITS	AVERAGE PISTON SKIRT VARNISH SEVERITY ADJUSTMENT (MERITS)
470	4	VG	TOSCRSA	7	4	N	TRANS UNITS	OIL SCREEN SLUDGE SEVERITY ADJUSTMENT (TRANS UNITS)
480	4	VG	NHSRSA	2	0	N		NUMBER OF HOT STUCK RINGS SEVERITY ADJUSTMENT
490	4	VG	TOSCRFNL	7	4	N	TRANS UNITS	TRANSFORMED OIL SLUDGE SCREEN FINAL RESULT (TRANS UNITS)
500	4	VG	AESFNL	6	2	N	MERITS	AVERAGE ENGINE SLUDGE FINAL RESULT (MERITS)
510	4	VG	RACSFNL	6	2	N	MERITS	AVG ROCKER COVER SLUDGE FINAL RESULT (MERITS)
520	4	VG	AEV3FNL	6	2	N	MERITS	AVERAGE ENGINE VARNISH 3-PART FINAL RESULT (MERITS)
530	4	VG	APVFNL	6	2	N	MERITS	AVERAGE PISTON SKIRT VARNISH FINAL RESULT (MERITS)

Fig A12.1 Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
540	4	VG	OSCRFNL	6	2	N	% AREA	OIL SCREEN SLUDGE FINAL RESULT (% AREA)
550	4	VG	NHSRFNL	6	2	N		NUMBER OF HOT STUCK RINGS FINAL RESULT
560	4	VG	OSCRNDEB	4	0	N	% AREA	OIL SCREEN DEBRIS CLOGGING (% AREA)
570	4	VG	NCSCMPRG	2	0	N		NUMBER COLD STUCK COMPRESSION RINGS
580	4	VG	OILRING	4	0	N	% AREA	OIL RING CLOGGING (% AREA)
590	4	VG	ACBLWRT2	6	2	N	L/min	AVG CORRECTED BLOWBY FLOW RATE STAGE II (L/min)
600	4	VG	PCV25	6	2	N	%	PCV VALVE AT 25 KPA CLOGGING (%)
610	4	VG	TOILCONS	7	0	N	g	TOTAL OIL CONSUMED (g)
620	4	VG	PCV60	6	2	N	%	PCV VALVE AT 60 KPA CLOGGING (%)
630	4	VG	RSTAND	5	0	C		LAST CALIBRATION TEST STAND
640	4	VG	RTOTSRUN	5	0	C		LAST CALIBRATION TOTAL RUNS-TEST STAND
650	4	VG	ROILCODE	38	0	C		LAST CALIBRATION TEST OILCODE
660	4	VG	RIND	6	0	C		LAST CALIBRATION TMC OIL CODE
670	4	VG	RENGINE	6	0	C		LAST CALIBRATION TEST ENGINE
680	4	VG	RSAEVISC	7	0	C		LAST CALIBRATION TEST SAE VISCOSITY GRADE
690	4	VG	RDTCOMP	8	0	C	YYYYMMDD	LAST CALIBRATION TEST DATE COMPLETED (YYYYMMDD)
700	4	VG	RTESTLEN	3	0	Z	HHH	LAST CALIBRATION TEST TEST LENGTH (HHH)
710	4	VG	RFUELBID	8	0	C		LAST CALIBRATION TEST FUEL BATCH IDENTIFIER
720	4	VG	RDTCALEX	8	0	C	YYYYMMDD	LAST CALIBRATION TEST EXPIRATION DATE (YYYYMMDD)
730	4	VG	ROSCRDEB	4	0	N	% AREA	LAST CALIBRATION TEST OIL SCREEN DEBRIS CLOGGING (% AREA)
740	4	VG	RCSCMPRG	2	0	N		LAST CALIBRATION TEST NUMBER COLD STUCK COMPRESSION RINGS
750	4	VG	ROILRING	4	0	N	% AREA	LAST CALIBRATION TEST OIL RING CLOGGING (% AREA)
760	4	VG	RACBLWR2	6	2	N	L/min	LAST CALIBRATION TEST AVG. CORR. BLOWBY STAGE II (L/min)
