**Date: <Enter Date>**

**To: Subcommittee D02.0B**

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**Work Item #: <Enter Work Item number>**

**Ballot Action: New test method**

**Rationale: This method, commonly referred to as the Caterpillar C13 Engine Oil Aeration Test, defines a heavy‑duty diesel engine test procedure conducted under high‑idle conditions to evaluate engine oil performance with regards to engine lubricant aeration. The method forms part of PC-11 the heavy-duty diesel engine oil category.**

*Note:**This document is a draft procedure submitted for consideration by ASTM and the appropriate sub committees and groups for use in the development of a new ASTM standard. Modifications to this procedure will be made throughout development before being accepted.*

*Prepared by: Martin Thompson and Terry Bates*

*Reviewed by:*

*Accepted by:*

**Standard Test Method for**

**Evaluation of Engine Oil Aeration Resistance in a Caterpillar C13 Direct‑Injected Turbocharged Automotive Diesel Engine[[1]](#footnote-1)1**

This standard is issued under the fixed designation DXXXX; 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 is written for use by laboratories that utilize the portions of the test method that refer to ASTM Test Monitoring Center (TMC)[[2]](#footnote-2) services (see Annex A1). Laboratories that choose not to use the TMC services may simply disregard these portions.[[3]](#footnote-3)

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

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

**1. Scope**

1.1  This test method evaluates an engine oil's resistance to aeration in automotive diesel engine service. It is commonly referred to as the Caterpillar C13 Engine Oil Aeration Test (CAT EOAT). The test is conducted under high-engine-speed (1800 r/min) idling conditions using a specified Caterpillar 32 kW, direct-injection, turbocharged, after-cooled, six-cylinder diesel engine designed for heavy-duty, on-highway truck use. This test method was developed as a replacement for Test Method D6894 after it was determined that this test did not correlate with oil aeration in actual service and that the test engine was no longer available.

Note 1—Companion test methods used to evaluate engine oil performance for specification requirements are discussed in the latest revision of Specification [D4485](" \l "refa00019_2).

1.2  The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.2.1  *Exception—*Where there is no direct SI equivalent, for example, screw threads, national pipe threads/diameters, and tubing size.

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.* See Annex A2 for general safety precautions.

1.4  This test method is arranged as follows:

|  |  |
| --- | --- |
|  | Section |
| Scope | [1](#s00001) |
| Referenced Documents | [2](#s00006) |
| Terminology | [3](#s00010) |
| Summary of Test Method | [4](#s00028) |
| Significance and Use | [5](#s00032) |
| Apparatus | [6](#s00037) |
| Reagents and Materials | [7](#s00047) |
| Preparation of Apparatus | [8](#s00057) |
| Calibration | [9](#s00069) |
| Test Procedure | [10](#s00084) |
| Determination of Test Results | [11](#s00127) |
| Report | [12](#s00129) |
| Precision and Bias | [13](#s00135) |
| Keywords | [14](#s00144) |

**2.  Referenced Documents**

2.1  *ASTM Standards:[[4]](#footnote-4)*

D235

[D445](#refa00006_1)  Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)

D3524 Diesel Fuel Diluent in Used Diesel Engine Oils by Gas Chromatography

D5185 Multielement Determination of Used and Unused Lubricating Oils and Base Oils by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)

D4052

D6894  Test Method for Evaluation Aeration Resistance of Engine Oils in Direct-Injected Turbocharged Automotive Diesel Engine

D7549  Test Method for Evaluation of Heavy-Duty Engine Oils under High Output Conditions–Caterpillar C13 Test Procedure

[E29](" \l "refa00026_1)  Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

[IEEE/ASTM SI 10](" \l "refa00028_1)  Standard for Use of the International System of Units (SI): The Modern Metric System

2.2  *SAE Standard:[[5]](#footnote-5)*

[J 304](" \l "refr00001_1)  Engine Oil Tests

2.3  *API Standard:[[6]](#footnote-6)*

[API 1509](" \l "refr00002_1)  Engine Oil Licensing and Certification System

**3.  Terminology**

3.1  *Definitions:*

3.1.1  *automotive*, *adj*—descriptive of equipment associated with self-propelled machinery, usually vehicles driven by internal combustion engines.        **[D6594](" \l "a00025)**

3.1.2  *calibrate*, *v*—to determine the indication or output of a device (e.g., thermometer, manometer, engine) with respect to that of a standard.

3.1.3  *candidate oil*, *n*—an oil that is intended to have the performance characteristics necessary to satisfy a specification and is to be tested against that specification.        **[D5844](" \l "refa00021_2)**

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

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

**[D5862](" \l "refa00022_2)**

3.1.5  *foam*, *n*—*in liquids*, a collection of bubbles formed in or on the surface of a liquid in which the air or gas is the major component on a volumetric basis.        **[D6082](" \l "a00023)**

3.1.6  *heavy-duty*, *adj*— *in internal combustion engine operation*, characterized by average speeds, power output and internal temperatures that are close to the potential maximums.        **[D4485](" \l "a00019)**

3.1.7  *heavy-duty engine*, *n*—*in internal combustion engine types*, one that is designed to allow operation continuously at or close to its peak output.

