Designation: D 6202 – 02

An American National Standard

Standard Test Method for Automotive Engine Oils on the Fuel Economy of Passenger Cars and Light-Duty Trucks in the Sequence VIA Spark Ignition Engine[1]

This standard is issued under the fixed designation D 6202; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This test method can be used by any properly equipped laboratory, without outside assistance. However, the ASTM Test Monitoring Center (TMC)[2] provides reference oils and assessment of the test results obtained on those oils by the laboratory (see Annex A1). By this means, the laboratory will know whether their use of the test method gives results statistically similar to those obtained by other laboratories. Furthermore, various agencies require that a laboratory utilize the TMC services in seeking qualification of oils against specifications. For example, the U.S. Army imposes such a requirement, in connection with several Army engine lubricating oil specifications.

Accordingly, this test method is written for use by laboratories that utilize the TMC services. Laboratories that choose not to use those services may simply ignore those portions of the test method that refer to the TMC.

This test method may be modified by means of Information Letters issued by the TMC. In addition, the TMC may issue supplementary memoranda related to the test method. Users of this test method shall contact the Administrator of TMC to obtain the most recent of these.

1. Scope

1.1 This test method covers an engine test procedure for the measurement of the effects of automotive engine oils on the fuel economy of passenger cars and light-duty 3856 kg (8500 lb), or less, gross vehicle weight trucks. The tests are conducted using a specified 4.6-L spark-ignition engine on a dynamometer test stand. It applies to multiviscosity grade oils used in these applications. Companion test methods used to evaluate engine oil performance for specification requirements are discussed in the latest revision of Specification D 4485.

1.2 The values stated in either SI units or other units shall be regarded separately as the standard. Within the text, the SI units are stated first with the other units shown in parentheses. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other, without combining values in any way.

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

1.4 This test method is arranged as follows:

[1] This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.B0 on Automotive Lubricants. The multi-cylinder engine test sequences were originally developed in 1956 by an ASTM Committee D02 group. Subsequently, the procedures were published in an ASTM special technical publication. The Sequence VIA was published as RR:D02-1364, dated August 24, 1995.

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[2] ASTM Test Monitoring Center, 6555 Penn Ave., Pittsburgh, PA 15206-4489. For other information, refer to RR: D02-1364 Sequence VIA Test Development. This research report and this test method are supplemented by Information Letters and Memoranda issued by the ASTM Test Monitoring Center. This edition incorporates revisions in all Information Letters through No. 01–1.

2. Referenced Documents

2.1 *ASTM Standards:*

D 86 Test Method for Distillation of Petroleum Products at Atmospheric Pressure[3]

D 240 Test Method for Heat of Combustion of Liquid Hydrocarbon Fuels by Bomb Calorimeter[3]

D 287 Test Method for API Gravity of Crude Petroleum and Petroleum Products (Hydrometer Method)[3]

D 323 Test Method for Vapor Pressure of Petroleum Products (Reid Method)[3]

D 381 Test Method for Gum Content in Fuels by Jet Evaporation[3]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids[3]

D 525 Test Method for Oxidation Stability of Gasoline (Induction Period Method)[3]

D 1319 Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption[3]

D 2699 Test Method for Research Octane Number of Spark-Ignition Engine Fuel[4]

D 3231 Test Method for Phosphorus in Gasoline[5]

D 3237 Test Method for Lead in Gasoline by Atomic Absorption Spectrometry[5]

D 3338 Test Method of Estimation of Net Heat of Combustion of Aviation Fuels[5]

D 4294 Test Method for Sulfur in Petroleum and Petroleum Products by Energy-Dispersive X-Ray Fluorescence Spectrometry[5]

D 4485 Specification for Performance of Engine Oils[5]

D 5302 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Deposit Formation and Wear in a Spark-Ignition Internal Combustion Engine Fueled with Gasoline and Operated Under Low-Temperature, Light-Duty Conditions[5]

D 5844 Test Method for Evaluation of Automotive Engine Oils for Inhibition of Rusting (Sequence IID)[6]

D 5862 Test Method for Evaluation of Engine Oils in the

[3] *Annual Book of ASTM Standards*, Vol 05.01.
[4] *Annual Book of ASTM Standards*, Vol 05.05.
[5] *Annual Book of ASTM Standards*, Vol 05.02.
[6] *Annual Book of ASTM Standards*, Vol 05.03.

Two-Stroke Cycle Turbo-Supercharged 6V92TA Diesel Engine[6]
E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications[7]
E 191 Specification for Apparatus for Microdetermination of Carbon and Hydrogen in Organic and Organo-Metallic Compounds[8]
IEEE/ASTM SI-10 Standard for Use of the International System of Units (SI): The Modern Metric System[7]

2.2 *SAE Standard:*[9]
J304 Engine Oil Tests
J1423 Classification of Energy-Conserving Engine Oil for Passenger Cars and Light-Duty Trucks

2.3 *API Standard:*[10]
API 1509 Engine Oil Licensing and Certification System

2.4 *ANSI Standard:*[11]
ANSI MC96.1-1975 Temperature Measurement-Thermocouples

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 induced into the combustion chambers. **D 5302**

3.1.2 *automotive*, *adj*—descriptive of equipment associated with self-propelled machinery, usually vehicles driven by internal combustion engines. **D 4485**

3.1.3 *calibration*, *n*—the act of determining the indication or output of a measuring device or a given engine with respect to a standard.

3.1.4 *calibration oil*, *n*—an oil that is used to determine the indication or output of a measuring device or a given engine with respect to a standard.

3.1.5 *engine oil*, *n*—a liquid that reduces friction or wear, or both, between the moving parts of an engine; removes heat particularly from the underside of pistons; and serves as a combustion gas sealant for the piston rings. **D 5862**

3.1.6 *lubricant*, *n*—any material interposed between two surfaces that reduces the friction or wear, or both, between them. **D 5862**

3.1.7 *non-reference oil*, *n*—any oil other than a reference oil, such as a research formulation, commercial oil, or candidate oil. **D 5844**

3.1.8 *purchaser*, *n—of an ASTM test*, a person or organization that pays for the conduct of an ASTM test method on a specified product.

3.1.8.1 *Discussion*—The preferred term is *purchaser*. Deprecated terms that have been used are *client*, *requester, sponsor*, and *customer.* **Sub. B Glossary**

3.1.9 *reference oil*, *n*—an oil of known performance characteristics, used as a basis for comparison. **D 5844**

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *aged test oil*, *n*—an engine oil to be tested that has been previously subjected to use in a spark-ignited operating engine for a prescribed length of service under prescribed conditions.

3.2.2 *aging*, *n*—subjecting of an engine oil to use in a spark-ignited operating engine for a prescribed length of service under prescribed conditions.

3.2.3 *break-in*, *n—in internal combustion engines*, the running of a new engine under prescribed conditions until it reaches stabilized conditions.

3.2.4 *flush*, *v*—to wash out with a rush of engine oil, during a prescribed mode of engine operation to minimize carryover effect from the previous oil and remove residues, before introducing a new test oil.

3.2.5 *flying flush*, *n—in internal combustion engines*, the washing out with a rush of engine oil, during a prescribed mode of engine operation to minimize carryover effect from the previously used oil and remove residues without stopping the engine after the previous test.

3.2.6 *fuel economy*, *n—in internal combustion engines*, the efficient use of gasoline.

3.2.6.1 *Discussion*—Determined by comparing the rate of fuel consumption of a test oil with that displayed by a baseline reference oil.

3.2.7 *pre-test verification*, *n*—the running of an engine to identify relative magnitudes of stage BSFC, confirm proper test controls, verify proper engine operation, and engine/stand suitability to run another test oil.

3.2.8 *test oil*, *n*—an oil subjected to a Sequence VIA engine oil test; either a reference oil or a non-reference oil.

4. Summary of Test Method

4.1 The 4.6-L internal combustion engine is installed on a dynamometer test stand equipped with the appropriate controls for speed, load, and various other operating parameters.

4.2 The test method consists of measuring the laboratory engine brake specific fuel consumption at six constant speed/load/temperature conditions for the reference oil, the test oil, and the reference oil once again, for a total of 50 h approximately.

4.3 Aged test oil is compared directly to fresh ASTM BC SAE 5W-30[2] reference oil, which is run before and after the test oil. When changing from test oil to reference oil, an intermediate flush with a special flushing oil (BC flush oil) is required to minimize the possibility of a carryover effect from the previous oil.

4.4 Test results are expressed as a percent change in brake specific fuel consumption relative to the reference oil.

5. Significance and Use

5.1 *Method*—The data obtained from the use of this test method provide a comparative index of the fuel-saving capabilities of automotive engine oils under repeatable laboratory conditions. A baseline calibration oil (hereafter referred to as BC oil) has been established for this test method to provide a reference against which all other oils can be compared. The BC

[7] *Annual Book of ASTM Standards*, Vol 14.02.

[8] *Annual Book of ASTM Standards*, Vol 14.04.

[9] Available from Society of Automotive Engineers, Inc., 400 Commonwealth Dr., Warrendale, PA 15096-0001. This standard is not available separately. Order either the SAE Handbook Vol. 3 or the SAE Fuels and Lubricants Standards Manual HS-23.

[10] Available from The American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005.

[11] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036.

oil is an SAE 5W-30 grade fully-formulated lubricant. There is a directional correlation of Test Method D 6202 (Sequence VIA) percent fuel economy improvement (FEI) with the fuel economy results obtained from vehicles representative of current production running under the current EPA testing cycles.

5.1.1 The test procedure was not designed to give a precise estimate of the difference between two test oils without adequate replication. Rather, it was developed to compare a test oil to BC oil.

5.2 *Use*—The Sequence VIA test method is useful for engine oil fuel economy specification acceptance. It is used in specifications and classifications of engine lubricating oils, such as the following:

5.2.1 Specification D 4485,

5.2.2 API 1509,

5.2.3 SAE J304, and

5.2.4 SAE J1423.

5.3 *Validity*—The results are valid only when all details of the procedure are followed and when the test is conducted on a TMC calibrated test stand. Good engineering practice should be followed in all aspects of the test procedure. Unexpected deviation in the controlled test parameters are to be judged in accordance with the applicable guidelines established in 14.2.2. Beyond these guidelines, good engineering judgment shall be applied in all unforeseen circumstances to protect the validity of the test results. If anomalies exist within the data generated during a test and are not addressed within this procedure, they should be reported as indicated in X1.1.1.

5.4 *Laboratory Engine/Stand Combination Calibration*—Engine test severity is monitored using reference oils (see X1.1.2). The TMC will assign reference oils for calibration tests. The reference oils used to calibrate Sequence VIA engine test stands have been formulated or selected to represent specific chemical types or performance levels, or both. These oils are normally supplied under code numbers (blind reference oils) to ensure that the testing laboratory is not influenced by preconceived opinions in assessing test results.

5.4.1 Number each Sequence VIA test to identify the stand number, the number of runs on that stand, the engine number, and the number of runs on the engine. For example, 56-21-3-8 defines a test on stand 56, which is the 21st test on stand 56; engine number three; and the eighth test on engine number three. For reruns of operationally invalid or unacceptable tests, the stand run number shall be incremented by one and the engine run number shall be followed by the letter *A* for the first re-run, *B* for the second re-run, and so forth. For example, the next test number for an operationally invalid or unacceptable test would be 56-22-3-8A.

5.4.2 To ensure proper response to various oil parameters, conduct a reference oil test when a new or previously used test engine is installed in a test stand. Reference test requirements, as described in 10.2, are administered by the TMC.

5.5 *Performance Characteristics of Automotive Engine Oils*:

5.5.1 *Precision Data*—Initial precision data for the individual reference oils are shown in Table 1.

5.5.2 *Reference Oil Data*—The precision data for reference oils are reviewed semiannually by the ASTM Sequence VI/VIA Surveillance Panel.

5.5.3 *Test Oil Data*—Precision data for non-reference oils are also reviewed semiannually by the ASTM Sequence VI/VIA Surveillance Panel.

TABLE 1 Reference Oil Precision Data

Oil	N	Mean	Standard Deviation	± 1.80 s
1002	5	0.37	0.17	0.06 – 0.68
530	8	-1.72	0.18	-2.04 – -.140
531	5	0.36	0.36	-0.29 – 1.01
532	9	0.64	0.23	0.23 – 1.05
533	9	0.67	0.25	0.22 – 1.12
534	5	0.58	0.22	0.18 – 0.98
535	9	1.39	0.14	1.14 – 1.64
536	5	1.05	0.14	0.80 – 1.30

6. Apparatus

6.1 *General*—Certain aspects of each test stand shall be commonized in terms of stand hardware. Examples of components that are specified are certain pumps, valves, heat exchangers, heaters, and piping nominal inner diameter (I.D.). Where specified, four classes or categories of stand hardware have been designated:

6.1.1 *Class*:

6.1.1.1 *1*—Shall use exact make/model/size specified.

6.1.1.2 *2*—Shall use the recommended make/brand/model or equivalent that meets the specifications as detailed in the text.

6.1.1.3 *3*—Shall include but use of make/model/size is optional.

6.1.1.4 *4*—Suggested or recommended for inclusion, but use is optional.

6.1.2 The class for each component is shown in the right hand column of Fig. A2.8 for the engine cooling system (see 6.5) and Fig. A2.16 for the external oil system (see 6.6). Prints for special parts are included in this procedure. When using these prints to fabricate special parts, the dimensions specified for the various parts should be used. Do not scale off the drawings or use them as a pattern. All equipment specified in the procedure shall be used. Substitution of equivalent equipment is allowed, but only after equivalency has been proven to the satisfaction of the TMC.

6.2 *Test Engine Configuration*—The test engine is a specially built 1993 4.6-L Ford V-8 engine[12] designed for use with an automatic overdrive electronic (AODE) transmission. (See X1.1.3 for procurement of this engine). Mount the engine on the test stand so that the flywheel friction face is 3.6 ± 0.5° from the vertical with the front of the engine higher than the rear. The U-joint angles shall not be greater than 2.0° in the vertical plane and 0.0° in the horizontal.

6.3 *Laboratory Ambient Conditions*—Do not permit air from fans or ventilation systems to blow directly on the engine. The ambient laboratory atmosphere shall be relatively free of dirt, dust, or other contaminants as required by good laboratory standards.

[12] A specially built 1993 4.6L Ford V-8 internal combustion engine is a product of Ford Motor Co., Dearborn, MI 48121. It is available as Part No. R2G-800-XB (AOD-E) from AER, 1605 Surveyor Blvd., P.O. Box 979, Carrollton, TX 75011-0979.

6.4 *Engine Speed and Load Control*—The dynamometer speed and load control systems shall be capable of maintaining the limits specified in Table 2, Table 3, and Table 4. A typical closed-loop control system maintains speed by engine throttle control and load by dynamometer control. Since these speed and load tolerances require sensitive and precise control, particular attention should be given to achieving and maintaining accurate calibration of the related instrument systems. Control average speed at ± 2 r/min and average load at ± 0.07 N-m (0.05 lbf-ft) as indicated by digital displays, measured over a 100 to 120 s interval.

6.4.1 *Dynamometer*—Use a Midwest or Eaton 37 kW (50 hp) Model 758 dry gap dynamometer (see X1.1.4).

6.4.2 *Dynamometer Load*:

6.4.2.1 *Dynamometer Load Cell*—Measure the dynamometer load by a 0 to 45 kg (0 to 100 lb) load cell. The dyno load cell shall have the following features:

(*1*) Good temperature stability:

(1) Zero ≤± 0.001 % full scale output (FSO) per °C (0.002 % FSO per °F).

(2) Span ≤ ± 0.001 % FSO per °C (0.002 % FSO per °F).

(*2*) Nonlinearity ≤± 0.05 % FSO.

(*3*) Temperature compensation over range expected in lab (10 to 49°C) (50 to 115°F).

6.4.2.2 A Lebow Model 3397 load cell is recommended (see X1.1.5).

6.4.2.3 *Dynamometer Load Cell Damper*—Do not use a load cell damper.

6.4.2.4 *Dynamometer Load Cell Ambient Temperature Control*—Control the load cell ambient temperature. Enclose the dynamometer load cell to protect it from the variability of laboratory ambient temperatures. Maintain air in the enclosure within the operating temperature range specified by the load cell manufacturer within a variability of no more than ± 3°C (± 5.4°F). Control temperature by a means that does not cause uneven temperatures on the body of the load cell.

6.4.2.5 *Dynamometer Connection to Engine*—Use U-joints for the dynamometer-to-engine connection (see 6.2).

6.5 *Engine Cooling System*—An external engine cooling system, as shown in Figs. A2.1-A2.8, is required to maintain the specified jacket coolant temperature and flow rate during the test. The system components are listed in Fig. A2.8. An alternative cooling system is shown in Fig. A2.3. The system shall have the following features:

6.5.1 The closed system is relieved of excess pressure using a normally closed 34.5 to 137.9 kPa (5 to 20 psi) cap (PC-1 in Figs. A2.1 and A2.2) (see X1.1.6).

6.5.2 The pumping system shall be capable of producing 130 ± 4 L/min (34.3 ± 1.1 gal/min). A Gould G and L centrifugal pump (P-1 in Figs. A2.1 and A2.2 and Fig. A2.6), Model NPE, size 1ST, mechanical seal, with a 1.49 kW (2 hp), 3450 r/min motor, is specified (see X1.1.7). Voltage and phase of the motor is optional.

6.5.3 The coolant system volume is not specified; however, certain cooling system components are specified, as shown in Figs. A2.1-A2.6, and adhere to the nominal I.D. of the line

TABLE 2 Sequence VIA Test Operating Conditions Stage Flush and Stage Aging[A]

Test Condition	SI Units	Inch-pound Units
Speed, r/min	1500 ± 5	
Nominal power, kW	15.4	(20.6 hp)
Load, N-m	98.00 ± 0.10	(72.28 ± 0.07 lbf-ft)
Oil gallery temperature,° C	125 ± 2	(257 ± 3°F)
Coolant in temperature,° C	105 ± 2	(221 ± 3°F)
Temperatures,° C		
Oil circulation	record	
Coolant out	record	
Intake air	27 ± 2	(80.6 ± 3.6°F)
Fuel temperature to flowmeter	20 to 32 (± 3 within this range)	(68 to 89.6 ± 4.8°F)
Fuel to fuel rail	20 ± 2	(68 ± 3.6°F)
Oil heater	205	(401°F)
Pressures		
Intake air, kPa	0.05 ± 0.02	(0.20 ± 0.10 in. H_2O)
Fuel to flowmeter, kPa	100 min.	(15 psi min)
Fuel to fuel rail, kPa	205 to 310	(29.7 to 45 psi)
Intake manifold, kPa abs.	record	
Exhaust back pressure, kPa abs	104.00 ± 0.20	(30.80 ± 0.05 in. Hg abs.)
Engine oil, kPa	record	
Flows		
Engine coolant, L/min	130 ± 4	(34.3 ± 1.1 gal/min)
Fuel flow, kg/h	record	
Humidity,intake air, g/kg, of dry air	11.4± 0.8	(79.8 ± 5.6 grains/lb)
AFR	14.25:1 to 15.25:1	(± 0.25 within this range)
Ignition timing	20° BTDC ± 2°	

[A] Counted from the time the temperature set points are initially adjusted to the specific levels. Controlled parameters should be targeted for the middle of the specification range.

TABLE 3 Sequence VIA Test Operating Conditions (SI Units)

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Speed, r/min[A]	800 ± 2	800 ± 2	1500 ± 2	1500 ± 2	1500 ± 2	800 ± 2
Nominal power, kW	2.18	2.18	5.81	15.39	15.39	2.18
Load, N-m[A]	26.00 ± 0.07	26.00 ± 0.07	37.00 ± 0.07	98.00 ± 0.07	98.00 ±0.07	26.00 ± 0.07
Oil gallery temperature,° C[A]	105 ± 1	70 ± 1	70± 1	70 ± 1	45 ± 1	45 ± 1
Coolant in temperature,° C[A]	95 ± 1	60 ± 1	60± 1	60 ± 1	45 ± 1	45 ± 1
Stabilization time, min[B]	60	60	60	60	60	60

	ALL STAGES
Temperatures,° C	
Oil circulation	record
Coolant out	record
Intake air[A]	27 ± 2
Fuel temperature to flowmeter	20 to 32 (delta from the maximum stage average reading shall be ≤ 4)[C]
Fuel to fuel rail[A]	20 ± 2
Load cell	variability no greater than ± 3
Oil heater	205 max
Delta load cell temperature	delta from the maximum stage average shall be ≤ 6[C]
Pressures	
Intake air, kPa	0.05± 0.02
Fuel to flowmeter, kPa	100 min
Fuel to fuel rail, kPa	205 to 310
Intake manifold, kPa abs.	record
[A]Exhaust back pressure, kPa abs.	104.00 ± 0.17
Engine oil, kPa	record
Flows	
Engine coolant, L/min	130 ± 4
Fuel flow, kg/h[A]	record
Humidity, intake Air, g/kg of dry air	11.4± 0.8
AFR[A]	14.25:1 to 15.25:1 (delta from the maximum stage average shall be ≤ 0.50)[C]
Ignition Timing	20° BTDC± 2°

[A] Critical measurement and control parameters,. Controlled parameters should be targeted for the middle of the specification range.
[B] Counted from the time the temperature set points are initially adjusted to the specific levels.
[C] Difference between the maximum stage average reading of the entire test and the individual stage average readings.

sizes, as shown in Figs. A2.1-A2.6.

6.5.4 The specified heat exchanger (HX-1 in Figs. A2.1-A2.6) is an ITT Standard brazed plate Model 320-20, Part No. 5-686-06-020-001 (see X1.1.8), or a ITT Bell and Gossett brazed plate Model BP-75H-20, Part No. 5-686-06-020-001 (see X1.1.8). Parallel or counterflow through the heat exchanger is permitted.

6.5.4.1 Approved replacement heat exchangers are ITT Bell and Gossett brazed plate Model BP-420-20, Part No. 5-686-06-020-005, and ITT Bell and Gossett brazed plate Model BP-422-20, Part No. 5-686-06-020-007.

6.5.4.2 The specified heat exchanger for the alternative cooling system (see Fig. A2.3) is an ITT shell and tube, Model BGF 5-030-06-048-001.

6.5.5 An orifice plate (OP-1 in Figs. A2.1-A2.6) is specified. Size this orifice plate to provide a pressure drop equal to that of heat exchanger HX-1 and install it in the bypass loop of the coolant system.

6.5.5.1 An orifice plate (OP-1) is not required when using the alternative cooling system (see Fig. A2.3).

6.5.6 An orifice plate (differential pressure) (FE-103) in Figs. A2.1-A2.6 is specified (see X1.1.9). This orifice plate is a Daniel Series No. 30 RT threaded orifice flange, 1 ½ NPT. Size this orifice plate to yield a pressure drop of 11.21± 0.50 kPa (45.0 ± 2.0 in. H_2O) at a flow rate of 130 L/min (34.3 gal/min). There should be ten diameters upstream and five diameters downstream of straight, smooth pipe with no reducers or increasers. Flange size shall be same size as pipe size. Threaded, slip-on, or weld neck styles can be used as long as a consistent pipe diameter is kept throughout the required lengths.

6.5.7 A control valve (TCV-104 in Figs. A2.1-A2.5) is required for controlling the engine coolant flow rate through the heat exchanger HX-1 and the heat exchanger bypass portion of the cooling system.

6.5.7.1 A Badger Meter Inc. Model No. 9003TCW36SV3AXXL36 (air-to-close), or Model No. 9003TCW36SV1AXXL36 (air-to-open) 3-way globe (divert), 50.8-mm (2-in.) valve is the specified valve (see X1.1.10).

6.5.7.2 A Badger Meter Inc. Model No. 9003TCW36SV3A29L36 (air-to-close) or Model No. 9003TCW36SV1A29L36 (air-to-open) is also acceptable if the trim package used with these valves has a C.V. value of 16.0.

6.5.7.3 Install the valve in a manner so that loss of air

TABLE 4 Sequence VIA Test Operating Conditions (Inch-Pound Units)

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Speed, r/min[A]	800 ± 2	800 ± 2	1500 ± 2	1500 ± 2	1500 ± 2	800 ± 2
Nominal power, hp	2.92	2.92	7.79	20.64	20.64	2.92
Load, lbf•ft[A]	19.18 ±0.05	19.18 ±0.05	27.29 ±0.05	72.28 ±0.05	72.28 ±0.05	19.18 ±0.05
Oil gallery temperature,°F[A]	221 ± 1.8	158 ± 1.8	158 ± 1.8	158 ± 1.8	113 ± 1.8	113 ± 1.8
Coolant in temperature,°F[A]	203 ± 1.8	140 ± 1.8	140 ± 1.8	140 ± 1.8	113 ± 1 .8	113 ± 1.8
Stabilization Time, minutes[B]	60	60	60	60	60	60

	ALL STAGES
Temperatures,° F	
Oil circulation	record
Coolant out	record
Intake air[A]	80.6 ± 3.6
Fuel temperature to flowmeter	68 to 89.6 (delta from the maximum stage average reading shall be ≤ 4)[C]
Fuel to fuel rail[A]	68 ± 3.6
Load cell	delta from the maximum stage average reading shall be ≤ 6[C]
Oil heater	401 max
Pressures	
Intake air, in. H_2O	0.2 ± 0.1
Fuel to flowmeter, psi	15 min
Fuel to fuel rail, psi	30 to 45
Intake manifold, in. Hg abs.	record
Exhaust back pressure, in. Hg abs.[A]	30.80 ± 0.05
Engine oil, psi	record
Flows	
Engines coolant, gal/min	34.3 ± 1
Fuel flow, ib/h[A]	record
Humidity, intake Air, grains/lb	79.8 ± 5.6
AFR[A]	14.25:1 to 15.25:1 (delta from the maximum stage average reading shall be ≤ 0.50)[C]
Ignition Timing	20° BTDC± 2°

[A] Critical measurement and control parameters. Controlled parameters should be targeted for the middle of the specification range.
[B] Counted from the time the temperature set points are initially adjusted to the specific levels.

pressure to the controller results in coolant flow through the heat exchanger rather than through the coolant bypass (*fail-safe*). Air-to-open/air-to-close is optional.

6.5.7.4 Control valve (TCV 104) is not required when using the alternative cooling system (see Fig. A2.3).

6.5.8 A control valve (FCV-103 in Figs. A2.1 and A2.2 and Fig. A2.6) is required for controlling the coolant flowrate to 130.0 ± 4 L/min (35 ± 1 gal/min). A Badger Meter Inc. Model No. 9003GCW36SV3A29L36, 2-way globe, 50.8 mm (2 in.), air-to-close valve is the specified valve (see X1.1.10).

6.5.9 A Viatran model 274/374, Validyne model DP15, or Rosemount model 1151 differential pressure transducer (see DPT-1 in Fig. A2.6) is required for reading the coolant flow rate at the orifice plate (see FE-103 in Fig. A2.2) (see X1.1.11).

6.5.10 The engine water pump shall either be (*1*) removed and replaced with a water pump plate as shown in Fig. A2.7 or (*2*) modified by removing the impeller and welding a block off plate onto the front of the pump or tapping the front of the pump and screwing in a pipe plug. The water pump plate can be fabricated by the laboratory or procured as Part No. OHT6A-014-A (see X1.1.12).

6.5.11 A coolant reservoir, a coolant overflow container, and a sight glass are required, as shown in Figs. A2.1 and A2.2 and Fig. A2.6. The design or model, or both of these items, is optional.

6.5.12 A control valve (TCV-101 in Fig. A2.1 and Figs. A2.4 and A2.5) is required for controlling the process water flow rate through the heat exchanger HX-1. A Badger Meter Inc. Model 9001GCW36SV3Axxx36 (air-to-close) or Model 9001GCW36SV1Axxx36 (air-to-open), 2-way globe, 25.4-mm (1-in.) valve is the specified valve (see X1.1.10). The type of trim package that may be used with this valve is optional and is designated with the fourteenth, fifteenth, and sixteenth position of the alphanumeric model number.

6.5.13 A 38.1-mm (1 ½-in.) NPT sight glass is required in the main coolant circuit (SG-1 in Figs. A2.1 and A2.2 and Fig. A2.6). The make/model is optional.

6.5.14 Brass, copper, or stainless steel materials are recommended for hard plumbing in the coolant system.

6.5.15 The materials used for process water, hot water, chilled water, process air, engine coolant overflow, and engine coolant transducer tubing are at the discretion of the laboratory.

6.5.16 The system shall have provisions (for example, low point drains) for draining all of the flushing water prior to installing a new coolant mixture.

6.6 *External Oil System*—An external oil system, as shown in Figs. A2.9-A2.19, is required. The external oil system components are listed in Fig. A2.16. Although all of the systems are interconnected in some manner, the overall external oil system is comprised of two separate circuits: (*1*) the flying flush system, which allows the oil to be changed while the engine is running, and (*2*) the circulation system for oil temperature control. The engine oil pan is considered a part of the external oil system. The external oil volume of all of the circuits as well as the length of connections and surfaces in contact with more than one oil in the flush system should be minimized to enable more thorough flying flushes.

6.6.1 The flush system has a high capacity scavenge pump, which fills a 5.68 L (6 qt) dump reservoir while fresh oil is drawn into the engine oil gallery. The dump reservoir float switch then resets certain solenoids and the engine refills to the level established by the float switch in the engine oil pan (which then closes the solenoid to the fresh oil reservoir).

6.6.2 The oil heat/cool loop uses a proportional controller to bypass the cooling heat exchanger. The temperature is controlled within narrow limits with minimal additional heat (and surface temperatures), and the system can respond quickly to establish the three different oil gallery temperatures required in the procedure. Arrange the proportional three-way control valve to go to its midpoint during the flying flushes to avoid trapping oil, and there shall be some cooling during test oil aging so that no oil is trapped in the cooler.

6.6.3 Cuprous materials are not allowed in any of the oil system (excluding the oil scavenge discharge system) except as may be required by the use of mandatory equipment in this procedure.

6.6.4 The flying flush system (see Fig. A2.9) shall have the following features (The items shown in the clouded areas in Fig. A2.9 are not specifically required. However, a system that performs these functions is required.)

6.6.4.1 A scavenge pump (P-3 in Figs. A2.9 and A2.10). A Viking Series 475, gear type, close-coupled pump, Model H475M is specified (see X1.1.13). The pump shall have an 1140 to 1150 r/min electric motor drive with a minimum of 0.56 kW (0.75 hp). Voltage and phase are optional.

6.6.4.2 A reservoir with a minimum capacity of 19 L (5 gal). It is recommended that the system include three reservoirs (one for BC oil, one for BC flush oil (BCF), and one for test oil).

6.6.4.3 An oil stirrer in each oil reservoir.

6.6.4.4 An oil heating system (with appropriate controls) for each oil reservoir with the capability of heating the oil in the reservoir to 107 ± 2.8 °C (224.6 ± 5 °F).

6.6.4.5 A dump reservoir (see Figs. A2.9-A2.12) with a minimum 6 L (6.34 qt) capacity.

6.6.4.6 A dump reservoir float switch (FLS-136 in Figs. A2.9-A2.12) is optional. A Gems Series ALS79999, catalog No. A79999, 20 VA, high temperature float switch is recommended (see X1.1.14).

6.6.4.7 Adhere to the nominal I.D. line sizes shown in Fig. A2.10.

6.6.4.8 The oil scavenge discharge system may use any plumbing materials.

6.6.5 The circulation system for oil temperature control shall have the following features:

6.6.5.1 A total volume (including oil volume in the oil pan to specified level) of not more than 5.68 L (6 qt) (see 6.6.5.16).

6.6.5.2 An engine oil pan float switch (FLS-152 in Fig. A2.9, Fig. A2.13, Fig. A2.19) is required. A Gems Series ALS79999, catalog No. A79999, 20 VA, high temperature float switch is specified (see X1.1.14).

6.6.5.3 A positive displacement oil circulation pump (P-4 in Fig. A2.9) is required. A Viking Series 4125, Model G4125, no relief valve, base mounted is specified (see X1.1.15). The pump shall have a V-belt or direct drive 1140 to 1150 r/min electric drive motor with a minimum of 0.56 kW (0.75 hp). Voltage and phase are optional.

NOTE 1—The explosion proof requirement for the motor is left to the discretion of the laboratory.

NOTE 2—Either V-belt drive or direct-coupled drive may be used. If V-belt drive is used, use a 1:1 pulley ratio so that the final speed of the pump is a nominal 1150 r/min.

6.6.5.4 Solenoid valves (FCV-150A, FCV-150C, FCV-150D, and FCV-150E, in Figs. A2.9 and A2.10) are required (see X1.1.16).

(*1*) FCV-150F and its related lines/piping are optional.

(*2*) FCV-150A is a Burkert Type 251 piston-operated valve with Type 312 solenoid valve (or a Burkert Type 2000 piston-operated valve used with a Type 311 or 330 solenoid valve) for actuation of air supply to piston valve, solenoid valve direct-coupled to piston valve, normally closed, explosion proof (left to the discretion of the laboratory), and watertight, 19.1 mm (¾ in.), 2-way, stainless steel.

(*3*) FCV-150C is a Burkert Type 251 piston-operated valve with Type 312 solenoid valve (or a Burkert Type 2000 piston-operated valve used with a Type 311 or 330 solenoid valve) for actuation of air supply to piston valve, solenoid valve direct-coupled to piston valve, normally open, explosion proof (left to the discretion of the laboratory) and watertight, 12.7 mm (½ in.), 2-way, stainless steel.

(*4*) FCV-150D, FCV-150E, and FCV-150F are Burkert Type 251 piston-operated valves used with Type 312 solenoid valve (or a Burkert Type 2000 piston-operated valve used with a Type 311 or 330 solenoid valve) for actuation of air supply to piston valve, solenoid valve, direct-coupled to piston valve, normally closed, explosion proof (left to the discretion of the laboratory) and watertight, 12.7 mm (½ in.), 2-way, stainless steel.

(*5*) Only one type of Burkert piston shall be used on a test stand.

6.6.5.5 Control valve (TCV-144 in Figs. A2.9 and A2.10) is required. The specified valve is a Badger Meter Inc. Model No. 1002TBN36SVOSALN36, 3-way globe (divert), 12.7 mm (½in.), air to open valve (X1.1.16).

6.6.5.6 Control valve (TCV-145 in Figs. A2.9 and A2.10) is optional (see X1.1.17).

6.6.5.7 A heat exchanger (HX-6 in Figs. A2.9 and A2.10) is required for oil cooling. The specified heat exchanger is an ITT Model 310-20 or a ITT Bell and Gossett, Model BP-25-20 (Part No. 5-686-04-020-001), brazed plate (see X1.1.18).

NOTE 3—The ITT Standard and ITT Bell and Gossett heat exchangers have been standardized under one model and part number. The new replacement is Model BP410-20, Part No. 5-686-04-020-002.

6.6.5.8 An electric heater (EH-5 in Figs. A2.9 and A2.10) is required for oil heating. The specified heater is a heating element inserted in the liquid Cerrobase inside a Labeco oil heater housing (see X1.1.19). Any 3000 W heater element may be used within the Labeco housing. There are two recommended heating elements: (*1*) a three element with Incaloy sheath, Chromolox Part No. GIC-MTT-330XX, 230 V, single phase, and (*2*) Wiegland Industries/Chromolox, Emerson Electric Model MTS-230A, Part No. 156-019136-014, 240 V single phase.

(1) It is specified that a thermocouple be installed in the external oil heater so that the temperature can be monitored. Install this thermocouple into the top of the heater into the Cerrobase (see Fig. A2.17) to an insertion depth of 244.48 ± 3.18 mm (9.625 ± 0.125 in.). The maximum temperature should not exceed 205°C (401°F).

(2) The procedure for replacing a heating element is detailed in Annex A3.

6.6.5.9 Install two oil filters (see FIL-2 in Figs. A2.9 and A2.10) in the external oil system. The filters specified are Oberg or Racor Model LFS-55 with an Oberg or Racor 28 µm stainless steel screen Part No. LFS 5528 (see X1.1.20).

(*1*) An alternative oil filter, Model LFS-62 with an Oberg or Racor 28-µm stainless steel screen, Part No. LFS 5528 (see X1.1.20), may be used.

(*2*) Both oil filters in the test stand shall have the same model number.

(*3*) Locate one filter anywhere in the external oil system after the oil circulation pump, and locate the other between the engine oil pump and where the oil enters the engine oil gallery.

(*4*) When replacing the test stand's oil filters to the alternative Model LFS-62, do so immediately prior to a calibration test.

6.6.5.10 Adhere to the nominal piping I.D. sizing shown in Fig. A2.9.

6.6.5.11 Use modified oil filter adapter assembly, Part No. OHT6A-007-1 (see X1.1.21) as shown in Fig. A2.18.

6.6.5.12 Engine oil plumbing shall be stainless steel tubing or piping or flexible hose suitable for use with oils at the temperatures specified. Where flexible hose is used in the external oil system, excluding the line to the dump tank, use either Aeroquip No. 8 (Part No. 2807-8) or Aeroquip No. 10 (Part No. 2807-10) (X1.1.22).

6.6.5.13 Insulation of plumbing for the external oil circulation system is mandatory, as shown in Fig. A2.6. Insulation material selection is optional but shall have a maximum thermal conductivity of 0.276 Btu • in./h • ft^2 • °F at a mean temperature of 90°F.

6.6.5.14 *Engine Oil Pan*—Oil pan (Ford Part No. F1AZ-6675-A or F2AZ-6675-A) is required. A modified oil pan may be fabricated by the laboratory or procured as Part No. OHT6A-006-1 (see X1.1.23). All stock baffles shall be removed from the pan. An oil pan baffle, as shown in Fig. A2.14, is required and shall be installed as shown in Fig. A2.13. The oil pan connections for connecting to the external oil system shall be as shown in Fig. A2.13 and Fig. A2.15. Install a viewing window on the right side of the oil pan, as shown in Fig. A2.13. An optional additional viewing window may be installed on the left side of the oil pan. Install a float switch (FLS-152 in Fig. A2.9, Gems Series ALS79999, catalog No. 79999) (see X1.1.14) in the oil pan. The float switch may be mounted from the pan bottom, as shown in Fig. A2.13 and Fig. A2.15, or from an adjustable rod through the dipstick hole (see Fig. A2.19).

(*a*) *Oil Pan Baffle*—Fig. A2.13 illustrates a side view of the oil pan and the position of the baffle on the left inside wall of the pan. The ears on each end of the baffle are bent about 45° toward the wall of the pan. The top edge of the baffle fits tight against the wall and is inclined downward toward the front of the engine approximately 23°, with respect to the pan rail. When the baffle is tack-welded in this position, the opening at the bottom of the baffle will divert the incoming stream of oil downward and a little toward the back of the pan.

6.6.5.15 *Oil Pump Screen and Pickup Tube*—Cut off the steel engine oil pick up tube immediately above the oil screen and weld a 15 to 18-cm (6 to 7-in.) long, straight, stainless steel tube of the same I.D. and outside diameter (O.D.) as the original tube to the end so the tube will project down through the fitting in the bottom of the pan. The pick up tube can be modified by the laboratory or procured as Part No. OHT6A-008-1 (see X1.1.23). Make the fitting in the bottom of the pan from a Swagelok SS-1210-1-8, ¾-in. compression by ½-in. NPT fitting. Cut the NPT end off and weld remaining part to the underside outside bottom of the oil pan. There will then be an inside shoulder in the fitting to drill out for the ¾-in. O.D. tube to pass through (see Fig. A2.13).

(1) Use the double nylon ferrules (Part No. T-1213-1 and T-1214-1) to seal against the steel tube rather than metal ones to avoid crimping the wall of the tube (which can make it difficult to reseal after removing the oil pan).

(2) After the oil pan is installed on the engine and the use of a compression fitting is arranged to connect the tube to an external oil hose, the suction tube may be shortened, if necessary.

6.6.5.16 *Engine Oil Level Control*—Fit the engine oil pan with a window on the right side, as shown in Fig. A2.13, as a provision for monitoring the oil level while the engine is running and to allow observation of the *flying flush* oil changes.

(*a*) An oil sump *full* level is specified as 40 ± 10 mm (1.57 ± 0.4 in.) below the machined surface of the oil pan rail at the bottom of the block, measured along the vertical centerline of the window while the engine is running under flush and aging conditions (125°C oil gallery, 105°C coolant in, 1500 r/min, 15.4 kW). A suitable mark is required on the window at this full level. At other oil temperatures, the oil level will be significantly different.

6.7 *Fuel System*—A typical fuel delivery system incorporating all of the required features is shown in Fig. A2.20. The fuel system shall include provisions for measuring and controlling fuel temperature and pressure into the fuel flow measuring equipment and into the engine fuel rail.

6.7.1 There shall be a minimum of 10 cm (3.9 in.) of flexible line at the inlet and outlet of the fuel flow meter (rubber/synthetic suitable for use with gasoline). Compression fittings are allowed for connecting the flexible lines to the fuel flow meter. Fuel supply lines from the fuel flow measurement equipment to the engine fuel rail shall be stainless steel tubing or piping or any flexible hose suitable for use with gasoline. The fuel return line from the engine shall have a minimum I.D. of 6.35 mm (0.25 in.).

6.7.2 *Fuel Flow Measurement*—Fuel flow rate measurement is critical and is recorded throughout the test. A Micro Motion Model D-6 mass flow meter with an RFT9712 Smart Family or RFT9739 transmitter, or a Model CMF010 mass flow meter with an RFT9739 transmitter are specified (see X1.1.24). The Micro Motion sensor may be mounted in a vertical or a horizontal position.

6.7.2.1 Fuel flow measurement is coordinated to allow a meaningful calculation of brake specific fuel consumption in kg/kW-h (lb/hp-h). Specifically, speed, load, fuel flow, and air-fuel ratio (AFR) are time averaged over the same 100 to 120 s interval with reasonable provision exercised to minimize measurement lag factors. The use of frequency output from the fuel flow meter is recommended to avoid electrical noise affecting analog signal output.

6.7.3 *Fuel Temperature and Pressure Control to the Fuel Flow Meter*—Maintain fuel temperature and pressure to the fuel flow meter at the values specified in Tables 2-5. Precise fuel pressure control without fluctuation or aeration is mandatory for test precision. The fuel pressure regulator PRG 116 shall have a safety pressure relief, or a pressure relief valve, PRV 113, parallel to PRG 116 for safety purposes.

6.7.4 *Fuel Temperature and Pressure Control to Engine Fuel Rail*—Maintain fuel temperature and pressure to the engine fuel at the values specified in Tables 2-5. Precise fuel pressure control without fluctuation or aeration is mandatory for test precision.