770	4	VG	RPCV25	6	2	N	%	LAST CALIBRATION TEST PCV VALVE AT 25 KPA CLOGGING (%)
780	4	VG	RTOILCON	7	0	N	g	LAST CALIBRATION TEST TOTAL OIL CONSUMED (g)
790	4	VG	RPCV60	6	2	N	%	LAST CALIBRATION TEST PCV VALVE AT 60 KPA CLOGGING (%)
800	4	VG	RAESFNL	6	2	N	MERITS	LAST CALIB TEST AVG ENG SLUDGE FNL RES (MERITS)
810	4	VG	RRACSFNL	6	2	N	MERITS	LAST CALIB TEST AVG ROCKER CVR SLUDGE FNL RES (MERITS)
820	4	VG	RAEV3FNL	6	2	N	MERITS	LAST CALIB TEST AVG ENG VARNISH 3-PART FNL RES (MERITS)
830	4	VG	RAPVFNL	6	2	N	MERITS	LAST CALIB TEST AVG PISTON SKIRT VARN FNL RES (MERITS)
840	4	VG	ROSCRSLG	4	0	N	% AREA	LAST CALIB TEST OIL SCREEN SLUDGE CLOGGING FNL RES (% AREA)
850	4	VG	RHSCMPRG	2	0	N		LAST CALIB TEST NUMBER HOT STUCK COMPRESSION RINGS FNL RES
860	5	VG	PRODNUM	15	0	C		HARDWARE IDENTIFICATION PRODUCTION NUMBER
870	5	VG	SERNUM	15	0	C		HARDWARE IDENTIFICATION SERIAL NUMBER
880	5	VG	BLKCAST	15	0	C		CASTING NUMBERS BLOCK
890	5	VG	CAMCASTL	15	0	C		CASTING NUMBERS CAM, LEFT
900	5	VG	CAMCASTR	15	0	C		CASTING NUMBERS CAM, RIGHT
910	5	VG	PISTPART	15	0	C		PISTON PART NUMBER
920	5	VG	PRINGNUM	15	0	C		PISTON RING CASTING NUMBER
930	5	VG	CYLHCSTL	30	0	C		CYLINDER HEAD CASTING NUMBER LEFT
940	5	VG	CYLHCSTR	30	0	C		CYLINDER HEAD CASTING NUMBER RIGHT
950	5	VG	RACLSRT	5	2	N	MERITS	ROCKER ARM COVER LEFT SLUDGE RATING (MERITS)
960	5	VG	RACRSRT	5	2	N	MERITS	ROCKER ARM COVER RIGHT SLUDGE RATING (MERITS)
970	5	VG	RACLVRT	5	2	N	MERITS	ROCKER ARM COVER LEFT VARNISH RATING (MERITS)
980	5	VG	CAMBLSRT	5	2	N	MERITS	CAMSHAFT BAFFLE LEFT SLUDGE RATING (MERITS)
990	5	VG	RACRVRT	5	2	N	MERITS	ROCKER ARM COVER RIGHT VARNISH RATING (MERITS)
1000	5	VG	CAMBRSRT	5	2	N	MERITS	CAMSHAFT BAFFLE RIGHT SLUDGE RATING (MERITS)
1010	5	VG	TCCSRT	5	2	N	MERITS	TIMING CHAIN COVER SLUDGE RATING (MERITS)
1020	5	VG	OILPBSRT	5	2	N	MERITS	OIL PAN BAFFLE SLUDGE RATING (MERITS)
1030	5	VG	OILPNSRT	5	2	N	MERITS	OIL PAN SLUDGE RATING (MERITS)
1040	5	VG	VLVDLSRT	5	2	N	MERITS	VALVE DECK AREA LEFT SLUDGE RATING (MERITS)
1050	5	VG	VLVDRSRT	5	2	N	MERITS	VALVE DECK AREA RIGHT SLUDGE RATING (MERITS)
1060	5	VG	CFPIN8I	6	1	N	micrometre	FOLLOWER PIN WEAR CYLINDER 8 INTAKE (micrometre)
1070	5	VG	PSVTH1	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST NUM 1 (MERITS)