3.1.8  *lubricant*, *n*—any material interposed between two surfaces that reduces the friction or wear, or both, between them.        **[D5862](" \l "a00022)**

3.1.9  *non-reference oil*, *n*—any oil other than a reference oil; such as a research formulation, commercial oil, or candidate oil.        **[D5844](" \l "refa00021_3)**

3.1.10  *reference oil*, *n*—an oil of known performance characteristics, used as a basis for comparison.        **[D5844](" \l "a00021)**

3.1.11  *test oil*, *n*—any oil subjected to evaluation in an established procedure.        **[D6557](" \l "a00024)**

3.1.12  *used oil*, *n*—any oil that has been in a piece of equipment (for example, an engine, gearbox, transformer, or turbine), whether operated or not.        **[D4175](" \l "a00018)**

3.2  *Definitions of Terms Specific to This Standard:*

3.2.1  *aeration*, *n*—*in liquids*, the action of impregnating with air that forms foam bubbles in or on the surface of a liquid or is entrained as a dispersion in that liquid.

3.2.2  *flush*, *n*—the action of cleaning out the engine oil system using new test oil to remove any residues as well as to minimize possible carryover effect from the previous test oil.

3.3  *Abbreviations and Acronyms*:

3.3.1  *A*—absolute

3.3.2  *ACERT*—Advanced Combustion Emission Reduction Technology

3.3.3  *BOT*—Beginning of Test

3.3.4  *Cat*[[7]](#footnote-7)—abbreviation for Caterpillar

3.3.5  ELC[[8]](#footnote-8)—Extended Life Coolant

3.3.6  EOAT—Engine Oil Aeration Test

3.3.7  EOT—End of Test

3.3.8  FDM—Flow and Density Meter

3.3.9  *G*—gauge

3.3.10  ICP-AES—Inductively Coupled Plasma Atomic Emission Spectrometry

3.3.11  P—Pressure

3.3.12  P/N—Part Number

3.3.13  T—Temperature

3.3.14  TMC—Test Monitoring Centre of ASTM

**4.  Summary of Test Method**

4.1  This test method uses a production Caterpillar C13 diesel engine. It is installed on a stand equipped with appropriate instrumentation to record and control various operating parameters.

4.2  The test operation involves two flushes of 30 min duration for each test, a test warm‑up for 30 min, a baseline reference period for 5 min and then a test length of 50 h at high‑engine speed (1800 r/min) idling conditions.

4.3  The percent aeration of the engine oil is determined using a flow and density meter to continuously monitor the density of a small portion of diverted gallery oil flow that has controlled pressure, temperature, and flow rate. The density of this oil is used to calculate the percentage of total sample volume that is entrained air.

**5.  Significance and Use**

5.1 *Background*—Prior to this test, the ability of an engine lubricant to resist aeration was measured by Test Method D6894. This test no longer correlated with the field in a study performed by Caterpillar. Concerns over the reliability of the volume aeration measurement method led to the need for a new method development on a modern engine platform. The Caterpillar C13 EOAT was developed, therefore, to provide a better measurement of the ability of a lubricant to resist aeration during engine operation.

5.2 *Test Method*—This test method assesses the performance of an engine oil with respect to resistance to entrained aeration under high‑speed operation in a turbocharged, heavy‑duty, four‑stroke diesel engine.

5.3 *Use*:

5.3.1 The tendency of engine oils to aerate in direct-injection, turbocharged diesel engines is influenced by a variety of factors, including engine oil formulation variables, oil temperature, sump design and capacity, residence time of the oil in the sump, and the design of the pressurized oil systems. In some engine-oil-activated injection systems, the residence time of the oil in the sump is insufficient to allow dissipation of aeration from the oil. As a consequence, aerated oil can be circulated to the injector intensifiers, adversely affecting the injection timing characteristics and engine operation.

5.3.2 The results from this test method may be compared against specification requirements to ascertain acceptance.

5.3.3 The design of the test engine used in this test method is representative of many, but not all, diesel engines. This factor, along with the unique operating conditions, needs to be considered when comparing the test results against specification requirements.

**6. Apparatus**

6.1  *Test Engine*—The test engine is a production 2004 Caterpillar 320 kW C13 engine[[9]](#footnote-9),[[10]](#footnote-10), designed for heavy‑duty, on‑highway truck use. It is an electronically controlled, turbocharged, after‑cooled, direct‑injected, six‑cylinder diesel engine with an in‑block camshaft and a four‑valve per cylinder arrangement. The engine uses Caterpillar’s ACERT technology featuring multiple injections per cycle and inlet‑valve‑actuation control. It features a 2004 US EPA emissions configuration with electronic control of fuel metering, fuel injection timing and inlet‑valve‑actuation timing. See [Annex A3](#an00010) of D7549 for source of the test engine and critical and non-critical parts.

6.2  *Test Engine Configuration*—Configure the test engine as described in 6.1 of D7549.

6.2.1  Use of an oil pan modified according to 6.1.3 of D7549 is acceptable; however, in this case, cap the added oil pan fittings.

6.3  *Test Stand Configuration*:

6.3.1  *For Full-Load Break in*—Configure the stand with a dynamometer and drive-line as described in 6.2 of D7549.

6.3.1.1  An external oil system such as that described in 6.2.8 of D7549 is not used.

6.4  *For* *the Aeration Measurements*—The aeration measurement system comprises of a heated line, pressure control valve, flow and density meter (FDM), variable speed pump, pressure transducers and thermocouples. Assemble the system with the indicated line lengths, fittings and components as shown in Annex A3.

6.5  *System Time Responses—*The maximum allowable system time responses are shown in Table X. Determine system time responses in accordance with the Data Acquisition and Control Automation II (DACA II) Task Force Report.[[11]](#footnote-11)

**TABLE X Maximum Allowable System Time Responses**

| Measurement | Time Response |
| --- | --- |
| Speed | 2.0 s |
| Temperature | 3.0 s |
| Pressure | 3.0 s |
| Fuel Flow  Oil Sample Flow | 40.0 s  ?? |

6.6  Oil Sample Containers—Preferably use high-density polyethylene containers for oil samples. (Warning—Avoid using glass containers which may break and cause injury or exposure to hazardous materials.)