6.7.5 *Fuel Supply Pumps*—The method of providing fuel to the fuel flow meter is at the laboratory's discretion as long as the requirements for fuel pressure and temperature are met. For providing fuel from the fuel flow meter to the engine fuel rail, use a car type fuel pump, Ford Part No. E7TF-9C407 or E7TC-9C407. The minimum fuel pressure is 205 kPa (30 psig) and the maximum is 310 kPa (45 psig).

6.7.6 *Fuel Filtering*—Filtering of the fuel supplied to the test stand is required in order to minimize fuel injector difficulties.

6.8 *Engine Intake Air Supply*—Suitable apparatus is required to deliver approximately 4.0 m^3/min (140 ft^3/min) of air to the engine intake air filter. The intake air supply system shall be capable of controlling moisture content, dry bulb temperature, and inlet air pressure, as specified in Table 2 and Table 3, which is 11.4 ± 0.8 g/kg of dry air (79.8 ± 5.6 grains/lb of dry air), 27 ± 2°C (80.8 ± 3.6°F), and 0.05 ± 0.02 kPa (0.2 ± 0.1 in H_2O). The engine intake air system components are considered part of the laboratory intake air system and are specified and are shown in Fig. A2.21 and in the 1993 Ford Service manual[13], page 03-12-2.

6.8.1 *Humidity*—Measure humidity with the laboratory's primary humidity system. Correct each reading for nonstandard barometric conditions, using the following equation:

$$\text{Humidity (corrected), grains/lb} = 4354\times (\text{Psat}/(\text{Pbar}-\text{Psat})) \quad (1)$$

where:
Psat = saturation pressure (in. Hg), and
Pbar = barometric pressure (in. Hg).

SI Units:

$$\text{Humidity (corrected), g/Kg} = 621.98 \times (\text{Psat}/(\text{Pbar}-\text{Psat})) \quad (2)$$

where:
Psat = saturation pressure (mm Hg), and
Pbar = barometric pressure (mm Hg).

6.8.2 *Intake Air Filtration*—The air supply system should provide either water-washed or filtered air to the duct. Any filtration apparatus utilized shall have sufficient flow capacity to permit control of the air pressure at the engine.

6.8.3 *Intake Air Pressure Relief*—The intake air system shall have a pressure relief device located upstream of the engine intake air filter snorkel. The design of the relief device is not specified.

6.9 *Temperature Measurement*—The test requires the accurate measurement of oil, coolant, and fuel temperatures, and care must be taken to ensure temperature measurement accuracy. Follow the guidelines outlined by RR:D02–1218.[14]

6.9.1 All temperature devices should be checked for accuracy at the temperature levels at which they are to be used. This is particularly true of the thermocouples used in the oil gallery, the coolant in, the inlet air, and the fuel to fuel rail. Iron-Constantan (Type J) thermocouples are recommended for temperature measurement, but either Type J or Type K (Chromel-Alumel) thermocouples may be used.

6.9.2 All thermocouples (excluding the oil heater thermocouple) shall be premium grade, sheathed types with premium wire. Use thermocouples of 3.2-mm (⅛-in.) diameter. Thermocouple lengths are not specified, but in all cases should be long

TABLE 5 Sequence VIA New Engine Cyclic Break-in

	Cycle	
	A	B
Time at each step, min.	4	1
Time to decelerate to Step A, s		15
Time to accelerate to Step B, s	4 to 5	
Speed, r/min	1500 ± 50	3500 ± 50
Power, kW (hp)	7.5 (10.1)	20.9 (28)
Load, N-m (lbf-ft)	48.00 (35.4) ± 5.00 (± 3.69)	57.00 (42.04) ±5.00 (± 3.69)
Oil gallery, °C (°F)	105 (221) ± 2 (± 3)	105 (221) ±2 (± 3)
Coolant, in, °C (°F)	95 (203) ± 2 (± 3)	95 (203) ±2 (± 3)
Coolant flow, L/min (g/min)	130 (34.3) ± 4 (± 2)	130 (34.3) ±4 (± 2)
Intake air temperature and humidity	control not required	
Ignition timing, ° BTDC	record	not specified
Exhaust back pressure, kPa (in. Hg, abs.)	104.0 (30.80) ± 0.34 (± 0.1)	not specified
AFR	record	not specified
Fuel pressure to fuel rail, kPa (psi)	205 to 310 (30 to 45)	205 to 310 (30 to 45)
Fuel temperature to fuel rail, °C (°F)	20 (68) ± 2 (± 3.6)	20 (68) ±2 (± 3.6)
Fuel flow, kg/h (kb/h)	record	not specified
BSFC, kg/kW•h (kb/hp•h)	record	not specified

[13] Available from HELM, Inc., 14310 Hamilton Ave., Highland Park, MI 48203.

[14] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: D02-1218.

enough to allow thermocouple tip insertion to be in mid-stream of the medium being measured. The thermocouples shall not have greater than 5 cm (2 in.) of thermocouple sheath exposed to laboratory ambient.

6.9.3 Some recommended sources of thermocouples are Leeds and Northrup, Conax, Omega, Revere, and Thermo Sensor. In any case, thermocouples, wires, and extension wires should be matched to perform in accordance with the special limits of error as defined by ANSI MC96.1-1975.

6.9.4 System quality shall be adequate to permit calibration to ± 0.56 °C (1 °F) for individual thermocouples.

6.9.5 *Thermocouple Location*—All thermocouple tips should be located in the center of the stream of the medium being measured unless otherwise specified.

6.9.5.1 *Oil Inlet (Gallery)*—Insert the thermocouple into the modified oil filter adapter plate so that the thermocouple tip is flush with the face of the adapter and located in the center of the stream of flow, as shown in Fig. A2.18, (that is, remove the O-ring from the adapter, place the adapter face on a flat surface, and insert the thermocouple into the adapter until the thermocouple tip is flush with the flat surface, and lock thermocouple into place).

6.9.5.2 *Oil Circulation*—Locate the oil circulation thermocouple in the tee in the rear of the oil pan where the oil from the external heat/cool circuit returns oil to the pan. The tip of the thermocouple shall be at the junction of the side opening in the tee with respect to the through passage in the tee.

6.9.5.3 *Engine Coolant In*—Locate the thermocouple tip in the center of the stream of flow and within 15 cm (5.9 in.) of the housing inlet.

6.9.5.4 *Engine Coolant Out*—Locate the thermocouple tip in the center of the stream of flow and in the coolant return neck within 8 cm (3.15 in.) of the housing outlet.

6.9.5.5 *Intake Air*—Locate the thermocouple in the Ford air cleaner assembly on the clean side of the filter as shown in Fig. A2.21.

6.9.5.6 *Fuel to Fuel Flow Meter*—Locate the thermocouple within 10 to 50-cm (3.9 to 19.7-in.) line length upstream of the fuel flow meter inlet.

6.9.5.7 *Fuel to Engine Fuel Rail*—Insert the thermocouple into the center of a tee or cross fitting and locate it a minimum of 15 cm (5.9 in.) downstream of the fuel pump and within 15-cm (5.9-in.) line length of the fuel rail inlet.

6.9.5.8 *Load Cell*—Locate the thermocouple within the load cell enclosure.

6.10 *AFR Determination*—Determine engine AFR by an AFR analyzer. Analysis equipment shall be capable of near continuous operation for 30-min periods.

6.10.1 The air fuel ratio analyzer shall meet the following specifications:

Measurement Range	AFR: 10.00 to 30.00 with H/C = 1.85, O/C = 0.00
Accuracy	± 0.1 AFR when 14.7 AFR with H/C = 1.85, O/C = 0.000

Temperature (exhaust gas used by sensor) 700 to 900 °C

A Horiba Model MEXA 110 analyzer is recommended (see X1.1.25).

6.10.2 The specified location of the analyzer sensing element is in the exhaust system, as shown in Fig. A2.22.

6.11 *Exhaust and Exhaust Back Pressure Systems*:

6.11.1 *Exhaust Manifolds*—Use production cast iron exhaust manifolds, Ford Part No. F1AZ-9430 or F1AE-9430 (casting No. RF F1AE-9430-BB) for right hand and Part No. F1AZ-9431 or F1AE-9431 (casting No. RF F1AE-9431-BB) for left hand.

6.11.2 *Laboratory Exhaust System*—The exhaust system specified is shown in Fig. A2.22. Components can be radially oriented to ease installation, but install all components in the order shown. The design of the system downstream from the location shown in Fig. A2.22 is at the discretion of the laboratory.

6.11.3 *Exhaust Back Pressure*—The exhaust system shall have the capability for controlling exhaust back pressure to the pressures specified in Tables 2-5. The specified exhaust back pressure probe is shown in Fig. A2.23, and the specified exhaust back pressure probe location in the exhaust system is shown in Fig. A2.22.

6.11.4 *AFR Analyzer Probe*—The specified AFR analyzer probe (see 6.10) location is shown in Fig. A2.22.

6.12 *Pressure Measurement and Pressure Sensor Locations*—Pressure measurement systems for this test method are specified in general terms of overall accuracy and resolution with explicit pressure tap locations specified. Gages or other pressure devices (such as electronic transducers) may be used but shall follow the guidelines outlined by RR:D02–1218.[14]

6.12.1 Connecting tubing between the pressure tap locations and the final pressure sensors should incorporate condensation traps as directed by good engineering judgment. This precaution is particularly important when low air pressures (as in this test method) are transmitted by way of lines that pass through low-lying trenches between the test stand and the instrument console. Pressure sensors should be mounted at the same elevation as the pressure taps.

6.12.2 *Engine Oil*—Locate the pressure tap for the engine oil pressure at the oil filter adapter. Accuracy of 1 % with 6.9 kPa (1 psi) resolution is required.

6.12.3 *Fuel to Fuel Flow Meter*—Locate the pressure tap within 5 m from the fuel inlet of the fuel flow meter. Accuracy of 3.5 kPa (0.5 psi) is required.

6.12.4 *Fuel to Engine Fuel Rail*—Locate the pressure tap a minimum of 15 cm (5.9 in.) from the outlet of the car type fuel pump and within 15-cm (5.9-in.) line length of the inlet to the fuel rail. Accuracy of 3.5 kPa (0.5 psi) is required.

6.12.5 *Exhaust Back Pressure*—Locate the exhaust back pressure probe, as shown in Fig. A2.23. The sensor shall be accurate to within 2 % with resolution of 25 Pa (0.1 in. H_2O).

6.12.6 *Intake Air*—Measure the intake air pressure at the location shown in Fig. A2.21. Sensor/readout accuracy required is 2 % with resolution of 5.0 Pa (0.02 in. H_2O).

6.12.7 *Intake Manifold Vacuum/Absolute Pressure*—Measure the intake manifold vacuum/absolute pressure at the throttle body adapter. A sensor having accuracy within 1 % and with 0.68 kPa (0.1 in. Hg) resolution is required.

6.12.8 *Coolant Flow Differential Pressure*—See 6.5.9.

6.13 *Engine Hardware and Related Apparatus*—This section describes engine related apparatus requiring special purchase, assembly, fabrication, or modification. Part numbers not otherwise identified are Ford service part numbers.

6.13.1 *Test Engine Configuration*—The test engine is a 1993 4.6-L Ford V-8 engine equipped with fuel injection. Purchase the engine as a test ready unit (for procurement see X1.1.3). The engine may not be disassembled and shall be used in an as received condition. Only external engine dress items are to be installed by the laboratory.

6.13.2 *ECM/EEC (Engine Control) Module*—Use a special modified ECM/EEC IV, Part No. OHT6A-002-1 engine control module, Ford part name SMO-100 (see X1.1.26). This module controls ignition and fuel supply functions. Equip this unit with a special EPROM No. GSALB-OH, Part No. OHT6A-005-1 (see X1.1.27).

6.13.3 *Thermostat/Orifice Plate*—Use an orifice plate, as shown in Fig. A2.24, in place of the thermostat. The orifice plate can be fabricated by the laboratory or procured as Part No. OHT6A-004-1 (see X1.1.28).

6.13.4 *Intake Manifold*—Modify the intake manifold, part No. F1AZ-9424-C, F1AE-9424 or F1AE-9425. Plug the intake manifold coolant by-pass passage (port under the orifice plate).

6.13.5 *Flywheel*—A special manual flywheel, Part No. F622-6375-AB is required (see X1.1.29). Modify the flywheel in accordance with laboratory practice to allow for connection to the test stand driveshaft.

6.13.6 *Wiring Harnesses*—Two wiring harnesses are used. One is a fuel injector sub-harness and the other is an engine ECM/EEC wiring harness. The fuel injector sub-harness is to be one of the following part numbers: F3VB-12522, F3VB-12A522, F3AB-12A522, F3BL-12A522, F2AZ-9D930-A, or F3AZ-12A522. These harnesses are available from Ford dealers and are similar to that shown in the 1993 Ford service manual, Fig. K16182-A, page 18-01-22. Disconnect items 11, 14, 21, and 23 shown in Fig. K16182-A from the harness. The other wiring harness is an engine wiring harness, Part No. OHT6A-001-1 (X1.1.30) and is used to connect the car-type harness to the ECM/EEC.

NOTE 4—A full size version of the engine wiring schematic may be obtained from ASTM-TMC. It is not possible to include a reduced size figure in this standard because of the complexity of the details.

6.13.7 *EGR Block-Off Plate*—Remove the EGR valve and replace with a block-off plate, which is to be fabricated by the laboratory. Cut off the EGR tube near the exhaust manifold, crimp, and weld shut or plug.

6.13.8 *Oil Pan*—Use oil pan, Part No. F1AZ-6675-A or F2AZ-6675-A. Modify the oil pan as detailed in 6.6.5.14 and Figs. A2.1-A2.5.

6.13.9 *Oil Pump Screen and Pickup Tube*—Use oil pump screen and pickup tube, Part No. F2AZ-6622. Remove the oil pump screen and modify the pickup tube as detailed in 6.6.5.15.

6.13.10 *Idle Speed Control Solenoid (ISC) Block-Off Plate*—Remove the idle speed control solenoid (idle air bypass valve) and replace with a block-off plate, which is to be fabricated by the laboratory.

6.13.11 *Engine Water Pump*—Modify or replace as detailed in 6.5.10.

6.13.12 *Thermostat Housing*—Use thermostat housing, Part No. F1VY-8592-A or F1AE-8594. Modify for engine coolant out thermocouple installation (see 6.9.5.4) or procure as Part No. OHT6A-010-1 (see X1.1.31).

6.13.13 *Oil Filter Adapter*—Use oil filter adapter, Part No. F1AZ-6881, F1AE-6881, or F1AE-6884. Modify for engine coolant in thermocouple installation (see 6.9.5.3) or procure as Part No. OHT6A-009-1 (see X1.1.32).

6.13.14 *Fuel Rail*—Use fuel rail, Part No. F2AZ-9F792-A or F2AE-9F792. Modify the fuel rail inlet and outlet connections for connection to the laboratory fuel supply system or use a fuel rail adapter set, which may be procurred as Part No. OHT6A-011-1 (see X1.1.33).

6.14 *Miscellaneous Apparatus Related to Engine Operation*:

6.14.1 *Timing Light*—Use an inductive pickup type timing light during the test. (**Warning**—Some types of timing lights will read out double the actual ignition timing when used on this engine.)

7. Reagents and Materials

7.1 *Engine Oil*:

7.1.1 *ASTM Baseline Calibration Oil (BC)*, (see X1.1.2) is used for new engine break-in and as a primary reference oil for evaluation of test oils. It is an SAE 5W-30 grade. Approximately 38 L (10 gal) of BC oil are required for each test.

7.1.2 *ASTM BCF*, (see X1.1.2) is a special flushing oil (BC oil with increased solubility) that is used when changing oil after a test oil has been in the engine. Approximately 6 L (6.3 qt) of flush oil are required for each test.

7.2 *Test Fuel*—The test fuel required is the U.S. Federal Emission Data fuel, blended to the somewhat tighter specification used by the U.S. test fuel supplier industry. Potential fuel suppliers are Amoco Oil Co.[15], Howell Hydrocarbons and Chemicals, Inc.[16], Phillips Chemical Co.[17], and Sun Refining and Marketing Co.[18] Test repeatability may be improved if one of the above fuels is used, but in any event the fuel used shall meet the specifications of Table 6. (**Warning**—Danger! Extremely flammable. Vapors harmful if inhaled. Vapors may cause flash fire. (see A6.2.1))

7.2.1 *Laboratory Fuel Sampling and Analysis*—Monitor the test fuel in a manner consistent with good laboratory practices. It is suggested that periodic samples be analyzed to ensure that the fuel has neither excessively deteriorated nor been contaminated in storage. The following inspections are recommended:

7.2.1.1 RVP, Test Method D 323 or Automatic Reid Vapor Pressure Analyzer,

7.2.1.2 API Gravity, Test Method D 287,

7.2.1.3 Existent Gum, Test Method D 381,

[15] Available from Amoco Oil Co., P.O. Box 3011, Naperville, IL 60566-7011.

[16] Available from Howell Hydrocarbons and Chemicals, Inc., 1201 South Sheldon Rd., P.O. Box 429, Channelview, TX 77530-0426.

[17] Available from Phillips Chemical Co., Specialty Chemicals, P.O. Box 968, Borger, TX 79008.

[18] Available from Sun Refining and Marketing Co., P.O. Box 11325, Marcus Hook, PA 19061.

TABLE 6 Sequence VIA Fuel Specification

Fuel Parameter	Test Method	Analytical Results SI Units	Inch-pound Units
Octane, research min	D 2699	96	
Pb (organic), mg/L, max	D 3237	13.2	(0.05 g/U.S. gal)
Sensitivity, min		7.5	
Distillation range			
IBP, °C	D 86	23.9 to 35	(75 to 95 °F)
10 % point, °C	D 86	48.9 to 57.2	(120 to 135 °F)
50 % point, °C	D 86	93.3 to 110	(200 to 230 °F)
90 % point, °C	D 86	148.9 to 162.8	(300 to 325 °F)
E.P., °C (max)	D 86	212.8	(415 °F)
Sulfur, weight %, max	D 4294	0.10	
Phosphorous, mg/L, max	D 3231	1.32	(0.005g/U.S. gal)
RVP, kPa	D 323	60.0 to 63.4	(8.7 to 9.2 psig)
Hydrocarbon composition			
Olefins, %, max	D 1319	10	
Aromatics, %, max	D 1319	35	
Saturates	D 1319	remainder	
Existent gum, mg/100mL, max	D 381	5.0	
Oxidation stability, min, min	D 525	500	
Carbon weight fraction	E 191 (Specification)	report	
Hydrogen/carbon ratio, mol basis	E 191 (Specification)	report	
Net heating value, Btu/lb	D 240	report	
Net heating value, Btu/lb	D 3338	report	
API gravity	D 287	report	

7.2.1.4 Oxidation Stability, Test Method D 525,

7.2.1.5 Distillation, Test Method D 86,

7.2.1.6 Sulfur, Test Method D 4294, and

7.2.1.7 Lead Content, Test Method D 3237.

7.2.2 *Fuel Batch Usage*—Run complete test sequences on a single batch of test fuel. If a new batch of test fuel is introduced to the laboratory fuel supply system, it shall be done between finite tests.

7.3 *Engine Coolant*—The engine coolant shall be 50/50 volume % commercial additized ethylene glycol coolant/water. Water should be deionized, demineralized, or distilled.

7.4 *Cleaning Materials*:

7.4.1 *Organic Solvent*—Penmul L460 (see X1.1.34). (**Warning**—Harmful vapor. Store at moderate temperature. See A6.2.2.2.)

7.4.2 *Oakite 811* (see X1.1.35). (**Warning**—Harmful vapor. Store at moderate temperature. See A6.2.2.3.)

7.4.3 *Aliphatic Naphtha* (see X1.1.36). (**Warning**—Combustible. Harmful vapor. See A6.2.2.4.)

7.4.4 *Engine Cooling System Cleanser* (**Warning**—Toxic Substance. Avoid contact with eyes, skin, and clothing. See A6.2.2.5.) Consists of the following (see X1.1.37):

7.4.4.1 *Oxalic Acid Dihydrate Tech*. (**Warning**—Toxic substance. Avoid contact with eyes, skin, and clothing. See A6.2.2.6.)

7.4.4.2 *Alkylated Naphthalene, Sodium Salt*—Petro dispersant 425 (soap).

7.4.4.3 *Soda Ash Light*—(Neutralization).

7.5 *Sealing Compounds*—No specific sealing compounds are required (see 9.3.3).

8. Preparation of Apparatus

8.1 This section assumes that the engine test stand facilities and hardware, as described in Section 6, are in place. Emphasis is on the recurring preparations needed in the routine conduct of the test.

8.2 *Test Stand Preparation*:

8.2.1 *Instrumentation Preparation*—Perform the calibration of the temperature measuring system, the dynamometer load measuring system, the fuel flow measuring system, and the pressure measuring system (see 10.3 for additional details concerning instrumentation calibration) in a manner consistent with good laboratory practices and record it for future reference.

8.2.2 *External Oil System Cleaning*—Clean the entire external oil system using the engine cleaning solvent (see 7.4.1) each time a newly built engine is installed.

8.2.3 *Exhaust Back Pressure Probe Renewal*—The exhaust back pressure probe can be used until it becomes cracked, brittle, or deformed. Clean the outer surface of the probe and clear all port holes. Check the probe for possible internal obstruction and reinstall the probe in the exhaust pipe. Stainless steel probes are generally serviceable or several tests; mild steel probes tend to become brittle after fewer tests.

8.2.4 *AFR Sensor Renewal*—Inspect AFR sensor (see 10.3 for AFR system calibration requirements).

8.2.5 *Hose Replacement*—Inspect all hoses and replace any that are deteriorated. Check for internal wall separations that would cause flow restriction.

9. Engine Preparation

9.1 Purchase the engine as a test ready unit (for procurement see X1.1.3). The engine may not be disassembled and shall be used in an as received condition. The only exceptions are external engine dress items to be installed by the laboratory and the valve stem seals can be replaced when necessary. Utilize Ford service parts for a 1993 model year engine (non-AODE transmission) or Sequence VIA parts.

9.2 *Cleaning of Engine Parts*:

9.2.1 *Cleaning*—Soak any parts to be cleaned in degreasing solvent until clean (see X1.1.36).

9.2.2 *Rinsing*—Wash the parts thoroughly with hot water.

9.3 *Engine Assembly Procedure*:

9.3.1 *General Assembly Instructions*—Assemble the external engine dress components in accordance with the detailed description in the 1993 Ford Service Manual. However, in cases of disparity, the explicit instructions contained in this test method take precedence over the service manual.

9.3.1.1 Do not use sealers in tape form (loose shreds of tape can circulate in the engine oil and plug critical orifices).

9.3.2 *Bolt Torque Specifications*—When installing the engine components, use a reliable torque wrench to obtain the values listed in Table 7. These specifications are for clean and lightly lubricated threads only. Dirty or dry threads produce

TABLE 7 Fastener Torque Specifications

Description	N-m	lbf-ft
Air bypass valve to intake manifold adapter	8-11	71-97 lbf-in
Air supply tube clamps	1.7-2.6	15-23
Cable bracket retaining bolt	8-12	70-106 lbf-in
Camshaft covers	8-12	70-106 lbf-in
Crankshaft damper to crankshaft	155-165	114-121
Crankshaft position sensor (CKP) and CID sensor retaining bolts	8-12	70-106 lbf-in
Engine coolant temperature sensor (ECT)	16-24	12-17
EGR valve to intake manifold (block-off plate)	20-30	15-22
EGR valve line nut to exhaust manifold connector	35-45	26-33
EGR tube connector	45-65	33-48
Exhaust manifold nuts	27-41	20-30
Exhaust manifold to cylinder head	20-30	15-22
Engine-to-transmission brackets	25-43	18-31
Flywheel to crankshaft	73-87	54-64
Front engine support insulators	20-30	15-22
Front engine support insulator through bolts	20-30	15-22
Fuel pressure regulator to fuel rail assembly	3.0-4.5	27-40 lbf-in
Fuel rail assembly retaining bolts	8-12	70-106 lbf-in
Heater water hose	20-30	15-22
Heater water hose retaining bolts	20-30	15-22
Heated oxygen sensor (HEGO)	37-45	27-33
Idle air control valve (IAC) bolts	8-12	70-106 lbf-in
Ignition wire tray-to-coil brackets	8-12	70-106 lbf-in
Intake manifold to cylinder head	20-30	15-22
Oil bypass filter to adapter	¾ turn past seal contact	
Oil filter adapter bolt	20-30	15-22
Oil level indicator tube to block	8-12	70-106 lbf-in
Oil pan drain plug	11-16	8-12
Oil pan to cylinder block	20-30	15-22
Oil pressure sender/sensor	16-24	12-18
Rear engine support insulator to support	20-30	15-22
Rear engine support insulator to transmission retaining bolts	40-60	30-44
Spark plug to cylinder head	9-12	80-106 lbf-in
Thermostat to intake manifold	20-30	15-22
Throttle body and adapter bolts	8-12	70-106 lbf-in
Throttle position sensor to throttle body	1.2-1.8	11-16 lbf-in
Water pump to cylinder block (or block-off plate)	20-30	15-22
Water temperature indicator sending unit	16-24	12-17

friction, which prevents accurate measurements of the actual torque. It is important that these specifications be observed. Overtightening can damage threads, which may prevent attainment of the proper torque and may require replacement of the damaged part.

9.3.3 *Sealing Compounds*—Sealing compounds are not specified. Use engineering judgment governing the use of sealing compounds. (**Warning**—Silicone-based sealers may elevate the indicated Si content of used oil.)

9.3.4 New parts required for each new engine (see X1.1.3) are listed in Annex A4.

9.3.5 *Harmonic Balancer*—The balancer, Part No. F1AZ-6316-A, is included on the engine by the engine supplier.

9.3.6 *Oil Pan*—Install oil pan, Part No. F1AZ-6675-A or F2AZ-6675-A, and modify as detailed in 6.6.5.14 and as shown in Figs. A2.13-A2.15. Use gasket, Part No. F1AZ-6710-A. Torque the bolts in the sequence shown in 1993 Ford Service Manual, Fig. A14940-A, page 03-01-19.

9.3.7 *Intake Manifold*—Install intake manifold, Part No. F1AZ-9424-C, F1AE-9424, or F1AE-9425. Use gaskets, Part No. F1AZ-9461-A. Torque the bolts in the sequence shown in 1993 Ford Service Manual, Fig. A14812-A, page 03-01-09. Modify the intake manifold as detailed in 6.13.4.

9.3.8 *Camshaft Covers*—Camshaft covers are right hand, Part No. F1AZ-6582-A; left hand, Part No. F1AZ-6582-B. Use gaskets, right hand, Part No. F1AZ-6584-A: left hand, Part No. F1AZ-6584-B. These are included on the engine by the engine supplier.

9.3.9 *Thermostat*—Remove the thermostat and replace with a thermostat orifice plate, as shown in Fig. A2.24 (see X1.1.28 and see 6.13.3).

9.3.10 *Thermostat Housing*—Install a modified thermostat housing (see 6.13.12), Part No. F1VY-8592-A, F1AE-8594, or OHT 6A-01010-1. Use gasket, Part No. F1VY-8255-A.

9.3.11 *Coolant Inlet*—Modify the coolant inlet connection, which is cast as a part of the oil filter adapter (see 9.3.12 and 6.13.13). This is included on the engine by the engine supplier.

9.3.12 *Oil Filter Adapter*—The oil filter adapter is Part No. F1AZ-6881, F1AE-6881, or F1AE-6884 and is included on the engine by the engine supplier. Modify the adapter (see 6.13.13) or use Part No. OHT 6A-009-1. Use gasket, Part No. F1AZ-6840-A.

9.3.13 *Dipstick Tube*—Dipstick tube, Part No. F1AZ-6754-A is included on the engine by the engine supplier.

9.3.14 *Water Pump*—Install a modified water pump or a water pump plate (see 6.5.10; Fig. A2.7).

9.3.15 *Sensors, Switches, Valves, and Positioners*:

9.3.15.1 *Oil Pressure Switch and Oil Pressure Sensor*—Install oil pressure switch, Part No. E9SZ-9278-A and oil pressure sensor, Part No. 90290 or plugs.

9.3.15.2 *Camshaft Positioner Sensor (CMP)*—Camshaft position sensor, Part No. F1AZ-6B288-A, is included on the engine by the engine supplier.

9.3.15.3 *Crankshaft Position Sensor (CKP)*—Crankshaft position sensor, Part No. F1AZ-6C315-A, is included on the engine by the engine supplier.

9.3.15.4 *Water Temperature Indicator Sender Unit*—Install water temperature indicator sender unit, Part No. F1SZ-10884-A or F1SF-10884.

9.3.15.5 *Idle Speed Control Solenoid (ISC)*—Idle air control valve (idle air bypass valve) is not used; replace with a block-off plate (see 6.13.10).

9.3.15.6 *EGR Valve*—The EGR valve is not used. Replace with a block-off plate (see 6.13.7).

9.3.15.7 *EGR Valve Positioner (EVP) Sensor*—EGR valve position sensor is not used.

9.3.15.8 *EGR Vacuum Regulator (EVR) Sensor*—EGR vacuum regulator sensor is not used. Plug the vacuum lines that would normally be connected to this sensor.

9.3.15.9 *Throttle Position (TP) Sensor*—Install TP sensor, Part No. F2AZ-9B989-A or FZAF-9B989.

9.3.15.10 *Engine Coolant Temperature (ECT) Sensor*—Install ECT sensor, Part No. F2AZ-12A648-A or F2AF-12A648.

9.3.15.11 *Heated Exhaust Gas Oxygen Sensors (HEGO)*—Use heated exhaust gas oxygen sensors, Part No. F0TZ-9F472, F0SZ-9F472-A or F1SZ-9F472-A. Make sure that the HEGOs are correctly connected. The left side (Cylinders 5 to 8) sensor harness has a red with black stripe wire coming from the bottom right pin of the connector when looking at the plug from the front. The right side sensor (Cylinders 1 to 4) has a gray with light blue striped wire in this position.

9.3.15.12 *PCV*—Remove the PCV valve and vent all PCV points of connection to atmosphere. Plug all associated vacuum lines.

9.3.15.13 *Air Charge Temperature (ACT) Sensor*—Use ACT sensor, Part No. F2DZ-12A697.

9.3.15.14 *Mass Air Flow Sensor*—Use mass air flow sensor, Part No. F0TZ-12B579 or F2VF-12B579 (70-mm diameter).

9.3.16 *Ignition System*:

9.3.16.1 *Ignition Coils*—Install right hand and left hand ignition coils, Part Nos. F1VY-12029, F1VU-12029, F3VU-12029, or F5LU-12029. Use Ignition coil bracket, right hand Part No. F3AZ-12257, and left hand Part No. F3AZ-12257.

9.3.16.2 *Ignition Wires*—Install ignition wires, Part No. F3PZ-12259-C. Note that spark plug wires to the coil shall be positioned 45° from centerline of crankshaft (outboard and forward) to ensure boot seal is fully seated against cylinder head (1993 Ford Service Manual, Fig. B4477–B, page 03-07-6).

9.3.16.3 *Ignition Control Module (ICM)*—Install ICM, Part No. F1AZ-12K072-A or F1AF-12K072.

9.3.16.4 *Spark Plugs*—Use spark plugs, Part No. AWSF 32C or AWSF 32P. Adjust spark plug gap to 1.31 to 1.41 mm (0.052 to 0.056 in.).

9.3.17 *Fuel Injection System*:

9.3.17.1 *Fuel Injectors*—Use fuel injectors, Part No. F0TZ-9F593. Refer to Annex A10 for injector flow specifications. Verification of each injector is required prior to use.

9.3.17.2 *Fuel Rail*—Install modified fuel rail, Part No. F2AZ-9F792-A or F2AE-9F792 (see 6.13.14).

9.3.17.3 *Fuel Pressure Regulator*—Use fuel pressure regulator, Part No. E6AZ-9C968 or E7DE-9C968.

9.3.18 *Intake Air System*—The engine intake air system components may be oriented in accordance with laboratory requirement. However, use all of the specified components.

9.3.18.1 *Air Cleaner Outlet Tube Assembly (Air Box)*—Use air cleaner outlet tube, Part No. F2AZ-9B659. Install with air cleaner outlet tube clamp (which comes with the outlet tube) and bolt, Part No. F2AZ-9A624-A.

9.3.18.2 *Crankcase Ventilation Tube*—Remove crankcase ventilation tube, Part No. F1AZ-6C324-A, and plug the port in the air cleaner assembly.

9.3.18.3 *Engine Air Cleaner Assembly*—Use engine air cleaner assembly, Part No. F2AZ-9600. Modify the assembly (see 6.9.5.5 and Fig. A2.21).

9.3.18.4 *Air Cleaner Element*—Use air cleaner element, Part No. E5TZ-9601.

9.3.18.5 *Resonator Box*—Use resonator box, Part No. F2AE-9R504.

9.3.18.6 *Throttle Body*—Use throttle body, Part No. F2AZ-9E926 or F2AE-9E926.

9.3.18.7 *Throttle Body Adapter*—Use throttle body adapter, Part No. F2AE-9A589 or FI-VY-9A589.

9.3.19 *Engine Management System (Spark and Fuel Control)*:

9.3.19.1 *Engine Wiring Harness*—Use a special engine wiring harness Part No. OHT6A-001-01, engine wiring harness without interface (see X1.1.30).

9.3.19.2 *Engine Control Module (ECM)*—Use EEC IV engine control module, Part No. OHT6A-002-1 or OHT6A-002-3 ECM/EEC (see X1.1.26). This module controls ignition and fuel supply functions.

(*a*) Equip this unit with EPROM GSALB-OH-LAH, Part No. OHT6A-005-1 (see X1.1.27).

(*b*) Supply the EEC power from a battery or a regulated power supply (12 V to red wire). Ground the EEC ground wire to the engine. From the same ground point, run a 2 gage wire back to the battery negative to prevent interruption/interference of the EEC operation.

(*c*) Measure and verify the ignition timing after every new ECM installation. The ignition timing shall be 20° BTDC ± 2° (see Table 3 and Table 4).

9.3.19.3 *Keep Alive Memory (KAM)*—Disconnect the KAM from the 12 V supply (yellow wire) while running oil tests.

9.3.20 *Accessory Drive Units*—Do not use external drive units, including alternators, fuel pumps, power steering units, air pumps, and air conditioning compressors.

9.3.21 *Exhaust Manifolds*—Use exhaust manifolds, right hand Part No. F1AZ-9430-B and left hand Part No. F1AZ-9431-B, which are included on the engine by the engine supplier. Torque bolts in the sequence shown in the 1993 Ford Service Manual, Fig. A13673-A, page 03-01-10.

9.3.22 *Engine Flywheel and Guards*—The flywheel is a special unit, Part No. F6ZZ-6375-AB, manual flywheel (see X1.1.29). An engine flywheel guard and safety housing should be installed to suit test stand requirements. Modify the flywheel in accordance with laboratory practice to allow for connection to the test stand driveshaft.

9.3.23 *Lifting of Assembled Engines*—Assembled engines should not be lifted by the intake manifold since this is known to cause engine coolant leaks.

9.3.24 *Engine Mounts*—Special dynamometer laboratory engine mounts may be used for the right hand, Part No. DTSC.080.128.001 and left hand, Part No. DTSC-80-126-1

TABLE 8 Example of Pre-test Verification

Stage	Mean Stage BSFC		6 Stage Mean BSFC		Difference
1	0.70870	-	0.58470	=	0.124
2	0.75409	-	0.58470	=	0.169
3	0.57393	-	0.58470	=	-0.011
4	0.34124	-	0.58470	=	-0.243
5	0.35096	-	0.58470	=	-0.234
6	0.77926	-	0.58470	=	0.194
6 stage mean	0.58470				

mounts (see X1.1.38). The right hand and left hand mount isolators (*biscuits*) are Part No. DTSC-40-132-1 (see X1.1.39). Rear mount configuration should be in accordance with laboratory practice.

9.3.25 *Valve Stem Seals*—Valve stem seals may be replaced at the laboratory's discretion. Use the 1993 Ford Service Manual procedure and recommended tools when the seals are replaced. The required replacement seal part number is F4AE-6A517-AA. Replace the seals immediately prior to a calibration test.

10. Calibration

10.1 *BC Pre-Test Verification*—Run a BC pre-test verification to identify stage BSFC relative magnitudes and to confirm proper test apparatus controls (that is, speed, load, and fuel flow measurements). BC pre-test verifications are also run to:

10.1.1 Verify that a new engine is performing properly before conducting the new engine/stand reference, and

10.1.2 Verify the engine/stand is suitable to evaluate another test oil once sequential testing of oils has commenced.

10.1.3 Run a pre-test verification at completion of new engine break-in and as a requirement of each lubricant test.

10.1.4 Calculate the pre-test verification using the mean BSFC for all six stages and calculating the difference of this mean from each of the six individual test stage mean BSFCs to three decimal places.

10.1.5 The pre-test verification of BC is considered operationally invalid if two or more of the pre-test verification limits are exceeded. A test oil should not be introduced if this occurs. The laboratory should investigate possible causes prior to additional BC testing attempts. Laboratories should make pretest verification data available upon request to the TMC.

10.1.6 If test oil tests are being run in a *string*, that is, BC/C1/BC/C2/BC, the pre-test verification requirement and limits apply only to the BC before test oil. In the example shown in Table 8, if the BC after test oil No. 1 does not meet the pre-test verification, Table 9, requirements, this failure does not result in the test on test oil No. 1 being operationally invalid. It would, however, require that the *failing* BC not be used as the BC before test oil for the test for test oil No. 2.

10.1.7 Actions possible if pre-test verification is not satisfactory:

10.1.7.1 Continue break-in if a new engine has not successfully completed break-in.

10.1.7.2 Investigate possible stand related causes, that is, measurement calibration of speed, load, or fuel flow, or combination thereof.

10.1.7.3 If chemical contamination is suspected, then decondition with additional treatment of BCF or extended running on BC and run another BC pre-test verification.

10.2 *Engine/Test Stand Calibration*—This event will be monitored by the ASTM TMC.

10.2.1 *Procedure*—Test stand calibration is accomplished by conducting tests on ASTM TMC reference oils (X1.1.2).

TABLE 9 Pre-test Verification Limits

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
Max	0.139	0.185	0.000	-0.225	-0.215	0.216
Min	0.102	0.152	-0.021	-0.262	-0.253	0.182

Conduct reference oil tests on each test stand/engine combination within a laboratory, which is to be considered calibrated, in accordance with ASTM TMC Lubricant Test Monitoring System (LTMS) guidelines. For a given test stand/engine combination, conduct a minimum of one operationally valid, statistically acceptable reference oil test after twelve non-reference oil tests starts, or after ten operationally valid non-reference oil tests have been conducted, or after 60 days have elapsed, whichever occurs first. The 60 elapsed days are judged from the end-of-test (EOT) day of the last operationally valid, statistically acceptable reference oil test to the start-of-test (SOT) day of a calibrated non-reference oil test. If more than 30 days elapse between operationally valid tests, EOT to SOT, on a stand/engine combination, a minimum of one operationally valid, statistically acceptable (per LTMS) test is required. If acceptable results are obtained on the reference oil and the pre-test verification is acceptable, the test stand/engine is calibrated. An operationally valid pre-test verification may be substituted for an operationally valid Sequence VIA test to fulfill the 30 day requirement. The pre-test verification run shall count as one of the twelve non-reference oil test starts and does not have to meet the pre-test verification acceptance criteria. Calibrate test engines once removed from the test stand and reinstalled, even if the test number and time criteria are met by the engine. Laboratories shall inform the TMC with a written explanation when a test engine is removed from a test stand and installed into another test stand. Only appropriate test engines (X1.1.3) can be calibrated.

10.2.1.1 For new test stand/engine combinations, run the three required reference tests as follows:

(1) BC/R1/BC; report results to TMC; BC/R2/BC; report results to TMC; BC/R3/BC; report results to TMC; or

(2) BC/R1/BC/R2/BC; report results to TMC; BC/R3/BC; report results to TMC; or

(3) BC/R1/BC; report results to TMC; BC/R2/BC/R3/BC; report results to TMC; or

(4) BC/R1/BC/R2/BC/R3/BC; report results to TMC.

10.2.1.2 Run the single reference test as – BC/R1/BC; report results to TMC.

10.2.1.3 Two categories of reference oils will be identified. The categories include reference oils that demonstrate response primarily related to viscometrics and those that do not. The ASTM TMC will assign reference oils from each category for the initial reference tests and will alternate appropriately for tests thereafter. The referencing system will be reviewed once the industry database has twenty tests on an appropriate number of reference oils to determine (*a*) appropriate referencing frequency; (*b*) applicability of a severity adjustment factor; (*c*) appropriate acceptance statistics.

10.2.1.4 The effective date of a reference test is the LTMS date and time of the reference test. Test start time is defined as the introduction of the reference oil into the engine. The LTMS date and time are defined as the date and time the test was completed (completion of the BC run following the reference oil) unless a different date and time are assigned by the TMC. The TMC may schedule more frequent reference oil tests (or approve less frequent reference oil tests) at its discretion. Under special circumstances (that is, extended downtime due to industry-wide parts or fuel outages) the TMC may extend reference periods. Non-reference oil tests conducted during the extended time allowance shall be annotated in the test note section of the report.

10.2.1.5 Failure of a reference oil test to meet Shewhart or exponentially weighted moving average (EWMA) control chart limits can be indicative of a false alarm, engine, test stand, test laboratory, or industry related problem. When this occurs, the laboratory, in conjunction with the TMC, shall attempt to determine the problem source. Industry problems shall be adjudicated by the ASTM Sequence VI/VIA Surveillance Panel.

10.2.1.6 The TMC will decide, with input as needed from Industry expertise (testing laboratories, test procedure developer, ASTM Technical Guidance Committee, Surveillance Panel, and so forth) if the reason for any unacceptable blind reference oil test is isolated to one particular engine or stand or related to other stands. If it is decided that the problem is isolated to an individual engine or stand, calibrated testing on other stands may continue throughout the laboratory.

10.2.1.7 If non-standard tests are conducted on a calibrated engine or test stand, recalibrate the engine and stand prior to running standard tests. Non-standard tests are defined as those conducted with operating conditions (that is, engine speeds, loads, temperatures, and so forth) outside the normal test operating conditions or with a fuel other than the specified test fuel.