Fig. A12.1 (cont'd) Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
1080	5	VG	CFPIN8E	6	1	N	micrometre	FOLLOWER PIN WEAR CYLINDER 8 EXHAUST (micrometre)
1090	5	VG	PSVTH2	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST NUM 2 (MERITS)
1100	5	VG	MXCYL818	6	1	N	micrometre	MAX CYLINDER BORE WEAR CYL. 1 & 8 (micrometre)
1110	5	VG	PSVTH3	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST NUM 3 (MERITS)
1120	5	VG	ACYLBW18	6	1	N	micrometre	AVG CYLINDER BORE WEAR CYL. 1 & 8 (micrometre)
1130	5	VG	PSVTH4	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST NUM 4 (MERITS)
1140	5	VG	MXRGINC	6	1	N	um	MAX RING GAP INCREASE CYL, 1 & 8 (um)
1150	5	VG	PSVTH5	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST NUM 5 (MERITS)
1160	5	VG	ARGINC	6	1	N	um	AVG RING GAP INCREASE. CYL 1 & 8. (um)
1170	5	VG	PSVTH6	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST NUM 6 (MERITS)
1180	5	VG	PSVTH7	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST NUM 7 (MERITS)
1190	5	VG	PSVTH8	5	2	N	MERITS	PISTON SKIRT VARNISH THRUST NUM 8 (MERITS)
1200	6	VG	QRPM	7	3	N		ENGINE SPEED QUALITY INDEX
1210	6	VG	ARPM1	5	0	N	r/min	AVG ENGINE SPEED STAGE I (r/min)
1220	6	VG	ARPM2	5	0	N	r/min	AVG ENGINE SPEED STAGE II (r/min)
1230	6	VG	ARPM3	5	0	N	r/min	AVG ENGINE SPEED STAGE III (r/min)
1240	6	VG	NRPM	6	0	N		SPEED SAMPLE TOTAL DATA POINTS
1250	6	VG	BRPM	6	0	N		SPEED BQD TOTAL DATA POINTS
1260	6	VG	ORPM	6	0	N		SPEED OVER/UNDER RANGE TOTAL DATA POINTS
1270	6	VG	QPOWER	7	3	N		ENGINE POWER QUALITY INDEX
1280	6	VG	APOWER1	6	2	N	kW	AVG POWER STAGE I (kW)
1290	6	VG	APOWER2	6	2	N	kW	AVG POWER STAGE II (kW)
1300	6	VG	APOWER3	6	2	N	kW	AVG POWER STAGE III (kW)
1310	6	VG	NPWR	6	0	N		POWER SAMPLE TOTAL DATA POINTS
1320	6	VG	BPWR	6	0	N		POWER BQD TOTAL DATA POINTS
1330	6	VG	OPWR	6	0	N		POWER OVER/UNDER RANGE TOTAL DATA POINTS
1340	6	VG	QMANABP	7	3	N		MANIFOLD ABSOLUTE PRESSURE QUALITY INDEX
1350	6	VG	AMANABP1	5	1	N	kPa	AVG MANIFOLD ABSOLUTE PRESSURE STAGE I (kPa)
1360	6	VG	AMANABP2	5	1	N	kPa	AVG MANIFOLD ABSOLUTE PRESSURE STAGE II (kPa)
1370	6	VG	AMANABP3	5	1	N	kPa	AVG MANIFOLD ABSOLUTE PRESSURE STAGE III (kPa)
1380	6	VG	NMAP	6	0	N		MAINFOLD ABS PRESSURE SAMPLE TOTAL DATA POINTS
1390	6	VG	BMAP	6	0	N		MANIFOLD ABS PRESSURE BQD TOTAL DATA POINTS
1400	6	VG	OMAP	6	0	N		MANIFOLD ABS PRESSURE OVER/UNDER RANGE TOTAL DATA PT
1410	6	VG	QENGOIN	7	3	N		ENGINE OIL IN TEMP QUALITY INDEX
1420	6	VG	AENGOIN1	6	1	N	°C	AVG ENGINE OIL IN TEMP STAGE I (°C)
1430	6	VG	AENGOIN2	6	1	N	°C	AVG ENGINE OIL IN TEMP STAGE II (°C)
1440	6	VG	AENGOIN3	6	1	N	°C	AVG ENGINE OIL IN TEMP STAGE III (°C)
1450	6	VG	NEOIN	6	0	N		ENGINE OIL INLET SAMPLE TOTAL DATA POINTS
1460	6	VG	BEOIN	6	0	N		ENGINE OIL INLET BQD TOTAL DATA POINTS
1470	6	VG	OEOIN	6	0	N		ENGINE OIL INLET OVER/UNDER RANGE TOTAL DATA POINTS
1480	6	VG	QCOLOUT	7	3	N		ENGINE COOLANT OUT TEMP QUALITY INDEX
1490	6	VG	ACOLOUT1	5	1	N	°C	AVG ENGINE COOLANT OUT TEMP STAGE I (°C)
1500	6	VG	ACOLOUT2	5	1	N	°C	AVG ENGINE COOLANT OUT TEMP STAGE II (°C)
1510	6	VG	ACOLOUT3	5	1	N	°C	AVG ENGINE COOLANT OUT TEMP STAGE III (°C)
1520	6	VG	NCOUT	6	0	N		ENGINE COOLANT OUTLET SAMPLE TOTAL DATA POINTS
1530	6	VG	BCOUT	6	0	N		ENGINE COOLANT OUTLET BQD TOTAL DATA POINTS
1540	6	VG	OCOUT	6	0	N		ENGINE COOLANT OUTLET OVER/UNDER RANGE TOTAL DATA PT
1550	6	VG	QCOLFRT	7	3	N		ENGINE COOLANT FLOW RATE QUALITY INDEX
1560	6	VG	ACOLFRT1	6	1	N	L/min	AVG ENGINE COOLANT FLOW RATE STAGE I (L/min)
1570	6	VG	ACOLFRT2	6	1	N	L/min	AVG ENGINE COOLANT FLOW RATE STAGE II (L/min)
1580	6	VG	ACOLFRT3	6	1	N	L/min	AVERAGE ENGINE COOLANT FLOW RATE STAGE III (L/min)
1590	6	VG	NCFRT	6	0	N		ENGINE COOLANT FLOW SAMPLE TOTAL DATA POINTS
1600	6	VG	BCFRT	6	0	N		ENGINE COOLANT FLOW BQD TOTAL DATA POINTS
1610	6	VG	OCFRT	6	0	N		ENGINE COOLANT FLOW OVER/UNDER RANGE TOTAL DATA PTS