**7.**   **Engine Liquids and Cleaning Solvent**

7.1  *Test Oil*—Approximately 115 L of test oil is required to complete the test.

7.2  *Test Fuel*—Approximately 490 L of Chevron Philips PC-10 ultra‑low‑sulfur diesel fuel[[12]](#footnote-12),8 is required to complete the test.

7.3  *Engine Coolant*9*,*10—Use a mixtureof mineral‑free water and Caterpillar‑brand, coolant concentrate containing 0.50 volume fraction of concentrate.

7.3.1  As an option, premixed coolant is available and may be used directly.

7.3.2  Table 1 shows Caterpillar part numbers for several sized containers of concentrate and premixed coolant.

7.3.3  The mineral-free water shall have a mineral content not exceeding 34.4 mg/kg of total dissolved solids.

7.3.4  Use the coolant mixture for a maximum of 6 test starts or up to 300 h. The mixture shall remain at 0.50 volume fraction concentrate during the course of the test. Verify by using either Caterpillar testers 5P3514 or 5P0957 or an equivalent tester. Keep the coolant mixture free from contamination.

7.3.5  Keep the total solids below 5000 mg/kg.

7.3.6  Maintain a correct additive concentration. Verify by checking the coolant using Caterpillar test kit P/N 8T5296.

7.4  *Cleaning Solvent*—Use a solvent meeting the requirements of Specification [D235](http://enterprise.astm.org/SUBSCRIPTION/NewValidateSubscription.cgi?D235-HTML), Type II, Class C for aromatic content (0 volume percent to 2 volume percent), flash point (61 °C, min), and color (not darker that +25 Saybolt or 25 Pt-Co). Obtain a certificate of analysis for each batch of solvent from the supplier. (**Warning—**Combustible. Health Hazard. Use adequate safety precautions.)

**TABLE 1 Part Numbers for Cat*A* ELC*B* Coolant Concentrate and Premixes**

**Containing 0.50 Volume Fraction Concentrate**

| Container Size | 3.8 L | 19 L | 208 L | | Tote,[*C*](#tfn00001) 275 g |
| --- | --- | --- | --- | --- | --- |
| Concentrate P/N | 119-5150 | ... | 136-3707 | | ... |
| Premix P/N | 101-2844 | 129-2151 | 101-2845 | 222-1534 | |

*A* Registered Trademark of Caterpillar Inc., 100 North East Adams St., Peoria, IL 61629.

*B*  Trademark of Caterpillar Inc., 100 North East Adams St., Peoria, IL 61629.

*C*  A small container.

**8.**   **Preparation of Apparatus**

8.1  *Cleaning of Parts*—Carry out in accordance with 8.1 of D7549.

8.2  *Engine Assembly*—Carry out in accordance with 8.2 of D7549.

8.2.1 *New engine Parts –* In addition to Engine Assembly instructions in 8.2 of D7549, a new set of turbo chargers, a new oil pump and a new oil pressure regulator must be used for all rebuilds.

8.2.2  Perform an engine assembly after every 20 full‑length tests, or when operational conditions cannot be met, or reference testing cannot meet acceptable limits.

**(The rebuild interval may be revised at a later date)**

8.3 *Operational Measurements:*

8.3.1 Specified *Units and Formats*—See Annex A4.

8.3.2 *Instrument Calibration*—Carry out calibrations of measurements of fuel rate, temperature, and pressure in accordance with 8.3.2 of D7549.

8.3.3 *Temperature, Pressure and Flow-rate Measurement Locations*—Install as described in 8.3.3, 8.3.4 and 8.3.5, respectively, of D7549.

8.3.4 *Parameters for Aerated Oil Samples—*Measure temperature, pressure, flow rate and density using the aeration system shown in Fig. A3.1.

8.3.4.1 Record the oil sample temperature as the average of the inlet and outlet thermocouple temperatures of the FDM. (This temperature is a theoretical temperature at the midpoint of the FDM.)

8.3.4.2 Record the oil sample pressure as the average of the inlet and outlet pressure transducers of the FDM. (This temperature is a theoretical pressure at the midpoint of the FDM.)

**9. Engine/Stand Calibration and Non-Reference Oil Tests**

**This section will contain:**

**ANNEX A5. ASTM TEST MONITORING CENTER: CALIBRATION PROCEDURES**

**ANNEX A6. ASTM TEST MONITORING CENTER: MAINTENANCE ACTIVITIES**

**ANNEX A7. ASTM TEST MONITORING CENTER: RELATED INFORMATION**

**10. Procedure**

10.1 *Engine Break-in Following Engine Assembly:*

10.1.1 Install the engine on a stand configured as described in 6.3 and connect the engine to the stand support system.

10.1.2 *Oil Fill for Break-in:*

10.1.2.1 Install a new Caterpillar IR-1808 oil filter.[[13]](#footnote-13)

10.1.2.2 Charge the engine with 32.8+/- .2 kg Caterpillar branded DEO-ULS CJ-4 15W-40 oil8 or an equivalent Caterpillar certified CJ-4 15W-40 oil8. Use a pressurized, oil‑fill system such as that described in 6.2.7 of D7549 or charge manually through the engine oil add tube.