10.2.2 *Reporting of Reference Results*—Transmit the reference oil test results to the TMC (see Annex A1) using Figs. A7.1-A7.15 shown in Annex A7 immediately after completion of test analysis. The TMC will review the transmitted reference oil test results and use the LTMS to determine test acceptability. If the test is judged acceptable, the reference oil code will be disclosed by the TMC. The complete final test report package as defined in Annex A7 shall be received within 30 days of test completion by the:

Manager of Operations
ASTM Test Monitoring Center
6555 Penn Avenue
Pittsburgh, PA 15206-4489

10.2.2.1 In the event the reference oil test is not acceptable, the laboratory may elect to attempt another reference in the same engine. In the event that the engine does not attain calibration, the laboratory shall remove the engine and go through the normal process of calibrating a new engine. Operationally valid, statistically unacceptable data on removed engines will be included in all appropriate databases (industry reference oil, laboratory severity, and precision...) unless the engine failing to calibrate is a new engine (has never been calibrated and conducted non-reference oil tests).

10.2.3 *Analysis of Reference Oils*:

10.2.3.1 *Reference Oils*—Do not subject reference oils to physical or chemical analyses, or both, for identification purposes. Identifying the oils by analyses could undermine the confidentiality required to operate an effective blind reference system. Therefore, reference oils are supplied with the explicit understanding that they will not be subjected to analyses other than those specified within this procedure unless specifically authorized by the ASTM TMC. In such instances, supply written confirmation of the circumstances involved, the data to be obtained, and the name of the person requesting the analysis to the TMC.

10.2.3.2 *BC Oil and BCF Flush Oil*—The BC oil and BCF flush oil may be analyzed only to the extent required to evaluate the effectiveness of a test stand's flushing system. This analysis will be limited to molybdenum content. The BC oil or BCF oil shall not be subjected to further physical or chemical analyses, or both, other than those specified within this procedure unless specifically authorized by the TMC. In such instances, supply written confirmation of the circumstances involved, the data to be obtained, and the name of the person requesting the analysis to the TMC.

10.2.4 *Flush Effectiveness Demonstration*—A laboratory shall demonstrate the flush effectiveness of its flying flush oil system for any new stand and for any stand that has had modifications made to the oil system. By using an oil containing metal traceable by inductive coupled plasma (ICP), a laboratory shall demonstrate a 99 % flush effectiveness after the final flush of a detergent flush (see 11.5.9.1 (*j*)) when detergent flushing from the demonstration oil to BC oil. ASTM oil FEEO-103 (FM) has proven satisfactory for use in this demonstration. The procedure is as follows (FM = FM or other suitable oil containing metal traceable by ICP):

10.2.4.1 With the engine already charged with BC oil, warm engine to Stage Flush (see Table 2).

10.2.4.2 Take a 118-mL (4-oz) sample of the FM oil from the oil reservoir (sample *new* oil).

10.2.4.3 Flush in FM oil, run 30 min.

10.2.4.4 Flush in FM oil, run 30 min.

10.2.4.5 Flush in FM oil (this completes the FM oil change).

10.2.4.6 Run 30 min, take a 118-mL (4-oz) purge sample, and pour back into the engine. Take a 118-mL (4-oz) retain sample (Sample 1).

10.2.4.7 Flush to BCF flush oil, run 2 h, take a 118-mL (4-oz) purge sample, and pour back into the engine. Take a 118-mL (4-oz) retain sample (Sample 2).

10.2.4.8 Flush in BC oil, run 30 min, take a 118-mL (4-oz) purge sample, and pour back into engine. Take a 118-mL (4-oz) retain sample (Sample 3).

10.2.4.9 Flush in BC oil, run 30 min, take a 118-mL (4-oz) purge sample, and pour back into engine. Take a 118-mL (4-oz) retain sample (Sample 4).

10.2.4.10 Flush in BC oil, take a 118-mL (4-oz) purge sample, and pour back into engine. Take a 118-mL (4-oz) retain sample (Sample 5).

10.2.4.11 Analyze samples–new oil, 1, 2, 3, 4, and 5 by ICP for the traceable metal and report the results to TMC (comparison is sample 10.2.4.10 versus 10.2.4.6).

10.3 *Instrument Calibration*—Record all instrument calibrations for further reference. Perform a complete test stand instrument calibration prior to conducting the initial reference test in a new engine. A previously calibrated (existing) stand/engine will require that the following be calibrated prior to the next reference test–(*a*) engine load measurement system; (*b*) fuel flow meter; (*c*) engine speed; and (*d*) AFR analysis equipment.

10.3.1 *Engine Load Measurement System*—Calibration by use of deadweights is required at the start of a series of tests and before each reference test. Prior to calibration, start the engine and run for a minimum of 30 min at 1500 r/min and a minimum torque of 37 N-m. Shut the engine down, leave dynamometer cooling water on, and start performing the load cell calibration within 3 min after shutdown.

10.3.2 *Fuel Flow Measurement System*—Use accurate weight scale/time measurements for calibrating. Perform this calibration at three fuel flow rates (approximately 1.4, 3.2, and 5.4 kg/h). Evaluate each flow rate a minimum of three times to verify repeatability.

10.3.2.1 The test stand flowmeter shall perform to within 0.25 % at 5.4 kg/h, 0.32 % at 3.2 kg/h, and 0.54 % at 1.4 kg/h of the calibration standard. For each flow rate, a minimum of three consecutive flow readings shall be within the specified tolerance. The calibration standard shall be at least four times more accurate than the test stand flowmeter at each specified flow rate.

10.3.3 *Coolant Flow Measurement System*—Calibrate the flow measuring device a minimum of once every three months.

10.3.4 *Thermocouple and Temperature Measurement System*—The calibration of the test stand temperature measurement system (thermocouple through readout) is checked at the test stand using the existing readout system prior to running a new engine reference or a minimum of once every three months whichever occurs first. For the critical temperatures (see Table 3 or Table 4) the individual temperature sensors shall indicate within ± 0.56°C (± 1°F) of the laboratory calibration standards. The calibration equipment utilized shall be appropriate for the ± 0.56°C (± 1°F) accuracy level here specified. See 6.9 for additional thermocouple calibration requirements.

10.3.5 *Humidity Measurement System*—Calibrate the primary laboratory measurement system at each stand on a semiannual basis using a hygrometer with a minimum dew point accuracy of ±0.55°C at 16°C (±1°F at 60°F). Locate the sample tap on the air supply line to the engine in the intake air cleaner.

10.3.5.1 The calibration consists of a series of paired humidity measurements comparing the laboratory system with the calibration hygrometer. The comparison period lasts from 20 min to 2 h, with measurements taken at 1 to 6 min intervals, for a total of 20 paired measurements. The measurement interval shall be appropriate for the time constant of the humidity measuring instruments.

10.3.5.2 Verify that the flow rate is within the equipment manufacturer's specification, and that the sample lines are nonhygroscopic. Correct dew point hygrometer measurements to standard conditions (101.12 kPa [29.92 in. Hg]), using the appropriate equation (see 6.8.1). Compute the difference between each pair of readings, and calculate the mean and standard deviation of the twenty paired readings, using Eq A9.1 and A9.2 in Annex A9. The absolute value of the mean difference shall not exceed 1.43 g/kg (10 grains/lb), and the standard deviation shall not be greater than 0.714 g/kg (5 grains/lb). If these conditions are not met, investigate the cause, make repairs, and recalibrate. Maintain calibration records for two years.

10.3.6 *Other Instrumentation*—As a minimum, calibrate instrumentation for measuring parameters other then those detailed in 10.3-10.3.5.1 after every 30 non-reference oil tests or every three months, whichever occurs first.

11. Test Procedure

11.1 *Preparation for Initial Start-Up of New Engine*—Measure and verify the ignition timing as specified in Tables 3 and 4.

11.1.1 *External Oil System*—The external oil system should be cleaned each time a new engine is installed (see 8.2.2).

11.1.2 *Preparation for Oil Charge*—Check the apparatus carefully to be sure that all oil lines and fittings are properly tightened and aligned. This includes the apparatus for the flying flush oil change system.

11.1.3 *Oil Charge for Coolant Flush*—Service both oil filters (see 6.6.5.9) to ensure they are clean and that the seals are in good condition. Charge the engine with 5.68 L (6.0 qt) of fresh BC oil. Check the oil level and add as necessary to bring oil level to *full* level, (see 6.6.5.16).

11.1.4 *Engine Coolant Charge for Coolant Flush*—The hoses or tubing leading from the venturi coolant flowmeter to the differential pressure sensor may be isolated (by closing the valves or disconnecting the hoses) to prevent contamination of the water in these hoses.

11.1.4.1 Prepare cooling system cleanser solution by adding oxalic acid at the ratio of 23 g/L (3 oz/gal) and adding Petro Dispersant 425 at the ratio of 1 g/L (0.15 oz/gal) of water for the coolant flush charge (see 7.4.4). Charge the coolant system with this solution.

11.2 *Initial Engine Start-Up*—Connect the fuel line to the engine fuel rail or open the fuel shut-off valves, or both. Ready the control console (engine ignition on, external oil circulation pump on, safety circuits ready). Crank the engine. When the engine is running at idle (approximately 800 r/min, zero load), check for fuel, oil, coolant, water, and exhaust leaks. Connect the intake air supply duct. During idle, check the ignition timing to verify it is 20° BTDC.

11.3 *Coolant Flush*:

11.3.1 Operate the engine at idle conditions (800 r/min, no load) for 40 min while maintaining a coolant temperature of 65 ± 5°C (150 ± 10°F). Then open the engine block petcock and heat exchanger drain valve. Add fresh tap water to the system until the drains run clear. Continue adding fresh tap water to the system for 5 min after the drains begin running clear. Close the block and heat exchanger drains and add the cooling system neutralizer (sodium carbonate) (see 7.4.4), which has previously been mixed at the ratio of 3.8 g/L (0.50 oz/gal) of hot water.

11.3.2 After the engine has run for 45 min with the neutralizer while maintaining a coolant temperature of 65 ± 5°C (150 ± 10°F), open the drain valves and add fresh water until the drains run clear. (The pH of the incoming and outgoing water should be the same at this point). Stop adding fresh water, close drain valves, and run engine for 20 min under coolant flushing operating conditions.

11.3.3 Shut down engine using the procedure given in

11.5.8. Disconnect the intake air supply duct as soon as the engine is shut down.

11.3.4 Drain coolant.

11.3.5 Fill coolant system with pre-mixed coolant consisting of 50/50 volume % mixture of additized ethylene glycol coolant and deionized, demineralized, or distilled water.

11.3.6 Coolant charge may be reused for additional tests; however, new coolant should be installed each time a new engine is installed.

11.3.7 Perform the coolant flush procedure at the completion of a new engine break-in.

11.4 *New Engine Break-In*—A broad overview of the engine break-in is as follows:

11.4.1 A minimum of 100 h of cyclical operation with BC oil are logged as specified in 11.4.5. Hourly BSFC measurements are routinely recorded. The intense care for precision required for test operation is not required for cyclical break-in operation (see 11.4.4). After each 10 h of cyclical operation, the engine is brought to Stage 1 test conditions (see Table 3), stabilized for 1 h, and six 5-min BSFC readings are taken. This operation should be performed with the care for precision required for test operation. The total minimum length for break-in is 115 h (100 h cyclic, 15 h at Stage 1 conditions).

11.4.2 If the engine meets the stability requirements (see 11.4.6), then the engine is considered to be adequately broken-in.

11.4.3 *Oil Charge for Break-In*—At completion of compression check (see 11.3.4), service both oil filters to ensure that they are clean. Drain oil and charge the engine with 5.68 L (6 qt) of fresh BC oil. This oil charge is used for the entire new engine break-in.

11.4.4 *Break-In Operating Conditions*—Follow the break-in schedule for new engines as shown in Table 5. It is suggested that the cycling be a step function, rather than a ramped function. If a ramp function is used, take care to ensure that the ramp is not too mild, since too mild a ramp may not work the engine hard enough to successfully accomplish break-in.

11.4.5 *Break-In Operating Phases*:

11.4.5.1 *Cyclical Phase*— For ten 10-h segments, operate the engine through continuously repeating 5-min cycles defined by Cycles A and B in Table 5. Record data hourly during Cycle A, including the parameters given in 11.4.4 plus BSFC and fuel flow as a minimum. During the cyclic phase, pace measurements so as to be finished near the end of the 4-min (1500 r/min) run (Cycle A). This provides a rough indication of the BSFC (stability) trend during break-in.

11.4.5.2 *Stabilized Phase*— After each 10-h cyclical segment, operate the engine at Stage 1 for 1 h of stabilization followed by six 5-min readings (see Table 3). Run this stabilized Stage 1 phase ten times during the break-in.

11.4.5.3 *Break-In Hours*— The following is a description of the count of break-in hours (cyclic for 10 h followed by Stage 1 for 1.5 h)–10/1.5/10/1.5/10/1.5/10/1.5/10/1.5/10/1.5/10/1.5/10/1.5/10/1.5/10/1.5 = 115 h

11.4.6 *Break-In Acceptance Criteria*—The break-in operation may be terminated after a minimum of 100 h of cyclical operation and ten Stage 1 phases. As an indicator of stability, the BSFC trend of the BC oil in Stage 1 as indicated by a plot of time versus BSFC measurements should indicate an overall BSFC change after the tenth Stage 1 reading of not more than 1 % over four consecutive (70, 80, 90, and 100 h) Stage 1 readings. If the BSFC trend does not meet the suggested stability, break-in may be continued as detailed in 11.4.5 until the BSFC trend meets the suggested stability or break-in may be terminated and a BC pre-test verification run (see 10.1). In either event, a new engine shall meet the BC pre-test verification requirements (see 10.1) before a reference test is run.

11.5 *Routine Test Operation*—If no operational, calibration, or pre-test verification problems occur, non-reference oil tests may be run in a string of up to a maximum of five consecutive non-reference oil tests without a shutdown being required, for example–BC/NR1/BC/NR2/BC/NR3/BC/NR4/BC/NR5/BC. An overview of a single non-reference oil test is as follows (r/min,kW,oil temp °C):

11.5.1 Complete pre-test maintenance. A checklist for maintenance is shown in Table A11.1.

11.5.2 Start engine.

11.5.3 Warm up to flush conditions (1500/15.4/125).

11.5.4 Double flush to BC oil.

11.5.4.1 Stabilize at Stage 1 (800/2.2/105) and acquire data for Stage 1.

11.5.4.2 Stabilize at Stage 2 (800/2.2/70) and acquire data at Stage 2.

11.5.4.3 Stabilize at Stage 3 (1500/5.8/70) and acquire data at Stage 3.

11.5.4.4 Stabilize at Stage 4 (1500/15.4/70) and acquire data at Stage 4.

11.5.4.5 Stabilize at Stage 5 (1500/15.4/45) and acquire data at Stage 5.

11.5.4.6 Stabilize at Stage 6 (800/2.2/45) and acquire data at Stage 6.

11.5.5 Double flush to non-reference oil.

11.5.5.1 Age 16 h at stage age (1500/15.4/125).

11.5.5.2 Stabilize at Stage 1 (800/2.2/105) and acquire data at Stage 1.

11.5.5.3 Stabilize at Stage 2 (800/2.2/70) and acquire data at Stage 2.

11.5.5.4 Stabilize at Stage 3 (1500/5.8/70) and acquire data at Stage 3.

11.5.5.5 Stabilize at Stage 4 (1500/15.4/70) and acquire data at Stage 4.

11.5.5.6 Stabilize at Stage 5 (1500/15.4/45) and acquire data at Stage 5.

11.5.5.7 Stabilize at Stage 6 (800/2.2/45) and acquire data at Stage 6.

11.5.6 Detergent flush to BC oil.

11.5.6.1 Stabilize at Stage 1 (800/2.2/105) and acquire data at Stage 1.

11.5.6.2 Stabilize at Stage 2 (800/2.2/70) and acquire data at Stage 2.

11.5.6.3 Stabilize at Stage 3 (1500/5.8/70) and acquire data at Stage 3.

11.5.6.4 Stabilize at Stage 4 (1500/15.4/70) and acquire data at Stage 4.

11.5.6.5 Stabilize at Stage 5 (1500/15.4/45) and acquire data at Stage 5.

11.5.6.6 Stabilize at Stage 6 (800/2.2/45) and acquire data at Stage 6.

11.5.7 Shut down or continue with next non-reference oil.

11.5.8 *Start-Up and Shutdown Procedures*—In accomplishing a routine engine shutdown, disconnect the fuel lines or close the fuel valves for the fuel supply after the engine has been shut down. Remove the intake air supply duct. It is preferable to shut the engine down at Stage 6 (800/2.2/45) conditions.

11.5.8.1 *Unscheduled Shutdown and Restart*—There are no scheduled shutdown periods in the test. Continuous operation is expected from initial warm-up prior to flushing in the BC oil before test oil through the final testing of the BC oil segment after the test oil. If an unexpected shutdown does occur, the maximum allowable downtime per test is 10 h. Only four unscheduled shutdowns per test are allowed, and the maximum allowable downtime in any one unscheduled shutdown is 8 h. If unexpected shutdowns occur, the following guidelines apply:

Testing Phase	Restart and Continuation Procedure
During Stabilization Runs	Return to start of current step. Continue on existing schedule without deleting any of actual running stabilization time.
During BSFC Measurement Runs	Reaccomplish the stabilization run in entirety and acquire all new BSFC data after the designated stabilization.
During Oil Flushes or During Test Oil Aging	Continue on existing schedule without deleting any of the prescribed operating time.

11.5.9 *Flying Flush Oil Exchange Procedures*—These flushing procedures involve oil exchanges without stopping the engine. In all cases, bring the engine to stage flush (1500/15.4/125) temperature conditions (see Table 2) before initiating any flush. Flushing checklists are provided in Annex A5.

11.5.9.1 *Detergent Flush*—This procedure is intended to remove any residual effects from the previous oil and is performed when flushing from test oil to BC oil. A checklist for this detergent flush is shown in Fig. A5.1. Accomplish this detergent flush in the following steps:

(*1*) Heat the BC flush oil and BC oil external reservoirs within the range from 93 to 107°C (199.4 to 224.6°F).

(*2*) Bring the engine to 1500 r/min, 98 N-m (72.3 lbf-ft) load at stage flush temperatures (125°C/257°F oil).

(*3*) Switch external oil system (see Fig. A2.9) to flush mode and allow the engine to draw 5.68 L (6 qt) of BCF flush oil while 5.68 L (6 qt) of oil is being scavenged from the oil sump.

NOTE 5—The scavenge pump will draw oil from the oil sump until the oil level in the dump tank reaches the 5.68 L (6 qt) level and the float level switch tin the dump tank turns off the scavenge pump. When the scavenge pump is turned off, the solenoids switch so that oil starts recirculating to the engine as the oil sump fills to 5.68 L (6 qt). When the oil level in the sump reaches the full level (5.68 L) (6 qt), the float level switch in the oil pan closes the solenoid to the oil reservoir and the oil then fully recirculates to the engine.

(*4*) Allow the engine to continue running at 1500 r/min, 15 kW load, 125°C oil temp for 2 h at stage flush temperatures.

(*5*) With BC oil at the specified temperature for flushing, switch to the BC oil reservoir and reaccomplish Step *3* with BC (flush, fill, run).

(*6*) Allow the engine to continue running at 1500 r/min, 125 °C oil temperature for 30 min at stage flush temperatures.

(*7*) Reaccomplish Step *3*. with BC oil.

(*8*) Allow the engine to continue running at 1500 r/min, 125 °C oil temperature for 30 min at stage flush temperatures.

(*9*) Reaccomplish Step *3*. with BC oil.

(*10*) Return the engine to Stage 1 (800 r/min, 2.2 kW, 105°C), and follow stabilization procedure for BSFC measurement with BC oil.

11.5.9.2 *Double Flush From BC Oil to Test Oil*—This procedure removes the previous oil and is performed when flushing from BC oil to test oil. A checklist for this double flush is shown in Fig. A5.2. This double flush is accomplished as follows:

(*1*) Heat the test oil in the external reservoir within the range from 93 to 107°C (199.4 to 224.6°F).

(*2*) Bring the engine to 1500 r/min, 98 N-m (72.3 lbf-ft) load at stage flush temperatures (125°C/257°F oil).

(*3*) Switch the external oil system to flush mode (see Fig. A5.2) and allow the engine to draw 5.68 L (6 qt) of non-reference oil while 5.68 L (6 qt) of oil is being scavenged from the oil sump.

NOTE 6—The scavenge pump will draw oil until the level in the oil dump tank reaches the 5.68-L (6-qt) level and the float level switch in the dump tank turns off the scavenge pump. When the scavenge pump is turned off, the solenoids switch so that oil starts recirculating to the engine as the sump fills to 5.68 L (6 qt). When the oil level in the sump reaches the full level (5.68 L/6 qt), the float level switch in the oil pan closes the solenoid to the oil reservoir, and the oil fully recirculates to the engine.

(*4*) Allow the engine to continue running at 1500 r/min, 15 kW load, 125°C oil temp for 30 min at stage flush temperatures.

(*5*) Reaccomplish Step *3*.

(*6*) Allow the engine to continue running at 1500 r/min, 15 kW load, 125°C oil temperature for 30 min at stage flush temperatures.

(*7*) Reaccomplish Step *3*.

(*8*) Bring the engine to Stage Age (see Table 2).

11.5.9.3 *Double Flush From BC Oil to BC Oil*—This procedure removes the previous oil and is performed when flushing from BC oil to BC oil between strings of test oil tests. A checklist for this double flush is shown in Fig. A5.3. This double flush is accomplished as follows:

(*1*) Heat the test oil in the external reservoir within the range from 93 to 107°C (199.4 to 224.6°F).

(*2*) Bring the engine to 1500 r/min, 98 N-m (72.3 lbf-ft) load at stage flush temperatures (125°C/257°F oil).

(*3*) Switch the external oil system to flush mode (see Fig. A2.2) and allow the engine to draw 5.68 L (6 qt) of test oil while 5.68 L (6 qt) of oil is being scavenged from the oil sump.

NOTE 7—The scavenge pump will draw oil until the level in the oil dump tank reaches the 5.68-L (6-qt) level and the float level switch in the dump tank turns off the scavenge pump. When the scavenge pump is turned off, the solenoids switch so that oil starts recirculating to the engine as the sump fills to 5.68 L (6 qt). When the oil level in the sump reaches the full level 5.68 L (6 qt), the float level switch in the oil pan closes the solenoid to the oil reservoir, and the oil fully recirculates to the engine.

(*4*) Allow the engine to continue running at 1500 r/min, 15 kW load, 125°C oil temperature for 30 min at stage flush temperatures.

(*5*) Reaccomplish Step *3*.

(*6*) Allow the engine to continue running at 1500 r/min, 15 kW load, 125°C oil temperature for 30 min at stage flush temperatures.

(*7*) Reaccomplish Step *3*.

(*8*) Return the engine to Stage 1 (800 r/min, 2.2 kW, 105°C), and follow the stabilization procedure for BSFC measurement with BC oil.

11.5.10 *Test Operating Stages*—Table 3 depicts the test operating conditions for the stages, Table 10 depicts the schedule of operation, and Fig. 1 depicts the method of obtaining fuel flows and BSFC's for results comparison.

11.5.10.1 After an engine has been broken in and tests indicate that the engine responds properly to a reference oil, then test oils can be evaluated relative to BC oil. This entails comparing the total fuel consumed (mass) for aged test oil run at the six stages with that of the average of the fresh BC oil run before and after the test oil.

11.5.11 *Stabilization to Stage Conditions*—After the flying flush to each oil (BC or test oil) and for the change to each stage, a stabilization time of 1 h is specified prior to beginning the BSFC measurement cycle. This time is that which elapses between initially changing the speed/load/temperature set points and the beginning of the first BSFC measurement cycle for that stage. It, therefore, includes the time during which the temperatures are changing. Manage the speed, load, coolant, and oil temperature control loops such that the processes are brought to the desired set points expeditiously. (**Warning**—If stabilization or oil flush times are extended owing to operational problems, the test results may be adversely influenced.)

TABLE 10 Test Schedule

BC Oil Test		Estimated Elapsed Time, min[A]
Start, warm-up to stage flush, double flush to BC		2:00
S60, BSFC/fuel flow × 6 at Stage 1[B]		1:30
S60, BSFC/fuel flow × 6 at Stage 2		1:30
S60, BSFC/fuel flow × 6 at Stage 3		1:30
S60, BSFC/fuel flow × 6 at Stage 4		1:30
S60, BSFC/fuel flow × 6 at Stage 5		1:30
S60, BSFC/fuel flow × 6 at Stage 6		1:30
	Subtotal	11:00
Test Oil Test		
Warm-up to stage flush, double flush to test oil		1:30
Age 16 h at stage age		16:00
S60, BSFC/fuel flow × 6 at Stage 1		1:30
S60, BSFC/fuel flow × 6 at Stage 2		1:30
S60, BSFC/fuel flow × 6 at Stage 3		1:30
S60, BSFC/fuel flow × 6 at Stage 4		1:30
S60, BSFC/fuel flow × 6 at Stage 5		1:30
S60, BSFC/fuel flow × 6 at Stage 6		1:30
	Subtotal	26:30
BC Oil Test		
Warm-up to stage flush, detergent flush to BC		3:30
S60, BSFC/fuel flow × 6 at Stage 1		1:30
S60, BSFC/fuel flow × 6 at Stage 2		1:30
S60, BSFC/fuel flow × 6 at Stage 3		1:30
S60, BSFC/fuel flow × 6 at Stage 4		1:30
S60, BSFC/fuel flow × 6 at Stage 5		1:30
S60, BSFC/fuel flow × 6 at Stage 6		1:30
	Subtotal	12:30
	End of test shutdown	
	Overall total	50:00

[A] Adhere to stabilization times and times for the six replicate BSFC measurements. Warm-up and cool-down times included in flushing elapsed times are estimates (see 11.5.9.1, 11.5.9.2, and 11.5.9.3).

[B] Example—Stabilize 60 min followed by six replicate BSFC measurements at 5-min intervals (3 min for set-up, 2 min for time averaged BSFC with Stage 1 operating conditions).

11.5.12 *Stabilized BSFC Measurement Cycle*—After the stabilization period (1 h) has elapsed for each stage, run a series of six BSFC measurements by the cycle that is described in Fig. 1. During this 30 min period, control the operating conditions for all of the critical parameters as closely as possible to the mean value as shown in Table 3. A minimum of 100 data points are required for speed, load, fuel flow rate, and AFR for integration during each six of the approximate 2 min (100 to 120 s) data sample intervals. A minimum of a single snap shot reading of each of the other parameters shown in Table 3 should be taken during each 100 to 120 data sample period. BSFC is calculated for each of the six stages as follows. Table 11 shows detailed information for calculation of BSFC.

$$\frac{(\textit{integrated fuel flow})\ (9549.3)}{(\textit{integrated load})\ (\textit{integrated speed})} = \textit{BSFC in kg/kW•h} \quad (3)$$

where:

Integrated speed (r/min) to one decimal place,
Integrated load (N•m) to two decimal places, and
Integrated fuel flow rate (kg/h) to three decimal places.

11.5.12.1 Calculate BSFC measurements as in Eq 3 for each of the six steps in each stage to four decimal places and record after rounding (see Practice E 29) the average for each stage to five decimal places. Calculate the coefficient of variation (C.V.) of the six BSFC determinations. Due to the low engine operating speed and low fuel consumption in Stages 1, 2, and 6, it is recognized that the C.V. for these stages may tend to be higher than for Stages 3, 4, and 5.

(*a*) A test cannot be deemed operationally invalid for high C.V. alone.

11.5.13 *Data Logging*— Utilize the format shown in Report Format Annex A7. Include formal log sheet numbers and other administrative details as laboratory policy may require. In operations that involve computerized data acquisition systems, refer to the ASTM TMC for guidance.

11.5.14 *BC Oil Flush Procedure for BC Before Test Oil*—At the start of test, the engine is warmed up to stage flush conditions (see Table 2) and the BC oil is flushed into the engine without shutting the engine down. The sequence of events for this flush are as follows (see 11.5.9.3 and Fig. A5.3):

11.5.14.1 Warm engine to stage flush.

11.5.14.2 Double flush to BC oil.

11.5.14.3 Proceed with BC oil BSFC data acquisition.

11.5.15 *BSFC Measurement of BC Oil Before Test Oil*—Run Stages 1 through 6 as detailed in Table 3. Obtain six BSFC measurements at each stage according to the critical data acquisition period as detailed in Fig. 1 and 11.5.12.

11.5.15.1 When six data points have been obtained at Stage 1, immediately calculate the C.V. for the mean BSFC of the six runs. If the runs are satisfactory, continue on to Stage 2, 3, 4, 5 and 6 as shown in Table 3.

11.5.16 *Test Oil Flush Procedure*—After the BC oil before

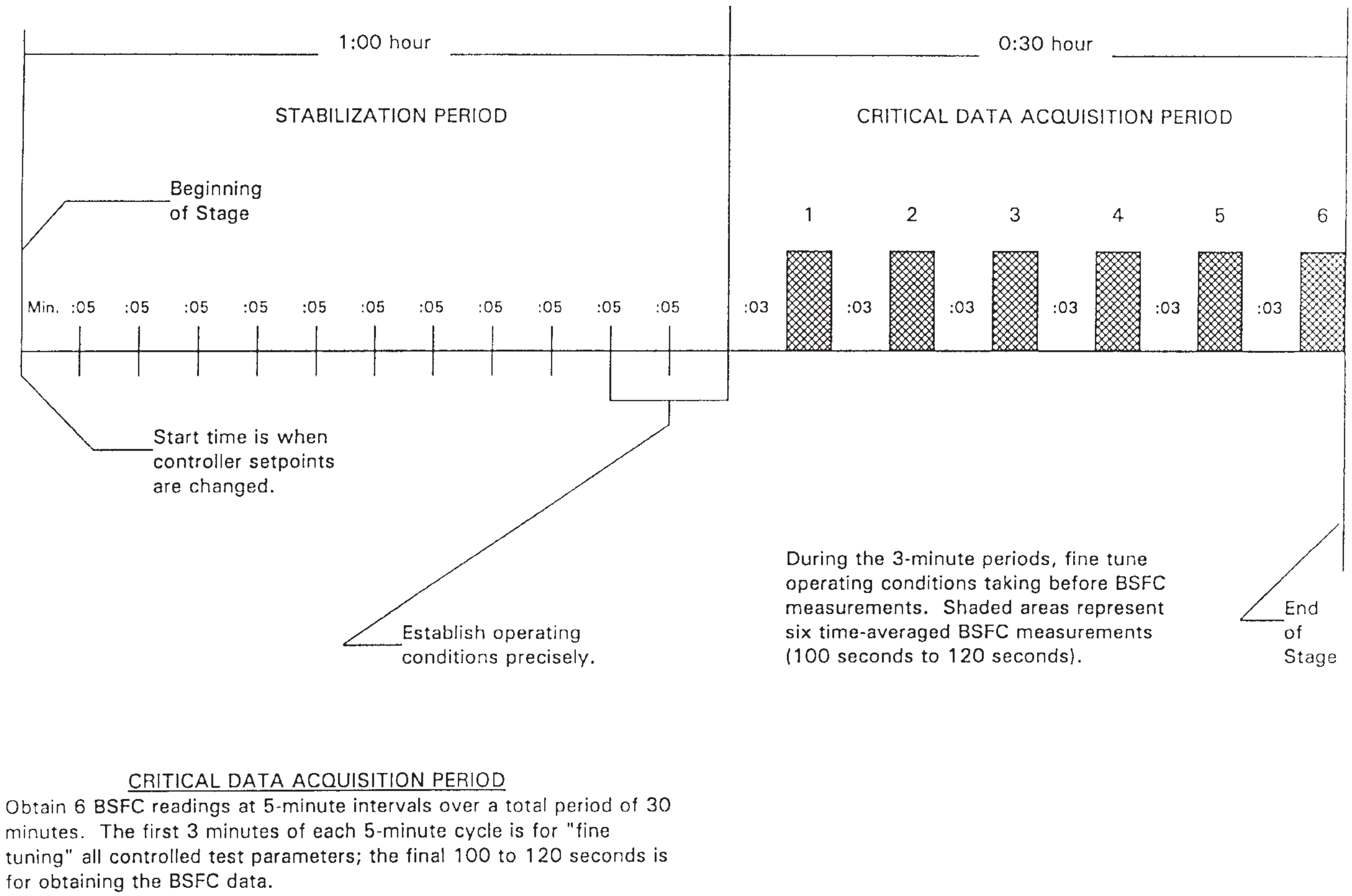


FIG. 1 Data Acquisition Sequence

TABLE 11 Information for Calculation of BSFC

1W = 1N•m/s
1kW = 1000 N•m/s
1kW = 60000 N•m/min
1kW = 2 π T N/60000
1kW = T N/9549.3
Example:
Speed = 800 r/min
Torque = 19.18 lbf-ft = 26.004 N•m
hp = T N/5252 = (800 × 19.18)/5252 = 2.92
kW = T N/9549.3 = (800 × 26.004)/9549.3 = 2.1785052
2.1785052 kw/•746 = 2.92 hp
In SI Units:

$$BSFC = \frac{(fuel\ flow,\ kg/h)(9549.3)}{(speed,\ r/min)\ (Torque,\ N\bullet m)} \quad (1)$$

In Inch-pound Units:

$$BSFC = \frac{(fuel\ flow,\ lb/h)(5252)}{(speed,\ r/min)\ (Torque,\ lbf-ft)} \quad (2)$$

test oil segment is completed, the test oil is flushed into the engine without shutting the engine down. The sequence of events for this flush are as follows (see 11.5.9.2 and Fig. A5.2):

11.5.16.1 Double flush to test oil, and

11.5.16.2 Proceed with test oil aging.

11.5.17 *Test Oil Aging*— A 16-h time period is specified for test oil aging at stage aging which are the same conditions as stage flush (see Table 2). The 16-h interval starts when the double flush procedure is completed and ends at the time the stage age set points are changed to Stage 1 for stabilization and BSFC measurement.

11.5.17.1 *Oil Consumption During Aging*—Monitor test oil consumption during the 16-h aging period by observing the running oil level in the engine sump viewing window. In the first 10 h of aging, make fresh oil additions as necessary so that the oil level will not be below the full mark at the end of the 16 h period. No oil additions are allowed after the first 10 h of aging. The oil level may not be more than 475 mL (16 oz) above the full mark at any time. If the oil level is above the full mark at 16 h of aging, drain the oil back to the full mark. Record all oil adds and drains. (**Warning**—The oil level is normally considerably higher in the viewing window when the engine is operating at stage age than when operating at the lower temperature stages.)

11.5.17.2 *Oil Sampling*—Obtain a 60-mL (2.03-oz) sample of aged oil at the end of the 16-h aging period.

11.5.17.3 *Data Logging During Aging*—A trouble log and oil consumption record are also required. Fuel consumption measurements and other operating conditions are recorded at least on an hourly basis. More frequent data logging is encouraged since averaging of repeat BSFC measurements is desirable in this test.

11.5.18 *BSFC Measurement of Aged Test Oil*—After 16 h of aging of the test oil, run Stages 1 through 6 as detailed in Table 3. Obtain 6 BSFC measurements at each stage in accordance with the critical data acquisition period as detailed in Fig. 1 and 11.5.12.

11.5.18.1 When six data points have been obtained at Stage 1, immediately calculate the C.V. for the mean BSFC of the six runs. If the runs are satisfactory, continue on to Stage 2, 3, 4, 5 and 6 as shown in Table 3.

11.5.19 *BC Oil Flush Procedure for BC Oil After Test Oil*—After the test oil segment of the test is completed, flush BC oil into the engine without shutting the engine down. The sequence of events for this flush are as follows (see 11.5.9.1 and Fig. A5.1):

11.5.19.1 Detergent flush to BC oil, and

11.5.19.2 Proceed with BC oil BSFC data acquisition.

11.5.20 *BSFC Measurement of BC Oil After Test Oil*—Run Stages 1 through 6 as detailed in Table 3. Obtain six BSFC measurements at each stage in accordance with the critical data acquisition period as detailed in Fig. 1 and 11.5.12.

11.5.20.1 When six data points have been obtained at Stage 1, immediately calculate the C.V. for the mean BSFC of the six runs. If the runs are satisfactory, continue on to Stage 2, 3, 4, 5, and 6, as shown in Table 3. When the BC after test oil is completed, calculate the BC shift as follows:

(*a*) Reference test: ((RBC1KG-RBC2KG) + RBC1KG)× 100 (see Fig. A7.3).

(*b*) Non-reference test: ((BC1KG-BC2KG) + BC1KG) × 100 (see Fig. A7.3).

11.5.20.2 It is recommended that the BC shift not exceed 0.5 %. However, a test cannot be deemed operationally invalid for high BC shift alone.

11.5.21 *General Test Data Logging Forms*—Utilize the format shown in Annex A7. Include formal log sheet numbers and other administrative details as laboratory policy may require. In operations that involve computerized data acquisition systems, refer to the ASTM TMC for guidance.

11.5.22 *Diagnostic Review Procedures*—To ensure test operational validity, critically review the data logs at frequent intervals during the test. The final review after the test is completed is only partially effective in identifying problems, since the indicated data cannot be cross examined by first hand observation. Early detection of instrumentation errors is essential and often the record for information parameters (dependent variables) indicate problem areas involving the primary control parameters. The following parameter response characteristics are significant:

11.5.22.1 Stabilization trends,

11.5.22.2 Air fuel ratio stability,

11.5.22.3 Fuel flow stability,

11.5.22.4 Intake manifold vacuum/absolute pressure,

11.5.22.5 Speed,

11.5.22.6 Load, and

11.5.22.7 Exhaust back pressure.

12. Determination of Test Results

12.1 Calculate the test results as detailed in Table 12.

TABLE 12 Calculation of Test Results

Test Stage	Nominal Speed, r/min	Nominal Power, kW	Nominal Oil Temperature, °C	Time Factor, h
1	800	2.18	105	0.077472
2	800	2.18	70	0.082500
3	1500	5.81	70	0.035417
4	1500	15.39	70	0.078250
5	1500	15.39	45	0.033139
6	800	2.18	45	0.045444

1 For test Stage 1, Steps 1 through 6, round and record the 5-min BSFC measurements to four decimal places using ASTM rounding.
2 Average the BSFC measurements of the six steps to five decimal places using ASTM rounding. Units for BSFC are kg/Kw-hr.
3 Multiply the average by the shown nominal power and time factor for Stage 1 and record the answer to six decimal places. The unit for this number is kg of fuel consumed.
4 Perform calculation Steps 1, 2, and 3 for the remaining test Stages (2 to 6) using the respective nominal power and time factors.
5 Total the mass fuel consumption values for all six stages.
6 Add 0.2540 kg to the total. This is a constant for a test condition (Stage) that is not run but that gives appropriate magnitude to the fuel economy improvement result. This stage was found to produce stable fuel consumption levels because the small changes in friction due to the oil were a very small percentage of overall engine friction relative to the total engine power output.
7 Complete the total fuel consumed calculation detailed in Steps 1 to 5 for the BC oil immediately preceding the test oil, the test oil, and the BC oil immediately after the test oil.
8 Calculate the average BC fuel consumption with $BC_{precede}$ and BC_{after}.
9 Compute the test oil fuel economy improvement (FEI) as follows:

$$\% \text{ FEI} = \{[BC_{average} \text{- Test Oil}]/BC_{average}\} \times 100$$

10 Adjust the FEI result on non-reference tests for the stand/engine severity in accordance with Annex A7.

13. Final Test Report

13.1 *Validity Statement*—Include a statement pertaining to the validity of the test at the bottom of the report title page (Fig. A7.1) which is signed by the person responsible for conducting the test.

13.2 *Report Format*—The standard ASTM Sequence VIA test report forms are shown in Annex A7.

13.2.1 *BC Start Date*—The BC start date is defined as the date when the BC before test oil flush enters into the engine.

13.2.2 *BC Start Time*—The BC start time is defined as the time when the BC before test oil flush enters into the engine.

13.2.3 *Non-Reference/Reference Oil Start Date*—This is defined as the date when the first non-reference or reference test oil flush enters into the engine.

13.2.4 *Non-Reference/Reference Oil Start Time*—This is defined as the time when the first non-reference or reference test oil flush enters into the engine.

13.2.5 *Total Engine Hours at End of Test*—This is defined as the cumulative engine hours at the completion of BC after test oil.

13.2.6 *Test Duration*—Engine hours accumulated during BC before test oil through BC after test oil.

13.2.7 *Fuel Batch*—This is defined as the batch number for the most recent batch of fuel that has been put into the fuel tank (it is recognized that in most cases a fuel tank will not be completely empty before a new load of fuel is put into the tank, so the fuel in the tank may actually be a mixture of two or more batches).

13.2.8 *Oil Viscosity Measurement*—Make the viscosity determinations on non-reference oils only in accordance with Test Method D 445. Make and report viscosity determinations at 40°C and 100°C (see Fig. A7.2) for new oil and for aged (16 h) oil.

13.2.9 *Use of SI Units*—Report all results in SI units. Follow the rules for conversion of inch-pound units to SI units as described in IEEE/ASTM SI-10.

13.2.10 *Precision of Reported Units*—Use Practice E 29 for rounding off data. Use the rounding-off method to report data to the required precision.

13.3 *Data Dictionary*—The Data Dictionary is shown in Appendix X2.

14. Precision, Validity, and Bias

14.1 *Precision*—Test precision is established on the basis of reference oil test results (for operationally-valid tests) monitored by the TMC. The data are reviewed semi-annually by the Sequence VI/VIA Surveillance Panel. Contact the ASTM TMC for current industry data.

14.1.1 Test precision as established for the official acceptance of this procedure is shown in Table 1.

NOTE 8—Contact the ASTM TMC for up-to-date data.

14.1.2 *Repeatability (r)*—This is defined as the difference between successive results obtained by the same laboratory under constant operating conditions on the same oil would, in the long run, in the normal and correct conduct of the test method, exceed the values shown in Table 13, in only one case in twenty.

TABLE 13 Sequence by way of Reference Oil Precision Statistics[A]

Variable	Repeatability[B]		Reproducibility[C]	
	S_r[D]	r[E]	S_R[D]	R[E]
Fuel economy improvement, %	[F]	[F]	0.15	0.42

[A] These statistics are based on results obtained on Test Monitoring Reference Oils 529, 531, 534, 535–1, 536, and 1002.
[B] Repeatability values refer to tests run on the same oil in the same stand/engine combination.
[C] Reproducibility values refer to test run on the same oil on different stand/engine combinations.
[D] s = standard deviation
[E] On the basis of test error alone, the difference, in absolute value, between two test results will be expected to exceed this value only about 5 % of the time.
[F] Due to limited data these values are not available.

14.1.3 *Reproducibility (R)*—This is defined as the difference between two single and independent results obtained by different operators working in different laboratories on the same oil would, in the long run, in the normal and correct conduct of the test method, exceed the values shown in Table 13, in only one case in twenty.

14.2 *Validity*—The following guidelines provide a basis for judgements regarding the validity of test results. The ASTM TMC administers reference test requirements utilizing these and other guidelines.