Fig. A12.1 (cont'd) Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
1620	6	VG	QCOLPRE	7	3	N		ENGINE COOLANT PRESSURE QUALITY INDEX
1630	6	VG	ACOLPRE1	6	1	N	kPa	AVG ENGINE COOLANT PRESSURE STAGE I (kPa)
1640	6	VG	ACOLPRE2	6	1	N	kPa	AVG ENGINE COOLANT PRESSURE STAGE II (kPa)
1650	6	VG	ACOLPRE3	6	1	N	kPa	AVG ENGINE COOLANT PRESSURE STAGE III (kPa)
1660	6	VG	NCPRE	6	0	N		ENGINE COOLANT PRESSURE SAMPLE TOTAL DATA POINTS
1670	6	VG	BCPRE	6	0	N		ENGINE COOLANT PRESSURE BQD TOTAL DATA POINTS
1680	6	VG	OCPRE	6	0	N		ENGINE COOLANT PRESSURE OVER/UNDER RANGE TTL DATA PT
1690	6	VG	QRACCTP	7	3	N		RAC COOLANT IN TEMP QUALITY INDEX
1700	6	VG	ARACCTP1	5	1	N	°C	AVG RAC COOLANT IN TEMP STAGE I (°C)
1710	6	VG	ARACCTP2	5	1	N	°C	AVG RAC COOLANT IN TEMP STAGE II (°C)
1720	6	VG	ARACCTP3	5	1	N	°C	AVG RAC COOLANT IN TEMP STAGE III (°C)
1730	6	VG	NRACC	6	0	N		RAC COOLANT INLET SAMPLE TOTAL DATA POINTS
1740	6	VG	BRACC	6	0	N		RAC COOLANT INLET BQD TOTAL DATA POINTS
1750	6	VG	ORACC	6	0	N		RAC COOLANT INLET OVER/UNDER RANGE TOTAL DATA POINTS
1760	6	VG	QRACCFR	7	3	N		RAC COOLANT FLOW RATE QUALITY INDEX
1770	6	VG	ARACCFR1	5	1	N	L/min	AVG RAC COOLANT FLOW RATE STAGE I (L/min)
1780	6	VG	ARACCFR2	5	1	N	L/min	AVG RAC COOLANT FLOW RATE STAGE II (L/min)
1790	6	VG	ARACCFR3	5	1	N	L/min	AVG RAC COOLANT FLOW RATE STAGE III (L/min)
1800	6	VG	NRACF	6	0	N		RAC COOLANT FLOW SAMPLE TOTAL DATA POINTS
1810	6	VG	BRACF	6	0	N		RAC COOLANT FLOW BQD TOTAL DATA POINTS
1820	6	VG	ORACF	6	0	N		RAC COOLANT FLOW OVER/UNDER RANGE TOTAL DATA POINTS
1830	6	VG	QINAIRT	7	3	N		INTAKE AIR TEMP QUALITY INDEX
1840	6	VG	AINAIRT1	5	1	N	°C	AVG INTAKE AIR TEMP STAGE I (°C)
1850	6	VG	AINAIRT2	5	1	N	°C	AVG INTAKE AIR TEMP STAGE II (°C)
1860	6	VG	AINAIRT3	5	1	N	°C	AVG INTAKE AIR TEMP STAGE III (°C)
1870	6	VG	NINAT	6	0	N		INTAKE AIR TEMPERATURE SAMPLE TOTAL DATA POINTS
1880	6	VG	BINAT	6	0	N		INTAKE AIR TEMPERATURE BQD TOTAL DATA POINTS