10.1.3  Carry out a break‑in as described in 10.5 and Table 3 of D7549 with an additional 85 h as described in ANNEX?? C13 On test conditions or until oil consumption and engine conditions stabilize. During this period oil changes must be performed according to ANNEX (??) The purpose of the oil changes is primarily to passivate and flush any engine build silicon and fluid remnants.

note 2—After the engine has performed the break-in it can be transferred to the stand equipped with the aeration measurement system and instrumented according to this procedure. Alternatively, both the break-in and the aeration testing can be carried out on the same stand provided as it can meet the break-in procedure conditions and can also maintain the operation conditions defined in this procedure for aeration testing.

10.2  *Pretest Procedure:*

10.2.1  Install a new Caterpillar 1R-1808 oil filter.8

10.2.2  Charge the engine with 32.2 L ± ?? L of test oil.

10.2.2.1 Either use a pressurized system such as that described in 6.2.7 of D5749 or charge manually through the engine oil add tube.

10.2.3  *Warm‑up—*Start the engine and perform the warm-up described by Steps 1 and 2 of Table 2. After completion of Step 2, perform a 2 min cool‑down at Step 1 conditions before stopping the engine.

10.2.4  Drain the engine of the initial oil charge while allowing the oil sampling circuit pump to run and drain.

10.2.5  Repeat 10.2.2 to 10.2.4.

10.2.6 Measure out 36 L ± ?? L of test oil and determine its mass. Record the volume and mass of the oil. Charge the engine as described in 10.2.2.1.

10.3  *Shutdowns and Maintenance—*The test may be shutdown at the discretion of the laboratory to perform repairs. However, the intent of this test method is to conduct the 50 h test procedure without shutdowns.

10.3.1  *Normal Shutdown—*A normal shutdown is accomplished by ramping down to warm-up Step 1 conditions, running for 2 min and then stopping the engine.

10.3.2  *Emergency Shutdown—*An emergency shutdown occurs when the normal shutdown cannot be completed, such as under an alarm condition. During an emergency shutdown ignition can be turned off immediately and the engine allowed to stop.

10.3.3  *Maintenance—*Engine components or stand support equipment or both may be repaired or replaced at the discretion of the laboratory and in accordance with this method.

10.3.4  *Downtime—*The limit for total downtime and number of shutdowns is not specified. Record on the appropriate form all shutdowns, pertinent actions and total downtime during the 50 h test procedure.

10.3.5  *Engine* *Restarting—*Each time the engine is re-started, perform the warm-up described in 10.2.3 before proceeding onto test.

**TABLE 2 Warm-up and Baseline Conditions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameter** | **Units** | **Step 1** | **Step 2** | **Step 3** |
| Stage Length | min | 5 | 30 |  |
| Speed | r/min | 900 | 1800 |  |
| Coolant Out Temperature*A* | º C | 90 | 90 |  |
| Intake Air Temperature*A* | º C | 25 | 25 |  |
| Manifold Temperature*A* | º C | 40 | 40 |  |
| Fuel Temperature*A* | º C | 40 | 40 |  |
| Gallery Oil Temperature*A* | º C | 90 | 90 |  |
| Sample Oil Temperature*A* | º C | 90 | 90 |  |
| Sample Oil Flow*A* | L/min | 1.5 | 1.5 |  |
| Sample Oil Pressure*A* | kPaA | 150 | 150 |  |
| Intake Air Pressure*A* | kPaA | 96 | 96 |  |
| Fuel Flow | g/min | Record | Record |  |
| Blowby Flow | L/min | Record | Record |  |
| Intake Manifold Pressure | kPaG | Record | Record |  |
| Exhaust After Turbo Temperature*A* | º C | Record | Record |  |
| Fuel Pressure | kPaG | Record | Record |  |
| Oil Gallery Pressure | kPaG | Record | Record |  |
| Coolant System Pressure | kPaG | 100 | 100 |  |
| Exhaust Restriction Pressure | kPaG | 104 | 104 |  |
| Crankcase Pressure | kPaA | Record | Record |  |

*A This is the control set-point. It can require up to 30 min of operation to achieve.*

10.4  *Baseline Reference Procedure:*

10.4.1  *General—*Carry out a baseline reference procedure after completion of the pretest procedure described in 10.2 and prior to carrying out the 50 h test procedure. The purpose of the baseline reference procedure is to determine the baseline value of various parameters required for the 50 h test procedure.

10.4.2  After 10.2.6, start the engine and perform the warm-up described in Step 3 of Table 2.

10.4.3  *Thermal expansion coefficient baseline:*

10.4.3.1  Record the oil sample density, as measured by the FDM, and its corresponding temperature for all data points between 80 ºC and 90 ºC. This temperature window is typically seen during the last 10 min of warm-up Step 2.

10.4.3.2  Determine the baseline thermal expansion coefficient by calculating the linear slope of oil sample density versus oil sample temperature through a 10 ºC oil sample temperature increase using the least squares method.

10.4.3.3  Use Annex A8 to interpret the results and the accuracy of the correlation to determine if the thermal expansion coefficient is appropriate. Support modifications to this coefficient calculation or data set with comments if the test laboratory calculates this value in any other manner.

10.4.3.4  The baseline value for the thermal expansion coefficient so determined is used for all subsequent restarts and warm-ups.

10.4.4  *Chemical Analysis Baseline—*Determine a chemical analysis baseline using D4052M at 50 ºC, 70 ºC and 90 ºC. The value at 90 ºC is used for a second baseline. Report the calculated aeration using this baseline in addition to the calculated aeration using the aeration sampling system calculated baseline.

10.4.5  *Unaerated Density Baseline*:

10.4.5.1  Immediately following Step 2 of this warm-up, run the engine for 5 min under Step 2 warm-up conditions. All controlled parameters defined in the warmup table (??) shall be within limits.