14.2.1 *Test Stand Calibration Status*—The essential requirements of 10.1 and 10.2 provide the basis for official recognition of test stand calibration.

14.2.2 *Validity Interpretation of Deviant Operational Conditions*—In the general case, engineering judgment at the laboratory governs the validity acceptance of tests having deviant operational history. The TMC is involved in this process for tests conducted using reference oils and is available for consultation for tests conducted on non-reference oils. Averages of critical parameters (speed, load, exhaust back pressure, engine oil gallery temperature, engine coolant in temperature, intake air temperature, fuel to fuel rail temperature, and AFR), taken as sets of six 5 min readings at test Stages 1 through 6 that do not meet procedural specifications, will invalidate a test if the BSFC values from such deviant blocks of data are used in the final computation of the results. Excursions during the six passes that make up the average are acceptable as long as the average is within procedural limits.

14.3 *Bias*—Bias is determined by applying an acceptable statistical technique to reference oil test results, and when a significant bias is determined, a severity adjustment is permitted for non-reference oil test results (see Annex A8).

15. Keywords

15.1 aged test oil; break-in; calibration oil; flying flush; fuel economy; pre-test verification; reference oil; Sequence VIA; spark-ignition automotive engine

ANNEXES

(Mandatory Information)

A1. THE ROLE OF THE ASTM TEST MONITORING CENTER AND THE CALIBRATION PROGRAM

A1.1 *Nature and Functions of the ASTM Monitoring Center (TMC)*—The ASTM TMC[2] is a non-profit organization located in Pittsburgh, Pennsylvania and is staffed to administer engineering studies; conduct laboratory visits; perform statistical analyses of reference oil test data; blend, store, and ship reference oils; and provide the associated administrative functions to maintain the referencing calibration program for various lubricant tests as directed by Subcommittee D02.B and the Test Monitoring Board. The TMC coordinates its activities with the test sponsors, the test developers, the surveillance panels, and the testing laboratories.

A1.2 *Rules of Operation of the ASTM TMC*—The TMC operates in accordance with the ASTM Charter, the ASTM Bylaws, with Regulations Governing ASTM Technical Committees, the Bylaws Governing ASTM Committee D02, and the Rules and Regulations Governing the ASTM Test Monitoring System.

A1.3 *Management of the ASTM TMC*—The management of the Test Monitoring System is vested in the Test Monitoring Board (TMB) elected by Subcommittee D02.B. The TMB selects the TMC Administrator who is responsible for directing the activities of the TMC staff.

A1.4 *Operating Income of the ASTM TMC*—The TMC operating income is obtained from fees levied on the reference oils supplied and on the calibration tests conducted. Fee schedules are established and reviewed by Subcommittee D02.B.

A1.5 *Conducting a Reference Oil Test*:

A1.5.1 For those laboratories that choose to utilize the services of the ASTM TMC in maintaining calibration of test stands, full-scale calibration testing shall be conducted at regular intervals. These full-scale tests are conducted using coded reference oils supplied by the ASTM TMC. It is a laboratory's responsibility to keep the on-site reference oil inventory at or above the minimum level specified by the TMC test engineers.

A1.5.2 When laboratory personnel decide to run a reference calibration test, they shall request an oil code from the cognizant TMC engineer. Upon completion of the reference oil test, the data shall be sent in summary form (use TMC-acceptable forms) to the TMC by telephone facsimile transmission, or some other method acceptable to the TMC. The TMC will review the data and contact the laboratory engineer to report the laboratory's calibration status. All reference oil tests, whether aborted, invalidated, or successfully completed, shall be reported to the TMC. Subsequent to sending the data in summary form to the TMC, the laboratory is required to submit to the TMC the written test report specified in the test procedure.

A1.6 *New Laboratories*—Laboratories wishing to become part of the ASTM Test Monitoring System will be requested to conduct reference oil tests to ensure that the laboratory is using the proper testing techniques. Information concerning fees, laboratory inspection, reagents, testing practices, appropriate committee membership, and rater training can be obtained by contacting the TMC Administrator at:

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

A1.7 *Introducing New Sequence VIA Reference Oils*—The calibrating reference oils produce various fuel economy results. When new reference oils are selected, member laboratories will be requested to conduct their share of tests to enable the TMC to establish the proper industry average and test acceptable limits. The ASTM D02.B0.01 Sequence VIA Surveillance Panel will require a minimum number of tests to establish the industry average and test acceptance targets for new reference oils.

A1.8 *TMC Information Letters*:

A1.8.1 Occasionally it is necessary to change the procedure, and to notify the test laboratories of the change, prior to consideration of the change by either Subcommittee D02.B on Automotive Lubricants, or ASTM Committee D02 on Petroleum Products and Lubricants. In such a case, the TMC will issue an Information Letter. Information Letters are balloted by Subcommittee D02.B. By this means, the Society due process procedures are applied to these Information Letters.

A1.8.2 The review of an Information Letter prior to its original issue will differ in accordance with its nature. In the case of an Information Letter concerning a part number change that does not affect test results, the TMC is authorized to issue such a letter. Long-term studies by the Surveillance Panel to improve the test procedure through improved operation and hardware control may result in a recommendation to issue an Information Letter. If obvious procedural items affecting test results need immediate attention, the test sponsor and the TMC will issue an Information Letter and present the background and data to the Surveillance Panel for approval prior to the semiannual Subcommittee D02.B meeting.

A1.8.3 Authority for the issuance of Information Letters was given by the committee on Technical Committee Operations in 1984, as follows: "COTCO recognizes that D-2 has a unique and complex situation. The use of Information Letters is approved providing each letter contains a disclaimer to the affect that such has not obtained ASTM consensus. These Information Letters should be moved to such consensus as rapidly as possible."

A1.8.4 Information Letters appertaining to this procedure issued prior to 1996-7-09 are incorporated into this standard. A listing of such Information Letters, and copies of the letters, may be obtained from the TMC. Information Letters issued subsequent to this date may also be obtained from the TMC.

A1.9 *TMC Memoranda*—In addition to the aforementioned Information Letters, supplementary memoranda are issued. These are developed by the TMC and distributed to the Sequence VIA Surveillance Panel and to participating laboratories. They convey such information as batch approvals for test parts or materials, and clarification of the test procedure, notes and suggestions of the collection and analysis of special data that the TMC may request, or any other pertinent matters having no direct effect on the test performance, results, or precision and bias.

A1.10 *Precision Data*—The TMC determines the current Sequence VIA test precision by analyzing results of calibration tests conducted on reference oils. Current precision data can be obtained from the TMC.

A2. DETAILED SPECIFICATIONS AND DRAWINGS OF APPARATUS

A2.1 Figs. A2.1-A2.29 present the detailed specifications and drawings of apparatus.

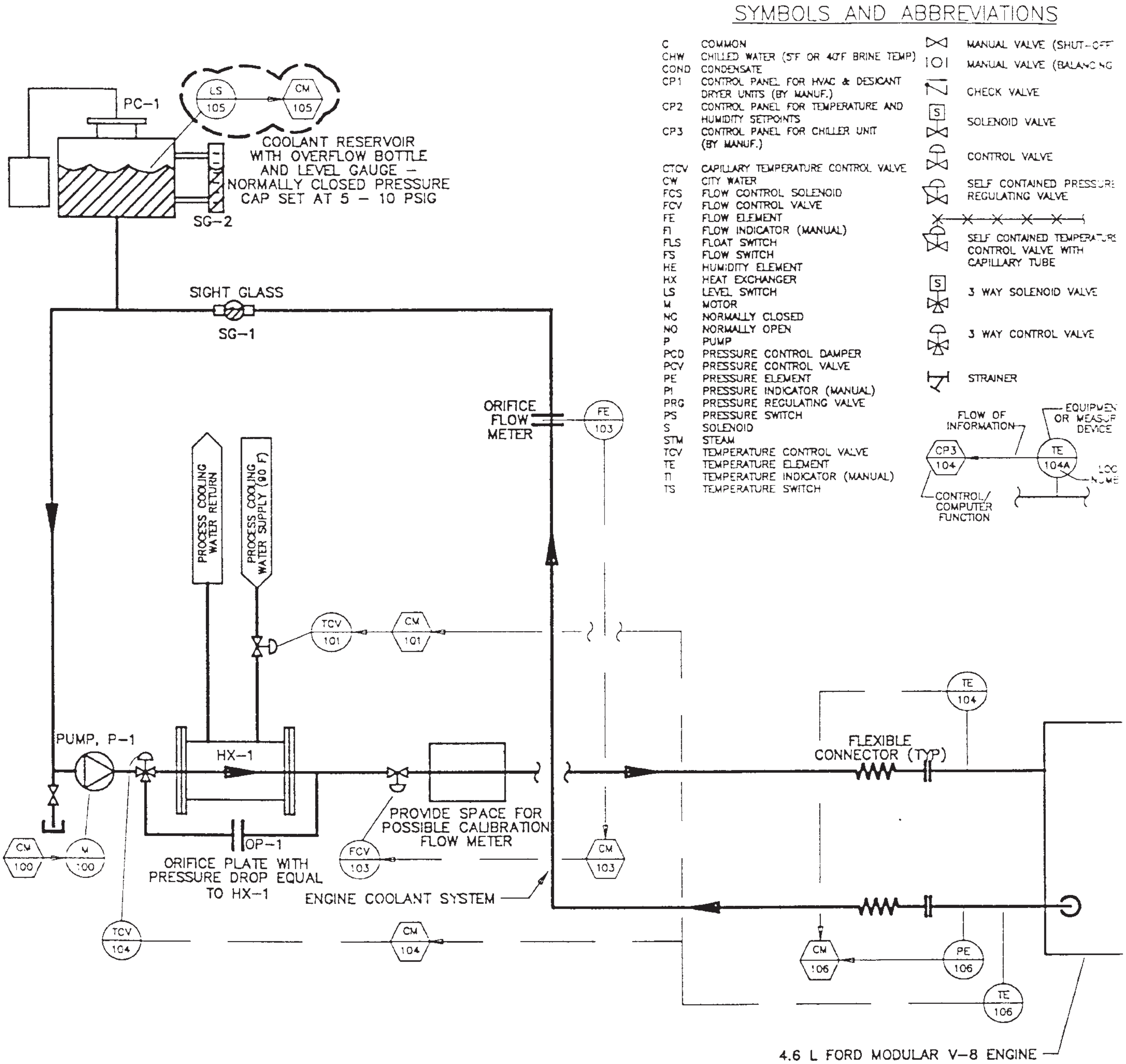


FIG. A2.1 Engine Cooling System

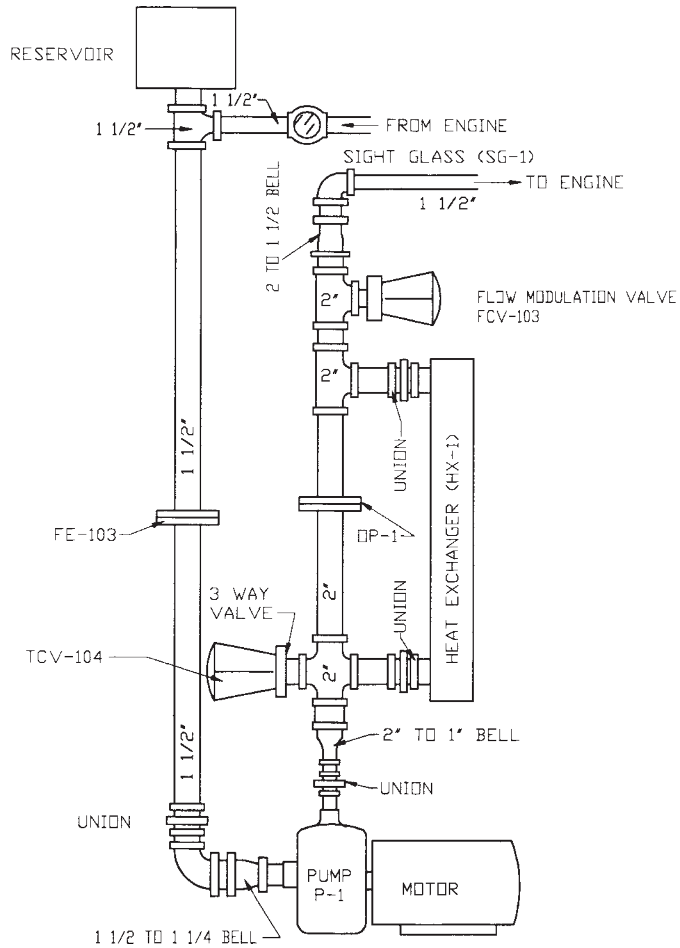


FIG. A2.2 Typical Engine Coolant System in Air-to-Close Configuration

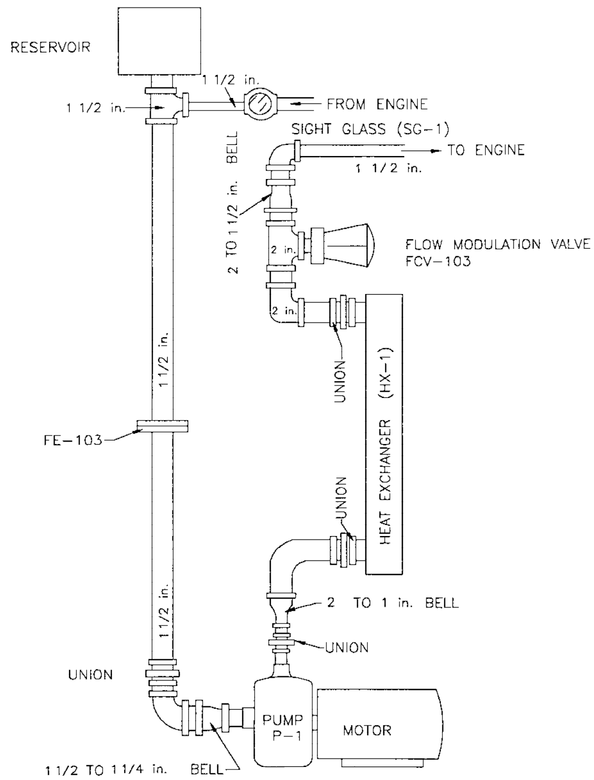
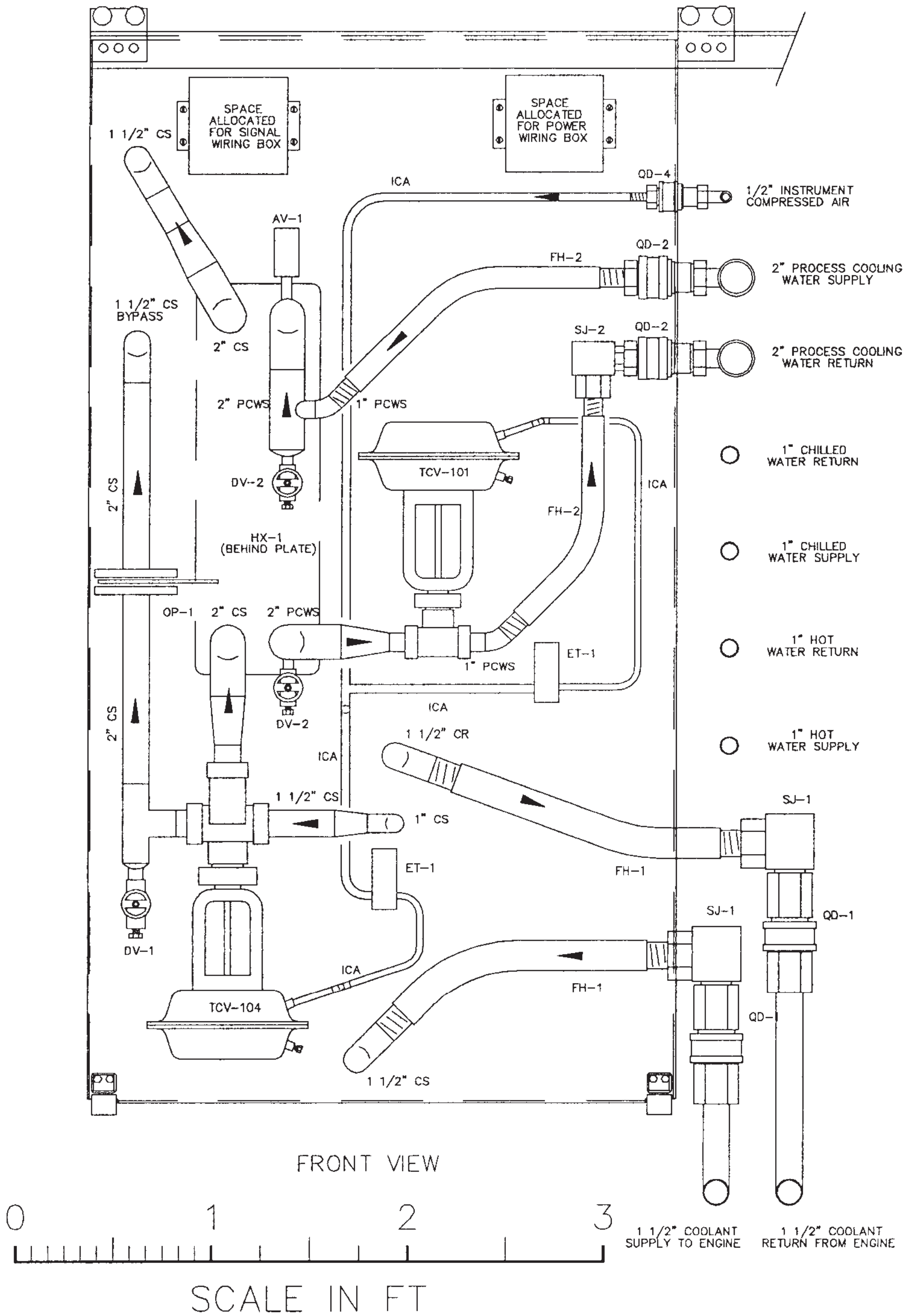


FIG. A2.3 Alternative Engine System Configuration



NOTE 1—Air vents shown are optional and at the discretion of the owner. If air vents are not used, provide an extra set of disconnects for use in opening the internal shut-off valve of the quick disconnect (when draining the system).

FIG. A2.4 Engine Cooling System

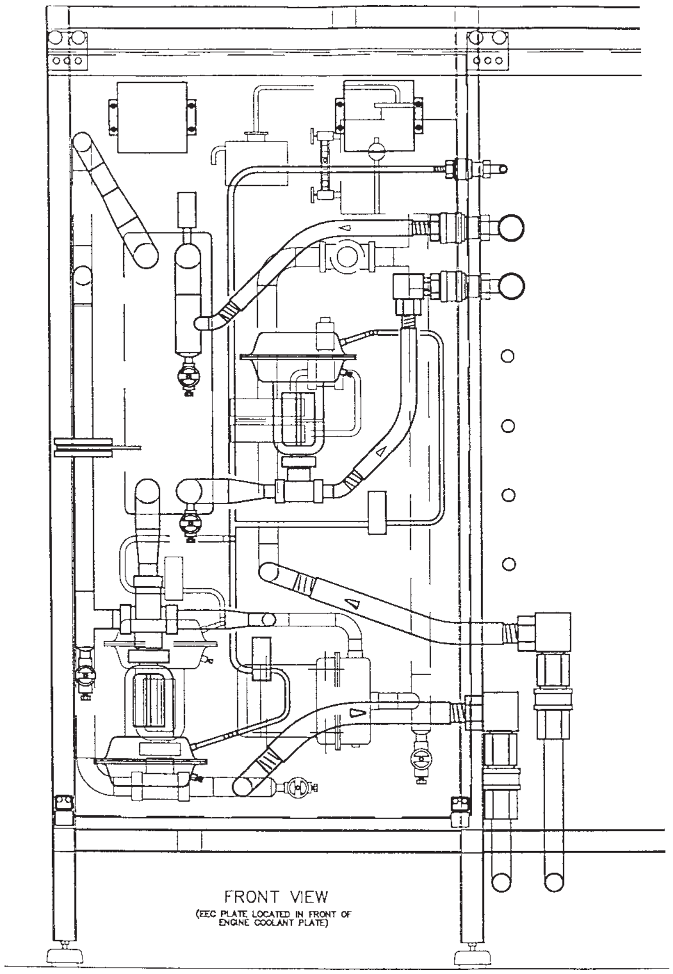
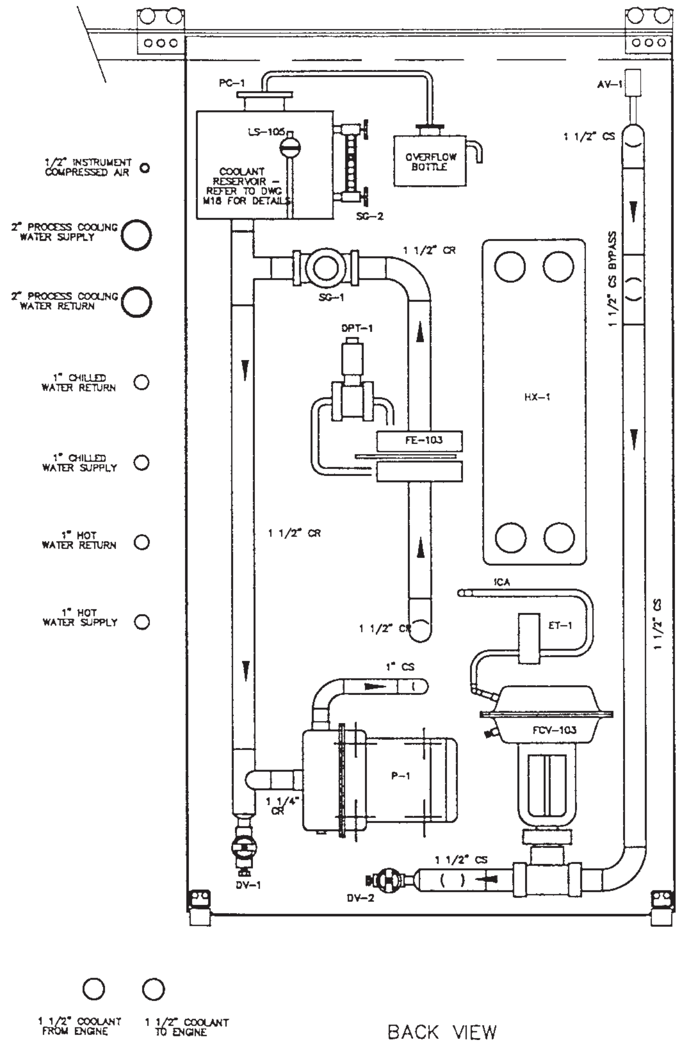


FIG. A2.5 Engine Cooling System - Front View



NOTE 1—Air vents shown are optional and at the discretion of the owner. If air vents are not used, provide an extra set of disconnects for use in opening the internal shut-off valve of the quick disconnect (when draining the system).

FIG. A2.6 Engine Cooling System - Back View

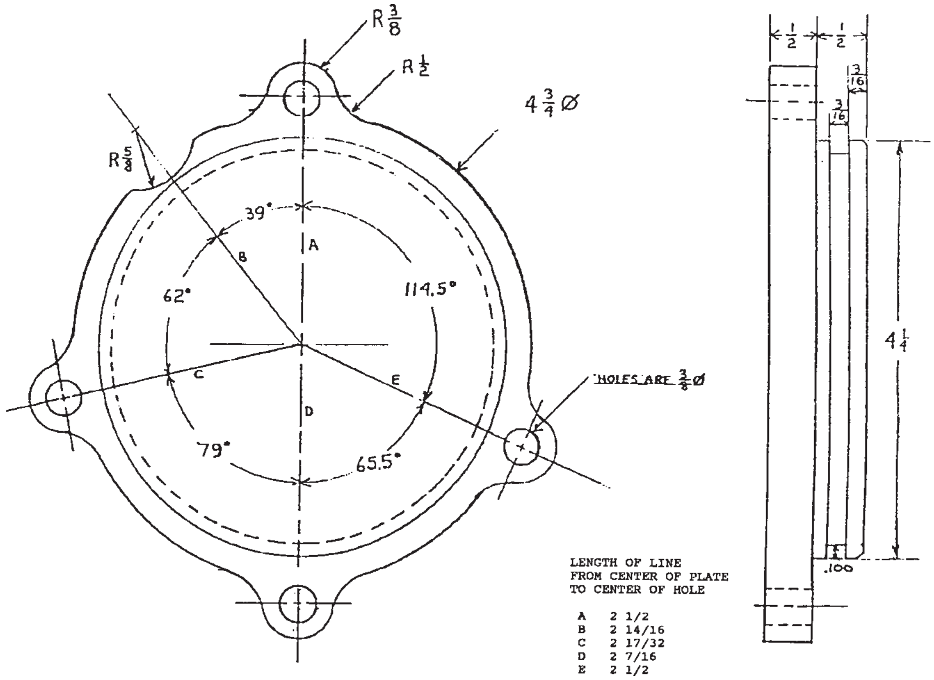


FIG. A2.7 Water Pump Plate

CONTROL VALVES

EQUIP TAG #	FLUID CONDITIONS: FLUID TYPE	GPM	MIN/MAX FLUID TEMP (F)	INLET PRESS (PSI)	DESIGN PRESS DROP (PSI)	VALVE BODY: SIZE	TYPE	CV	ACTUATOR: TYPE	POSITION	SIGNAL (PSI)	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
TCV-101	PROCESS WATER	0-11	50/90	15 (?)		1	2-WAY GLOBE	53 (LINEAR)	PNEUMATIC, SPRING OPPOSED DIAPHRAGM	AIR TO CLOSE	3 TO 15	BADGER METER INC MODEL# 9001GCW36SV3Axxx36	OR USE AIR TO OPEN MODEL# 9001GCW36SV1Axxx36	1
FCV-103	ENGINE COOLANT	35	100/220	25 (?)		2	2-WAY GLOBE	21 0 (LINEAR)	PNEUMATIC, SPRING OPPOSED DIAPHRAGM	AIR TO CLOSE	3 TO 15	BADGER METER INC MODEL# 9003GCW36SV3A29L36		1
TCV-104	ENGINE COOLANT	0-35	100/220	15	8 (MAX)	2	2-WAY GLOBE	16 0 (LINEAR)	PNEUMATIC, SPRING OPPOSED DIAPHRAGM	AIR TO OPEN	3 TO 15	BADGER METER INC MODEL# 9003TCW36SV1A29L36	OR TO USE AIR TO CLOSE MODEL# 9003TCW36SV3A29L36	1

DIFFERENTIAL PRESSURE TRANSDUCER

EQUIP TAG #	SERVING FLOW METER NUMBER	FLUID CONDITIONS: FLUID TYPE	GPM	DIFF PRESS RANGE (W C)	MIN/MAX FLUID TEMP (F)	TRANSDUCER: INLET PRESS (PSI)	OUTPUT SIGNAL (V DC)	MATERIAL	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
DPT-1	FE-103	ENGINE COOLANT	35	0-50	100/220	5 (?)	0-5	STAINLESS STEEL	VIATRAN MODEL #274	PROVIDE MOUNTING BRACKET	2

DRAIN / SHUT-OFF / CHECK VALVES

EQUIP TAG #	FLUID CONDITIONS: FLUID TYPE	MIN/MAX FLUID TEMP (F)	MAX PRESS (PSI)	VALVE BODY: SIZE	MATERIAL	TYPE	CV	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
DV-1	ENGINE COOLANT	100 / 220	15	3/4"	BRASS	2 WAY, BALL		NIBCO SERIES T-560-BR-Y-66, ROUND HANDLE	END CONNECTIONS TO BE FEMALE NPT THREADED	4
DV-2	PROCESS, CHILLED, HOT WATER	44 / 190	35	1/2"	BRASS	2 WAY, BALL		NIBCO SERIES T-560-BR-Y-66, ROUND HANDLE	END CONNECTIONS TO BE FEMALE NPT THREADED	4

FLEXIBLE HOSE MATERIALS

EQUIP TAG #	FLUID CONDITIONS: FLUID TYPE	MIN/MAX FLUID TEMP (F)	MAX SYSTEM PRESS (PSI)	FLEXABLE HOSE: SIZE	MIN BEND RADIUS (IN)	HOSE END CONNECTIONS	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
FH-1	ENGINE COOLANT	100 / 220	25 (?)	1 1/2"	7 50	MALE NPT THREADED (BOTH ENDS)	AEROQUIP FC563-24		2
FH-2	PROCESS, CHILLED, HOT WATER	44 / 190	45	1"	5 00	MALE NPT THREADED (BOTH ENDS)	AEROQUIP FC563-16		4

ELECTROPNEUMATIC TRANSDUCERS

EQUIP TAG #	SUPPLY AIR PRESSURE (PSI)	INPUT SIGNAL (mA DC)	ACTUATOR FLOW REQUIRED	TRANSDUCER: OUTPUT AIR PRESSURE (PSI)	AIR FLOW RATE (SCFM)	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
ET-1	20 - 120	4 TO 20		3 TO 15	4 5 AT 25 PSI	BELOFRAMS TYPE 1000 I/P TRANSDUCER	TRANSDUCER TO BE MOUNTED TO "PLATE" WITH BACKING FOR VIBRATION ISOLATION	3

FLOW METERS/ORIFICE PLATES

EQUIP TAG #	TYPE	PROCESS FLUID: FLUID TYPE	MIN/MAX FLOW (GPM)	MIN/MAX FLOW (LBS/HR)	MIN/MAX TEMP (F)	INLET PRESS (PSI)	DESIGN DROP (PSI)	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
FE-103	ORIFICE PLATE (DIFFERENTIAL PRESSURE)	ENGINE COOLANT	35/35		100/220	15 (?)	45 IN W C	DANIEL SERIES NO. 30 RT THREADED ORIFICE FLANGE, 1.5" NPT AND ORIFICE PLATE	11.21±0.50 KPa (45.0±2.0 IN H_2O) AT 130 L/MIN (34.3 GPM)	2
OP-1	ORIFICE PLATE	ENGINE COOLANT	0/35		100/220	10 (?)	4 AT 30 GPM	DANIEL	ORIFICE PLATE TO PROVIDE PRESSURE DROP EQUAL TO HX-1 ON ENGINE COOLANT BYPASS	3

FIG. A2.8 Engine Cooling System Components

HEAT EXCHANGERS															
		PROCESS FLUID						COOLING/HEATING FLUID							
EQUIP TAG #	TYPE	FLUID TYPE	CAPACITY (BTUH)	GPM	INLET TEMP (F)	OUTLET TEMP (F)	MAX PRESS DROP (PSI)	FLUID TYPE	GPM	INLET TEMP (F)	OUTLET TEMP (F)	MAX PRESS DROP (PSI)	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
HX-1	BRAZED PLATE	ENGINE COOLANT	60,000	30	103	98.3	9	PROCESS WATER	11	90	100	1	ITT BELL & GOSSETT BP 75H-20, P/N 5-686-06-020-001	7.5" X 24.5" X 3.0" 2"NPT CONNECTIONS	1

LEVEL SWITCHES									
	FLUID		LEVEL SWITCH						
EQUIP TAG #	FLUID TYPE	MIN/MAX TEMP (F)	POSITION BEING SENSED	CONTACT POSITION	SIGNAL	MATERIAL	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
LS-105	ENGINE COOLANT	100/220	HIGH AND LOW LEVEL (COOLANT RESERVOIR)	NORMALLY OPEN, CLOSED AT LOW LEVEL	12 V DC	STAINLESS STEEL	GEMS SERIES 1950	THIS LEVEL SWITCH IS OPTIONAL	4

MISCELLANEOUS EQUIPMENT						
EQUIP TAG #	DESCRIPTION	SIZE	MATERIAL	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
SG-1	SIGHT GLASS	1 1/2" NPT THREADED CONNECTIONS	BRONZE	ERNST GAGE MODEL 472, WITH FLAPPER		3
SG-2	SIGHT GAGE	1/2" NPT PIPE, 5/8" GLASS O D	STAINLESS STEEL	ERNST GAGE MODEL 8 SS-FB, NON-AUTOMATIC		3
AV-1	AUTOMATIC VENT			AS MANUFACTURED BY ARMSTRONG OR ITT BELL & GOSSETT		4
PC-1	ENGINE COOLANT RESERVOIR PRESSURE CAP			STANT MODEL R 28	NORMALLY CLOSED, OPEN AT SYSTEM PRESSURE OF 7 PSI	2
SJ-1	SWIVEL JOINT (ENGINE COOLANT)	1 1/2"	BRASS	AEROQUIP MODEL BD55000-2424-01		4
SJ-2	SWIVEL JOINT (CHILLED WATER)	1"	BRASS	AEROQUIP MODEL BD55000-1616-01		4

PIPING / TUBING MATERIALS								
FLUID CONDITIONS			PIPING / TUBING					
FLUID TYPE	MIN/MAX FLUID TEMP (F)	MAX SYSTEM PRESS (PSI)	SIZES	MATERIAL	CONNECTIONS	FITTINGS	REMARKS	CLASS
PROCESS WATER	50 / 90	45	1/2", 3/4", 1", 1 1/4" AND 2"	TYPE L SEAMLESS COPPER TUBING, HARD DRAWN	BRAZED, NPT THREADED	SOCKET JOINT, THREADED		3
HOT WATER	190 / 190	35	1/2", 3/4" AND 1"	TYPE L SEAMLESS COPPER TUBING, HARD DRAWN	BRAZED, NPT THREADED	SOCKET JOINT, THREADED		3
CHILLED WATER	44 / 44	35	1/2", 3/4", 1" AND 1 1/4"	TYPE L SEAMLESS COPPER TUBING, HARD DRAWN	BRAZED, NPT THREADED	SOCKET JOINT, THREADED		3
ENGINE COOLANT	100 / 220	25	3/4", 1", 1 1/4" AND 2"	TYPE L SEAMLESS COPPER TUBING, HARD DRAWN	BRAZED, NPT THREADED	SOCKET JOINT, THREADED		2
ENGINE COOLANT OVERFLOW	100 / 220	25	3/8"	PLASTIC				4
TRANSDUCER TUBING (ENGINE COOLANT)	100 / 220	25	1/4"	TYPE L SEAMLESS COPPER TUBING, HARD DRAWN	COMPRESSION, NPT THREADED	COMPRESSION, NPT THREADED		4

FIG. A2.8 Engine Cooling System Components *(continued)*

PIPING INSULATION							
FLUID CONDITIONS			INSULATION				
FLUID TYPE	MIN/MAX FLUID TEMP (F)	MAX SYSTEM PRESS (PSI)	SIZES	THICKNESS (IN)	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
PROCESS WATER	50 / 90	45	1/2", 3/4", 1", 1 1/4" AND 2"		NONE		4
HOT WATER	190 / 190	35 (?)	1/2", 3/4" AND 1"	1"	MANVILLE MICRO-LOK SERIES RIGID, MOLDED FIBERGLASS INSULATION, 3 1/2 LBS PER CUBIC FOOT DENSITY, VAPOR BARRIER AND SELF SEALING LAP SEAM		4
CHILLED WATER	44 / 44	35 (?)	1/2", 3/4" AND 1"	1/2"	MANVILLE MICRO-LOK SERIES RIGID, MOLDED FIBERGLASS INSULATION, 3 1/2 LBS PER CUBIC FOOT DENSITY, VAPOR BARRIER AND SELF SEALING LAP SEAM		4
ENGINE COOLANT	100 / 220	25 (?)	3/4", 1", 1 1/4" AND 2"	1"	MANVILLE MICRO-LOK SERIES RIGID, MOLDED FIBERGLASS INSULATION, 3 1/2 LBS PER CUBIC FOOT DENSITY, VAPOR BARRIER AND SELF SEALING LAP SEAM		4

PUMPS															
		FLUID HANDLED				PUMP CAPACITY				MOTOR					
EQUIP TAG #	TYPE	FLUID TYPE	MIN / MAX VISCOSITY (SSU)	MIN TEMP (F)	MAX TEMP (F)	GPM	TOTAL PUMP HEAD AT RATED FLOW (FT. WATER)	TOTAL PUMP PRESSURE AT RATED FLOW (PSI)	MAX BHP	MIN. HP	RPM	VOLTS, PHASE	MANUFCTURER AND MODEL NUMBER	REMARKS	CLASS
P-1	CENTRI-FUGAL	ENGINE COOLANT		100	220	35	90		1.50	2	3450	240 / 1 OR 3 PHASE	GOULDS G & L MODEL NPE, SIZE 1ST, MECH SEAL	STAINLESS STEEL CONSTRUCTION, PROVIDE VIBRATION ISOLATION FOR PLATE MOUNTING	1

QUICK DISCONNECTS									
	FLUID CONDITIONS			QUICK DISCONNECT					
EQUIP TAG #	FLUID TYPE	MIN/MAX FLUID TEMP (F)	MAX SYSTEM PRESS (PSI)	SIZE	TYPE	MATERIAL	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
QD-1	ENGINE COOLANT	100 / 220	25	1 1/2"	TWO WAY SHUT-OFF	BRASS	HANSEN SERIES 12-HK		2
QD-2	CHILLED WATER	44 / 44	35	1"	TWO WAY SHUT-OFF	BRASS	HANSEN SERIES 8-HK		4
QD-4	INSTRUMENT AIR	50 / 90	100	1/2"	TWO WAY SHUT-OFF	BRASS	HANSEN SERIES 4-HK		4

FIG. A2.8 Engine Cooling System Components *(continued)*

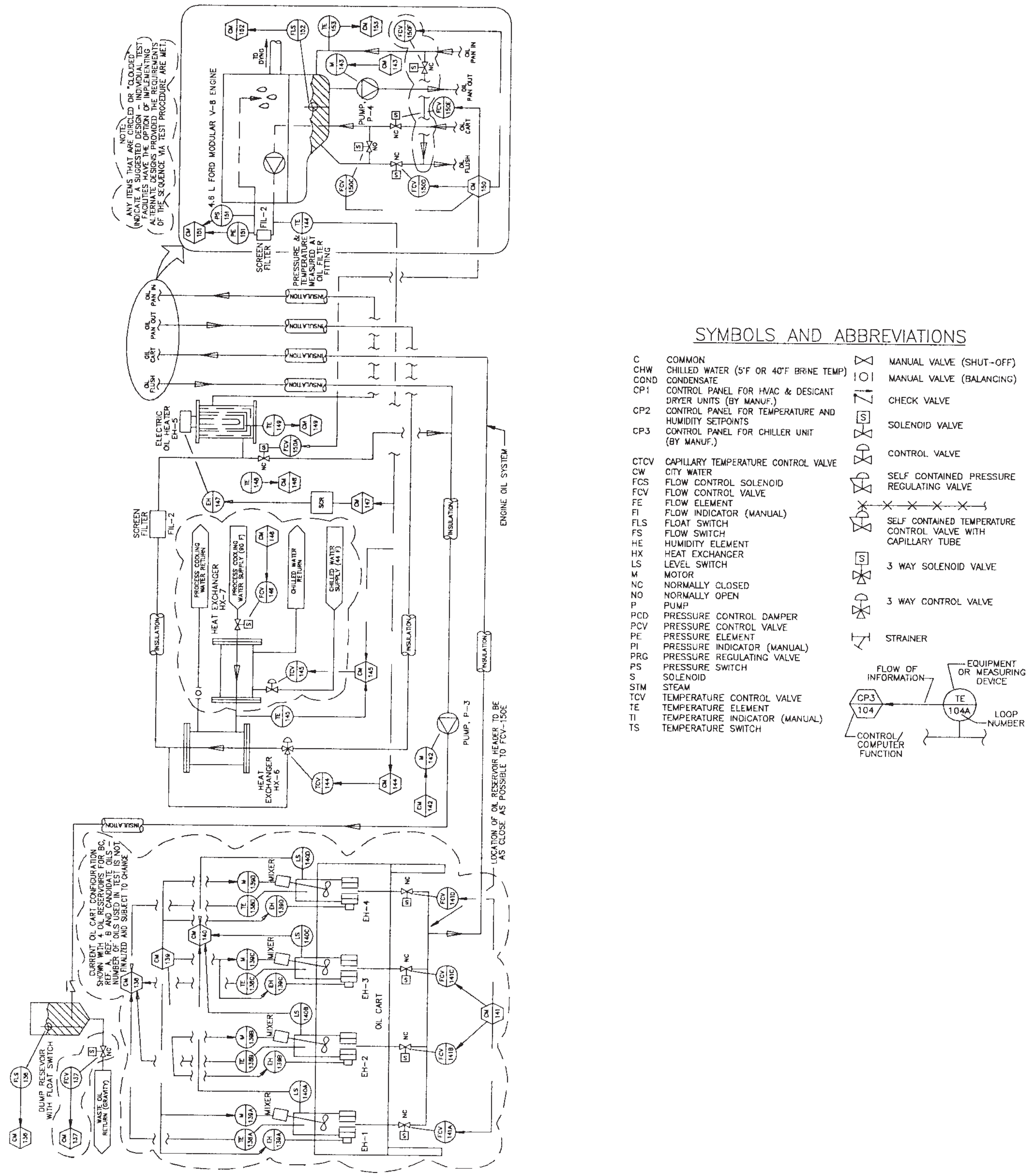


FIG. A2.11 External Oil System

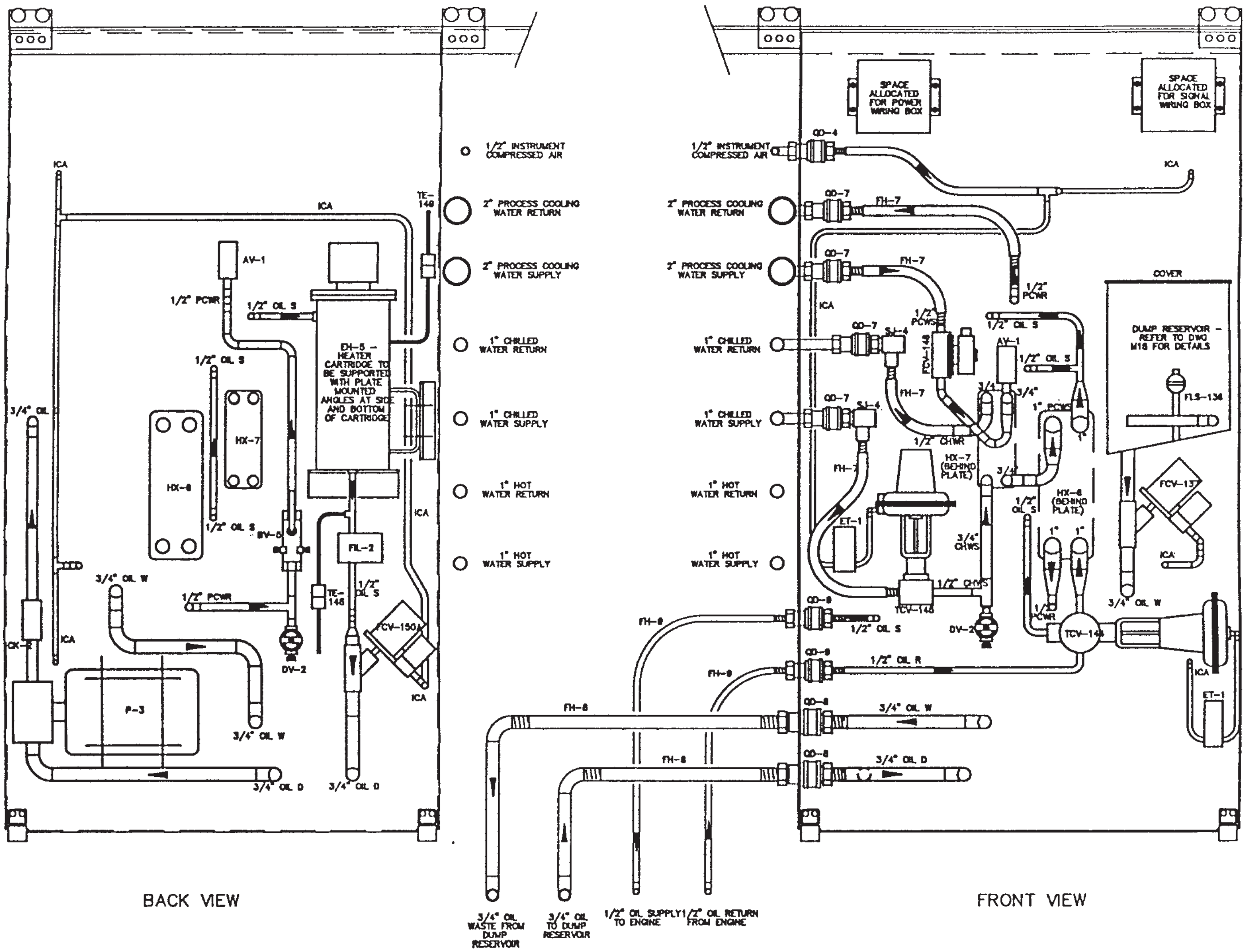


FIG. A2.12 External Oil System (Back and Front Views)