1890	6	VG	OINAT	6	0	N		INTAKE AIR TEMPERATURE OVER/UNDER RANGE TTL DATA PTS
1900	6	VG	QINAIRP	7	3	N		INTAKE AIR PRESSURE QUALITY INDEX
1910	6	VG	AINAIRP1	6	3	N	kPa	AVG INTAKE AIR PRESSURE STAGE I (kPa)
1920	6	VG	AINAIRP2	6	3	N	kPa	AVG INTAKE AIR PRESSURE STAGE II (kPa)
1930	6	VG	AINAIRP3	6	3	N	kPa	AVG INTAKE AIR PRESSURE STAGE III (kPa)
1940	6	VG	NINAP	6	0	N		INTAKE AIR PRESSURE SAMPLE TOTAL DATA POINTS
1950	6	VG	BINAP	6	0	N		INTAKE AIR PRESSURE BQD TOTAL DATA POINTS
1960	6	VG	OINAP	6	0	N		INTAKE AIR PRESSURE OVER/UNDER RANGE TOTAL DATA PTS
1970	6	VG	QAIRHUM	7	3	N		INTAKE AIR SPECIFIC HUMIDITY QUALITY INDEX
1980	6	VG	AAIRHUM1	5	1	N	g/kg	AVG INTAKE AIR SPECIFIC HUMIDITY STAGE I (g/kg)
1990	6	VG	AAIRHUM2	5	1	N	g/kg	AVG INTAKE AIR SPECIFIC HUMIDITY STAGE II (g/kg)
2000	6	VG	AAIRHUM3	5	1	N	g/kg	AVG INTAKE AIR SPECIFIC HUMIDITY STAGE III (g/kg)
2010	6	VG	NAHUM	6	0	N		HUMIDITY SAMPLE TOTAL DATA POINTS
2020	6	VG	BAHUM	6	0	N		HUMIDITY BQD TOTAL DATA POINTS
2030	6	VG	OAHUM	6	0	N		HUMIDITY OVER/UNDER RANGE TOTAL DATA POINTS
2040	6	VG	QEXBKPR	7	3	N		EXHAUST BACKPRESSURE QUALITY INDEX
2050	6	VG	AEXBKPR1	6	1	N	kPa	AVG EXHAUST BACK PRESSURE STAGE I (kPa)
2060	6	VG	AEXBKPR2	6	1	N	kPa	AVG EXHAUST BACK PRESSURE STAGE II (kPa)
2070	6	VG	AEXBKPR3	6	1	N	kPa	AVG EXHAUST BACK PRESSURE STAGE III (kPa)
2080	6	VG	NEXBP	6	0	N		EXHAUST BACKPRESSURE SAMPLE TOTAL DATA POINTS
2090	6	VG	BEXBP	6	0	N		EXHAUST BACKPRESSURE BQD TOTAL DATA POINTS
2100	6	VG	OEXBP	6	0	N		EXHAUST BACKPRESSURE OVER/UNDER TOTAL DATA POINTS
2110	6	VG	AFUELRT1	5	1	N	kg/h	AVG FUEL FLOW RATE STAGE I (kg/h)
2120	6	VG	AFUELRT2	5	1	N	kg/h	AVG FUEL FLOW RATE STAGE II (kg/h)
2130	6	VG	AFUELRT3	5	1	N	kg/h	AVG FUEL FLOW RATE STAGE III (kg/h)
2140	6	VG	ALEXGO1	5	2	N	% VOL	AVG LEFT EXHAUST GAS OXYGEN STAGE I (% VOL)
2150	6	VG	ALEXGO2	5	2	N	% VOL	AVG LEFT EXHAUST GAS OXYGEN STAGE II (% VOL)