10.4.5.2  Record the oil sample density as measured by the FDM during the 5 min. and calculate the average. This is the unaerated baseline density which is used for all subsequent restarts and warm-ups.

10.4.5.3  Use Annex A8 to interpret the results and the accuracy of this step to determine if the baseline density is appropriate. Support modifications to this baseline density calculation or data set with comments if the test laboratory calculates this value in any other manner.

10.5  *50 h Test Procedure:*

10.5.1  Immediately after completing the baseline reference procedure described in 10.4 and without shutting down the engine, start the 50 h test procedure described in Table 3.

10.5.2  *New Oil Sample—*Take a 240 mL sample of the fresh test oil from the original oil container. Measure and record the parameters shown in Table 4.

10.5.3  *Test Timer—*The 50 h test timer starts when all controlled parameters shown in Table 3 are within specification requirements. If a shutdown occurs, stop the test timer immediately at the initiation of the shutdown. The test timer shall resume after the warmup described in table (??) and when the test has been returned to the test operation schedule and all controlled parameters are within specification requirements.

10.5.4  *Operational Data Acquisition—*Record all operational parameters shown in Table 3 with automated data acquisition at a minimum frequency of once every 6 min. Recorded values shall have a minimum resolution in accordance with Annex A4. Report on the appropriate form of the test report.

10.5.5  *Oil Sampling and Analyses—*Take oil samples and carry out analyses according to the schedule and methods shown in Annex A9.

10.6  *End of Test*:

10.6.1  After completion of the 50 h test perform a normal shutdown as described in 10.3.1.

10.6.2  Drain the test oil charge from the engine with the oil sample circuit pump running, weigh the drained oil and calculate the total oil consumed during the test as the difference in mass between the initial charge (as recorded in 10.2.6) and the drained oil.

**TABLE 3 50 h Test Schedule of Conditions**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Unit** | **Step 1** |
| Stage Length | h | 50 |
| Speed | r/min | 1800 |
| Coolant Out Temperature | º C | 90 |
| Intake Air Temperature | º C | 25 |
| Manifold Temperature | º C | 40 |
| Fuel Temperature | º C | 40 |
| Gallery Oil Temperature | º C | 90 |
| Sample Oil Temperature | º C | 90 |
| Sample Oil Flow | L/min | 1.5 |
| Sample Oil Pressure | kPaA | 84 |
| Intake Air Pressure | kPaA | 96 |
| Fuel Flow | g/min | Record |
| Blowby Flow | L/min | Record |
| Intake Manifold Pressure | kPaG | Record |
| Exhaust After Turbo Temperature | ° C | Record |
| Fuel Pressure | kPaG | Record |
| Oil Gallery Pressure | kPaG | Record |
| Coolant System Pressure | kPaG | 100 |
| Exhaust Restriction Pressure | kPaG | 104 |
| Crankcase Pressure | kPaG | 103 |

**TABLE 4 Analytical Parameters**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Test Method | Units | BOT | EOT | After  1 h 5 h 25 h |
| Diesel Fuel Dilution | D3524 | mass percent | No | Yes | No |
| Kinematic Viscosity at 100 °C | D445 | mm2/s | Yes | Yes | Yes |
| Wear Metals*A* by ICP-AES | D5185 | ppm*B* | Yes | Yes | Yes |

*A* Al, Cr, Cu, Fe, Pb, Si

*B* Mass fraction

**11. Calculation, Test Validity and Test Results**

11.1  *Oil Aeration Calculations*—Calculate the oil aeration and aeration averages from the data acquired in 10.5.4 using the equations in Table 5. Report on the appropriate form of the test report.

11.1.1  Do not include in the calculation of oil aeration averages any values obtained within a 4 h period following an engine shutdown and restart.

11.2 *Test Results*—Report the average aeration value for the operational period 30  h to 50 h, the maximum aeration value, and a plot of the oil aeration values for the operational period 0 h to 50 h.

11.2.1  Report this information on the appropriate form of the test report.

**Table 5 Parameters and equations for calculating oil aeration**

**Parameter Unit Source**

Sample Oil Density g/mL Direct Measurement

Sample Oil Temperature º C

Sample Oil Pressure kPaA

Sample Oil Flow  L/min Direct Measurement

Ambient Pressure kPaA Direct Measurement

Air Density g/mL

Baseline Oil Density g/ml D4052 at 90 º C Average density during baseline step

Thermal Expansion Coef. g/mLº C Linear slope of density from D4052 30 º C to 90 º C Linear slope of density decrease from 80 ºC to 90 ºC during warm up

Temp. Corrected Density g/mL

Oil Aeration percent

**12.  Report**

12.1  For reference oil results, use the standardized report form set available from the ASTM TMC and data dictionary for reporting test results and for summarizing operational data.

Note 3—Report the non-reference oil test results on these same forms if the results are intended to be submitted as candidate oil results against a specification.

12.1.1  Fill out the report forms according to the formats shown in the data dictionary.

12.1.2  Transmit results to the TMC within 5 working days of test completion.

12.1.3  Transmit the results electronically as described in the ASTM Data Communications Committee Test Report Transmission Model (Section 2 — Flat File Transmission Format) available from the ASTM TMC. Upload files via the TMC’s website.

12.2  Report all reference oil test results, whether aborted, invalidated, or successfully completed, to the TMC.

12.3  *Deviations from Test Operational Limits—*Report all deviations from specified test operational limits.

12.4  *Precision of Reported Units—*Use the Practice [E29](#a00031) rounding‑off method for critical pass/fail test result data. Report the data to the same precision as indicated in data dictionary.