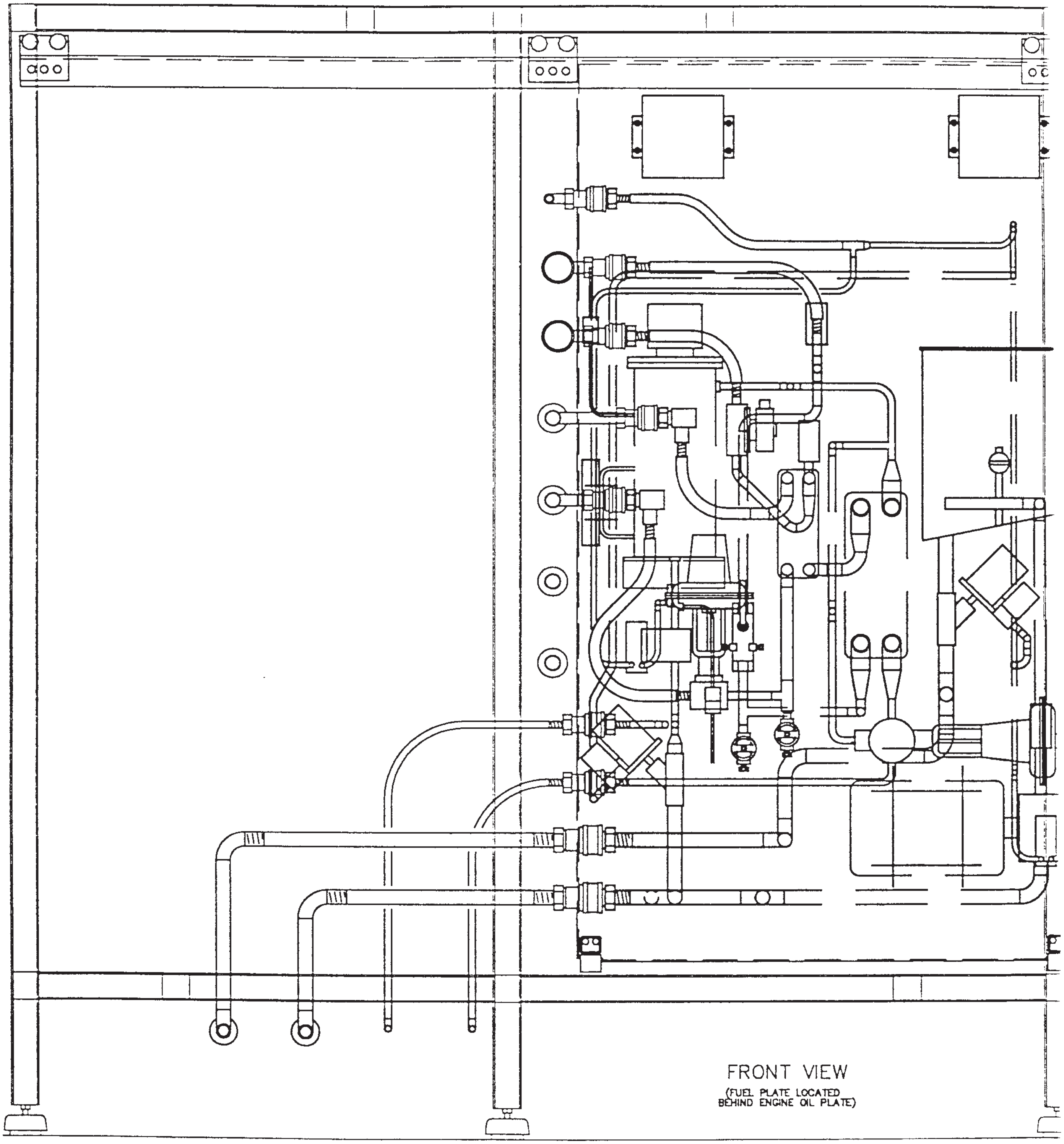
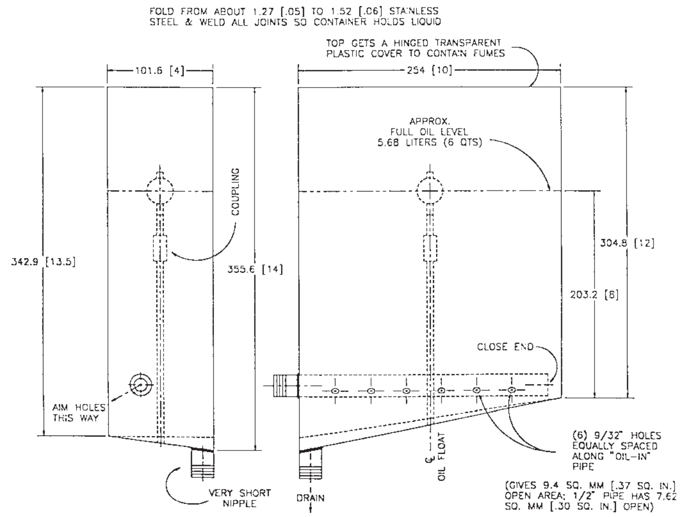


FIG. A2.13 External Oil System (Front View)



NOTE 1—Dimensions are in millimeters and (inches).

NOTE 2—Oil-in black ½ pipe, oil drain short ½ nipple.

NOTE 3—Stand pipe to hold float switch is ¼ pipe; use a short nipple of selected length between float switch and ¼ coupling to get exact level needed to trip switch at 5.68 litres (6 qts).

NOTE 4—Tank is later mounted by tack welding an angle iron leg along one of the vertical corners and welding a square plate at the bottom of the leg, which can be bolted to the floor or other horizontal surface.

NOTE 5—The floor of the tank tips in two planes to give one low corner to drain the oil.

FIG. A2.14 Typical oil Dump Tank

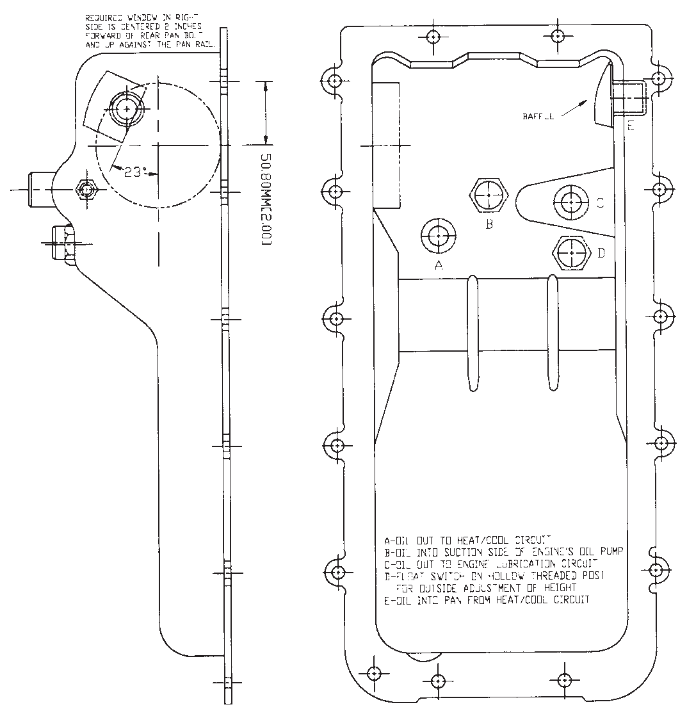


FIG. A2.15 Sequence VIA Pan Modifications

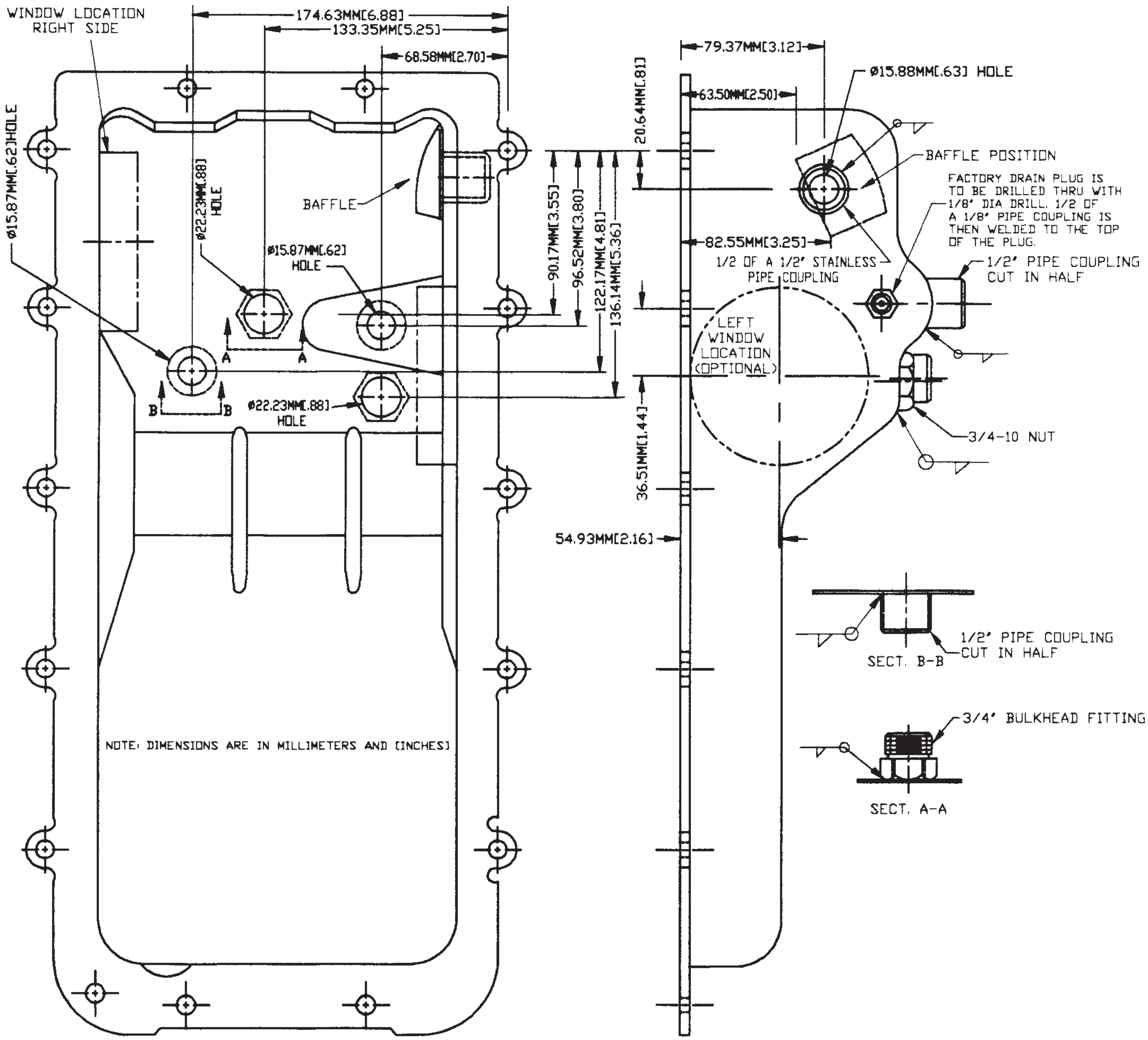


FIG. A2.15 Sequence VIA Pan Modifications *(continued)*

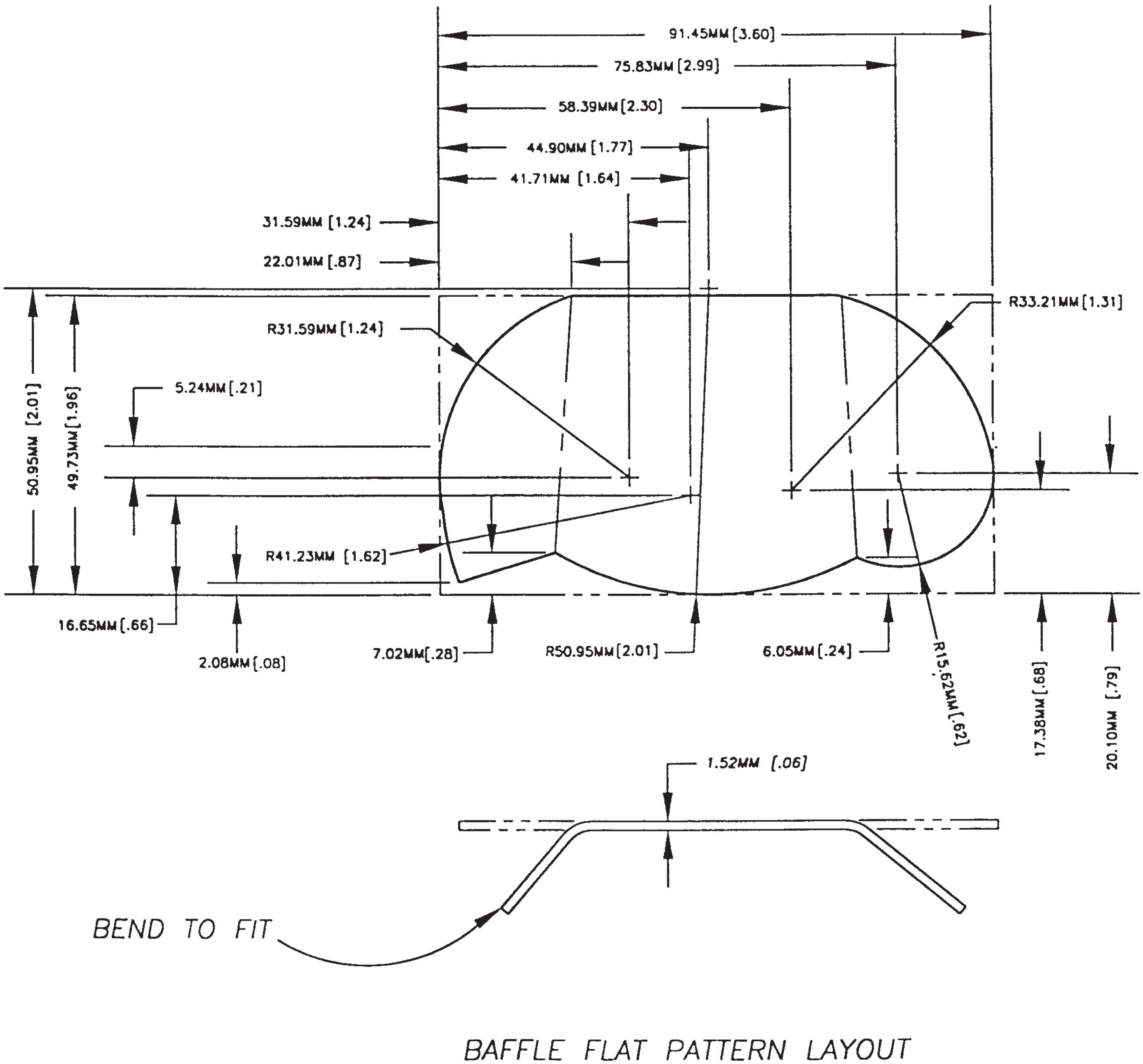


FIG. A2.17 Sequence VIA Oil Pan Baffle

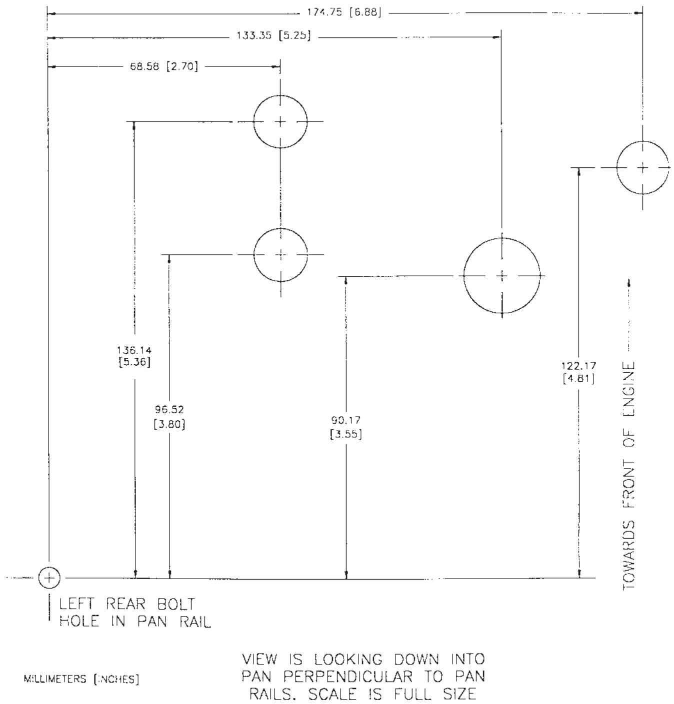


FIG. A2.18 Template For Oil Pan Connections

CONTROL VALVES														
	FLUID CONDITIONS					VALVE BODY			ACTUATOR					
EQUIP TAG #	FLUID TYPE	GPM	MIN/MAX FLUID TEMP (F)	INLET PRESS (PSI)	DESIGN PRESS DROP (PSI)	SIZE	TYPE	CV	TYPE	POSITION	SIGNAL (PSI)	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
TCV-144	ENGINE OIL	0 - 3	100 / 260	50		1/2"	3-WAY GLOBE (DIVERT)	2.5 (LINEAR)	PNEUMATIC, SPRING OPPOSED DIAPHRAGM	AIR TO OPEN	3 TO 15	BADGER METER INC MODEL# 1002TBN36SVOSALN36		1
TCV-145	CHILLED WATER	0 - 7	44 / 44	15 (?)		1/2"	2-WAY GLOBE	2.0 (LINEAR)	PNEUMATIC, SPRING OPPOSED DIAPHRAGM	AIR TO CLOSE	3 TO 15	BADGER METER INC MODEL# 1002GCN36SVCSBLN36		4

DRAIN / SHUT-OFF / CHECK VALVES										
	FLUID CONDITIONS			VALVE BODY						
EQUIP TAG #	FLUID TYPE	MIN/MAX FLUID TEMP (F)	MAX PRESS (PSI)	SIZE	MATERIAL	TYPE	CV	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
CK-2	ENGINE OIL	100 / 260	25 (?)	1/2"	STAINLESS STEEL	BALL CONE CHECK		APOLLO 62-100 SERIES MODEL 62-103	END CONNECTIONS TO BE FEMALE NPT THREADED	4

ELECTRIC HEATING ELEMENT								
	HEATING ELEMENT							
EQUIP TAG #	TYPE	WATTS	VOLTS	PHASE	CYCLE	MANUFCTURER AND MODEL NUMBER	REMARKS	CLASS
EH-5	IMMERSION HEATER - SCREW PLUG	3000	240	3	60	CHROMALOX MTI-330XX: 3 ELEMENT, 27 WATTS/SQ IN, INCALOY SHEATH. LABECO OIL HEATER PROVIDED BY CUSTOMER.	HEATING ELEMENT INSERTED IN LIQUID CERROBASE INSIDE LABECO OIL HEATER USED ON SEQ VI; OIL HEATER ASSEMBLY TO HAVE ENOUGH CAPACITY TO MAINTAIN ENGINE OIL TEMP AT 260 DEG F.	2

FLEXIBLE HOSE MATERIALS									
	FLUID CONDITIONS			FLEXABLE HOSE					
EQUIP TAG #	FLUID TYPE	MIN/MAX FLUID TEMP (F)	MAX SYSTEM PRESS (PSI)	SIZE	MIN BEND RADIUS (IN)	HOSE END CONNECTIONS	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
FH-8	ENGINE OIL	100 / 260	100	3/4"	9.00	MALE NPT THREADED (BOTH ENDS)	AEROQUIP 2807-16		3
FH-9	ENGINE OIL	100 / 260	100	1/2"	5.25	MALE NPT THREADED (BOTH ENDS)	AEROQUIP 2807-8 OR 2807-10		1

HEAT EXCHANGERS															
		PROCESS FLUID						COOLING/HEATING FLUID							
EQUIP TAG #	TYPE	FLUID TYPE	CAPACITY (BTUH)	GPM	INLET TEMP (F)	OUTLET TEMP (F)	MAX PRESS DROP (PSI)	FLUID TYPE	GPM	INLET TEMP (F)	OUTLET TEMP (F)	MAX PRESS DROP (PSI)	MANUFACTURER AND MODEL	REMARKS	CLASS
HX-6	BRAZED PLATE	ENGINE OIL	8,700	4.5	116	106	12	PROCESS WATER	5	78	81.5	1	ITT BELL & GOSSETT BP-25-20 OR ITT STANDARD 310-20 PART #5-686-04-020-001	4.5" X 12.25" X 2.0", 1" NPT CONNECTIONS; VOLUME OF HEAT EXCHANGER IS APPROX. 0.53 QUARTS	1
HX-6	BRAZED PLATE	PROCES S OIL	29,932	5	90	78	1	CHILLED WATER	6	44	52	<1	ITT BELL & GOSSETT BP-12-20	3.0" X 8.0" X 2.0", 3/4" NPT CONNECTIONS	3

LEVEL SWITCHES									
	FLUID		LEVEL SWITCH						
EQUIP TAG #	FLUID TYPE	MIN/MAX TEMP (F)	POSITION BEING SENSED	CONTACT POSITION	SIGNAL	MATERIAL	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
FLS-136	ENGINE OIL	100/260	HIGH LEVEL (DUMP RESERVOIR FULL)	NORMALLY OPEN, CLOSED AT HIGH LEVEL	12 V DC	STAINLESS STEAL	GEMS SERIES 1950 MODEL 79999		4
FLS-152	ENGINE OIL	100/260	HIGH LEVEL (OIL PAN FULL)	NORMALLY OPEN, CLOSED AT HIGH LEVEL	12 V DC	STAINLESS STEAL	GEMS SERIES 1950 MODEL 79999	THIS LEVEL SWITCH NO PART OF MODULE (LOCATED IN OIL PAN)	1

FIG. A2.19 External Oil System Components

MISCELLANEOUS EQUIPMENT						
EQUIP TAG #	DESCRIPTION	SIZE	MATERIAL	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
FIL-2	OIL FILTER	3/8" NPT THREADED CONNECTIONS		OBERG MODEL LFS 5528, 28 MICRON FILTER	2 REQUIRED	1

PIPING / TUBING MATERIALS									
FLUID CONDITIONS			PIPING / TUBING						
FLUID TYPE	MIN/MAX FLUID TEMP (F)	MAX SYSTEM PRESS (PSI)	SIZES	MATERIAL	CONNECTIONS	FITTINGS	REMARKS	CLASS
ENGINE OIL	100 / 260	100	1/2"	316L STAINLESS STEEL TUBING	WELDED, NPT THREADED	WELDED, NPT THREADED	USED FOR SUCTION AND DISCHARGE PIPING FOR RECIRC PUMP P-4; DUE TO VOLUME CONSTRAINTS WALL THICKNESS MUST BE 0.035 IN	2
ENGINE OIL	100 / 260	100	1/2" AND 3/4"	BLACK CARBON STEEL, SCHEDULE 40	NPT THREADED	NPT THREADED	USED FOR SUCTION AND DISCHARGE PIPING FOR SCAVENGE PUMP P-3	2

PIPING INSULATION							
FLUID CONDITIONS			INSULATION				
FLUID TYPE	MIN/MAX FLUID TEMP (F)	MAX SYSTEM PRESS (PSI)	SIZES	THICKNESS (IN)	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
ENGINE OIL	100 / 260	100	1/2" AND 3/4"	1"	MANVILLE MICRO-LOK SERIES RIGID, MOLDED FIBERGLASS INSULATION, 3 1/2 LBS PER CUBIC FOOT DENSITY, VAPOR BARRIER AND SELF SEALING LAP SEAM	MAX. THERMAL COND. 0.276 BTU •IN/HR•FT²•°F AT MEAN TEMP OF 90°F	2

QUICK DISCONNECTS									
	FLUID CONDITIONS			QUICK DISCONNECT					
EQUIP TAG #	FLUID TYPE	MIN/MAX FLUID TEMP (F)	MAX SYSTEM PRESS (PSI)	SIZE	TYPE	MATERIAL	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
QD-8	ENGINE OIL	100 / 260	100	3/4"	TWO WAY SHUT-OFF	316 STAINLESS STEEL	HANSEN SERIES 6-HK-143		2
QD-9	ENGINE OIL	100 / 260	100	1/2"	TWO WAY SHUT-OFF	316 STAINLESS STEEL	HANSEN SERIES 4-HK-143		2

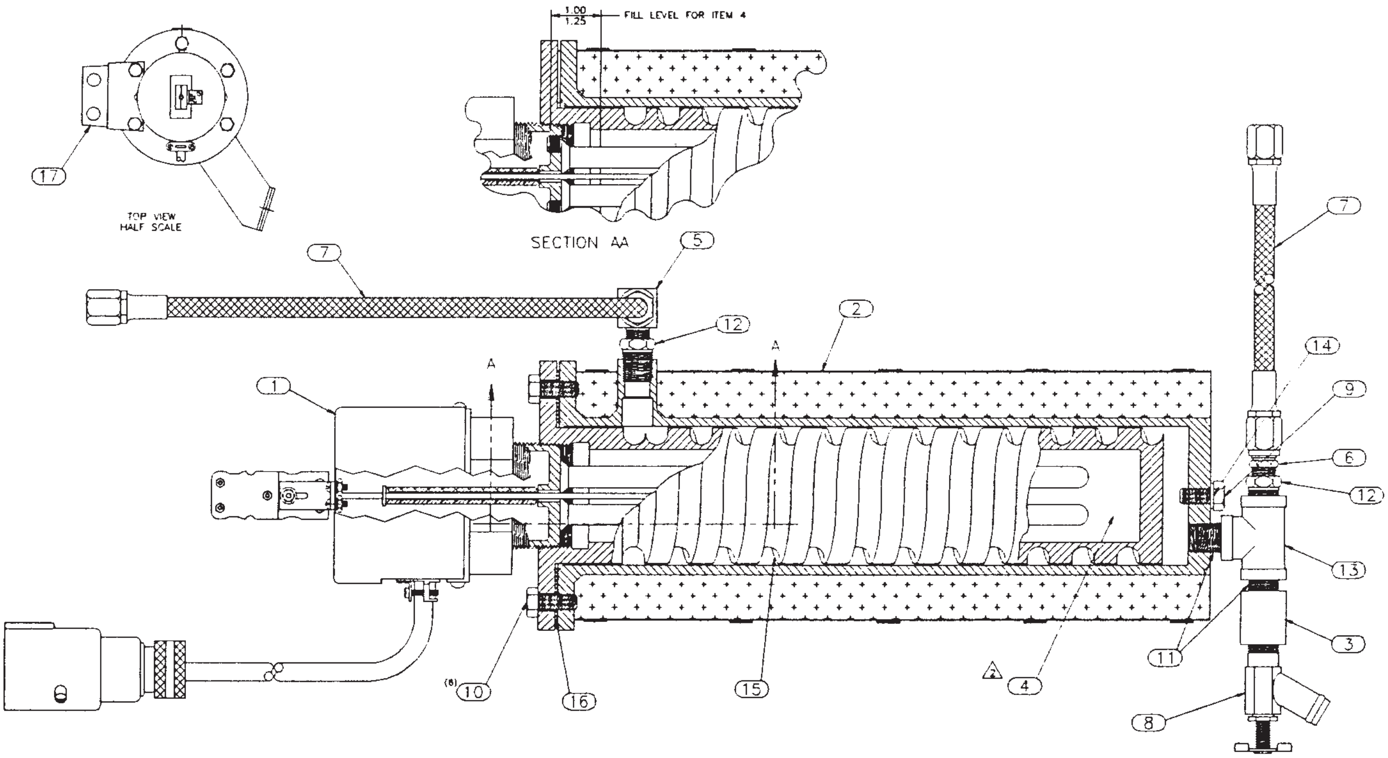
PUMPS															
		FLUID HANDLED				PUMP CAPACITY				MOTOR					
EQUIP TAG #	TYPE	FLUID TYPE	MIN / MAX VISCOSITY (SSU)	MIN TEMP (F)	MAX TEMP (F)	GPM	TOTAL PUMP HEAD AT RATED FLOW (FT. WATER)	TOTAL PUMP PRESSURE AT RATED FLOW (PSI)	MAX BHP	MIN. HP	RPM	VOLTS, PHASE	MANUFCTURER AND MODEL NUMBER	REMARKS	CLASS
P-3	GEAR	ENGINE OIL	80 TO 750	100	260	11 AT 750 SSU		75	0.90	0.75	1150	240 / 1 OR 3 PHASE	VIKING SERIES 475 CLOSE COUPLED PUMP MODEL H475M	HIGH TEMPERATURE CONSTRUCTION, PROVIDE VIBRATION ISOLATION FOR PLATE MOUNTING	1
P-4	GEAR	ENGINE OIL	80 TO 750	100	260	5 AT 750 SSU		175	1.20	0.75	1150	240 / 1 OR 3 PHASE	VIKING SERIES 4125, BASE MOUNTED, V-BELT DRIVE WITH EXPLOSION PROOF MOTOR, MODELG4125 (OPTIONAL)	HIGH TEMPERATURE CONSTRUCTION; PUMP NOT PART OF MODULE (LOCATE NEAR OIL DRAIN PAN)	1

FIG. A2.19 External Oil System Components *(continued)*

SOLENOID VALVES														
	FLUID CONDITIONS					VALVE BODY			SOLENOID					
EQUIP TAG #	FLUID TYPE	GPM	MIN/MAX FLUID TEMP (F)	INLET PRESS (PSI)	DESIGN PRESS DROP (PSI)	SIZE	TYPE	CV	ENCLOSURE	POSITION	VOLTS, HZ	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
FCV-146	PROCESS WATER	6	50 / 90	30		1/2"	2 WAY, BRASS		EXPLOSION PROOF AND WATERTIGHT	NORMALLY CLOSED	120, 60	ASCO RED HAT II MODEL 8210G2		4
FCV-137, FCV-150A	ENGINE OIL		100 / 260	150 MAX		3/4"	2 WAY, STAINLESS STEEL		EXPLOSION PROOF AND WATERTIGHT	NORMALLY CLOSED	120, 60	BURKERT TYPE 251 PISTON OPERATED VALVE WITH TYPE 312 SOLENOID VALVE FOR ACTUATION OF AIR SUPPLY TO PISTON VALVE; SOLENOID VALVE DIRECT COUPLED TO PISTON VALVE	MATERIALS OF CONSTRUCTION MUST BE STAINLESS STEEL	1
FCV-150C	ENGINE OIL		100 / 260	150 MAX		1/2"	2 WAY, STAINLESS STEEL		EXPLOSION PROOF AND WATERTIGHT	NORMALLY OPEN	120, 60	SAME AS FCV-137 EXCEPT NORMALLY OPEN	MATERIALS OF CONSTRUCTION MUST BE STAINLESS STEEL	1
FCV-150D, FCV-150E, FCV-150F	ENGINE OIL		100 / 260	150 MAX		1/2"	2 WAY, STAINLESS STEEL		EXPLOSION PROOF AND WATERTIGHT	NORMALLY CLOSED	120, 60	BURKERT TYPE 251 PISTON OPERATED VALVE WITH TYPE 312 SOLENOID VALVE FOR ACTUATION OF AIR SUPPLY TO PISTON VALVE; SOLENOID VALVE DIRECT COUPLED TO PISTON VALVE	MATERIALS OF CONSTRUCTION MUST BE STAINLESS STEEL FCV 150F IS OPTIONAL	1

THERMOCOUPLES									
	FLUID / SURFACE CONDITIONS			THERMOCOUPLE					
EQUIP TAG #	FLUID / SURFACE TYPE	MIN/MAX FLUID / SURFACE TEMP (F)	MAX SYSTEM PRESS (PSI)	TYPE	TEMP RANGE (F)	OUTPUT	MANUFACTURER AND MODEL NUMBER	REMARKS	CLASS
TE-145	PROCESS WATER	50 / 90	45	"J"	32 TO 900	mV	TEMPREL	SYSTEM INTEGRATOR TO SPECIFY AND PROVIDE THERMOCOUPLE; PROVISIONS FOR 1/4" FEMALE NPT OUTLET BY BUILDER OF MODULE	4
TE-148	ENGINE OIL	100 / 260	100	"J"	32 TO 900	mV	TEMPREL	SYSTEM INTEGRATOR TO SPECIFY AND PROVIDE THERMOCOUPLE; PROVISIONS FOR 1/4" FEMALE NPT OUTLET BY BUILDER OF MODULE	2
TE-149	OIL HEATER EH-5 SURFACE	100 / 320(?)	100 (OIL PRESSURE)	"J"	32 TO 900	mV	TEMPREL	SYSTEM INTEGRATOR TO SPECIFY AND PROVIDE THERMOCOUPLE; PROVISIONS FOR 1/4" FEMALE NPT OUTLET BY BUILDER OF MODULE	2

FIG. A2.19 External Oil System Components *(continued)*

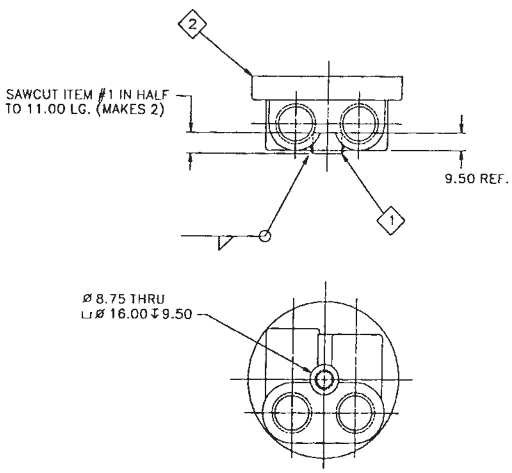


3. TWO ITEMS 9 NOT ASSEMBLED

2 FILL WITH APPROXIMATELY 12 LB. 11 OZ. OF CERRO-CAST (ITEM 4)

1. OIL CAPACITY 425–475 CC INCLUDING HOSE AND FITTINGS AS SHOWN

FIG. A2.22 Thermocouple in Oil Heater



3	1	INSERT #OHT6A–007A–1
2	1	KIT #100292–01 HAYDEN (.62 O.D.x.94 LG.) #6061 ALUM.
1	1	(.12–27 NPT) FULL PIPE COUPLING
◇	REQ'D	DESCRIPTION
BILL OF MATERIAL		

ITEM #3 IS REQ'D FOR ASS'Y.

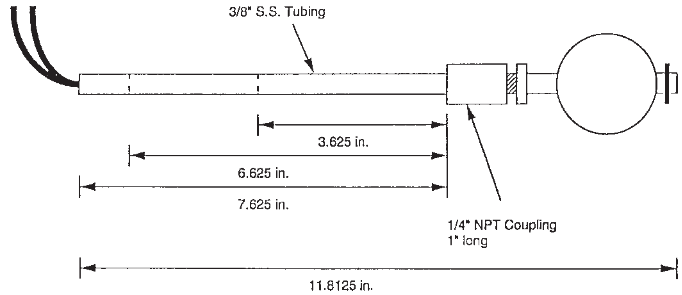
BRACKETED DIMENSIONS ARE IN INCHES

WELDED CONSTRUCTION

USE CROWN #2319 WELDING ROD OR EQUIVALENT

NOTE: REPLACEMENT O–RING #2–230–N674–70 CBB SEAL

FIG. A2.23 Oil Filter Adapter Assembly



NOTE 1—Weld the coupling to the tubing. Place two marks on the tubing. First mark is 3.625 in. from coupling. This is the highest the float switch can be adjusted without making contact to the crankshaft. The second mark is 6.625 in. from the coupling. This is the lowest the float can be adjusted without making contact with the bottom of the pan. The dipstick hole in the block will have to be drilled and tapped for a 3⁄8 in. compression fitting (hole is about the right size already). Remove the farrels and replace with rubber O-rings. This allows the fitting to be loosened and the 3⁄8 in. tubing to be adjusted to the proper float switch setting. Each lab should double check the crank contact distance and oil pan bottom contact distance in their application as well as ensuring that the oil pan level their system requires can be met with this device. Overall length of the tubing is not critical, our is 11.8125 in.