Fig. A12.1 (cont'd) Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
2160	6	VG	ALEXGO3	5	2	N	% VOL	AVG LEFT EXHAUST GAS OXYGEN STAGE III (% VOL)
2170	6	VG	AREXGO1	5	2	N	% VOL	AVG RIGHT EXHAUST GAS OXYGEN STAGE I (% VOL)
2180	6	VG	AREXGO2	5	2	N	% VOL	AVG RIGHT EXHAUST GAS OXYGEN STAGE II (% VOL)
2190	6	VG	AREXGO3	5	2	N	% VOL	AVG RIGHT EXHAUST GAS OXYGEN STAGE III (% VOL)
2200	6	VG	ALEXGCO1	6	2	N	% VOL	AVG LEFT EXHAUST GAS CARBON MONOXIDE STAGE I (% VOL)
2210	6	VG	ALEXGCO2	6	2	N	% VOL	AVG LEFT EXHAUST GAS CARBON MONOXIDE STAGE II (% VOL)
2220	6	VG	ALEXGCO3	6	2	N	% VOL	AVG LEFT EXHAUST GAS CARBON MONOXIDE STAGE III (% VOL)
2230	6	VG	AREXGCO1	6	2	N	% VOL	AVG RIGHT EXHAUST GAS CARBON MONOXIDE STAGE I (% VOL)
2240	6	VG	AREXGCO2	6	2	N	% VOL	AVG RIGHT EXHAUST GAS CARBON MONOXIDE STAGE II (% VOL)
2250	6	VG	AREXGCO3	6	2	N	% VOL	AVG RIGHT EXHAUST GAS CARBON MONOXIDE STAGE III (% VOL)
2260	6	VG	ALEXCO21	6	2	N	% VOL	AVG LEFT EXHAUST GAS CARBON DIOXIDE STAGE I (% VOL)
2270	6	VG	ALEXCO22	6	2	N	% VOL	AVG LEFT EXHAUST GAS CARBON DIOXIDE STAGE II (% VOL)
2280	6	VG	ALEXCO23	6	2	N	% VOL	AVG LEFT EXHAUST GAS CARBON DIOXIDE STAGE III (% VOL)
2290	6	VG	AREXCO21	6	2	N	% VOL	AVG RIGHT EXHAUST GAS CARBON DIOXIDE STAGE I (% VOL)
2300	6	VG	AREXCO22	6	2	N	% VOL	AVG RIGHT EXHAUST GAS CARBON DIOXIDE STAGE II (% VOL)
2310	6	VG	AREXCO23	6	2	N	% VOL	AVG RIGHT EXHAUST GAS CARBON DIOXIDE STAGE III (% VOL)
2320	6	VG	ALEXGNO2	5	0	N	ppm	AVG LEFT EXHAUST GAS NOX STAGE II (ppm)
2330	6	VG	AREXGNO2	5	0	N	ppm	AVG RIGHT EXHAUST GAS NOX STAGE II (ppm)
2340	6	VG	AEXGNO2	5	0	N	ppm	AVG EXHAUST GAS NOX STAGE II (ppm)
2350	6	VG	CUMEXNO2	5	0	N	ppm	CUMULATIVE REF OIL TEST AVG NOX (ppm)
2360	7	VG	OILARxxx	5	0	N	g	OIL LEVEL CYCLE XXX (g)
2370	7	VG	OILCRxxx	5	0	N	g	OIL CONSUMPTION CYCLE XXX (g)
2380	7	VG	TOILADD	7	0	N	g	TOTAL OIL ADDED (g)
2390	7	VG	BLBYHxxx	6	2	N	L/min	CORRECTED BLOWBY READINGS XXX (L/min)
2400	7	VG	XCBLWRT2	6	2	N	L/min	MAX CORRECTED BLOWBY STAGE II READINGS (L/min)
2410	7	VG	MCBLWRT2	6	2	N	L/min	MIN CORRECTED BLOWBY STAGE II READINGS (L/min)
2420	7	VG	ABLW2120	6	2	N	L/min	AVERAGE BLOWBY, HOURS 23 -119 (L/min)
2430	8	VG	TST_Hxxx	3	0	C	HHH	TEST HOUR XXX (HHH)
2440	8	VG	AGWMHxxx	6	0	A	ppm	AG - WEAR METALS AT XXX HOURS [<] (ppm)
2450	8	VG	ALWMHxxx	6	0	A	ppm	AL - WEAR METALS AT XXX HOURS [<] (ppm)
2460	8	VG	CRWMHxxx	6	0	A	ppm	CR - WEAR METALS AT XXX HOURS [<] (ppm)
2470	8	VG	CUWMHxxx	6	0	A	ppm	CU - WEAR METALS AT XXX HOURS [<] (ppm)
2480	8	VG	FEWMHxxx	6	0	A	ppm	FE - WEAR METALS AT XXX HOURS [<] (ppm)
2490	8	VG	PBWMHxxx	6	0	A	ppm	PB - WEAR METALS AT XXX HOURS [<] (ppm)
2500	8	VG	SIWMHxxx	6	0	A	ppm	SI - WEAR METALS AT XXX HOURS [<] (ppm)
2510	8	VG	SNWMHxxx	6	0	A	ppm	SN - WEAR METALS AT XXX HOURS [<] (ppm)
2520	8	VG	FUELHxxx	5	1	N	% WT	D3525 FUEL DILUTION BY GC AT XXX HOURS (% WT)
2530	8	VG	PEN_Hxxx	5	2	N	% WT	D893B PENTANE INSOLUBLES AT XXX HOURS (% WT)
2540	8	VG	TBN_Hxxx	6	2	A		D4739 TBN AT XXX HOURS [<]
2550	8	VG	V40_Hxxx	7	2	N	cSt	D445 VISCOSITY @ 40 °C AT XXX HOURS (cSt)
2560	8	VG	V100Hxxx	7	2	N	cSt	D445 VISCOSITY @ 100 °C AT XXX HOURS (cSt)
2570	9	VG	DWNOCR	2	0	Z		NUMBER OF DOWNTIME OCCURRENCES
2580	9	VG	DOWNRxxx	6	0	C	HHH:MM	DOWNTIME TEST HOURS XXX (HHH:MM)
2590	9	VG	DDATRxxx	8	0	C	YYYYMMDD	DOWNTIME DATE XXX (YYYYMMDD)
2600	9	VG	DTIMRxxx	6	0	C	HHH:MM	DOWNTIME TIME XXX (HHH:MM)
2610	9	VG	DREARxxx	60	0	C		DOWNTIME REMARKS/REASONS XXX
2620	9	VG	TOTLDOWN	6	0	C	HHH:MM	DOWNTIME TIME TOTAL (HHH:MM)
2630	9	VG	TOTCOM	2	0	Z		TOTAL LINES OF COMMENTS AND OUTLIERS
2640	9	VG	OCOMRxxx	70	0	C		OTHER DOWNTIME COMMENT XXX