12.5  In the space provided, note the time, date, test hour, and duration of any shutdown or off-test condition. Document the outcome of all prior reference oil tests from the current calibration sequence that were operationally or statistically invalid.

12.6  If a calibration period is extended beyond the normal calibration period length, make a note in the comment section and attach a written confirmation of the granted extension from the TMC to the test report. List the outcomes of previous runs that may need to be considered as part of the extension in the comment section.

**13. Precision and Bias**

**14. Keywords**

14.1 Caterpillar C13, diesel engine oil, lubricants, aeration; automotive; EOAT; heavy-duty diesel engine.

**ANNEXES**

**(Mandatory Information)**

**ANNEX A1.  ASTM TEST MONITORING CENTER ORGANIZATION**

**ANNEX A2. SAFETY PRECAUTIONS**

**ANNEX A3. AERATION MEASUREMENT SYSTEM**

**ANNEX A4. SPECIFIED UNITS AND FORMATS**

**ANNEX A5. ASTM TEST MONITORING CENTER: CALIBRATION PROCEDURES**

**ANNEX A6. ASTM TEST MONITORING CENTER: MAINTENANCE ACTIVITIES**

**ANNEX A7. ASTM TEST MONITORING CENTER: RELATED INFORMATION**

**ANNEX A8. INTERPRETATION OF BASELINE PARAMETERS**

**ANNEX A9. SCHEDULE FOR TAKING OIL SAMPLES AND CARRYING OUT ANALYSES**

**A1. ASTM TEST MONITORING CENTER ORGANIZATION**

A1.1  *Nature and Functions of the ASTM Test Monitoring Center (TMC)—*The TMC is a non‑profit organization located in Pittsburgh, Pennsylvania and is staffed to: administer engineering studies; conduct laboratory inspections; 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 ASTM Subcommittee D02.B0 and the ASTM Executive Committee. The TMC coordinates its activities with the test sponsors, the test developers, the surveillance panels, and the testing laboratories. Contact TMC through the TMC Director at:

ASTM Test Monitoring Center

6555 Penn Avenue

Pittsburgh, PA 15206-4489

www.astmtmc.cmu.edu

A1.2  *Rules of Operation of the ASTM TMC—*The TMC operates in accordance with the ASTM Charter, the ASTM Bylaws, the 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 Executive Committee elected by Subcommittee D02.B0. The Executive Committee selects the TMC Director who is responsible for directing the activities of the TMC.

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 by the Executive Committee and reviewed by Subcommittee D02.B0.

**A2.  SAFETY PRECAUTIONS**

A2.1  The operation of engine tests may expose personnel and facilities to safety hazards. Personnel trained and experienced with engine testing shall perform the design, installation and operation of the test stands.

A2.2  Install guards (shields) around all external moving, hot, or cold components. Design the guard to contain the energy level of a rotating component should the component break free. Properly route fuel, oil and electrical wiring, and guard, ground and keep in good order.

A2.3  Keep the test stand free of oil and fuel spills and tripping hazards. Do not permit containers of oil or fuel, or both, to accumulate in the testing area. Fire fighting equipment shall be immediately accessible. Observe normal precautions whenever using combustible solvents for cleaning purposes.

A2.4  Safety masks, glasses or hearing protection, or a combination thereof, shall be worn by personnel working on the test stand. Do not wear loose or flowing clothing, including neither long hair nor other accessory to dress, near rotating equipment. Caution personnel against working alongside the engine and driveline while the engine is running.

A2.5  Interlocks shall automatically shut down the engine when an anomaly in any of the following occurs: engine or dynamometer coolant temperature, engine oil pressure, dynamometer field current, engine speed, exhaust temperature, excessive vibration, or when the fire protection system is activated. The interlock shall include a method to cut off the fuel supply to the engine at the injector pipe (including the return line). A remote fuel cutoff station (external to the test stand) is recommended.

A2.6  Employ other safety precautions as required be regulations.

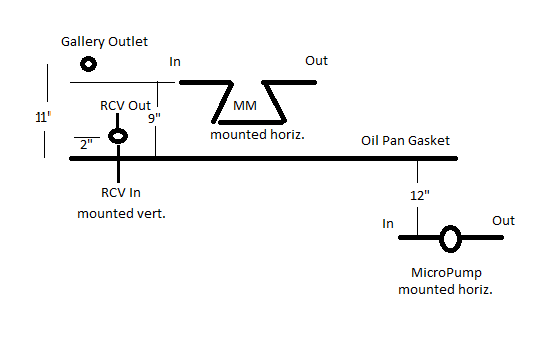
**A3. AERATION MEASUREMENT SYSTEM**

**A3.1 See Fig A3.1**



**FIG A3.1 General layout of the engine and aeration system**

**A3.2 See Fig A3.2.**



**FIG. A3.2 Diagram of Aeration System Orientation Compared to Engine**

**A3.3 See Fig. A3.3**

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |
| **Table ?? Aeration System Piping Orientation (Order of Flow)** | | | |
| Gallery Inlet | The system inlet will be plumbed to the lower left side drain plug with a 90deg NPT to #10 AN fitting (1/2") | | |
| Heated Line | A 5'x1/2" heated line will run under the engine and to the right side and connected to the regulator | | |
| SS Line | A 1'x1/2" (#10AN) SS PTFE line will run from the regulator to the temp/pressure coupling | | |
| 4 way coupling | A 4x1/2" coupling will be placed with the thermocouple fitting facing upwards and pressure line downwards | | |
| Flow and density meter (FDM) | A CMF 025 Elite Micromotion will be oriented with the inlet centerline horizontal and the unit plane vertical | | |
| Mount | A height adjustable mount must be used for mounting the Micromotion. (9”+/- 2” in from oil pan gasket to MM centerline) | | |
| 4 way coupling | A 4x1/2" coupling will be placed with the thermocouple fitting facing upwards and pressure line downwards | | |
| SS Line | A 4'x3/8" (#6AN) SS PTFE line will run from the temp/pressure coupling to the Pump | | |
| Pump | The pump should be mounted with the inlet centerline horizontal and attached to the Mount | | |
| Sump Return | A 4'x3/8" (#6AN) SS PTFE line will run from the Pump to the lower right side drain plug | | |