FIG. A2.24 Oil Pan Float Switch

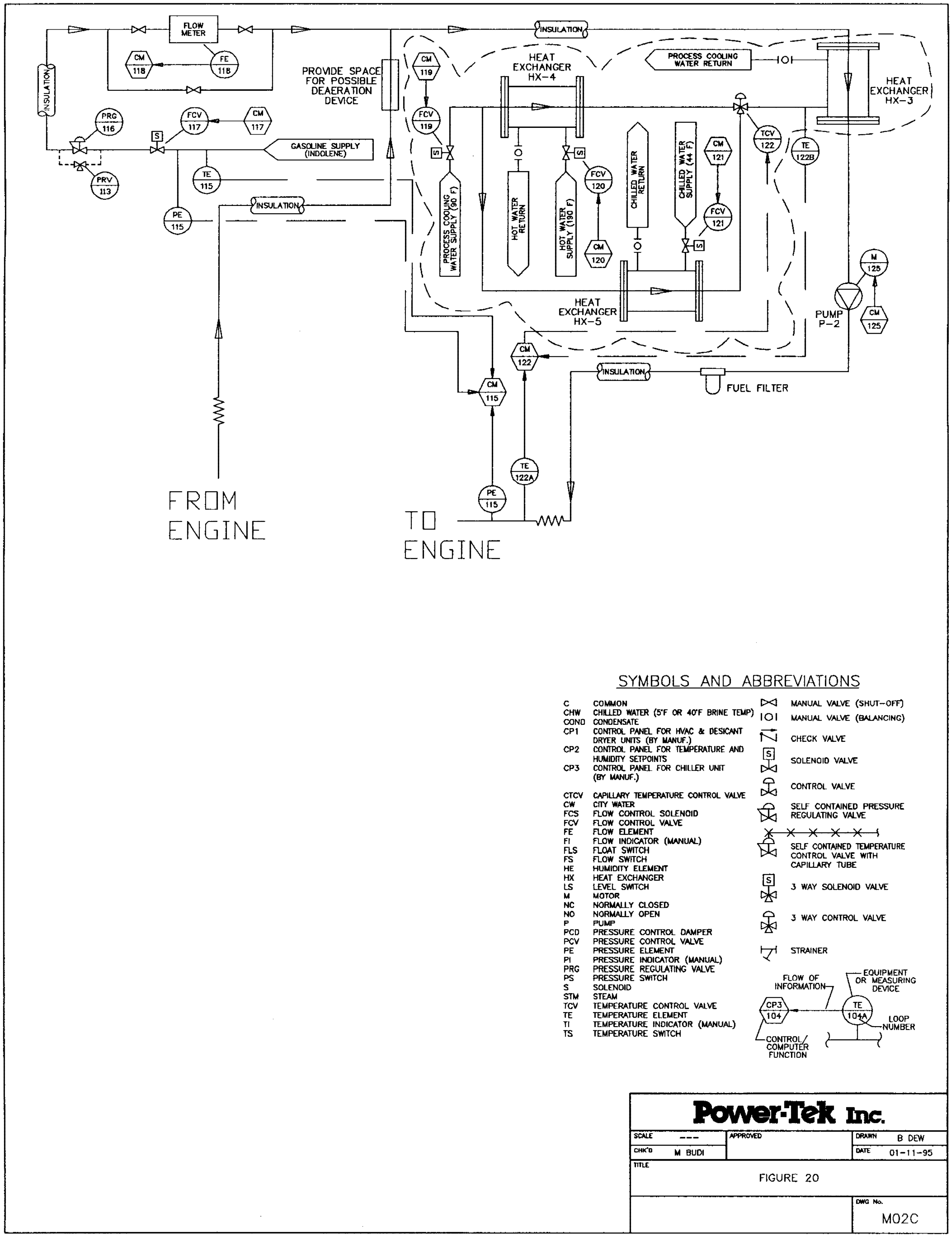


FIG. A2.25 Typical Fuel System

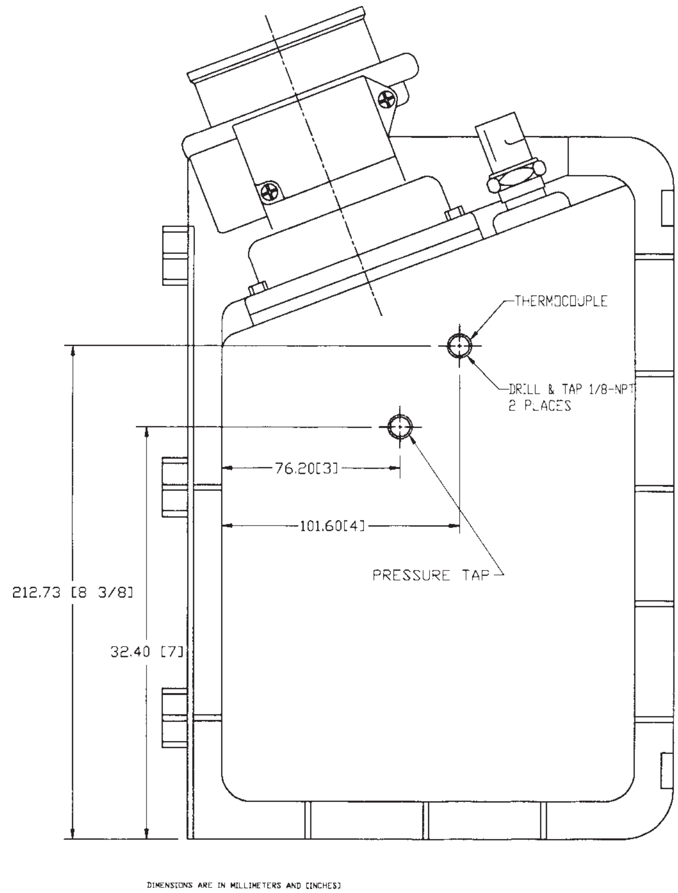


FIG. A2.26 Intake Air Cleaner Assembly

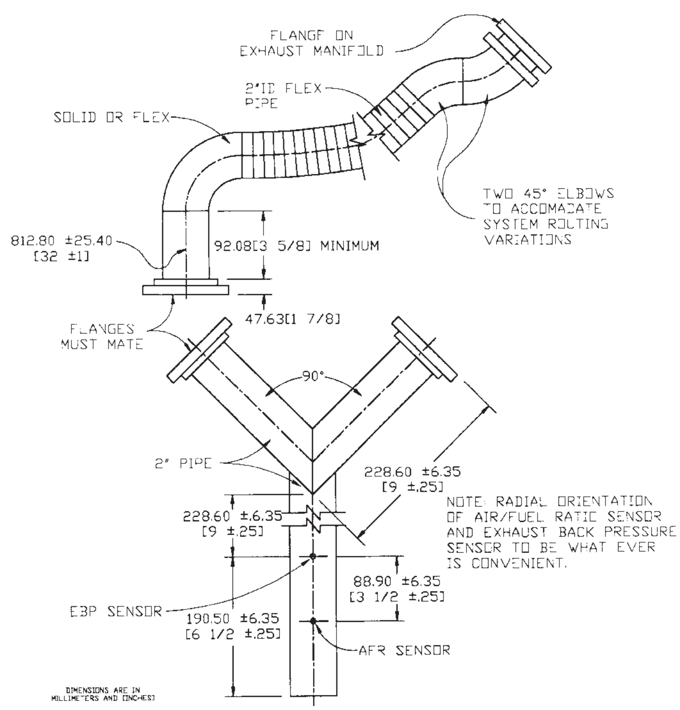
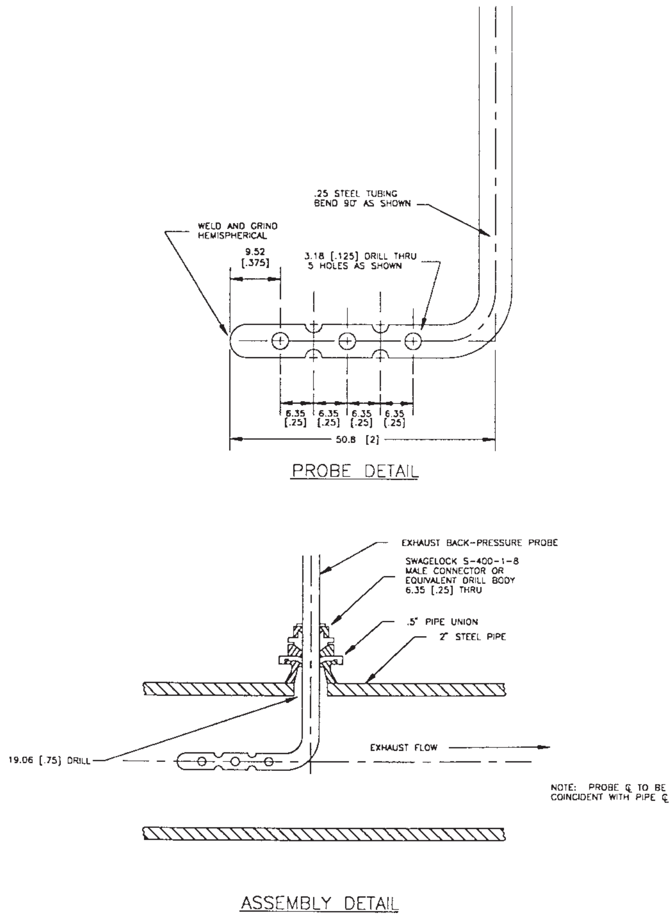


FIG. A2.27 Laboratory Exhaust System



NOTE 1—Bend external tubing segment after assembly parallel with probe axis as shown. This permits visual alignment check during operation.

FIG. A2.28 Exhaust Back Pressure Probe

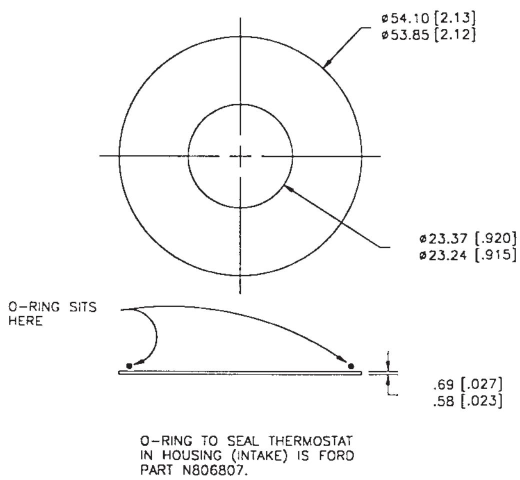


FIG. A2.29 Thermostat Orifice Plate

A3. OIL HEATER CERROBASE REFILL PROCEDURE

A3.1 The cylinder that holds the Cerrobase, Chromalox heater element, and thermocouple is called the cartridge. Take the cartridge out of its insulated case at the engine by backing out six 3 8-16 by 7⁄8hex head screws. Hold the cartridge upright in a vise at the work bench.

A3.2 Remove the cable cover and cable connections at the heater element. It is a good idea to make a sketch of the cable connections and shorting bars because this arrangement is not always the same. Remove two ⅛NPT pipe plugs at the top of the cartridge so that the Cerrobase chamber will be fully vented to atmosphere.

A3.3 Using an acetylene torch, play it on all accessible surfaces of the cartridge until the Cerrobase is completely melted. The Cerrobase must be liquid. Check with a preheated welding rod through one of the ⅛NPT holes. Put a wrench on the 3-in. hex flat and try to remove the heater element from the cartridge. Again, be sure the Cerrobase is completely melted before screwing out on the 3-in. hex. Cerrobase melts at 255°F. Don't force the hex. Keep heating the cartridge and pumping the wrench until the heater element can be backed out of the cartridge.

A3.4 After removing the heater element, lay it aside and pour the melted Cerrobase out of the cartridge into a suitable, dry receiver. Keep heat on the cartridge and be sure it is completely empty of Cerrobase and oxide. Clean all surfaces of the cartridge thoroughly by heating and wire brushing.

A3.5 Hold the heater element in a vise across the hex flats. Remove the thermocouple. Play the torch along the heater elements and wire brush, as necessary, to remove oxide.

A3.6 Replace the cartridge in the vise and heat it with a torch. If the Cerrobase is clean and bright, reuse it. In any case, melt 8.5 lbs of Cerrobase, enough to fill the cartridge about two-thirds full. A good way to melt the Cerrobase is to hold the ladle in a vise. Heat the ladle and Cerrobase until melted, remembering to put occasional heat on the cartridge to keep Cerrobase in the cartridge liquid. Pour from the ladle carefully to avoid splashing. Avoid thermal shock by keeping all parts coming into contact with Cerrobase well heated.

A3.7 Preheat the heater element and immerse it in the liquid Cerrobase. Pull up on the 3-in. hex to secure the assembly. Screw the heater funnel into one of the ⅛ NPT holes. The heater funnel is made up of a heavy wall funnel welded to a 3-in. long, ⅛ in. pipe nipple. (**Warning**—Do not over-torque the 3-in. hex because differential contraction can lock the hex.)

A3.8 Keep playing the torch on the cartridge while working, and when the heater funnel has been screwed in place, heat it also. Finish filling the cartridge with Cerrobase. Look through the open ⅛ NPT hole to see the Cerrobase liquid level and pour Cerrobase through the funnel until the liquid level is within 2.250 and 2.375 in. of the top of the plug. As shown on TD-428, this will leave expansion space for the Cerrobase in the cartridge. If the cartridge should be overfilled, use the following technique to remove Cerrobase.

A3.8.1 Cool a piece of welding rod in ice water. Wipe the rod completely dry and immerse it in the Cerrobase. Pull it out. Some Cerrobase will have solidified and frozen to the rod. Slide Cerrobase off the rod and repeat as necessary to get the liquid level to within ¼ in. of the plug.

A3.9 Use a new thermocouple. Thread eleven heat insulation beads on the thermocouple. Check the Cerrobase with welding rod to be sure it is liquid. Preheat the thermocouple and push it into the Cerrobase through the center, 0.250-in. diameter drilled hole. The eleven beads will serve as a gage to determine immersion depth of the thermocouple. Be sure the 0.250-in. hole is clean. In the final assembly, clearance between this hole and the thermocouple will be the only vent between the Cerrobase and atmosphere. Tie the thermocouple down; otherwise, the thermocouple will float out of the liquid Cerrobase.

A3.10 Let the cartridge cool to room temperature. Remove the heater funnel and install two ⅛ NPT pipe plugs. Connect the cable and shorting bars in their original arrangement. Replace the thermocouple connector and cable cover. Reinstall the cartridge in its insulated case at the engine.

A4. ENGINE PART NUMBER LISTING

A4.1 Table A4.1 lists the new parts required for each new engine and Table A4.2 lists other specified engine parts.

TABLE A4.1 New Parts Required for Each New Engine

Part Name	Part No.
Gasket, camshaft cover (R.H.)	F1AZ-6584-A
Gasket, camshaft cover (L.H.)	F1AZ-6584-B
Gasket, intake manifold to cylinder head (2 required)	F1AZ-9461-A
Gasket, oil filter adapter	F1AZ-6840-A
Gasket, oil pan	F1AZ-6710-A
Gasket, thermostat housing (O-ring)	F1VY-8255-A
Gasket, throttle body adapter	F1AZ-9H486-A
Gasket, throttle body	F1AZ-9E936-A
Gasket, EGR	GAZ-90476-B
Gasket, idle air control valve	E83T8F760
Gasket, water pump	F1VY-8507-A
Spark plugs	AWSF 32C

TABLE A4.2 Other Specified Engine Parts

Part Name	Part Number
Harmonic balancer	F1AZ-6316-A
Oil pan	F1AZ-6675-A
Intake manifold	F1AZ-9424-C or F1AE-9424 or F1AE-9425
Camshaft cover (R.H.)	F1AZ-6582-A
Camshaft cover (L.H.)	F1AZ-6582-B
Thermostat housing	F1VY-8592-A or F1AE-8594
Oil filter adapter	F1AZ-6881 or F1AE-6881 or F1AE-6884
Dipstick tube	F1AZ-6754-A
Oil pressure switch	E95Z-9278-A
Oil pressure sensor	90290
Camshaft positioner sensor (CMP)	F1AZ-6B288-A
Crankshaft position sensor (CKP)	F1AZ-6C315-A
Water temperature indicator sender	F1SZ-10884-A or F1SF-10884
Throttle position sensor (TP)	F2AZ-9B989-A or F2AF-9B989
Engine coolant temperature sensor	F2AZ-12648-A or F2AF-12A648
Heated exhaust gas oxygen sensor	FOTZ-9F472
Air charge temperature (ACT) sensor	F2DZ-12A697
Mass Air Flow Sensor	F2VF-12B579
Manifold absolute pressure (MAP) sensor	F7FZ-9F479 or E7EF-9F479
Ignition coil (R.H.)	F1VY-12029 or F1VU-12029
Ignition coil (L.H.)	F3VU-12029 or F5LU-12029
Ignition coil bracket (R.H.)	F1AZ-12257
Ignition coil bracket (L.H.)	F3AZ-12257
Ignition wires	F3PZ-12259-C
Ignition control module (ICM)	F1AZ-12K072-A or F1AF-12K072
Fuel injectors	FOTZ-9F593
Fuel rail	F2AZ-9F792-A or F2AE-9F792
Fuel pressure regulator	E6AZ-9C968 or E7DE-9C968
Air cleaner outlet tube	F2AZ-9B659
Air cleaner outlet tube clamp	F2AZ-9A624-A
Crankcase ventilation tube	F1AZ-6C324-A
Engine air cleaner assembly	F2AZ-9600
Air cleaner element	E5TZ-9601
Resonator box	F2AE-9R504
Throttle body	F2AZ-9E926 or F2AE-9E926
Throttle body adapter	F2AE-9A589
Engine wiring harness	OHT6A-001-01
Engine control module	OHT6A-002-1, ECM/EEC
Special EPROM	OHT6A-005-1
Exhaust manifold (R.H.)	F1AZ-9430-B
Exhaust manifold (L.H.)	F1AZ-9431-B
Engine flywheel	OHT6A-003-1
Engine mounts (R.H.)	DTSC-80-128-1
Engine mounts (L.H.)	DTSC-80-126-1
Engine mount isolators	DTSC-40-132-1

A5. FLYING FLUSH CHECKLISTS

A5.1 Figs. A5.1-A5.3 are examples of flying flush checklists. Fig. A5.1 is the detergent flush checklist; Fig. A5.2 is the double flush to test oil checklist; and Fig. A5.3 is the double flush to BC oil checklist.

STANDARD CHECKLIST FOR DETERGENT FLUSH

[ ] Set 1500/98/105/125[A] until oil temp is at 125°C (257°F)

[ ] Set 1500 r/min//98 N-m load

[ ] F/F[B] to BCF[C], time ________

[ ] Set 1500/98/105/125[A]

[ ] Run 2 h (until ____________)

[ ] Set 1500 r/min//98 N-m load

[ ] F/F[B] to BC Oil, time ____________

[ ] Set 1500/98/105/125[A]

[ ] Run 30 min (until ________ time)

[ ] Set 1500 r/min//98 N-m load

[ ] F/F[B] to BC Oil, time __________

[ ] Set 1500/98/105/125[A]

[ ] Run 30 min (until __________ time)

[ ] Set 1500 r/min//98 N-m load[A]

[ ] F/F[B] toBC Oil, time ___________

[ ] Continue with routine test operating checklist

[A] This designation represents speed (r/min), load (N-m), coolant inlet temperature (°C), oil gallery temperature (°C) in all places where it appears in this checklist. English equivalent is (1500 r/min, 72.3 lbf-ft, 221°F, 257°F).

[B] Designation for flush/fill procedure in which (*a*) 5.68L (6 qt) of oil are flushed in while (*b*) 5.68 L (6 qt) of sump oil is scavenged out.

[C] Designation for flush oil, ASTM BCF.

FIG. A5.1 Detergent Flush Checklist, BC After Test Oil

STANDARD CHECKLIST FOR DOUBLE FLUSH

[ ] Set 1500/98/105/125^A until oil temp is at 125°C (257°F)

[ ] Set 1500 r/min//98 N-m load

[ ] F/F^B to ____________ Oil, time ____________

[ ] Set 1500/98/105/125^A

[ ] Run 30 min (until ____________ time)

[ ] Set 1500 r/min//98 N-m load

[ ] F/F^B to ____________ Oil, time ____________

[ ] Set 1500/98/105/125^A

[ ] Run 30 min (until ____________ time)

[ ] Set 1500 rpm/98 N-m load^A

[ ] F/F^B to ____________ Oil, time ____________

[ ] Establish proper sump level with ____________ oil

[ ] Continue with routine test operating checklist

^A This designation represents speed (r/min), load (N-m), coolant inlet temperature (°C), oil gallery temperature (°C) in all places where it appears in this checklist. English equivalent is (1500 r/min, 72.3 lbf-ft, 221°F, 257°F).

^B Designation for flush/fill procedure in which (*a*) 5.68L (6 qt) of oil are flushed in while (*b*) 5.68L (6 qt) of sump oil is scavenged out.

FIG. A5.2 Double Flush to Test Oil Checklist

STANDARD CHECKLIST FOR DOUBLE FLUSH

[ ] Set 1500/98/105/125^A until oil temp is at 125°C (257°F)

[ ] Set 1500 r/min/98 N-m load

[ ] F/F^B to BC Oil time ____________

[ ] Set 1500/98/105/125^A

[ ] Run 30 min (until ____________ time)

[ ] Set 1500 r/min/98 N-m load

[ ] F/F^B to BC Oil, time ____________

[ ] Set 1500/98/105/125^A

[ ] Run 30 min (until ____________ time)

[ ] Set 1500 rpm/98 N-m load^A

[ ] F/F^B to BC Oil, time ____________

[ ] Establish proper sump level with ____________ oil

[ ] Continue with routine test operating checklist

^A This designation represents speed (r/min), load (N-m), coolant inlet temperature (°C), oil gallery temperature (°C) in all places where it appears in this checklist. English equivalent is (1500 r/min, 72.3 lbf-ft, 221°F, 257°F).

^B Designation for flush/fill procedure in which (*a*) 5.68L (6 qt) of oil are flushed in while (*b*) 5.68L (6 qt) of sump oil is scavenged out.

FIG. A5.3 Double Flush to BC Oil Checklist

A6. SAFETY PRECAUTIONS

A6.1 *General Information*:

A6.1.1 The operating of engine tests can expose personnel and facilities to a number of safety hazards. It is recommended that only personnel who are thoroughly trained and experienced in engine testing should undertake the design, installation, and operation of engine test stands.

A6.1.2 Each laboratory conducting engine tests should have its test installation inspected and approved by its Safety Department. Personnel working on the engines should be provided with the proper tools, be alert to common sense safety practices, and avoid contact with moving or hot engine parts, or both. Guards should be installed around all external moving or hot parts. When engines are operating at high speeds, heavy duty guards are required and personnel should be cautioned against working alongside the engine and coupling shaft. Barrier protection should be provided for personnel. All fuel lines, oil lines, and electrical wiring should be properly routed, guarded, and kept in good order. Scraped knuckles, minor burns, and cuts are common if proper safety precautions are not taken. Safety masks or glasses should always be worn by personnel working on the engines and no loose or flowing clothing should be worn near running engines.

A6.1.3 The external parts of the engine and the floor area around the engines should be kept clean and free of oil and fuel spills. In addition, the working areas should be free of all tripping hazards. In case of injury, no matter how slight, first aid attention should be applied at once and the incident reported. Personnel should be alert for leaking fuel or exhaust gas. Leaking fuel represents a fire hazard and exhaust gas fumes are noxious. Containers of oil or fuel cannot be permitted to accumulate in the testing area.

A6.1.4 The test installation should be equipped with a fuel shut-off valve that is designed to automatically cut off the fuel supply to the engine when the engine is not running. A remote station for cutting off fuel from the test stand is recommended. Suitable interlocks should be provided so that the engine is automatically shut down when any of the following events occur: dynamometer loses field current, engine overspeeds, engine oil pressure is lost, exhaust system fails, room ventilation fails, or the fire protection system activates. Consider an excessive vibration pick-up interlock if equipment operates unattended. Fixed fire protection equipment should be provided.

A6.1.5 ASTM Sequence Tests use chemicals to clean engines between tests. Some of these chemicals require that personnel wear face masks, dust breathers, and gloves as exothermic reactions are possible. Emergency showers and face rinse facilities should be provided when handling such materials.

A6.2 *Physical and Chemical Hazards List*:

A6.2.1 *Physical Hazards*:

A6.2.1.1 Hot engine parts, exhaust pipe,

A6.2.1.2 Rotating engine/test stand parts (belts, pulleys, shafts),

A6.2.1.3 Electrical shock, and

A6.2.1.4 Noise.

A6.2.2 *Chemical and Materials Hazards*:

A6.2.2.1 *Gasoline - (Unleaded)*:

(1) Extremely flammable. Vapors harmful if inhaled. Vapors may cause flash fire.

(2) Keep away from heat, sparks, and open flames.

(3) Keep containers closed; use positive shut off valves on fuel lines.

(4) Use with adequate ventilation.

(5) Avoid buildup of vapors and eliminate all sources of ignition, especially non-explosion proof electrical apparatus and heaters.

(6) Avoid prolonged breathing of vapor.

(7) Avoid prolonged or repeated skin contact.

(8) In case of spillage, soak up with clay or diatomaceous earth, or similar materials.

(9) In case of fire, use foam, dry chemical, or CO_2.

A6.2.2.2 *Organic Solvent (Penmul L460)*:

(1) Before opening the container, relieve pressure. Keep the container tightly closed when not in use.

(2) Store at moderate temperatures and keep away from heat, sparks, open flame, and strong oxidizing agents.

(3) Use dry chemical, foam, or CO_2 as extinguishing media.

(4) In case of spillage, cover with absorbent material and sweep. Dispose in accordance with RCRA procedures.

(5) Use safety glasses and impervious gloves when handling.

(6) Use respiratory hydrocarbon vapor canister in enclosed areas.

(7) Use only if adequate ventilation is available.

(8) Avoid contact with eyes, skin, and clothing.

(9) Flush eyes with water for 15 min after contact. Wash skin thoroughly with soap and water.

A6.2.2.3 *Organic Solvent (Oakite 811)*:

(1) Before opening the container, relieve pressure. Keep the container tightly closed when not in use.

(2) Store at moderate temperatures and keep away from heat, sparks, open flame, and strong oxidizing agents.

(3) Use dry chemical, foam, or CO_2 as extinguishing media.

(4) In case of spillage, cover with absorbent material and sweep. Dispose in accordance with RCRA procedures.

(5) Use safety glasses and impervious gloves when handling.

(6) Use respiratory hydrocarbon vapor canister in enclosed areas.

(7) Use only if adequate ventilation is available.

(8) Avoid contact with eyes, skin, and clothing.

(9) Flush eyes with water for 15 min after contact. Wash skin thoroughly with soap and water.

A6.2.2.4 *Aliphatic Naphtha (Stoddard Solvent)*:

(1) Combustible vapor harmful if inhaled.

(2) Keep away from heat, sparks, and open flame.

(3) Use with adequate ventilation.

(4) Avoid breathing vapor or spray mist.

(5) Avoid prolonged or repeated contact with skin.

(6) In case of spillage, soak up with clay, diatomaceous earth, or similar material.

(7) In case of fire, use foam, dry chemical, or CO_2.

A6.2.2.5 *Cooling System Cleanser*:

(1) Store at moderate temperatures. Keep container closed until used.

(2) Use water spray, dry chemical, foam, or CO_2 as extinguishing media.

(3) In case of spillage, sweep up. Prevent entry into natural bodies of water.

(4) Use safety glasses and impervious gloves when handling.

(5) Use respiratory protection in absence of proper environmental control.

(6) Use only if adequate ventilation is available.

(7) Avoid contact with eyes, skin, and clothing.

(8) Flush eyes with water for 15 min after contact. Wash skin thoroughly with soap and water.

A6.2.2.6 *Oxalic Acid (Cooling System Cleanser)*:

(1) Toxic substance. Avoid contact with eyes, skin and clothing.

(2) Do not inhale dust.

(3) Keep away from feed or food products.

(4) In case of contact, flush skin or eyes with water.

(5) If swallowed, induce vomiting immediately by giving Ipecac syrup.

A6.2.2.7 *New and Used Oil Samples*:

(1) Store at moderate temperatures and keep away from extreme heat, sparks, open flame, and oxidizing agents.

(2) Use dry chemical, foam, or CO_2 as extinguishing media. In case of spillage, cover with absorbent material and sweep up.

(3) Use safety glasses and impervious gloves when handling.

(4) Avoid contact with eyes, skin, and clothing.

(5) Flush eyes with water for 15 min after contact.

(6) Wash skin thoroughly with soap and water.

A6.2.2.8 *Used Oil Samples Only*—Since used oils contain compounds that were not originally present in the new oil, follow the most stringent Materials Safety Data Sheets guidelines for all components present.

NOTE A6.1—In addition to other precautions, note that continuous contact with used automotive engine oils has caused skin cancer in laboratory mice.

A7. REPORT FORMAT

A7.1 Figs. A7.1-A7.15 are examples of report forms as follows:

Fig. A7.1–Evaluation Report Version 19990729

Fig. A7.2–Test Report on a Non-Reference Oil

Fig. A7.3–Test Report on a Reference Oil

Fig. A7.4–Operational Data Analysis

Fig. A7.5–General Parameter Listing - 16 h Aging

Fig. A7.6–General Parameter Summary - BC Before Test Oil

Fig. A7.7–General Parameter Summary - Test Oil

Fig. A7.8–General Parameter Summary - BC Oil After Test Oil

Fig. A7.9–Critical Parameter Summary - Stage 1

Fig. A7.10–Critical Parameter Summary - Stage 2

Fig. A7.11–Critical Parameter Summary - Stage 3

Fig. A7.12–Critical Parameter Summary - Stage 4

Fig. A7.13–Critical Parameter Summary - Stage 5

Fig. A7.14–Critical Parameter Summary - Stage 6

Fig. A7.15–Supplemental Operational and Maintenance Record

SEQUENCE VIA

Version: *19990729*

CONDUCTED FOR:

TSTSPON1

TSTSPON2

LABVALID	V = VALID	
	I = INVALID	

Lab: *LAB*	Date Completed: *RDTCOMP/DTCOMP*	Time Completed: *REOTTIME/EOTTIME*	
Test Number			
Test Stand: *STAND*	Runs On The Stand: *RSTRUN/STRUN*	Engine No.: *RENGNO/ENGNO*	Runs on Engine: *RENRUN/ENRUN*
Oil Code: *CMIR/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 Test Method D6202 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 Test Report Cover

SEQUENCE VIA
FORM 2
TEST REPORT ON A NON-REFERENCE OIL

Lab: *LAB*	Date Completed: *RDTCOMP/DTCOMP*		Time Completed: *REOTTIME/EOTTIME*
Test Number			
Test Stand: *STAND*	Runs On The Stand: *RSTRUN/STRUN*	Engine No.: *RENGNO/ENGNO*	Runs on Engine: *RENRUN/ENRUN*
Oil Code: *CMIR/OILCODE*			
Formulation/Stand Code: *FORM*			
Alternate Codes	*ALTCODE1*	*ALTCODE2*	*ALTCODE3*

TEST DOCUMENTATION

SAE Grade:	*SAEVISC*	BC Start Date:	*BCDTST*
New Oil Viscosity @ 40 °C, cSt	*V40NEW*	BC Start Time:	*BCSTIME*
New Oil Viscosity @ 100°C, cSt	*V100NEW*	Non-Reference Oil Start Date:	*DTSTRT*
Aged (16 hr.) Oil Viscosity @ 40 °C, cSt	*VINI40*	Non-Reference Oil Start Time:	*STRTTIME*
Aged (16 hr.) Oil Viscosity @ 100°C, cSt	*VINI100*	Test Duration, Hours	*TESTLEN*
Calibration Oil Batch	*CALOILBT*	Total Engine Hours @ End of Test:	*ENHREND*
Laboratory Oil Code	*LABOCODE*	Most Recent Fuel Batch	*FUELBTID*

OVERALL RESULTS

kg	1	2	3	BC Shift% Delta
BC Oil	*BC1KG*		*BC2KG*	*BCSFTDLT*
Average of BC Oil		*ABCKG*		
Test Oil		*KGO*		

Fuel Economy Improvement Relative to the Average of BC (%)	*FEI*
Severity Adjustment	*FEISA*
Final Result	*FEIFNL*

BC Before Non-Reference Pre-Test Verification

Stage	1	2	3	4	5	6	
Max.	0.139	0.185	0.000	-0.225	-0.215	0.216	
Stage Delta	*SDLTR001*	*SDLTR002*	*SDLTR003*	*SDLTR004*	*SDLTR005*	*SDLTR006*	
Min.	0.102	0.152	-0.021	-0.262	-0.253	0.182	6 Stage Mean
Accept Y/N	*ACPTR001*	*ACPTR002*	*ACPTR003*	*ACPTR004*	*ACPTR005*	*ACPTR006*	*SDLTRMEN*

FIG. A7.2 Test Report on a Non-reference Oil

SEQUENCE VIA
FORM 2A
TEST REPORT ON A REFERENCE OIL

Lab: LAB	Date Completed: RDTCOMP/DTCOMP	Time Completed: REOTTIME/EOTTIME

Test Number

Test Stand: STAND	Runs On The Stand: RSTRUN/STRUN	Engine No.: RENGNO/ENGNO	Runs on Engine: RENRUN/ENRUN
Oil Code: CMIR/OILCODE			Engine Serial # ENGSN
Formulation/Stand Code: FORM			
Alternate Codes	ALTCODE1	ALTCODE2	ALTCODE3

REFERENCE TEST DOCUMENTATION

SAE Grade:	RSAEVISC	BC Start Date:	RBCDTST
Calibration Oil Batch	RCALOIL	BC Start Time:	RBCSTIME
Laboratory Oil Code	RLABOCOD	Reference Oil Start Date:	RDTSTRT
Most Recent Fuel Batch	RFUELBID	Reference Oil Start Time:	RSTRTIME
Test Duration, Hours	RTESTLEN	Total Engine Hours @ End of Test:	RENHREND

OVERALL RESULTS

kg	Sequence of Tests			
	1	2	3	BC Shift% Delta
BC Oil	RBC1KG		RBC2KG	RBCSFTDT
Average of BC Oil		RABCKG		
Test Oil		RKGO		

Fuel Economy Improvement Relative to the Average of BC (%)	RFEI
Corrected Result	RFEICF
Final Result	RFEIFNL

BC Before Reference Pre-Test Verification

Stage	1	2	3	4	5	6	
Max.	0.139	0.185	0.000	-0.225	-0.215	0.216	
Stage Delta	RSDTR001	RSDTR002	RSDTR003	RSDTR004	RSDTR005	RSDTR006	
Min.	0.102	0.152	-0.021	-0.262	-0.253	0.182	6 Stage Mean
Accept Y/N	RCPTR001	RCPTR002	RCPTR003	RCPTR004	RCPTR005	RCPTR006	RSDTRMEN

Reference Oil Statistics

TMC Oil Code	Variable	Mean	S.D.	Effective Date:
IND	FEI	RFEIMEAN	RFEISD	ROSTDTE

FIG. A7.3 Test Report on a Reference Oil

SEQUENCE VIA
FORM 3
OPERATIONAL DATA ANALYSIS

Lab: *LAB*		Date Completed: *RDTCOMP/DTCOMP*		Time Completed: *REOTTIME/EOTTIME*	
Test Number					
Test Stand: *STAND*	Runs On The Stand: *RSTRUN/STRUN*		Engine No.: *RENGNO/ENGNO*	Runs on Engine: *RENRUN/ENRUN*	
Oil Code: *CMIR/OILCODE*					
Formulation/Stand Code: *FORM*					
Alternate Codes	*ALTCODE1*		*ALTCODE2*	*ALTCODE3*	

Computed Averages

Oil	Stage	BSFC kg/kW h	BSFC C.V.%	Nominal Power kW	Weight Factor	Weighted Fuel Consumed kg
BC Before Test Oil	1	*BFCARB1A*	*BFCCRB1A*	2.18	0.077472	*WFC_RB1A*
	2	*BFCARB2A*	*BFCCRB2A*	2.18	0.082500	*WFC_RB2A*
	3	*BFCARB3A*	*BFCCRB3A*	5.81	0.035417	*WFC_RB3A*
	4	*BFCARB4A*	*BFCCRB4A*	15.39	0.078250	*WFC_RB4A*
	5	*BFCARB5A*	*BFCCRB5A*	15.39	0.033139	*WFC_RB5A*
	6	*BFCARB6A*	*BFCCRB6A*	2.18	0.045444	*WFC_RB6A*
Total Fuel Consumed including constant of 0.254 kg						*RBC1KG/BC1KG*
Test Oil	1	*BFCARC1A*	*BFCCRC1A*	2.18	0.077472	*WFC_RC1A*
	2	*BFCARC2A*	*BFCCRC2A*	2.18	0.082500	*WFC_RC2A*
	3	*BFCARC3A*	*BFCCRC3A*	5.81	0.035417	*WFC_RC3A*
	4	*BFCARC4A*	*BFCCRC4A*	15.39	0.078250	*WFC_RC4A*
	5	*BFCARC5A*	*BFCCRC5A*	15.39	0.033139	*WFC_RC5A*
	6	*BFCARC6A*	*BFCCRC6A*	2.18	0.045444	*WFC_RC6A*
Total Fuel Consumed including constant of 0.254 kg						*RKGO/KGO*
BC After Test Oil	1	*BFCARA1A*	*BFCCRA1A*	2.18	0.077472	*WFC_RA1A*
	2	*BFCARA2A*	*BFCCRA2A*	2.18	0.082500	*WFC_RA2A*
	3	*BFCARA3A*	*BFCCRA3A*	5.81	0.035417	*WFC_RA3A*
	4	*BFCARA4A*	*BFCCRA4A*	15.39	0.078250	*WFC_RA4A*
	5	*BFCARA5A*	*BFCCRA5A*	15.39	0.033139	*WFC_RA5A*
	6	*BFCARA6A*	*BFCCRA6A*	2.18	0.045444	*WFC_RA6A*
Total Fuel Consumed including constant of 0.254 kg						*RBC2KG/BC2KG*

FIG. A7.4 Operational Data Analysis

SEQUENCE VIA
FORM 4
GENERAL PARAMETER LISTING

Lab: *LAB*	Date Completed: *RDTCOMP/DTCOMP*	Time Completed: *REOTTIME/EOTTIME*	
Test Number			
Test Stand: *STAND*	Runs On The Stand: *RSTRUN/STRUN*	Engine No.: *RENGNO/ENGNO*	Runs on Engine: *RENRUN/ENRUN*
Oil Code: *CMIR/OILCODE*			
Formulation/Stand Code: *FORM*			
Alternate Codes	*ALTCODE1*	*ALTCODE2*	*ALTCODE3*

16 h Aging

	SPEC	AVERAGE [A]	MAX [A]	MIN [A]
1. Speed, r/min	1500 ± 2	*ARPM16H*	*XRPM16H*	*IRPM16H*
2. Load, N-m	98 ± 0.07	*ALD16H*	*XLD16H*	*ILD16H*
3. Oil Gallery Temperature, °C	125 ± 2	*AOGT16H*	*XOGT16H*	*IOGT16H*
4. Coolant Inlet Temperature, °C	105 ± 2	*ACINT16H*	*XCINT16H*	*ICINT16H*
5. Oil Circulation Temperature, °C	Record	*ASMPT16H*	*XSMPT16H*	*ISMPT16H*
6. Coolant Out Temperature, °C	Record	*ACOT16H*	*XCOT16H*	*ICOT16H*
7. Intake Air Temperature, °C	27 ± 2	*AINAT16H*	*XINAT16H*	*IINAT16H*
8. Fuel to Flowmeter Temperature, °C	18 - 32	*AFTMM16H*	*XFTMM16H*	*IFTMM16H*
9. Fuel to Fuel Rail Temperature, °C	20 ± 2	*AFTFR16H*	*XFTFR16H*	*IFTFR16H*
10. Load Cell Temperature, °C	± 3	*ALCT16H*	*XLCT16H*	*ILCT16H*
11. Oil Heater Temperature, °C	205 max	*AHEAT16H*	*XHEAT16H*	*IHEAT16H*
12. Intake Air Pressure, kPa	0.05 ± 0.02	*AINAP16H*	*XINAP16H*	*IINAP16H*
13. Fuel to Flowmeter Pressure, kPa	100 min	*AFPMM16H*	*XFPMM16H*	*IFPMM16H*
14. Fuel to Fuel Rail Pressure, kPa	205 - 310	*AFPFR16H*	*XFPFR16H*	*IFPFR16H*
15. Intake Manifold Pressure, kPa abs.	Record	*AINTV16H*	*XINTV16H*	*IINTV16H*
16. Exhaust Back Pressure, kPa abs.	104 ± 0.17	*AEXBP16H*	*XEXBP16H*	*IEXBP16H*
17. Engine Oil Pressure, kPa	Record	*AOGP16H*	*XOGP16H*	*IOGP16H*
18. Coolant Flow, L/min	130 ± 4	*AMCF16H*	*XMCF16H*	*IMCF16H*
19. Fuel Flow, kg/h	Record	*AFFLO16H*	*XFFLO16H*	*IFFLO16H*
20. Intake Air Humidity, g/kg	11.4 ± 0.8	*AINAH16H*	*XINAH16H*	*IINAH16H*
21. Air/Fuel Ratio	Record	*AAFR16H*	*XAFR16H*	*IAFR16H*

[A] *Based on a minimum of one determination per hour*

FIG. A7.5 General Parameter Listing - 16 h Aging

SEQUENCE VIA
FORM 5
GENERAL PARAMETER SUMMARY

Lab: *LAB*	Date Completed: *RDTCOMP/DTCOMP*	Time Completed: *REOTTIME/EOTTIME*	
Test Number			
Test Stand: *STAND*	Runs On The Stand: *RSTRUN/STRUN*	Engine No.: *RENGNO/ENGNO*	Runs on Engine: *RENRUN/ENRUN*
Oil Code: *CMIR/OILCODE*			
Formulation/Stand Code: *FORM*			
Alternate Codes	*ALTCODE1*	*ALTCODE2*	*ALTCODE3*

BC Before Test Oil

General Parameters

	Spec	Stage 1	2	3	4	5	6
1. Oil Circulation Temperature, °C	Record	*OCT RB01*	*OCT RB02*	*OCT RB03*	*OCT RB04*	*OCT RB05*	*OCT RB06*
2. Coolant Out Temperature, °C	Record	*COT RB01*	*COT RB02*	*COT RB03*	*COT RB04*	*COT RB05*	*COT RB06*
3. Fuel to Flowmeter Temperature, °C	20-32	*FFT RB01*	*FFT RB02*	*FFT RB03*	*FFT RB04*	*FFT RB05*	*FFT RB06*
4. Delta Fuel to Flowmeter Temperature, °C [A]	≤ 4	*FFTDRB01*	*FFTDRB02*	*FFTDRB03*	*FFTDRB04*	*FFTDRB05*	*FFTDRB06*
5. Test Cell Temperature, °C	Record	*TCT RB01*	*TCT RB02*	*TCT RB03*	*TCT RB04*	*TCT RB05*	*TCT RB06*
6. Load Cell Temperature, °C	Record	*LCT RB01*	*LCT RB02*	*LCT RB03*	*LCT RB04*	*LCT RB05*	*LCT RB06*
7. Delta Load Cell Temperature, °C [A]	≤ 6	*LCTDRB01*	*LCTDRB02*	*LCTDRB03*	*LCTDRB04*	*LCTDRB05*	*LCTDRB06*
8. Oil Heater Temperature, °C	200 max	*OHT RB01*	*OHT RB02*	*OHT RB03*	*OHT RB04*	*OHT RB05*	*OHT RB06*
9. Intake Air Pressure, kPa	0.05 ± .02	*IAP RB01*	*IAP RB02*	*IAP RB03*	*IAP RB04*	*IAP RB05*	*IAP RB06*
10. Fuel to Flowmeter Pressure, kPa	100 min	*FFP RB01*	*FFP RB02*	*FFP RB03*	*FFP RB04*	*FFP RB05*	*FFP RB06*
11. Fuel to Fuel Rail Pressure, kPa	205 - 310	*FFRPRB01*	*FFRPRB02*	*FFRPRB03*	*FFRPRB04*	*FFRPRB05*	*FFRPRB06*
12. Intake Manifold Pressure, kPa abs.	Record	*IMP RB01*	*IMP RB02*	*IMP RB03*	*IMP RB04*	*IMP RB05*	*IMP RB06*
13. Engine Oil Pressure, kPa	Record	*EOP RB01*	*EOP RB02*	*EOP RB03*	*EOP RB04*	*EOP RB05*	*EOP RB06*
14. Coolant Flow, L/min	130 ± 4	*CF RB01*	*CF RB02*	*CF RB03*	*CF RB04*	*CF RB05*	*CF RB06*
15. Intake Air Humidity, g/kg	11.4 ± 0.8	*IAH RB01*	*IAH RB02*	*IAH RB03*	*IAH RB04*	*IAH RB05*	*IAH RB06*

[A] Difference between the maximum stage average reading of the entire test and the individual stage average readings

FIG. A7.6 General Parameter Summary - BC Before Test Oil

SEQUENCE VIA
FORM 6
GENERAL PARAMETER SUMMARY

Lab: *LAB*	Date Completed: *RDTCOMP/DTCOMP*	Time Completed: *REOTTIME/EOTTIME*	
Test Number			
Test Stand: *STAND*	Runs On The Stand: *RSTRUN/STRUN*	Engine No.: *RENGNO/ENGNO*	Runs on Engine: *RENRUN/ENRUN*
Oil Code: *CMIR/OILCODE*			
Formulation/Stand Code: *FORM*			
Alternate Codes	*ALTCODE1*	*ALTCODE2*	*ALTCODE3*