Fig. A12.1 (cont'd) Data Dictionary

```
##########################################################################
#                                                                        #
#         D a t a   D i c t i o n a r y   R e p e a t i n g              #
#             F i e l d   S p e c i f i c a t i o n s                    #
#                                                                        #
##########################################################################
# The following contains specifications and field groupings for fields in the
# Data Dictionary that are REPEATING Fields.  These fields can be identified
# in the Data Dictionary by the Hxxx or Rxxx in the last four positions of the
# field name.
#
# Repeating fields are used to specify repeating measurements.
#
# The format for a repeating field name is 4 descriptive characters followed
# by the letter H or R followed by 3 characters for the actual interval
# the measurement was taken. The field will always be a total of 8 characters.
#
# Example ABCDHxxx.
#
# The following is the format of this specification:
#
# Column 1 - 8:   Repeating Field Name
# Column 10 - 17: The Parent Field Name of the Group
# Column 19 - 26: The Measurement Interval Group Name
# Column 30 - 80: Comments about the Repeating Field Group.
#
# The lines following the Repeating Field Name Record will contain the required
# measurements for the particular field.  Multiple 80 characters lines
# can be specified.  A blank line marks the end of each specification.
#
# The Field Name in Column 10-17 designates the the Group in which the field
# belongs.  The First field name in a group is the Parent of the grouping
# and can be used to determine how fields should be grouped.
# The changing of the Parent Field marks the end of a repeating group
# specification.
#
# Example:
#
# VIS_Hxxx, DVISHxxx and PVISHxxx expanded for transmission (8 and 16 hours):
#
#           VIS_H008
#           DVISH008
#           PVISH008
#           VIS_H016
#           DVISH016
#           PVISH016
#
# Note:  During electronic transmission, repeating field groups must be kept
#        together within the specified group but the order within the group
#        does not have to be maintained.
#
##########################################################################
#              Start of Field Grouping Specifications                    #
##########################################################################
#
VG VERSION 20001214
OILARxxx OILARxxx OILARxxx   OIL LEVEL CYCLE XXX (g)
006 012 018 024 030 036 042 048

OILCRxxx OILARxxx OILCRxxx   OIL CONSUMPTION CYCLE XXX (g)
```