**A3.2 List of Aeration Parts – see Table A3.1**

|  |  |  |  |
| --- | --- | --- | --- |
| **Table A3.1 Aeration Parts List (Order of Flow)** | | | |
| 1 | Heated Line | SII-B-8-060-S-E8-PPO-A-AK-D72-000 5 FT HEATED 1/2" stainless steel line | |
| 2 | Regulator | 2‑way Research Control Valve (1/4", H, ATO), 1001GCN36SVOHLN36[[14]](#footnote-14),8 | |
| 3 | Line | 1 FT 1/2" stainless steel line | |
| 4 | T and P | 4-way coupling with thermocouple and pressure line | |
| 5 | Flow and density meter (FDM) | Elite Coriolis Micro Motion Model CMF025[[15]](#footnote-15),8 | |
| 6 | T and P | 4-way coupling with thermocouple and pressure line | |
| 7 | Line | 4 FT 3/8" stainless steel line (SS-6BHT-48) | |
| 8 | Micropump | S-74014-40 GEAR PUMP SYSTEM 115V 14.700 LBS 38 Days | |
| 9 | Line | 4 FT 3/8" stainless steel line (SS-6BHT-48) | |
|  |  |  |  |
|  |  |  |  |

**ANNEX A4. SPECIFIED UNITS AND FORMATS**

A7.1  *Specified Units*:

A7.1.1  *Test Report—*Record operational parameters according to [Table A7.1](" \l "ta00004). Report test results in the units and with the significant digits shown in [Table A7.2](" \l "ta00005). Round test results in compliance with Practice [E29](" \l "a00030).

**TABLE A7.1 Units and precision ~~Piston Rating Locations~~**

| Parameter | Record Data  to Nearest |
| --- | --- |
| Speed | 1 rpm |
| Power | 1 kW |
| Torque | 1 N.m |
| Fuel Flow | 1 g/min |
| Coolant In Temperature | 0.1 °C |
| Coolant Out Temperature | 0.1 °C |
| Fuel In Temperature | 0.1 °C |
| Oil Gallery Temperature | 0.1 °C |
| Intake Air Temperature | 0.1 °C |
| Exhaust (Tailpipe) Temperature | 1 °C |
| Intake Manifold Pressure | 0.1 kPa |
| Crankcase Pressure | 0.01 kPa |
| Exhaust Pressure | 0.1 kPa |
| Carbon Dioxide | 0.01 % |

**TABLE A7.2 Significant Digits for Test Results**

| Parameter | Round Off  to Nearest |
| --- | --- |
| Oil Consumption | 0.1 g |
| Aeration | 0.01 % volume |
|  |  |

A7.1.2  *Measurements and Conversions—*Except for the exceptions noted in [1.2.1](" \l "s00004), all parameters have been specified in SI units. The intent of this test method is to measure all parameters directly in SI units. If parameters are measured in inch-pound units, then the laboratory shall show to the TMC that the measurements are within the tolerances after conversion to SI units.

A7.1.2.1  Significant error may occur due to rounding or tolerance stacking, or both, when converting from inch-pound units to SI units.

A7.2  *Specification Format*—Specifications are listed in three formats: *(1)* target, *(2)*  target and range, and *(3)* range with no target.

A7.2.1  *Target—*A target specification has no tolerance. Therefore, the only acceptable value is the target. A representative specification format is xx.xx (target). For example, the oil pan charge is listed as 30.8 kg.

A7.2.1.1  Do not intentionally calibrate or control a parameter with a target at a level other than the target.

A7.2.2  *Target and Range—*A target and a range specification implies that the correct value is the target and the range is intended as a guide for maximum acceptable variation about the mean. A representative specification format is xx.xx ± x.xx (target ± range). For example, the engine speed is (1800 ± 5) r/min.

Note A7.1—The mean of a random sample should be equivalent to the target. Operation within the range does not imply that the parameter will not bias the final test results.

A7.2.3  *Range with No Target—*A range with no target specification is used when *(1)* the parameter is not critical and control within the range is sufficient or *(2)* the measurement technique is not precise, or both. A representative format is xx.xx – xx.xx (rangelow – rangehigh). For example, the system coolant pressure is (99 to 107) kPa.

**ANNEX A5. ASTM TEST MONITORING CENTER: CALIBRATION PROCEDURES**

**ANNEX A6. ASTM TEST MONITORING CENTER: MAINTENANCE ACTIVITIES**

**ANNEX A7. ASTM TEST MONITORING CENTER: RELATED INFORMATION**

**ANNEX A8. INTERPREATIOIN OF BASELINE RESULTS**

A8.1 Baseline thermal expansion coefficient

A8.2 Baseline density

**ANNEX A9. SCHEDULE FOR TAKING OIL SAMPLES AND CARRYING OUT ANALYSES**

At test hours 0, 1, 5, 25 and 50 remove an 8oz sample after a 4oz purge and perform the following tests on the engine oil: Fuel Dilution (D3524), Viscocity at 100c (D445), Metals ICP (D5185), Soot By TGA Analysis (by annex A4 of test method D5967). Return the 4oz purge to the engine through the oil add tube.