Test Oil

General Parameters

		Stage					
	Spec	**1**	**2**	**3**	**4**	**5**	**6**
1. Oil Circulation Temperature, °C	Record	*OCT RC01*	*OCT RC02*	*OCT RC03*	*OCT RC04*	*OCT RC05*	*OCT RC06*
2. Coolant Out Temperature, °C	Record	*COT RC01*	*COT RC02*	*COT RC03*	*COT RC04*	*COT RC05*	*COT RC06*
3. Fuel to Flowmeter Temperature, °C	20-32	*FFT RC01*	*FFT RC02*	*FFT RC03*	*FFT RC04*	*FFT RC05*	*FFT RC06*
4. Delta Fuel to Flowmeter Temperature, °C [A]	≤ 4	*FFTDRC01*	*FFTDRC02*	*FFTDRC03*	*FFTDRC04*	*FFTDRC05*	*FFTDRC06*
5. Test Cell Temperature, °C	Record	*TCT RC01*	*TCT RC02*	*TCT RC03*	*TCT RC04*	*TCT RC05*	*TCT RC06*
6. Load Cell Temperature, °C	Record	*LCT RC01*	*LCT RC02*	*LCT RC03*	*LCT RC04*	*LCT RC05*	*LCT RC06*
7. Delta Load Cell Temperature, °C [A]	≤ 6	*LCTDRC01*	*LCTDRC02*	*LCTDRC03*	*LCTDRC04*	*LCTDRC05*	*LCTDRC06*
8. Oil Heater Temperature, °C	200 max	*OHT RC01*	*OHT RC02*	*OHT RC03*	*OHT RC04*	*OHT RC05*	*OHT RC06*
9. Intake Air Pressure, kPa	0.05 ± .02	*IAP RC01*	*IAP RC02*	*IAP RC03*	*IAP RC04*	*IAP RC05*	*IAP RC06*
10. Fuel to Flowmeter Pressure, kPa	100 min	*FFP RC01*	*FFP RC02*	*FFP RC03*	*FFP RC04*	*FFP RC05*	*FFP RC06*
11. Fuel to Fuel Rail Pressure, kPa	205 - 310	*FFRPRC01*	*FFRPRC02*	*FFRPRC03*	*FFRPRC04*	*FFRPRC05*	*FFRPRC06*
12. Intake Manifold Pressure, kPa abs.	Record	*IMP RC01*	*IMP RC02*	*IMP RC03*	*IMP RC04*	*IMP RC05*	*IMP RC06*
13. Engine Oil Pressure, kPa	Record	*EOP RC01*	*EOP RC02*	*EOP RC03*	*EOP RC04*	*EOP RC05*	*EOP RC06*
14. Coolant Flow, L/min	130 ± 4	*CF RC01*	*CF RC02*	*CF RC03*	*CF RC04*	*CF RC05*	*CF RC06*
15. Intake Air Humidity, g/kg	11.4 ± 0.8	*IAH RC01*	*IAH RC02*	*IAH RC03*	*IAH RC04*	*IAH RC05*	*IAH RC06*

[A] Difference between the maximum stage average reading of the entire test and the individual stage average readings

FIG. A7.7 General Parameter Summary – Test Oil

SEQUENCE VIA
FORM 7
GENERAL PARAMETER SUMMARY

Lab: *LAB*	Date Completed: *RDTCOMP/DTCOMP*		Time Completed: *REOTTIME/EOTTIME*
Test Number			
Test Stand: *STAND*	Runs On The Stand: *RSTRUN/STRUN*	Engine No.: *RENGNO/ENGNO*	Runs on Engine: *RENRUN/ENRUN*
Oil Code: *CMIR/OILCODE*			
Formulation/Stand Code: *FORM*			
Alternate Codes	*ALTCODE1*	*ALTCODE2*	*ALTCODE3*

BC After Test Oil

General Parameters

		Stage					
	Spec	**1**	**2**	**3**	**4**	**5**	**6**
1. Oil Circulation Temperature, °C	Record	*OCT RA01*	*OCT RA02*	*OCT RA03*	*OCT RA04*	*OCT RA05*	*OCT RA06*
2. Coolant Out Temperature, °C	Record	*COT RA01*	*COT RA02*	*COT RA03*	*COT RA04*	*COT RA05*	*COT RA06*
3. Fuel to Flowmeter Temperature, °C	20-32	*FFT RA01*	*FFT RA02*	*FFT RA03*	*FFT RA04*	*FFT RA05*	*FFT RA06*
4. Delta Fuel to Flowmeter Temperature, °C[A]	≤ 4	*FFTDRA01*	*FFTDRA02*	*FFTDRA03*	*FFTDRA04*	*FFTDRA05*	*FFTDRA06*
5. Test Cell Temperature, °C	Record	*TCT RA01*	*TCT RA02*	*TCT RA03*	*TCT RA04*	*TCT RA05*	*TCT RA06*
6. Load Cell Temperature, °C	Record	*LCT RA01*	*LCT RA02*	*LCT RA03*	*LCT RA04*	*LCT RA05*	*LCT RA06*
7. Delta Load Cell Temperature, °C[A]	≤ 6	*LCTDRA01*	*LCTDRA02*	*LCTDRA03*	*LCTDRA04*	*LCTDRA05*	*LCTDRA06*
8. Oil Heater Temperature, °C	200 max	*OHT RA01*	*OHT RA02*	*OHT RA03*	*OHT RA04*	*OHT RA05*	*OHT RA06*
9. Intake Air Pressure, kPa	0.05 ± .02	*IAP RA01*	*IAP RA02*	*IAP RA03*	*IAP RA04*	*IAP RA05*	*IAP RA06*
10. Fuel to Flowmeter Pressure, kPa	100 min	*FFP RA01*	*FFP RA02*	*FFP RA03*	*FFP RA04*	*FFP RA05*	*FFP RA06*
11. Fuel to Fuel Rail Pressure, kPa	205 - 310	*FFRPRA01*	*FFRPRA02*	*FFRPRA03*	*FFRPRA04*	*FFRPRA05*	*FFRPRA06*
12. Intake Manifold Pressure, kPa abs.	Record	*IMP RA01*	*IMP RA02*	*IMP RA03*	*IMP RA04*	*IMP RA05*	*IMP RA06*
13. Engine Oil Pressure, kPa	Record	*EOP RA01*	*EOP RA02*	*EOP RA03*	*EOP RA04*	*EOP RA05*	*EOP RA06*
14. Coolant Flow, L/min	130 ± 4	*CF RA01*	*CF RA02*	*CF RA03*	*CF RA04*	*CF RA05*	*CF RA06*
15. Intake Air Humidity, g/kg	11.4 ± 0.8	*IAH RA01*	*IAH RA02*	*IAH RA03*	*IAH RA04*	*IAH RA05*	*IAH RA06*

[A] Difference between the maximum stage average reading of the entire test and the individual stage average readings

FIG. A7.8 General Parameter Summary – BC Oil After Test Oil

SEQUENCE VIA
FORM 8
CRITICAL PARAMETER SUMMARY - STAGE 1

Lab: *LAB*	Date Completed: *RDTCOMP/DTCOMP*	Time Completed: *REOTTIME/EOTTIME*	
Test Number			
Test Stand: *STAND*	Runs On The Stand: *RSTRUN/STRUN*	Engine No.: *RENGNO/ENGNO*	Runs on Engine: *RENRUN/ENRUN*
Oil Code: *CMIR/OILCODE*			
Formulation/Stand Code: *FORM*			
Alternate Codes	*ALTCODE1*	*ALTCODE2*	*ALTCODE3*

BC Before Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 800 ± 2	Load N m 26 ± .07	Oil Gallery Temp. °C 105 ± 1	Coolant In Temp, °C 95 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] ≤ .50
1	BFC_RB11	RPM_RB11	LD_RB11	OGT_RB11	CINTRB11	IAT_RB11	FRT_RB11				
2	BFC_RB12	RPM_RB12	LD_RB12	OGT_RB12	CINTRB12	IAT_RB12	FRT_RB12				
3	BFC_RB13	RPM_RB13	LD_RB13	OGT_RB13	CINTRB13	IAT_RB13	FRT_RB13				
4	BFC_RB14	RPM_RB14	LD_RB14	OGT_RB14	CINTRB14	IAT_RB14	FRT_RB14				
5	BFC_RB15	RPM_RB15	LD_RB15	OGT_RB15	CINTRB15	IAT_RB15	FRT_RB15				
6	BFC_RB16	RPM_RB16	LD_RB16	OGT_RB16	CINTRB16	IAT_RB16	FRT_RB16				
AVG.	BFCARB1A	RPM_RB1A	LD_RB1A	OGT_RB1A	CINTRB1A	IAT_RB1A	FRT_RB1A				
SD											
C.V.	BFCCRB1A										

Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 800 ± 2	Load N m 26 ± .07	Oil Gallery Temp. °C 105 ± 1	Coolant In Temp, °C 95 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] ≤ .50
1	BFC_RC11	RPM_RC11	LD_RC11	OGT_RC11	CINTRC11	IAT_RC11	FRT_RC11				
2	BFC_RC12	RPM_RC12	LD_RC12	OGT_RC12	CINTRC12	IAT_RC12	FRT_RC12				
3	BFC_RC13	RPM_RC13	LD_RC13	OGT_RC13	CINTRC13	IAT_RC13	FRT_RC13				
4	BFC_RC14	RPM_RC14	LD_RC14	OGT_RC14	CINTRC14	IAT_RC14	FRT_RC14				
5	BFC_RC15	RPM_RC15	LD_RC15	OGT_RC15	CINTRC15	IAT_RC15	FRT_RC15				
6	BFC_RC16	RPM_RC16	LD_RC16	OGT_RC16	CINTRC16	IAT_RC16	FRT_RC16				
AVG.	BFCARC1A	RPM_RC1A	LD_RC1A	OGT_RC1A	CINTRC1A	IAT_RC1A	FRT_RC1A				
SD											
C.V.	BFCCRC1A										

BC After Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 800 ± 2	Load N m 26 ± .07	Oil Gallery Temp. °C 105 ± 1	Coolant In Temp, °C 95 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] ≤ .50
1	BFC_RA11	RPM_RA11	LD_RA11	OGT_RA11	CINTRA11	IAT_RA11	FRT_RA11	EBP_RA11			
2	BFC_RA12	RPM_RA12	LD_RA12	OGT_RA12	CINTRA12	IAT_RA12	FRT_RA12	EBP_RA12			
3	BFC_RA13	RPM_RA13	LD_RA13	OGT_RA13	CINTRA13	IAT_RA13	FRT_RA13	EBP_RA13			
4	BFC_RA14	RPM_RA14	LD_RA14	OGT_RA14	CINTRA14	IAT_RA14	FRT_RA14	EBP_RA14			
5	BFC_RA15	RPM_RA15	LD_RA15	OGT_RA15	CINTRA15	IAT_RA15	FRT_RA15	EBP_RA15			
6	BFC_RA16	RPM_RA16	LD_RA16	OGT_RA16	CINTRA16	IAT_RA16	FRT_RA16	EBP_RA16			
AVG.	BFCARA1A	RPM_RA1A	LD_RA1A	OGT_RA1A	CINTRA1A	IAT_RA1A	FRT_RA1A	EBP_RA1A			
SD											
C.V.	BFCCRA1A										

[A]Difference between the maximum stage average reading of the entire test and the individual stage average readings.

FIG. A7.9 Critical Parameter Summary – Stage 1

SEQUENCE VIA
FORM 9
CRITICAL PARAMETER SUMMARY - STAGE 2

Lab: *LAB*	Date Completed: *RDTCOMP/DTCOMP*	Time Completed: *REOTTIME/EOTTIME*	
Test Number			
Test Stand: *STAND*	Runs On The Stand: *RSTRUN/STRUN*	Engine No.: *RENGNO/ENGNO*	Runs on Engine: *RENRUN/ENRUN*
Oil Code: *CMIR/OILCODE*			
Formulation/Stand Code: *FORM*			
Alternate Codes	*ALTCODE1*	*ALTCODE2*	*ALTCODE3*

BC Before Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 800 ± 2	Load N m 26 ± .07	Oil Gallery Temp. °C 70 ± 1	Coolant In Temp, °C 60 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] ≤ .50
1	BFC_RB21	RPM_RB21	LD_RB21	OGT_RB21	CINTRB21	IAT_RB21	FRT_RB21				
2	BFC_RB22	RPM_RB22	LD_RB22	OGT_RB22	CINTRB22	IAT_RB22	FRT_RB22				
3	BFC_RB23	RPM_RB23	LD_RB23	OGT_RB23	CINTRB23	IAT_RB23	FRT_RB23				
4	BFC_RB24	RPM_RB24	LD_RB24	OGT_RB24	CINTRB24	IAT_RB24	FRT_RB24				
5	BFC_RB25	RPM_RB25	LD_RB25	OGT_RB25	CINTRB25	IAT_RB25	FRT_RB25				
6	BFC_RB26	RPM_RB26	LD_RB26	OGT_RB26	CINTRB26	IAT_RB26	FRT_RB26				
AVG.	BFCARB2A	RPM_RB2A	LD_RB2A	OGT_RB2A	CINTRB2A	IAT_RB2A	FRT_RB2A				
SD											
C.V.	BFCCRB2A										

Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 800 ± 2	Load N m 26 ± .07	Oil Gallery Temp. °C 70 ± 1	Coolant In Temp, °C 60 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] ≤ .50
1	BFC_RC21	RPM_RC21	LD_RC21	OGT_RC21	CINTRC21	IAT_RC21	FRT_RC21				
2	BFC_RC22	RPM_RC22	LD_RC22	OGT_RC22	CINTRC22	IAT_RC22	FRT_RC22				
3	BFC_RC23	RPM_RC23	LD_RC23	OGT_RC23	CINTRC23	IAT_RC23	FRT_RC23				
4	BFC_RC24	RPM_RC24	LD_RC24	OGT_RC24	CINTRC24	IAT_RC24	FRT_RC24				
5	BFC_RC25	RPM_RC25	LD_RC25	OGT_RC25	CINTRC25	IAT_RC25	FRT_RC25				
6	BFC_RC26	RPM_RC26	LD_RC26	OGT_RC26	CINTRC26	IAT_RC26	FRT_RC26				
AVG.	BFCARC2A	RPM_RC2A	LD_RC2A	OGT_RC2A	CINTRC2A	IAT_RC2A	FRT_RC2A				
SD											
C.V.	BFCCRC2A										

BC After Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 800 ± 2	Load N m 26 ± .07	Oil Gallery Temp. °C 70 ± 1	Coolant In Temp, °C 60 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] ≤ .50
1	BFC_RA21	RPM_RA21	LD_RA21	OGT_RA21	CINTRA21	IAT_RA21	FRT_RA21	EBP_RA21			
2	BFC_RA22	RPM_RA22	LD_RA22	OGT_RA22	CINTRA22	IAT_RA22	FRT_RA22	EBP_RA22			
3	BFC_RA23	RPM_RA23	LD_RA23	OGT_RA23	CINTRA23	IAT_RA23	FRT_RA23	EBP_RA23			
4	BFC_RA24	RPM_RA24	LD_RA24	OGT_RA24	CINTRA24	IAT_RA24	FRT_RA24	EBP_RA24			
5	BFC_RA25	RPM_RA25	LD_RA25	OGT_RA25	CINTRA25	IAT_RA25	FRT_RA25	EBP_RA25			
6	BFC_RA26	RPM_RA26	LD_RA26	OGT_RA26	CINTRA26	IAT_RA26	FRT_RA26	EBP_RA26			
AVG.	BFCARA2A	RPM_RA2A	LD_RA2A	OGT_RA2A	CINTRA2A	IAT_RA2A	FRT_RA2A	EBP_RA2A			
SD											
C.V.	BFCCRA2A										

[A] Difference between the maximum stage average reading of the entire test and the individual stage average readings

FIG. A7.10 Critical Parameter Summary – Stage 2

SEQUENCE VIA
FORM 10
CRITICAL PARAMETER SUMMARY - STAGE 3

Lab: LAB	Date Completed: RDTCOMP/DTCOMP	Time Completed: REOTTIME/EOTTIME	
Test Number			
Test Stand: STAND	Runs On The Stand: RSTRUN/STRUN	Engine No.: RENGNO/ENGNO	Runs on Engine: RENRUN/ENRUN
Oil Code: CMIR/OILCODE			
Formulation/Stand Code: FORM			
Alternate Codes	ALTCODE1	ALTCODE2	ALTCODE3

BC Before Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 1500 ± 2	Load N m 37 ± .07	Oil Gallery Temp. °C 70 ± 1	Coolant In Temp, °C 60 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] ≤ .50
1	BFC_RB31	RPM_RB31	LD_RB31	OGT_RB31	CINTRB31	IAT_RB31	FRT_RB31				
2	BFC_RB32	RPM_RB32	LD_RB32	OGT_RB32	CINTRB32	IAT_RB32	FRT_RB32				
3	BFC_RB33	RPM_RB33	LD_RB33	OGT_RB33	CINTRB33	IAT_RB33	FRT_RB33				
4	BFC_RB34	RPM_RB34	LD_RB34	OGT_RB34	CINTRB34	IAT_RB34	FRT_RB34				
5	BFC_RB35	RPM_RB35	LD_RB35	OGT_RB35	CINTRB35	IAT_RB35	FRT_RB35				
6	BFC_RB36	RPM_RB36	LD_RB36	OGT_RB36	CINTRB36	IAT_RB36	FRT_RB36				
AVG.	BFCARB3A	RPM_RB3A	LD_RB3A	OGT_RB3A	CINTRB3A	IAT_RB3A	FRT_RB3A				
SD											
C.V.	BFCCRB3A										

Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 1500 ± 2	Load N m 37 ± .07	Oil Gallery Temp. °C 70 ± 1	Coolant In Temp, °C 60 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] ≤ .50
1	BFC_RC31	RPM_RC31	LD_RC31	OGT_RC31	CINTRC31	IAT_RC31	FRT_RC31				
2	BFC_RC32	RPM_RC32	LD_RC32	OGT_RC32	CINTRC32	IAT_RC32	FRT_RC32				
3	BFC_RC33	RPM_RC33	LD_RC33	OGT_RC33	CINTRC33	IAT_RC33	FRT_RC33				
4	BFC_RC34	RPM_RC34	LD_RC34	OGT_RC34	CINTRC34	IAT_RC34	FRT_RC34				
5	BFC_RC35	RPM_RC35	LD_RC35	OGT_RC35	CINTRC35	IAT_RC35	FRT_RC35				
6	BFC_RC36	RPM_RC36	LD_RC36	OGT_RC36	CINTRC36	IAT_RC36	FRT_RC36				
AVG.	BFCARC3A	RPM_RC3A	LD_RC3A	OGT_RC3A	CINTRC3A	IAT_RC3A	FRT_RC3A				
SD											
C.V.	BFCCRC3A										

BC After Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 1500 ± 2	Load N m 37 ± .07	Oil Gallery Temp. °C 70 ± 1	Coolant In Temp, °C 60 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] ≤ .50
1	BFC_RA31	RPM_RA31	LD_RA31	OGT_RA31	CINTRA31	IAT_RA31	FRT_RA31	EBP_RA31			
2	BFC_RA32	RPM_RA32	LD_RA32	OGT_RA32	CINTRA32	IAT_RA32	FRT_RA32	EBP_RA32			
3	BFC_RA33	RPM_RA33	LD_RA33	OGT_RA33	CINTRA33	IAT_RA33	FRT_RA33	EBP_RA33			
4	BFC_RA34	RPM_RA34	LD_RA34	OGT_RA34	CINTRA34	IAT_RA34	FRT_RA34	EBP_RA34			
5	BFC_RA35	RPM_RA35	LD_RA35	OGT_RA35	CINTRA35	IAT_RA35	FRT_RA35	EBP_RA35			
6	BFC_RA36	RPM_RA36	LD_RA36	OGT_RA36	CINTRA36	IAT_RA36	FRT_RA36	EBP_RA36			
AVG.	BFCARA3A	RPM_RA3A	LD_RA3A	OGT_RA3A	CINTRA3A	IAT_RA3A	FRT_RA3A	EBP_RA3A			
SD											
C.V.	BFCCRA3A										

A Difference between the maximum stage average reading of the entire test and the individual stage average readings

FIG. A7.11 Critical Parameter Summary – Stage 3

SEQUENCE VIA
FORM 11
CRITICAL PARAMETER SUMMARY - STAGE 4

Lab: *LAB*	Date Completed: *RDTCOMP/DTCOMP*	Time Completed: *REOTTIME/EOTTIME*	
Test Number			
Test Stand: *STAND*	Runs On The Stand: *RSTRUN/STRUN*	Engine No.: *RENGNO/ENGNO*	Runs on Engine: *RENRUN/ENRUN*
Oil Code: *CMIR/OILCODE*			
Formulation/Stand Code: *FORM*			
Alternate Codes	*ALTCODE1*	*ALTCODE2*	*ALTCODE3*

BC Before Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 1500 ± 2	Load N m 98 ± .07	Oil Gallery Temp. °C 70 ± 1	Coolant In Temp, °C 60 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] ≤ .50
1	BFC_RB41	RPM_RB41	LD_RB41	OGT_RB41	CINTRB41	IAT_RB41	FRT_RB41				
2	BFC_RB42	RPM_RB42	LD_RB42	OGT_RB42	CINTRB42	IAT_RB42	FRT_RB42				
3	BFC_RB43	RPM_RB43	LD_RB43	OGT_RB43	CINTRB43	IAT_RB43	FRT_RB43				
4	BFC_RB44	RPM_RB44	LD_RB44	OGT_RB44	CINTRB44	IAT_RB44	FRT_RB44				
5	BFC_RB45	RPM_RB45	LD_RB45	OGT_RB45	CINTRB45	IAT_RB45	FRT_RB45				
6	BFC_RB46	RPM_RB46	LD_RB46	OGT_RB46	CINTRB46	IAT_RB46	FRT_RB46				
AVG.	BFCARB4A	RPM_RB4A	LD_RB4A	OGT_RB4A	CINTRB4A	IAT_RB4A	FRT_RB4A				
SD											
C.V.	BFCCRB4A										

Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 1500 ± 2	Load N m 98 ± .07	Oil Gallery Temp. °C 70 ± 1	Coolant In Temp, °C 60 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] ≤ .50
1	BFC_RC41	RPM_RC41	LD_RC41	OGT_RC41	CINTRC41	IAT_RC41	FRT_RC41				
2	BFC_RC42	RPM_RC42	LD_RC42	OGT_RC42	CINTRC42	IAT_RC42	FRT_RC42				
3	BFC_RC43	RPM_RC43	LD_RC43	OGT_RC43	CINTRC43	IAT_RC43	FRT_RC43				
4	BFC_RC44	RPM_RC44	LD_RC44	OGT_RC44	CINTRC44	IAT_RC44	FRT_RC44				
5	BFC_RC45	RPM_RC45	LD_RC45	OGT_RC45	CINTRC45	IAT_RC45	FRT_RC45				
6	BFC_RC46	RPM_RC46	LD_RC46	OGT_RC46	CINTRC46	IAT_RC46	FRT_RC46				
AVG.	BFCARC4A	RPM_RC4A	LD_RC4A	OGT_RC4A	CINTRC4A	IAT_RC4A	FRT_RC4A				
SD											
C.V.	BFCCRC4A										

BC After Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 1500 ± 2	Load N m 98 ± .07	Oil Gallery Temp. °C 70 ± 1	Coolant In Temp, °C 60 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] ≤ .50
1	BFC_RA41	RPM_RA41	LD_RA41	OGT_RA41	CINTRA41	IAT_RA41	FRT_RA41	EBP_RA41			
2	BFC_RA42	RPM_RA42	LD_RA42	OGT_RA42	CINTRA42	IAT_RA42	FRT_RA42	EBP_RA42			
3	BFC_RA43	RPM_RA43	LD_RA43	OGT_RA43	CINTRA43	IAT_RA43	FRT_RA43	EBP_RA43			
4	BFC_RA44	RPM_RA44	LD_RA44	OGT_RA44	CINTRA44	IAT_RA44	FRT_RA44	EBP_RA44			
5	BFC_RA45	RPM_RA45	LD_RA45	OGT_RA45	CINTRA45	IAT_RA45	FRT_RA45	EBP_RA45			
6	BFC_RA46	RPM_RA46	LD_RA46	OGT_RA46	CINTRA46	IAT_RA46	FRT_RA46	EBP_RA46			
AVG.	BFCARA4A	RPM_RA4A	LD_RA4A	OGT_RA4A	CINTRA4A	IAT_RA4A	FRT_RA4A	EBP_RA4A			
SD											
C.V.	BFCCRA4A										

A
Difference between the maximum stage average reading of the entire test and the individual stage average readings

FIG. A7.12 Critical Parameter Summary – Stage 4

SEQUENCE VIA
FORM 12
CRITICAL PARAMETER SUMMARY - STAGE 5

Lab: *LAB*	Date Completed: *RDTCOMP/DTCOMP*		Time Completed: *REOTTIME/EOTTIME*
Test Number			
Test Stand: *STAND*	Runs On The Stand: *RSTRUN/STRUN*	Engine No.: *RENGNO/ENGNO*	Runs on Engine: *RENRUN/ENRUN*
Oil Code: *CMIR/OILCODE*			
Formulation/Stand Code: *FORM*			
Alternate Codes	*ALTCODE1*	*ALTCODE2*	*ALTCODE3*

BC Before Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 1500 ± 2	Load N m 98 ± .07	Oil Gallery Temp. °C 45 ± 1	Coolant In Temp, °C 45 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] $\leq$ .50
1	BFC_RB51	RPM_RB51	LD_RB51	OGT_RB51	CINTRB51	IAT_RB51	FRT_RB51				
2	BFC_RB52	RPM_RB52	LD_RB52	OGT_RB52	CINTRB52	IAT_RB52	FRT_RB52				
3	BFC_RB53	RPM_RB53	LD_RB53	OGT_RB53	CINTRB53	IAT_RB53	FRT_RB53				
4	BFC_RB54	RPM_RB54	LD_RB54	OGT_RB54	CINTRB54	IAT_RB54	FRT_RB54				
5	BFC_RB55	RPM_RB55	LD_RB55	OGT_RB55	CINTRB55	IAT_RB55	FRT_RB55				
6	BFC_RB56	RPM_RB56	LD_RB56	OGT_RB56	CINTRB56	IAT_RB56	FRT_RB56				
AVG.	BFCARB5A	RPM_RB5A	LD_RB5A	OGT_RB5A	CINTRB5A	IAT_RB5A	FRT_RB5A				
SD											
C.V.	BFCCRB5A										

Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 1500 ± 2	Load N m 98 ± .07	Oil Gallery Temp. °C 45 ± 1	Coolant In Temp, °C 45 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] $\leq$ .50
1	BFC_RC51	RPM_RC51	LD_RC51	OGT_RC51	CINTRC51	IAT_RC51	FRT_RC51				
2	BFC_RC52	RPM_RC52	LD_RC52	OGT_RC52	CINTRC52	IAT_RC52	FRT_RC52				
3	BFC_RC53	RPM_RC53	LD_RC53	OGT_RC53	CINTRC53	IAT_RC53	FRT_RC53				
4	BFC_RC54	RPM_RC54	LD_RC54	OGT_RC54	CINTRC54	IAT_RC54	FRT_RC54				
5	BFC_RC55	RPM_RC55	LD_RC55	OGT_RC55	CINTRC55	IAT_RC55	FRT_RC55				
6	BFC_RC56	RPM_RC56	LD_RC56	OGT_RC56	CINTRC56	IAT_RC56	FRT_RC56				
AVG.	BFCARC5A	RPM_RC5A	LD_RC5A	OGT_RC5A	CINTRC5A	IAT_RC5A	FRT_RC5A				
SD											
C.V.	BFCCRC5A										

BC After Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 1500 ± 2	Load N m 98 ± .07	Oil Gallery Temp. °C 45 ± 1	Coolant In Temp, °C 45 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] $\leq$ .50
1	BFC_RA51	RPM_RA51	LD_RA51	OGT_RA51	CINTRA51	IAT_RA51	FRT_RA51	EBP_RA51			
2	BFC_RA52	RPM_RA52	LD_RA52	OGT_RA52	CINTRA52	IAT_RA52	FRT_RA52	EBP_RA52			
3	BFC_RA53	RPM_RA53	LD_RA53	OGT_RA53	CINTRA53	IAT_RA53	FRT_RA53	EBP_RA53			
4	BFC_RA54	RPM_RA54	LD_RA54	OGT_RA54	CINTRA54	IAT_RA54	FRT_RA54	EBP_RA54			
5	BFC_RA55	RPM_RA55	LD_RA55	OGT_RA55	CINTRA55	IAT_RA55	FRT_RA55	EBP_RA55			
6	BFC_RA56	RPM_RA56	LD_RA56	OGT_RA56	CINTRA56	IAT_RA56	FRT_RA56	EBP_RA56			
AVG.	BFCARA5A	RPM_RA5A	LD_RA5A	OGT_RA5A	CINTRA5A	IAT_RA5A	FRT_RA5A	EBP_RA5A			
SD											
C.V.	BFCCRA5A										

A
Difference between the maximum stage average reading of the entire test and the individual stage average readings

FIG. A7.13 Critical Parameter Summary – Stage 5

SEQUENCE VIA
FORM 13
CRITICAL PARAMETER SUMMARY - STAGE 6

Lab: LAB	Date Completed: RDTCOMP/DTCOMP	Time Completed: REOTTIME/EOTTIME	
Test Number			
Test Stand: STAND	Runs On The Stand: RSTRUN/STRUN	Engine No.: RENGNO/ENGNO	Runs on Engine: RENRUN/ENRUN
Oil Code: CMIR/OILCODE			
Formulation/Stand Code: FORM			
Alternate Codes	ALTCODE1	ALTCODE2	ALTCODE3

BC Before Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 800 ± 2	Load N m 26 ± .07	Oil Gallery Temp. °C 45 ± 1	Coolant In Temp, °C 45 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] ≤ .50
1	BFC_RB61	RPM_RB61	LD_RB61	OGT_RB61	CINTRB61	IAT_RB61	FRT_RB61				
2	BFC_RB62	RPM_RB62	LD_RB62	OGT_RB62	CINTRB62	IAT_RB62	FRT_RB62				
3	BFC_RB63	RPM_RB63	LD_RB63	OGT_RB63	CINTRB63	IAT_RB63	FRT_RB63				
4	BFC_RB64	RPM_RB64	LD_RB64	OGT_RB64	CINTRB64	IAT_RB64	FRT_RB64				
5	BFC_RB65	RPM_RB65	LD_RB65	OGT_RB65	CINTRB65	IAT_RB65	FRT_RB65				
6	BFC_RB66	RPM_RB66	LD_RB66	OGT_RB66	CINTRB66	IAT_RB66	FRT_RB66				
AVG.	BFCARB6A	RPM_RB6A	LD_RB6A	OGT_RB6A	CINTRB6A	IAT_RB6A	FRT_RB6A				
SD											
C.V.	BFCCRB6A										

Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 800 ± 2	Load N m 26 ± .07	Oil Gallery Temp. °C 45 ± 1	Coolant In Temp, °C 45 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] ≤ .50
1	BFC_RC61	RPM_RC61	LD_RC61	OGT_RC61	CINTRC61	IAT_RC61	FRT_RC61				
2	BFC_RC62	RPM_RC62	LD_RC62	OGT_RC62	CINTRC62	IAT_RC62	FRT_RC62				
3	BFC_RC63	RPM_RC63	LD_RC63	OGT_RC63	CINTRC63	IAT_RC63	FRT_RC63				
4	BFC_RC64	RPM_RC64	LD_RC64	OGT_RC64	CINTRC64	IAT_RC64	FRT_RC64				
5	BFC_RC65	RPM_RC65	LD_RC65	OGT_RC65	CINTRC65	IAT_RC65	FRT_RC65				
6	BFC_RC66	RPM_RC66	LD_RC66	OGT_RC66	CINTRC66	IAT_RC66	FRT_RC66				
AVG.	BFCARC6A	RPM_RC6A	LD_RC6A	OGT_RC6A	CINTRC6A	IAT_RC6A	FRT_RC6A				
SD											
C.V.	BFCCRC6A										

BC After Test Oil

Step SPEC	BSFC kg/kW h	Speed r/min 800 ± 2	Load N m 26 ± .07	Oil Gallery Temp. °C 45 ± 1	Coolant In Temp, °C 45 ± 1	Intake Air Temp, °C 27 ± 2	Fuel Rail Temp, °C 20 ± 2	EBP kPa 104 ± .17	Fuel Flow kg/h Record	AFR 14.25-15.25	Delta AFR[A] ≤ .50
1	BFC_RA61	RPM_RA61	LD_RA61	OGT_RA61	CINTRA61	IAT_RA61	FRT_RA61	EBP_RA61			
2	BFC_RA62	RPM_RA62	LD_RA62	OGT_RA62	CINTRA62	IAT_RA62	FRT_RA62	EBP_RA62			
3	BFC_RA63	RPM_RA63	LD_RA63	OGT_RA63	CINTRA63	IAT_RA63	FRT_RA63	EBP_RA63			
4	BFC_RA64	RPM_RA64	LD_RA64	OGT_RA64	CINTRA64	IAT_RA64	FRT_RA64	EBP_RA64			
5	BFC_RA65	RPM_RA65	LD_RA65	OGT_RA65	CINTRA65	IAT_RA65	FRT_RA65	EBP_RA65			
6	BFC_RA66	RPM_RA66	LD_RA66	OGT_RA66	CINTRA66	IAT_RA66	FRT_RA66	EBP_RA66			
AVG.	BFCARA6A	RPM_RA6A	LD_RA6A	OGT_RA6A	CINTRA6A	IAT_RA6A	FRT_RA6A	EBP_RA6A			
SD											
C.V.	BFCCRA6A										

[A] **Difference between the maximum stage average reading of the entire test and the individual stage average readings**

FIG. A7.14 Critical Parameter Summary – Stage 6

SEQUENCE VIA
FORM 14
SUPPLEMENTAL OPERATIONAL AND MAINTENANCE RECORD

Lab: *LAB*	Date Completed: *RDTCOMP/DTCOMP*	Time Completed: *REOTTIME/EOTTIME*	
Test Number			
Test Stand: *STAND*	Runs On The Stand: *RSTRUN/STRUN*	Engine No.: *RENGNO/ENGNO*	Runs on Engine: *RENRUN/ENRUN*
Oil Code: *CMIR/OILCODE*			
Formulation/Stand Code: *FORM*			
Alternate Codes	*ALTCODE1*	*ALTCODE2*	*ALTCODE3*

Downtime Occurrences			
Test Hours	**Date**	**Downtime**	**Reasons**
Total Downtime			

Total Number of Comments & Outlier Lines	

FIG. A7.15 Supplemental Operational and Maintenance Record

A8. CONTROL CHART TECHNIQUE FOR A STAND/ENGINE'S SEVERITY ADJUSTMENT (SA)

A8.1 An EWMA technique is applied to standardized calibration test FEI results. The targets and standard deviations for current reference oils are published by the ASTM TMC.

A8.2 Include all operationally valid reference tests in the stand control chart. Chart tests in order of completion date and time. A minimum of three operationally valid calibration tests are required to initialize a control chart. Calculate EWMA values using Eq A8.1.

$$Z_i = 0.30\,(Y_i) + 0.70\,(Z_{i-1}) \quad \text{(A8.1)}$$

where:
Z_o = Median Y_i of the first three operationally valid tests,
Y_i = standardized test result, and
Z_i = EWMA of the standardized test result at test order *i*.

If absolute value of the EWMA, rounded to three places after the decimal, exceeds 0.000, then apply an SA to subsequent non-reference results. The following example illustrates the application of Eq A8.1 for determining the application of FEI SA.

$$Z_2 = 1.567 \textit{ and } Y_3 = 1.571 \quad \text{(A8.2)}$$
$$\text{EWMA} = 0.30\,(1.571) + 0.70\,(1.567) = 1.568$$

A8.3 Since ‖ 1.568 ‖ > 0.000, an SA shall be applied. Multiply 1.568 by 0.15. This value (0.15) was determined by the Sequence VI/VIA Surveillance Panel to represent the pooled standard deviation of the Sequence VIA oils. Multiply this value by –1 and round to two places after the decimal. Record this value on the test summary of the test report in the space for FEI applied SA. Add this value to the non-reference result. Enter this number in the FEI final result space on the test summary page of the test report. An SA will remain in effect until the next reference test. At that time, calculate a new EWMA.

A9. STATISTICAL EQUATIONS FOR MEAN AND STANDARD DEVIATION

A9.1 See Eq A9.1 and A9.2.

$$\text{mean} = \frac{1}{n}\sum_{i=1}^{n}\left[Yi(standard) - Zi(reading)\right] \quad \text{(A9.1)}$$

$$\text{standard deviation} = \sqrt{\frac{\sum_{i=1}^{n}\left[(Yi - Zi) - mean\right]^2}{df}} \quad \text{(A9.2)}$$

where:
n = total number of data pairs, and
df = degrees of freedom = n–1.

A10. FUEL INJECTOR EVALUATION

A10.1 *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 in A10.2. Since no suitable commercially available apparatus has been identified, design of the test rig is up to the laboratory. Flow test the injectors, using Stoddard solvent as the test fluid.

A10.2 *Fuel Injectors*—Prior to engine installation, evaluate all injectors (new and used) for spray pattern and flow-rate, using the test rig in A10.1. Injectors may be cleaned and reused if the criteria outlined in this procedure are satisfied.

A10.2.1 Perform a visual inspection of each injector to ensure that each injector has been cleaned of all oily deposits.

A10.2.2 Check the injector O-ring for cracking or tearing and replace as required.

A10.2.3 Flush new injectors for 30 s to remove any assembly residue before flow testing.

A10.2.4 Place the injector(s) in the test rig and turn the test fluid on. Verify the flow of test fluid through the injector(s). Maintain the test fluid pressure supplied to the injector(s) at 290 ± 3.4 kPa during the entire test. The maintenance of this pressure is critical as 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.

A10.2.5 Flow-test each injector for a 60 s 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.

A10.2.6 The acceptable total flow for each injector after the 60 s test shall be 188 to 198 mL at 290 ± 3.4 kPa of test fluid pressure. Discard any injector that flows above or below this range.

A10.2.7 At completion of the 60 s period, close the injector and maintain the test fluid pressure for a minimum of 30 s. Discard any injector that leaks or drips.

A11. PRE-TEST MAINTENANCE CHECKLIST

A11.1 A checklist for pre-test maintenance is shown in Table A11.1.

TABLE A11.1 Pre-test Maintenance Checklist

Required Maintenance	Prior to Each Test Start	[A]Prior to Each Reference Start	As Noted
Replace spark plugs		X	
Service racor filtors	X[B]		
Verify injector flows		X	
Clean/recondition throttle body			[C]
Clean coolant heat exchanger			[D]
Clean/flush oil heat exchanger			[C]
Replace fuel filters		X	
Inspect/service driveline		X	
Rotate dyno trunion bearings			[E]
Clean/replace EBP probe			[E]

[A]Only required on initial reference in a series.
[B]Not required on tests run in a string.
[C]With installation of new engine.
[D]As required by normal laboratory practice.
[E]Every six months.

APPENDIXES

(Nonmandatory Information)

X1. PROCUREMENT OF TEST MATERIALS

X1.1 Throughout the test method, references are made to necessary hardware, reagents, materials, and apparatus. In many cases, for the sake of uniformity and ease of acquisition, certain suppliers are named. If substitutions are deemed appropriate for the specified suppliers, permission in writing must be obtained from the TMC before such will be considered to be equivalent. The following entries for this appendix represent a consolidated listing of the ordering information necessary to complete the references found in the text.

X1.1.1 *General Communications Concerning Sequence VIA Reference Tests, Procedural Questions, and Non-Reference Tests* :

ASTM Test Monitoring Center
Attention: Administrator
6555 Penn Ave.
Pittsburgh, PA 15206-4489
Telephone: (412) 365-1005

X1.1.2 *Reference Oils and Calibration Oils*—Reference oils and calibration oils may be purchased by contacting:

ASTM Test Monitoring Center
Attention: Operations Manager
6555 Penn Ave.
Pittsburgh, PA 15206-4489
Telephone: (412) 365-1010

X1.1.3 *Test Engines*— Sequence VIA engines, Part No. R2G-800-XB (AOD-E):

AER
1605 Surveyor Blvd.
P.O. Box 979
Carrollton, TX 75011-0979

X1.1.4 *Dynamometer*— A Midwest Model 758 (50 HP) dry gap dynamometer may be ordered from:

Midwest Dynamometer Engineering Co.
3100 River Rd.
River Grove, IL 60171

X1.1.5 *Dynamometer Load Cell*—The recommended load cell is a Lebow Model 3397, which may be ordered from:

Eaton Corp.
Lebow Products
1728 Maplelawn Rd.
P.O. Box 1089
Troy, MI 48099

X1.1.6 *Cooling System Pressure Cap*—A satisfactory coolant system pressure cap (Stant, R-28, 7 psi, normally closed cap) is available through local distributors.

X1.1.7 *Cooling System Pump (P-1)*—The specified cooling system pump may be obtained from:

Gould Pumps, Inc.
240 Fall St.
Seneca Falls, NY 13148

X1.1.8 *Coolant Heat Exchanger (HX-1)*—ITT (Model 320-20) or Bell and Gossett (BP 75H-20 or BP 420-20):

ITT Standard
175 Standard Pkwy.
Buffalo, NY 14227

Bell and Gossett ITT
8200 N. Austin Ave.
Morton Grove, IL 60053

X1.1.9 *Coolant Orifice Plate (Differential Pressure)*:

Daniel Flow Products, Inc.
Flow Measurement Products Division

P.O. Box 19097
Houston, TX 77224

X1.1.10 *Coolant Control Valves (TCV-104, FCV-103 and TCV-101)*:
Badger Meter, Inc.
P.O. Box 581390
Tulsa, OK 74158

X1.1.11 *Differential Pressure Transducer (DPT-1)*—The recommended transducer is a Viatran Model 274 or Model 374, Validyne Model DP15, and Rosemount Model 1151, which may be ordered from:

Viatran Corp.
300 Industrial Dr.
Grand Island, NY 14072

Validyne Engineering Corp.
8626 Wilbur Ave.
Northridge, CA 91324

Rosemount Inc.
4001 Greenbriar Street 150B
Straford, Texas 77477

X1.1.12 *Water Pump Plate*—The water pump may be modified by the laboratory, a water pump plate may be fabricated by the laboratory, or a water pump plate may be purchased from:
OHT Technologies, Inc.
9300 Progress Pkwy.
P.O. Box 5039
Mentor, OH 44061-5039

X1.1.13 *Oil Scavenge Pump (P-3)*:
Houdaille Industries, Inc.
Viking Pump Div.
George and Wyeth St.
Cedar Falls, IA 50613

X1.1.14 *Float Switch (FLS-136 and FLS-152)*:
Imo Industries Inc.
Gems Sensor Div.
1 Cowles Rd.
Plainville, CT 06062-1198

X1.1.15 *Oil Circulation Pump (P-4)*:
Houdaille Industries, Inc.
Viking Pump Div.
George and Wyeth St.
Cedar Falls, IA 50613

X1.1.16 *External Oil System Solenoid Valves (FCV-150A, FCV-150C, FCV-150D, FCV-150E and FCV-150F)*:
Burkert Contromatic Corp.
1091 N. Batavia St.
Orange, CA 92667

X1.1.17 *External Oil System Control Valves (TCV-144 and TCV-145)*:
Badger Meter, Inc.
P.O. Box 581390
Tulsa, OK 74158

X1.1.18 *Oil Heat Exchanger (HX-6)*—ITT (Model 310-20) or Bell and Gossett (Model BP 25-20 or BP 410-020):

ITT Standard	Bell and Gossett ITT
175 Standard Pkwy.	8200 N. Austin Ave.
Buffalo, NY 14227	Morton Grove, IL 60053

X1.1.19 *Electric Oil Heater Housing (EH-5)*:
Labeco
156 East Harrison St.
Mooresville, IN 46158

X1.1.20 *Oil Filter Housing Assembly and Filters (Screen) (FIL-2)*:
RACOR
P.O. Box 3108
Modesto, CA 95353
or
OH Technologies Inc.
9300 Progress Pkwy.
P.O. Box 5039
Mentor, OH 44061-5039

X1.1.21 *Modified Oil Filter Adapter Assembly*:
OH Technologies, Inc.
9300 Progress Pkwy.
P.O. Box 5039
Mentor, OH 44061-5039

X1.1.22 *External Oil System Hose and Quick Disconnect Fittings*—Aeroquip products are available through local distributors or:
Aeroquip Corp.
Industrial Div.
1225 W. Main St.
Van Wert, OH 45891

X1.1.23 *Modified Oil Pan and Modified Oil Pick-Up Tube*—The oil pan and the oil pick-up tube may be modified by the laboratory or may be purchased from:
OH Technologies, Inc.
9300 Progress Pkwy.
P.O. Box 5039
Mentor, OH 44061-5039

X1.1.24 *Fuel Flow Measurement Mass Flow Meter*:
Micro Motion, Inc.
7070 Winchester Circle
Boulder, CO 80301

X1.1.25 *AFR Analyzer*—The recommended AFR analyzer is a Horiba MEXA 110, which may be ordered from:
Horiba Instruments, Inc.
17671 Armstrong
Irvine Industrial Complex
Irvine, CA 92614

X1.1.26 *ECM/EEC (Engine Control Module)*:
OH Technologies Inc.
9300 Progress Pkwy.
P.O. Box 5039
Mentor, OH 44061-5039

X1.1.27 *EPROM for EEC/ECM Module*:
OH Technologies Inc.
9300 Progress Pkwy.
P.O. Box 5039
Mentor, OH 44061-5039

X1.1.28 *Thermostat Orifice Plate*—The thermostat orifice plate may be fabricated by the laboratory or may be purchased from:
OH Technologies Inc.
9300 Progress Pkwy.