Fig. A12.2 Repeating Fields Document

```
006 012 018 024 030 036 042 048 054

BLBYHxxx BLBYHxxx BLBYHxxx   CORRECTED BLOWBY READINGS XXX (L/min)
001 023 047 071 095 119 143 167 191 215

TST_Hxxx TST_Hxxx TST_Hxxx   TEST HOUR XXX (HHH)
NEW 024 048 072 096 120 144 168 192 216

AGWMHxxx TST_Hxxx TST_Hxxx   AG - WEAR METALS AT XXX HOURS [<] (ppm)
NEW 024 048 072 096 120 144 168 192 216

ALWMHxxx TST_Hxxx TST_Hxxx   AL - WEAR METALS AT XXX HOURS [<] (ppm)
NEW 024 048 072 096 120 144 168 192 216

CRWMHxxx TST_Hxxx TST_Hxxx   CR - WEAR METALS AT XXX HOURS [<] (ppm)
NEW 024 048 072 096 120 144 168 192 216

CUWMHxxx TST_Hxxx TST_Hxxx   CU - WEAR METALS AT XXX HOURS [<] (ppm)
NEW 024 048 072 096 120 144 168 192 216

FEWMHxxx TST_Hxxx TST_Hxxx   FE - WEAR METALS AT XXX HOURS [<] (ppm)
NEW 024 048 072 096 120 144 168 192 216

PBWMHxxx TST_Hxxx TST_Hxxx   PB - WEAR METALS AT XXX HOURS [<] (ppm)
NEW 024 048 072 096 120 144 168 192 216

SIWMHxxx TST_Hxxx TST_Hxxx   SI - WEAR METALS AT XXX HOURS [<] (ppm)
NEW 024 048 072 096 120 144 168 192 216

SNWMHxxx TST_Hxxx TST_Hxxx   SN - WEAR METALS AT XXX HOURS [<] (ppm)
NEW 024 048 072 096 120 144 168 192 216

FUELHxxx TST_Hxxx FUELHxxx   D3525 FUEL DILUTION BY GC AT XXX HOURS (% WT)
024 048 072 096 120 144 168 192 216

PEN_Hxxx TST_Hxxx PEN_Hxxx   D893B PENTANE INSOLUBLES AT XXX HOURS (% WT)
048 096 144 192 216

TBN_Hxxx TST_Hxxx TST_Hxxx   D4739 TBN AT XXX HOURS [<]
NEW 024 048 072 096 120 144 168 192 216

V40_Hxxx TST_Hxxx TST_Hxxx   D445 VISCOSITY @ 40 DEG C AT XXX HOURS (cSt)
NEW 024 048 072 096 120 144 168 192 216

V100Hxxx TST_Hxxx TST_Hxxx   D445 VISCOSITY @ 100 DEG C AT XXX HOURS (cSt)
NEW 024 048 072 096 120 144 168 192 216

DOWNRxxx DOWNRxxx DOWNRxxx   DOWNTIME TEST HOURS XXX (HHH:MM)


DDATRxxx DOWNRxxx DOWNRxxx   DOWNTIME DATE XXX (YYYYMMDD)


DTIMRxxx DOWNRxxx DOWNRxxx   DOWNTIME TIME XXX (HHH:MM)


DREARxxx DOWNRxxx DOWNRxxx   DOWNTIME REMARKS/REASONS XXX


OCOMRxxx OCOMRxxx OCOMRxxx   OTHER DOWNTIME COMMENT XXX
```

Fig. A12.2 (cont'd) Repeating Fields Document

A13.1 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.

A13.2 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.

A13.3 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.

A13.4 Flush new injectors for 30s to remove any assembly residue before flow testing.

A13.5 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.

A13.6 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. The injector(s) shall not leak or drip. Discard any injector that leaks or drips.

A13.7 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.

A13. Fuel Injector Flow Measurements

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. *Piston Ring Grinder*--A Sanford Piston Ring Grinder is available from the following supplier (purchasers should specify the Ford 4.6 L engine application):

Sanford Manufacturing Co.
300 Cox Street
P.O. Box 318
Roselle, NJ 07203

X2.1.17. *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

X2.1.18. *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

X2.1.19. *Rating Lamps*--Suitable rating lamps are available from the following supplier:

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

X2.1.20. *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

X2.1.21. *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

X2.1.22. *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