In addition to the analysis above, the 0 hour sample must also perform a test to determine the density at the following temperatures using method D4052: 30, 40, 50, 60, 70, 80, 90 º C

**ANNEX ?? Outline for engine break-in procedure**

**CAT Aeration Test Rebuilt Engine Break-in Procedure (Rev 2, 20140703):**

Install engine in test stand capable of running the engine at the conditions specified in the C13 Deposit test procedure. Measure oil consumption, crankcase pressure and blowby. Aeration measurement not required or feasible.

Use Cat DEO-ULS 15W-40 oil for the break-in. Fill per the C13 deposit test procedure. Measure silicon on new oil.

Run the C13 deposit test one hour break-in. Let cool 4 hours and check valve lash per the C13 deposit test procedure.

**Hours 0-25:** Proceed to test conditions following the C13 Deposit Test warm-up procedure. Run for 25 hours and shut down per the C13 deposit test procedure. **Take oil samples at hours 1 and 25** and measure silicon.

Drain oil from the engine, oil cooler, and oil weigh system. Replace oil filter.

Refill engine with new Cat DEO-ULS 15W-40 per the C13 deposit test procedure.

**Hours 25-50:** Proceed to test conditions following the C13 Deposit Test warm-up procedure. Run for 25 more hours and shut down per the C13 deposit test procedure. **Take oil samples at hours 30, 40, and 50** and measure silicon.

Drain oil from the engine, oil cooler, and oil weigh system. Replace oil filter.

Refill engine with new Cat DEO-ULS 15W-40 per the C13 deposit test procedure.

**Hours 50-75:** Proceed to test conditions following the C13 Deposit Test warm-up procedure. Run for 25 more hours and shut down per the C13 deposit test procedure. **Take oil samples at hours 51, 60, 70, and 75** and measure silicon.

Drain oil from the engine, oil cooler, and oil weigh system. Replace oil filter.

Refill engine with new Cat DEO-ULS 15W-40 per the C13 deposit test procedure.

**Hours 75-80:** Proceed to test conditions following the C13 Deposit Test warm-up procedure**. Run for 5 more hours** and shut down per the C13 deposit test procedure. **Take oil samples at hours 75, 76 and 80** and measure silicon.

Continue 5 hour segments until silicon shows zero increase. Note final engine hours.

Drain and fill and silicon sample hours (summarized):

1, 25. Drain and fill. 30, 40, 50. Drain and fill. 51, 60, 70, 75 (end of period). Drain and fill. 75 (start of period), 76, 80 (end of period). Drain and fill. 80 (start of period), 81, 85 (end of period). Continue 5 hour pattern of samples when “on-test” conditions are met (zero hour), 1 hour into run and at 5 hours before shutting down as necessary until silicon shows zero increase.

1. This test method is under the jurisdiction of ASTM Committee [D02](http://www.astm.org/COMMIT/COMMITTEE/D02.htm) on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee [D02.B0.02](http://www.astm.org/COMMIT/SUBCOMMIT/.htm) on Heavy-Duty Engine Oils.

   Current edition approved XXXX. Published YYYY. [↑](#footnote-ref-1)
2. ASTM Test Monitoring Center, 6555 Penn Avenue, Pittsburgh, PA 15206-4489. www.astmtmc.cmu.edu. [↑](#footnote-ref-2)
3. The advantage of utilizing the TMC services to calibrate test stands is that the test laboratory (and hence the Test Purchaser has an assurance that the test stand was operating at the proper level of test severity. It should also be borne in mind that results obtained in a non‑calibrated test stand may not be the same as those obtained in a test stand participating in the ASTM TMC services process. [↑](#footnote-ref-3)
4. For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For  *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website. [↑](#footnote-ref-4)
5. Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001. This standard is not available separately. Either order the SAE Handbook Vol. 3 or the SAE Fuels and Lubricants Standards Manual HS-23. [↑](#footnote-ref-5)
6. Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, http://www.api.org. [↑](#footnote-ref-6)
7. Registered trademark of Caterpillar Inc., 100 North East Adams St., Peoria, IL 61629. [↑](#footnote-ref-7)
8. Trade mark of Caterpillar Inc., 100 North East Adams St., Peoria, IL 61629. [↑](#footnote-ref-8)
9. The sole source of supply of the apparatus known to the committee at this time is Caterpillar Inc., 100 North East Adams St., Peoria, IL 61629. [↑](#footnote-ref-9)
10. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee1 which you may attend. [↑](#footnote-ref-10)
11. Available from ASTM Test Monitoring Center, 6555 Penn Avenue, Pittsburgh, PA 15206-4489, Attention: Administrator. [↑](#footnote-ref-11)
12. The sole source of supply of the fuel known to the committee at this time is Chevron Philips Chevron Phillips Chemical Company LP, 10001 Six Pines Drive, Suite 4036B, The Woodlands, TX 77387-4910, www.cpchem.com. [↑](#footnote-ref-12)
13. Available from a Caterpillar parts distributor. [↑](#footnote-ref-13)
14. The sole source of supply of the apparatus known to the committee at this time is Barger Meter, 4545 W Brown Deer Road, PO Box 245034, Milwaukee, WI 53224-9536. Tel 414-355-0400 [↑](#footnote-ref-14)
15. The sole source of supply of the apparatus known to the committee at this time is Emerson Process Management, Micro Motion, 7070 Winchester Circle Boulder, CO 80301 USA, Phone: (800) 522-6277, Fax: (303) 530-8459.  [↑](#footnote-ref-15)