P.O. Box 5039
Mentor, OH 44061-5039

X1.1.29 *Flywheel*:
Part No. OHT6A-003-1
OH Technologies Inc.
9300 Progress Pkwy.
P.O. Box 5039
Mentor, OH 44061-5039

Part No. F6ZZ-6375AB
Ford Power Products
and Ford or Mercury
Dealerships

X1.1.30 *Engine Wiring Harness Without Interface*:
OH Technologies Inc.
9300 Progress Pkwy.
P.O. Box 5039
Mentor, OH 44061-5039

X1.1.31 *Modified Coolant Outlet (Thermostat Housing)*—The thermostat housing may be modified by the laboratory or may be purchased from:
OH Technologies Inc.
9300 Progress Pkwy.
P.O. Box 5039
Mentor, OH 44061-5039

X1.1.32 *Modified Coolant Inlet (Oil Filter Adapter)*—The coolant inlet adapter may be modified by the laboratory or may be purchased from:
OH Technologies Inc.
9300 Progress Pkwy.
P.O. Box 5039
Mentor, OH 44061-5039

X1.1.33 *Fuel Fail Adapter Set*—The fuel rail may be modified by the laboratory or a fuel rail adapter set may be purchased from:
OH Technologies Inc.
9300 Progress Pkwy.
P.O. Box 5039
Mentor, OH 44061-5039

X1.1.34 *Organic Solvent (Penmul L460)*:
Penetone Corp.
74 Hudson Ave.
Tenafly, NJ 07670

X1.1.35 *Oakite 811*:
Oakite Products, Inc.
50 Valley Rd.
Berkley Heights, NJ 07922

X1.1.36 *Aliphatic Naphtha*—Aliphatic naphtha is available from local suppliers.

X1.1.37 *Cooling System Cleanser or Premixed Coolant Flush Chemicals*:

X1.1.37.1 Oxalic acid in 55-lb bags and
sodium carbonate in 50-lb bags are available from
Ashland Chemical Co.
P.O. Box 391
Ashland, KY 41114

X1.1.37.2 Petro dispersant No. 425 powder in 50-lb bags is available from:
Witco Corp.
3230 Brookfield
Houston, TX 77045

X1.1.37.3 Oxalic acid 17.5 g/L (2.3 oz/gal) and Petro dispersant No. 425 1 g/L (0.15 oz/gal) premixed in a single use container is available from:
Wrico Corp.
4835 Whirlwind
San Antonio, TX 78217

X1.1.38 *Engine Mounts*:
Lybrook Precision Products

X1.1.39 *Engine Mount Isolators (Biscuits)*:
World Class Engineered Products
20994 Bridge St.
Southfield, MI 48034

X2. DATA DICTIONARY

X2.1 The data dictionary is provided in Fig. X2.1.

X2.2 The repeating field specifications are provided in Fig. X2.5.

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Data Dictionary

Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
10	1	VIA	VERSION	8	0	C	YYYYMMDD	VIA VERSION 19990729
20	1	VIA	TSTSPON1	40	0	C		CONDUCTED FOR, FIRST LINE
30	1	VIA	TSTSPON2	40	0	C		CONDUCTED FOR, SECOND LINE
40	1	VIA	LABVALID	1	0	C	V, I OR N	TEST LAB VALIDATION (V, I OR N)
50	1	VIA	LAB	2	0	C		LAB CODE
60	1	VIA	RDTCOMP	8	0	C	YYYYMMDD	REFERENCE COMPLETED DATE (YYYYMMDD)
70	1	VIA	DTCOMP	8	0	C	YYYYMMDD	COMPLETED DATE (YYYYMMDD)
80	1	VIA	REOTTIME	5	0	C	HH:MM	REFERENCE COMPLETED TIME (HH:MM)
90	1	VIA	EOTTIME	5	0	C	HH:MM	COMPLETED TIME (HH:MM)
100	1	VIA	STAND	5	0	C		STAND
110	1	VIA	RSTRUN	4	0	C		REFERENCE STAND RUN
120	1	VIA	STRUN	4	0	C		STAND RUN
130	1	VIA	RENGNO	15	0	C		REFERENCE LABORATORY INTERNAL ENGINE NUMBER
140	1	VIA	ENGNO	15	0	C		LABORATORY INTERNAL ENGINE NUMBER
150	1	VIA	RENRUN	4	0	C		REFERENCE ENGINE NUMBER RUNS
160	1	VIA	ENRUN	4	0	C		ENGINE NUMBER RUNS
170	1	VIA	OILCODE	38	0	C		NON-REFERENCE OIL CODE
180	1	VIA	CMIR	6	0	C		CMIR
190	1	VIA	FORM	38	0	C		FORMULATION/STAND CODE
200	1	VIA	OPVALID	8	0	C		OPERATIONAL VALID - HAS OR HAS NOT
210	1	VIA	ALTCODE1	10	0	C		ALTERNATE OIL CODE 1
220	1	VIA	ALTCODE2	10	0	C		ALTERNATE OIL CODE 2
230	1	VIA	ALTCODE3	10	0	C		ALTERNATE OIL CODE 3
240	1	VIA	SUBLAB	40	0	C		SUBMITTED BY: TESTING LABORATORY
250	1	VIA	SUBSIGIM	70	0	C		SUBMITTED BY: SIGNATURE IMAGE
260	1	VIA	SUBNAME	40	0	C		SUBMITTED BY: SIGNATURE TYPED NAME
270	1	VIA	SUBTITLE	40	0	C		SUBMITTED BY: TITLE
280	2	VIA	SAEVISC	7	0	C		SAE VISCOSITY GRADE
290	2	VIA	BCDTST	8	0	C	YYYYMMDD	BC START DATE (YYYYMMDD)
300	2	VIA	V40NEW	8	2	N	cSt	NEW OIL VISCOSITY @ 40 °C (cSt)
310	2	VIA	BCSTIME	5	0	C	HH:MM	BC START TIME (HH:MM)
320	2	VIA	V100NEW	8	2	N	cSt	NEW OIL VISCOSITY @ 100 °C (cSt)
330	2	VIA	DTSTRT	8	0	C	YYYYMMDD	NON-REFERENCE OIL START DATE (YYYYMMDD)
340	2	VIA	VINI40	8	2	N	cSt	AGED 16HR. OIL VISCOSITY @ 40 °C (cSt)
350	2	VIA	STRTTIME	5	0	C	HH:MM	NON-REFERENCE OIL START TIME (HH:MM)
360	2	VIA	VINI100	8	2	N	cSt	AGED 16HR. OIL VISCOSITY @ 100 °C (cSt)
370	2	VIA	TESTLEN	3	0	Z	HHH	TEST LENGTH (HHH)
380	2	VIA	CALOILBT	10	0	C		CALIBRATION OIL BATCH
390	2	VIA	ENHREND	5	0	C	HHHHH	NON-REFERENCE ENGINE HOURS @ END OF TEST (HHHHH)
400	2	VIA	LABOCODE	12	0	C		NON-REFERENCE LABORATORY INTERNAL OIL CODE
410	2	VIA	FUELBTID	10	0	C		NON-REFERENCE FUEL BATCH IDENTIFIER
420	2	VIA	BC1KG	9	6	N	kg	BC OIL BEFORE NON-REFERENCE OVERALL RESULTS (kg)
430	2	VIA	ABCKG	9	6	N	kg	AVERAGE OF BC OIL OVERALL RESULTS (kg)
440	2	VIA	KGO	9	6	N	kg	TEST OIL OVERALL RESULTS (kg)
450	2	VIA	FEI	6	2	N	%	FUEL ECONOMY IMPROVEMENT OVERALL RESULTS (%)
460	2	VIA	BC2KG	9	6	N	kg	BC OIL AFTER NON-REFERENCE OVERALL RESULTS (kg)
470	2	VIA	FEISA	6	2	N	%	FEI - SEVERITY ADJUSTMENT (%)
480	2	VIA	BCSFTDLT	6	2	N	%	BC SHIFT % DELTA (%)
490	2	VIA	FEIFNL	6	2	N	%	FEI - FINAL RESULT (%)
500	2	VIA	SDLTRxxx	6	3	N	kg/kWh	BC STAGE DELTA (kg/kWh)
510	2	VIA	ACPTRxxx	1	0	C		BC ACCEPT Y/N
520	2a	VIA	ENGSN	11	0	C		ENGINE SERIAL NUMBER
530	2a	VIA	RSAEVISC	7	0	C		REFERENCE SAE VISCOSITY GRADE

FIG. X2.1 Data Dictionary

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Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
540	2a	VIA	RBCDTST	8	0	C	YYYYMMDD	BC START DATE (YYYYMMDD)
550	2a	VIA	RCALOIL	10	0	C		REFERENCE CALIBRATION OIL BATCH
560	2a	VIA	RBCSTIME	5	0	C	HH:MM	BC START TIME (HH:MM)
570	2a	VIA	RLABOCOD	12	0	C		REFERENCE LABORATORY INTERNAL OIL CODE
580	2a	VIA	RDTSTRT	8	0	C	YYYYMMDD	REFERENCE OIL START DATE (YYYYMMDD)
590	2a	VIA	RFUELBID	10	0	C		REFERENCE FUEL BATCH IDENTIFIER
600	2a	VIA	RSTRTIME	5	0	C	HH:MM	REFERENCE OIL START TIME (HH:MM)
610	2a	VIA	RTESTLEN	3	0	Z	HHH	REFERENCE TEST LENGTH (HHH)
620	2a	VIA	RENHREND	5	0	C	HHHHH	REFERENCE ENGINE HOURS @ END OF TEST (HHHHH)
630	2a	VIA	RBC1KG	9	6	N	kg	REFERENCE BC OIL BEFORE TEST OIIL OVERALL RESULTS (kg)
640	2a	VIA	RBC2KG	9	6	N	kg	REFERENCE BC OIL AFTER TEST OIL OVERALL RESULTS (kg)
650	2a	VIA	RBCSFTDT	6	2	N	%	REFERENCE BC SHIFT % DELTA (%)
660	2a	VIA	RABCKG	9	6	N	kg	REFERENCE AVERAGE OF BC OIL OVERALL RESULTS (kg)
670	2a	VIA	RKGO	9	6	N	kg	REFERENCE TEST OIL OVERALL RESULTS (kg)
680	2a	VIA	RFEI	6	2	N	%	REFERENCE FUEL ECONOMY IMPROVEMENT OVERALL RESULTS (%)
690	2a	VIA	RFEICF	6	2	N	%	REFERENCE FEI CORRECTED RESULTS (%)
700	2a	VIA	RFEIFNL	6	2	N	%	REFERENCE FEI FINAL RESULTS (%)
710	2a	VIA	RSDTRxxx	6	3	N	BSFC	REFERENCE BC STAGE DELTA XXX (BSFC)
720	2a	VIA	RCPTRxxx	1	0	C		REFERENCE BC ACCEPT Y/N XXX
730	2a	VIA	IND	6	0	C		TMC OIL CODE
740	2a	VIA	RFEIMEAN	5	2	N	NONE	REFERENCE OIL STATISTICS FEI MEAN (NONE)
750	2a	VIA	RFEISD	5	2	N	NONE	REFERENCE OIL STATISTICS FEI S.D. (NONE)
760	2a	VIA	ROSTDTE	8	0	C	YYYYMMDD	REFERENCE OIL STATISTICS DATE (YYYYMMDD)
770	3	VIA	BFCARxxx	8	5	N	kg/kWh	AVERAGE BSFC (kg/kWh)
780	3	VIA	BFCCRxxx	5	2	N		COEFFICIENT OF VARIATION COMPUTED AVERAGES
790	3	VIA	WFC_Rxxx	9	6	N	kg	WEIGHT FUEL CONSUMED (kg)
800	4	VIA	ARPM16H	7	1	N	r/min	AVG ENGINE SPEED 16 HOUR AGING (r/min)
810	4	VIA	XRPM16H	7	1	N	r/min	MAX ENGINE SPEED 16 HOUR AGING (r/min)
820	4	VIA	IRPM16H	7	1	N	r/min	MIN ENGINE SPEED 16 HOUR AGING (r/min)
830	4	VIA	ALD16H	6	2	N	N-m	AVG. LOAD 16 HOUR AGING (N-m)
840	4	VIA	XLD16H	6	2	N	N-m	MAX. LOAD 16 HOUR AGING (N-m)
850	4	VIA	ILD16H	6	2	N	N-m	MIN. LOAD 16 HOUR AGING (N-m)
860	4	VIA	AOGT16H	6	1	N	°C	AVG OIL GALLERY TEMPERATURE 16 HOUR AGING (°C)
870	4	VIA	XOGT16H	6	1	N	°C	MAX. OIL GALLERY TEMPERATURE 16 HOUR AGING (°C)
880	4	VIA	IOGT16H	6	1	N	°C	MIN. OIL GALLERY TEMPERATURE 16 HOUR AGING (°C)
890	4	VIA	ACINT16H	6	1	N	°C	AVG ENGINE COOLANT INLET TEMP. 16 HOUR AGING (°C)
900	4	VIA	XCINT16H	6	1	N	°C	MAX ENGINE COOLANT INLET TEMP 16 HOUR AGING (°C)
910	4	VIA	ICINT16H	6	1	N	°C	MIN ENGINE COOLANT INLET TEMP 16 HOUR AGING (°C)
920	4	VIA	ASMPT16H	6	1	N	°C	AVG OIL CIRCULATION TEMP 16 HOUR AGING (°C)
930	4	VIA	XSMPT16H	6	1	N	°C	MAX OIL CIRCULATION TEMP 16 HOUR AGING (°C)
940	4	VIA	ISMPT16H	6	1	N	°C	MIN OIL CIRCULATION TEMP 16 HOUR AGING (°C)
950	4	VIA	ACOT16H	6	1	N	°C	AVG ENGINE COOLANT OUT TEMPERATURE 16 HOUR AGING (°C)
960	4	VIA	XCOT16H	6	1	N	°C	MAX ENGINE COOLANT OUT TEMP 16 HOUR AGING (°C)
970	4	VIA	ICOT16H	6	1	N	°C	MIN ENGINE COOLANT OUT TEMP 16 HOUR AGING (°C)
980	4	VIA	AINAT16H	6	1	N	°C	AVG INTAKE AIR TEMPERATURE 16 HOUR AGING (°C)
990	4	VIA	XINAT16H	6	1	N	°C	MAX INTAKE AIR TEMPERATURE 16 HOUR AGING (°C)
1000	4	VIA	IINAT16H	6	1	N	°C	MIN INTAKE AIR TEMPERATURE 16 HOUR AGING (°C)
1010	4	VIA	AFTMM16H	6	1	N	°C	AVERAGE FUEL TO FLOWMETER TEMPERATURE 16 HOUR AGING (°C)
1020	4	VIA	XFTMM16H	6	1	N	°C	MAX. FUEL TO FLOWMETER TEMPERATURE 16 HOUR AGING (°C)
1030	4	VIA	IFTMM16H	6	1	N	°C	MIN. FUEL TO FLOWMETER TEMPERATURE 16 HOUR AGING (°C)
1040	4	VIA	AFTFR16H	6	1	N	°C	AVG. FUEL TEMPERATURE TO FUEL RAIL 16 HOUR AGING (°C)
1050	4	VIA	XFTFR16H	6	1	N	°C	MAX. FUEL TEMPERATURE TO FUEL RAIL 16 HOUR AGING (°C)
1060	4	VIA	IFTFR16H	6	1	N	°C	MIN. FUEL TEMPERATURE TO FUEL RAIL 16 HOUR AGING (°C)
1070	4	VIA	ALCT16H	6	1	N	°C	AVG. LOAD CELL TEMPERATURE 16 HOUR AGING (°C)

FIG. X2.1 Data Dictionary *(continued)*

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Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
1080	4	VIA	XLCT16H	6	1	N	°C	MAX. LOAD CELL TEMPERATURE 16 HOUR AGING (°C)
1090	4	VIA	ILCT16H	6	1	N	°C	MIN. LOAD CELL TEMPERATURE 16 HOUR AGING (°C)
1100	4	VIA	AHEAT16H	6	1	N	°C	AVG OIL HEATER TEMPERATURE 16 HOUR AGING (°C)
1110	4	VIA	XHEAT16H	6	1	N	°C	MAX. OIL HEATER TEMPERATURE 16 HOUR AGING (°C)
1120	4	VIA	IHEAT16H	6	1	N	°C	MIN. OIL HEATER TEMPERATURE 16 HOUR AGING (°C)
1130	4	VIA	AINAP16H	5	2	N	kPa	AVG INTAKE AIR PRESSURE 16 HOUR AGING (kPa)
1140	4	VIA	XINAP16H	5	2	N	kPa	MAX INTAKE AIR PRESSURE 16 HOUR AGING (kPa)
1150	4	VIA	IINAP16H	5	2	N	kPa	MIN INTAKE AIR PRESSURE 16 HOUR AGING (kPa)
1160	4	VIA	AFPMM16H	6	1	N	kPa	AVG FUEL PRESSURE TO MICROMOTION 16 HOUR AGING (kPa)
1170	4	VIA	XFPMM16H	6	1	N	kPa	MAX. FUEL PRESSURE TO MICROMOTION 16 HOUR AGING (kPa)
1180	4	VIA	IFPMM16H	6	1	N	kPa	MIN. FUEL PRESSURE TO MICROMOTION 16 HOUR AGING (kPa)
1190	4	VIA	AFPFR16H	6	1	N	kPa	AVG. FUEL PRESSURE TO FUEL RAIL 16 HOUR AGING (kPa)
1200	4	VIA	XFPFR16H	6	1	N	kPa	MAX. FUEL PRESSURE TO FUEL RAIL 16 HOUR AGING (kPa)
1210	4	VIA	IFPFR16H	6	1	N	kPa	MIN. FUEL PRESSURE TO FUEL RAIL 16 HOUR AGING (kPa)
1220	4	VIA	AINTV16H	5	1	N	kPa	AVG INTAKE VACUUM 16 HOUR AGING (kPa)
1230	4	VIA	XINTV16H	5	1	N	kPa	MAX INTAKE VACUUM 16 HOUR AGING (kPa)
1240	4	VIA	IINTV16H	5	1	N	kPa	MIN INTAKE VACUUM 16 HOUR AGING (kPa)
1250	4	VIA	AEXBP16H	7	2	N	kPa	AVG EXHAUST BACK PRESSURE 16 HOUR AGING (kPa)
1260	4	VIA	XEXBP16H	7	2	N	kPa	MAX EXHAUST BACK PRESSURE 16 HOUR AGING (kPa)
1270	4	VIA	IEXBP16H	7	2	N	kPa	MIN EXHAUST BACK PRESSURE 16 HOUR AGING (kPa)
1280	4	VIA	AOGP16H	6	1	N	kPa	AVG OIL GALLERY PRESSURE 16 HOUR AGING (kPa)
1290	4	VIA	XOGP16H	6	1	N	kPa	MAX OIL GALLERY PRESSURE 16 HOUR AGING (kPa)
1300	4	VIA	IOGP16H	6	1	N	kPa	MIN OIL GALLERY PRESSURE 16 HOUR AGING (kPa)
1310	4	VIA	AMCF16H	6	1	N	L/min	AVG ENGINE MAIN COOLANT FLOW 16 HOUR AGING (L/min)
1320	4	VIA	XMCF16H	6	1	N	L/min	MAX ENGINE MAIN COOLANT FLOW 16 HOUR AGING (L/min)
1330	4	VIA	IMCF16H	6	1	N	L/min	MIN ENGINE MAIN COOLANT FLOW 16 HOUR AGING (L/min)
1340	4	VIA	AFFLO16H	7	3	N	kg/h	AVERAGE FUEL FLOW 16 HOUR AGING (kg/h)
1350	4	VIA	XFFLO16H	7	3	N	kg/h	MAX. FUEL FLOW 16 HOUR AGING (kg/h)
1360	4	VIA	IFFLO16H	7	3	N	kg/h	MIN. FUEL FLOW 16 HOUR AGING (kg/h)
1370	4	VIA	AINAH16H	5	1	N	grains/kg	AVG INTAKE AIR HUMIDITY 16 HOUR AGING (grains/kg)
1380	4	VIA	XINAH16H	5	1	N	grains/kg	MAX INTAKE AIR HUMIDITY 16 HOUR AGING (grains/kg)
1390	4	VIA	IINAH16H	5	1	N	grains/kg	MIN INTAKE AIR HUMIDITY 16 HOUR AGING (grains/kg)
1400	4	VIA	AAFR16H	6	2	N		AVG AIR TO FUEL RATIO 16 HOUR AGING
1410	4	VIA	XAFR16H	6	2	N		MAX AIR TO FUEL RATIO 16 HOUR AGING
1420	4	VIA	IAFR16H	6	2	N		MIN AIR TO FUEL RATIO 16 HOUR AGING
1430	5	VIA	OCT_Rxxx	6	1	N	°C	OIL CIRCULATION TEMPERATURE (°C)
1440	5	VIA	COT_Rxxx	6	1	N	°C	COOLANT OUT TEMPERATURE (°C)
1450	5	VIA	FFT_Rxxx	5	1	N	°C	FUEL TO FLOWMETER TEMPERATURE (°C)
1460	5	VIA	FFTDRxxx	5	1	N	°C	DELTA FUEL TO FLOWMETER TEMPERATURE (°C)
1470	5	VIA	TCT_Rxxx	5	1	N	°C	TEST CELL TEMPERATURE (°C)
1480	5	VIA	LCT_Rxxx	5	1	N	°C	LOAD CELL TEMPERATURE (°C)
1490	5	VIA	LCTDRxxx	5	1	N	°C	DELTA LOAD CELL TEMPERATURE (°C)
1500	5	VIA	OHT_Rxxx	6	1	N	°C	OIL HEATER TEMPERATURE (°C)
1510	5	VIA	IAP_Rxxx	5	2	N	kPa	INTAKE AIR PRESSURE (kPa)
1520	5	VIA	FFP_Rxxx	6	1	N	kPa	FUEL TO FLOWMETER PRESSURE (kPa)
1530	5	VIA	FFRPRxxx	6	1	N	kPa	FUEL TO FUEL RAIL PRESSURE (kPa)
1540	5	VIA	IMP_Rxxx	5	1	N	kPa	INTAKE MANIFOLD PRESSURE (kPa)
1550	5	VIA	EOP_Rxxx	6	1	N	kPa	ENGINE OIL PRESSURE (kPa)
1560	5	VIA	CF__Rxxx	6	1	N	L/min	COOLANT FLOW (L/min)
1570	5	VIA	IAH_Rxxx	5	1	N	grains/kg	INTAKE AIR HUMIDITY (grains/kg)
1590	8	VIA	BFC_Rxxx	7	4	N	kg/kWh	BSFC (kg/kWh)
1600	8	VIA	RPM_Rxxx	7	1	N	r/min	SPEED (r/min)
1610	8	VIA	LD__Rxxx	6	2	N	N-m	LOAD (N-m)
1620	8	VIA	OGT_Rxxx	6	1	N	°C	OIL GALLERY TEMPERATURE (°C)

FIG. X2.1 Data Dictionary *(continued)*

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Sequence	Form	Test Area	Field Name	Field Length	Decimal Size	Data Type	Units/Format	Description
1630	8	VIA	CINTRxxx	6	1	N	°C	COOLANT IN TEMPERATURE (°C)
1640	8	VIA	IAT_Rxxx	5	1	N	°C	INTAKE AIR TEMPERATURE (°C)
1650	8	VIA	FRT_Rxxx	5	1	N	°C	FUEL RAIL TEMPERATURE (°C)
1660	8	VIA	EBP_Rxxx	7	2	N	kPa	EBP (kPa)
1670	8	VIA	FCR_Rxxx	6	3	N	kg/h	FUEL FLOW (kg/h)
1680	8	VIA	AFR_Rxxx	6	2	N		AIR TO FUEL RATIO
1690	8	VIA	AFRDRxxx	6	2	N		DELTA AIR TO FUEL RATIO
1700	8	VIA	BFCSRxxx	7	4	N	kg/kWh	BSFC STANDARD DEVIATION (kg/kWh)
1710	14	VIA	DWNOCR	3	0	Z		NUMBER OF DOWNTIME OCCURENCES
1720	14	VIA	DOWNHxxx	6	0	C	HHH:MM	DOWN TIME TEST HOURS (HH:MM)
1730	14	VIA	DDATHxxx	8	0	C	YYYYMMDD	DOWNTIME DATE (YYYYMMDD)
1740	14	VIA	DTIMHxxx	5	0	C	HH:MM	DOWNTIME TIME (HH:MM)
1750	14	VIA	DREAHxxx	60	0	C		DOWNTIME REASON
1760	14	VIA	TOTLDOWN	6	0	C	HHH:MM	DOWNTIME TIME TOTAL (HHH:MM)
1770	14	VIA	TOTCOM	2	0	Z		TOTAL LINES OF COMMENTS & OUTLIERS
1780	14	VIA	OCOMHxxx	70	0	C		OTHER DOWNTIME COMMENTS XXX

FIG. X2.1 Data Dictionary *(continued)*

```
################################################################################
#                                                                              #
#          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 - 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                        #
################################################################################
#
VIA VERSION 19990729
SDLTRxxx SDLTRxxx   BC STAGE DELTA (kg/kWh)
001 002 003 004 005 006 MEN

ACPTRxxx SDLTRxxx   BC ACCEPT Y/N
001 002 003 004 005 006
```

FIG. X2.5 Repeating Field Specifications

```
RSDTRxxx RSDTRxxx   REFERENCE BC STAGE DELTA XXX (BSFC)
001 002 003 004 005 006 MEN

RCPTRxxx RSDTRxxx   REFERENCE BC ACCEPT Y/N XXX
001 002 003 004 005 006

BFCARxxx BFCARxxx   AVERAGE BSFC (kg/kWh)
A1A A2A A3A A4A A5A A6A B1A B2A B3A B4A B5A B6A C1A C2A C3A C4A C5A C6A

BFCCRxxx BFCARxxx   COEFFICIENT OF VARIATION COMPUTED AVERAGES
A1A A2A A3A A4A A5A A6A B1A B2A B3A B4A B5A B6A C1A C2A C3A C4A C5A C6A

WFC_Rxxx BFCARxxx   WEIGHT FUEL CONSUMED (kg)
A1A A2A A3A A4A A5A A6A B1A B2A B3A B4A B5A B6A C1A C2A C3A C4A C5A C6A

OCT_Rxxx OCT_Rxxx   OIL CIRCULATION TEMPERATURE (DEG C)
A01 A02 A03 A04 A05 A06 B01 B02 B03 B04 B05 B06 C01 C02 C03 C04 C05 C06

COT_Rxxx OCT_Rxxx   COOLANT OUT TEMPERATURE (DEG C)
A01 A02 A03 A04 A05 A06 B01 B02 B03 B04 B05 B06 C01 C02 C03 C04 C05 C06

FFT_Rxxx OCT_Rxxx   FUEL TO FLOWMETER TEMPERATURE (DEG C)
A01 A02 A03 A04 A05 A06 B01 B02 B03 B04 B05 B06 C01 C02 C03 C04 C05 C06

FFTDRxxx OCT_Rxxx   DELTA FUEL TO FLOWMETER TEMPERATURE (DEG C)
A01 A02 A03 A04 A05 A06 B01 B02 B03 B04 B05 B06 C01 C02 C03 C04 C05 C06

TCT_Rxxx OCT_Rxxx   TEST CELL TEMPERATURE (DEG C)
A01 A02 A03 A04 A05 A06 B01 B02 B03 B04 B05 B06 C01 C02 C03 C04 C05 C06

LCT_Rxxx OCT_Rxxx   LOAD CELL TEMPERATURE (DEG C)
A01 A02 A03 A04 A05 A06 B01 B02 B03 B04 B05 B06 C01 C02 C03 C04 C05 C06

LCTDRxxx OCT_Rxxx   DELTA LOAD CELL TEMPERATURE (DEG C)
A01 A02 A03 A04 A05 A06 B01 B02 B03 B04 B05 B06 C01 C02 C03 C04 C05 C06

OHT_Rxxx OCT_Rxxx   OIL HEATER TEMPERATURE (DEG C)
A01 A02 A03 A04 A05 A06 B01 B02 B03 B04 B05 B06 C01 C02 C03 C04 C05 C06

IAP_Rxxx OCT_Rxxx   INTAKE AIR PRESSURE (kPa)
A01 A02 A03 A04 A05 A06 B01 B02 B03 B04 B05 B06 C01 C02 C03 C04 C05 C06

FFP_Rxxx OCT_Rxxx   FUEL TO FLOWMETER PRESSURE (kPa)
A01 A02 A03 A04 A05 A06 B01 B02 B03 B04 B05 B06 C01 C02 C03 C04 C05 C06

FFRPRxxx OCT_Rxxx   FUEL TO FUEL RAIL PRESSURE (kPa)
A01 A02 A03 A04 A05 A06 B01 B02 B03 B04 B05 B06 C01 C02 C03 C04 C05 C06

IMP_Rxxx OCT_Rxxx   INTAKE MANIFOLD PRESSURE (kPa)
A01 A02 A03 A04 A05 A06 B01 B02 B03 B04 B05 B06 C01 C02 C03 C04 C05 C06

EOP_Rxxx OCT_Rxxx   ENGINE OIL PRESSURE (kPa)
A01 A02 A03 A04 A05 A06 B01 B02 B03 B04 B05 B06 C01 C02 C03 C04 C05 C06

CF__Rxxx OCT_Rxxx   COOLANT FLOW (L/min)
A01 A02 A03 A04 A05 A06 B01 B02 B03 B04 B05 B06 C01 C02 C03 C04 C05 C06

IAH_Rxxx OCT_Rxxx   INTAKE AIR HUMIDITY (grains/kg)
A01 A02 A03 A04 A05 A06 B01 B02 B03 B04 B05 B06 C01 C02 C03 C04 C05 C06
```

FIG. X2.5 Repeating Field Specifications *(continued)*

```
BFC_Rxxx BFC_Rxxx   BSFC (kg/kWh)
A11 A12 A13 A14 A15 A16 A21 A22 A23 A24 A25 A26 A31 A32 A33 A34 A35 A36
A41 A42 A43 A44 A45 A46 A51 A52 A53 A54 A55 A56 A61 A62 A63 A64 A65 A66
B11 B12 B13 B14 B15 B16 B21 B22 B23 B24 B25 B26 B31 B32 B33 B34 B35 B36
B41 B42 B43 B44 B45 B46 B51 B52 B53 B54 B55 B56 B61 B62 B63 B64 B65 B66
C11 C12 C13 C14 C15 C16 C21 C22 C23 C24 C25 C26 C31 C32 C33 C34 C35 C36
C41 C42 C43 C44 C45 C46 C51 C52 C53 C54 C55 C56 C61 C62 C63 C64 C65 C66

RPM_Rxxx BFC_Rxxx   SPEED (r/min)
A11 A12 A13 A14 A15 A16 A1A A21 A22 A23 A24 A25 A26 A2A A31 A32 A33 A34
A35 A36 A3A A41 A42 A43 A44 A45 A46 A4A A51 A52 A53 A54 A55 A56 A5A A61
A62 A63 A64 A65 A66 A6A B11 B12 B13 B14 B15 B16 B1A B21 B22 B23 B24 B25
B26 B2A B31 B32 B33 B34 B35 B36 B3A B41 B42 B43 B44 B45 B46 B4A B51 B52
B53 B54 B55 B56 B5A B61 B62 B63 B64 B65 B66 B6A C11 C12 C13 C14 C15 C16
C1A C21 C22 C23 C24 C25 C26 C2A C31 C32 C33 C34 C35 C36 C3A C41 C42 C43
C44 C45 C46 C4A C51 C52 C53 C54 C55 C56 C5A C61 C62 C63 C64 C65 C66 C6A

LD__Rxxx BFC_Rxxx   LOAD (N-m)
A11 A12 A13 A14 A15 A16 A1A A21 A22 A23 A24 A25 A26 A2A A31 A32 A33 A34
A35 A36 A3A A41 A42 A43 A44 A45 A46 A4A A51 A52 A53 A54 A55 A56 A5A A61
A62 A63 A64 A65 A66 A6A B11 B12 B13 B14 B15 B16 B1A B21 B22 B23 B24 B25
B26 B2A B31 B32 B33 B34 B35 B36 B3A B41 B42 B43 B44 B45 B46 B4A B51 B52
B53 B54 B55 B56 B5A B61 B62 B63 B64 B65 B66 B6A C11 C12 C13 C14 C15 C16
C1A C21 C22 C23 C24 C25 C26 C2A C31 C32 C33 C34 C35 C36 C3A C41 C42 C43
C44 C45 C46 C4A C51 C52 C53 C54 C55 C56 C5A C61 C62 C63 C64 C65 C66 C6A

OGT_Rxxx BFC_Rxxx   OIL GALLERY TEMPERATURE (DEG C)
A11 A12 A13 A14 A15 A16 A1A A21 A22 A23 A24 A25 A26 A2A A31 A32 A33 A34
A35 A36 A3A A41 A42 A43 A44 A45 A46 A4A A51 A52 A53 A54 A55 A56 A5A A61
A62 A63 A64 A65 A66 A6A B11 B12 B13 B14 B15 B16 B1A B21 B22 B23 B24 B25
B26 B2A B31 B32 B33 B34 B35 B36 B3A B41 B42 B43 B44 B45 B46 B4A B51 B52
B53 B54 B55 B56 B5A B61 B62 B63 B64 B65 B66 B6A C11 C12 C13 C14 C15 C16
C1A C21 C22 C23 C24 C25 C26 C2A C31 C32 C33 C34 C35 C36 C3A C41 C42 C43
C44 C45 C46 C4A C51 C52 C53 C54 C55 C56 C5A C61 C62 C63 C64 C65 C66 C6A

CINTRxxx BFC_Rxxx   COOLANT IN TEMPERATURE (DEG C)
A11 A12 A13 A14 A15 A16 A1A A21 A22 A23 A24 A25 A26 A2A A31 A32 A33 A34
A35 A36 A3A A41 A42 A43 A44 A45 A46 A4A A51 A52 A53 A54 A55 A56 A5A A61
A62 A63 A64 A65 A66 A6A B11 B12 B13 B14 B15 B16 B1A B21 B22 B23 B24 B25
B26 B2A B31 B32 B33 B34 B35 B36 B3A B41 B42 B43 B44 B45 B46 B4A B51 B52
B53 B54 B55 B56 B5A B61 B62 B63 B64 B65 B66 B6A C11 C12 C13 C14 C15 C16
C1A C21 C22 C23 C24 C25 C26 C2A C31 C32 C33 C34 C35 C36 C3A C41 C42 C43
C44 C45 C46 C4A C51 C52 C53 C54 C55 C56 C5A C61 C62 C63 C64 C65 C66 C6A

IAT_Rxxx BFC_Rxxx   INTAKE AIR TEMPERATURE (DEG C)
A11 A12 A13 A14 A15 A16 A1A A21 A22 A23 A24 A25 A26 A2A A31 A32 A33 A34
A35 A36 A3A A41 A42 A43 A44 A45 A46 A4A A51 A52 A53 A54 A55 A56 A5A A61
A62 A63 A64 A65 A66 A6A B11 B12 B13 B14 B15 B16 B1A B21 B22 B23 B24 B25
B26 B2A B31 B32 B33 B34 B35 B36 B3A B41 B42 B43 B44 B45 B46 B4A B51 B52
B53 B54 B55 B56 B5A B61 B62 B63 B64 B65 B66 B6A C11 C12 C13 C14 C15 C16
C1A C21 C22 C23 C24 C25 C26 C2A C31 C32 C33 C34 C35 C36 C3A C41 C42 C43
C44 C45 C46 C4A C51 C52 C53 C54 C55 C56 C5A C61 C62 C63 C64 C65 C66 C6A

FRT_Rxxx BFC_Rxxx   FUEL RAIL TEMPERATURE (DEG C)
A11 A12 A13 A14 A15 A16 A1A A21 A22 A23 A24 A25 A26 A2A A31 A32 A33 A34
A35 A36 A3A A41 A42 A43 A44 A45 A46 A4A A51 A52 A53 A54 A55 A56 A5A A61
A62 A63 A64 A65 A66 A6A B11 B12 B13 B14 B15 B16 B1A B21 B22 B23 B24 B25
B26 B2A B31 B32 B33 B34 B35 B36 B3A B41 B42 B43 B44 B45 B46 B4A B51 B52
B53 B54 B55 B56 B5A B61 B62 B63 B64 B65 B66 B6A C11 C12 C13 C14 C15 C16
```

FIG. X2.5 Repeating Field Specifications *(continued)*

```
C1A C21 C22 C23 C24 C25 C26 C2A C31 C32 C33 C34 C35 C36 C3A C41 C42 C43
C44 C45 C46 C4A C51 C52 C53 C54 C55 C56 C5A C61 C62 C63 C64 C65 C66 C6A

EBP_Rxxx BFC_Rxxx   EBP (kPa)
A11 A12 A13 A14 A15 A16 A1A A21 A22 A23 A24 A25 A26 A2A A31 A32 A33 A34
A35 A36 A3A A41 A42 A43 A44 A45 A46 A4A A51 A52 A53 A54 A55 A56 A5A A61
A62 A63 A64 A65 A66 A6A B11 B12 B13 B14 B15 B16 B1A B21 B22 B23 B24 B25
B26 B2A B31 B32 B33 B34 B35 B36 B3A B41 B42 B43 B44 B45 B46 B4A B51 B52
B53 B54 B55 B56 B5A B61 B62 B63 B64 B65 B66 B6A C11 C12 C13 C14 C15 C16
C1A C21 C22 C23 C24 C25 C26 C2A C31 C32 C33 C34 C35 C36 C3A C41 C42 C43
C44 C45 C46 C4A C51 C52 C53 C54 C55 C56 C5A C61 C62 C63 C64 C65 C66 C6A

FCR_Rxxx BFC_Rxxx   FUEL FLOW (kg/h)
A11 A12 A13 A14 A15 A16 A1A A21 A22 A23 A24 A25 A26 A2A A31 A32 A33 A34
A35 A36 A3A A41 A42 A43 A44 A45 A46 A4A A51 A52 A53 A54 A55 A56 A5A A61
A62 A63 A64 A65 A66 A6A B11 B12 B13 B14 B15 B16 B1A B21 B22 B23 B24 B25
B26 B2A B31 B32 B33 B34 B35 B36 B3A B41 B42 B43 B44 B45 B46 B4A B51 B52
B53 B54 B55 B56 B5A B61 B62 B63 B64 B65 B66 B6A C11 C12 C13 C14 C15 C16
C1A C21 C22 C23 C24 C25 C26 C2A C31 C32 C33 C34 C35 C36 C3A C41 C42 C43
C44 C45 C46 C4A C51 C52 C53 C54 C55 C56 C5A C61 C62 C63 C64 C65 C66 C6A

AFR_Rxxx BFC_Rxxx   AIR TO FUEL RATIO
A11 A12 A13 A14 A15 A16 A1A A21 A22 A23 A24 A25 A26 A2A A31 A32 A33 A34
A35 A36 A3A A41 A42 A43 A44 A45 A46 A4A A51 A52 A53 A54 A55 A56 A5A A61
A62 A63 A64 A65 A66 A6A B11 B12 B13 B14 B15 B16 B1A B21 B22 B23 B24 B25
B26 B2A B31 B32 B33 B34 B35 B36 B3A B41 B42 B43 B44 B45 B46 B4A B51 B52
B53 B54 B55 B56 B5A B61 B62 B63 B64 B65 B66 B6A C11 C12 C13 C14 C15 C16
C1A C21 C22 C23 C24 C25 C26 C2A C31 C32 C33 C34 C35 C36 C3A C41 C42 C43
C44 C45 C46 C4A C51 C52 C53 C54 C55 C56 C5A C61 C62 C63 C64 C65 C66 C6A

AFRDRxxx BFC_Rxxx   DELTA AIR TO FUEL RATIO
A1A A2A A3A A4A A5A A6A B1A B2A B3A B4A B5A B6A C1A C2A C3A C4A C5A C6A

BFCSRxxx BFCSRxxx   BSFC STANDARD DEVIATION (kg/kWh)
A1A A2A A3A A4A A5A A6A B1A B2A B3A B4A B5A B6A C1A C2A C3A C4A C5A C6A

DOWNHxxx DOWNHxxx   DOWN TIME TEST HOURS (HH:MM)


DDATHxxx DOWNHxxx   DOWNTIME DATE (YYYYMMDD)


DTIMHxxx DOWNHxxx   DOWNTIME TIME (HH:MM)


DREAHxxx DOWNHxxx   DOWNTIME REASON


OCOMHxxx OCOMHxxx   OTHER DOWNTIME COMMENTS XXX


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FIG. X2.5 Repeating Field Specifications *(continued)*