



Designation: D8004 – 23

Standard Test Method for Fuel Dilution of In-Service Lubricants Using Surface Acoustic Wave Sensing¹

This standard is issued under the fixed designation D8004; 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.

1. Scope*

1.1 This test method describes a means for determining the amount of fuel dilution present in an in-service lubricant. This is achieved by drawing into a surface acoustic wave (SAW) sensor vapor from the lubricant. Fuel vapor will be absorbed by the SAW sensor's polymer coating. The amount of absorbance is then related to fuel content in the lubricant.

1.2 The range of fuel dilution capable of being measured by the test method is from 0.1 % to 10.0 % by mass fuel dilution.

1.3 This test method is specifically tailored to determining the fuel dilution of in-service lubricants, including newly utilized lubricants. The method is applicable to contamination with diesel, gasoline, and jet fuels.

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

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use. See Section 9.*

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

2. Referenced Documents

2.1 ASTM Standards:²

[E456 Terminology Relating to Quality and Statistics](#)

¹ This test method is under the jurisdiction of ASTM Committee [D02](#) on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee [D02.96.02](#) on Chemistry for the Evaluation of In-Service Lubricants.

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² 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.

[D4057 Practice for Manual Sampling of Petroleum and Petroleum Products](#)

[D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants](#)

[D6708 Practice for Statistical Assessment and Improvement of Expected Agreement Between Two Test Methods that Purport to Measure the Same Property of a Material](#)

[D7235 Guide for Establishing a Linear Correlation Relationship Between Analyzer and Primary Test Method Results Using Relevant ASTM Standard Practices](#)

[D7593 Test Method for Determination of Fuel Dilution for In-Service Engine Oils by Gas Chromatography](#)

[D7669 Guide for Practical Lubricant Condition Data Trend Analysis](#)

[D7720 Guide for Statistically Evaluating Measurand Alarm Limits when Using Oil Analysis to Monitor Equipment and Oil for Fitness and Contamination](#)

3. Terminology

3.1 Definitions:

3.1.1 For definitions of terms used in this test method, refer to Terminology [D4175](#).

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *fuel dilution sample holder, n*—a bottle that contains the lubricant to be analyzed.

3.2.2 *fuel dilution sample inlet, n*—a tube that connects the sample to the SAW sensor.

3.2.3 *fuel dilution sample stand, n*—mechanical device for holding the bottle of lubricant in the SAW fuel dilution apparatus in a way such that the headspace from the bottle is directly fed into the SAW element.

3.2.4 *fuel dilution seal, n*—a mechanism that seals the fuel dilution sample holder to the vapor path leading to the SAW sensor.

3.2.5 *SAW fuel dilution apparatus, n*—a device that measures fuel dilution using surface acoustic wave (SAW) technology. This is achieved by drawing vapor from the lubricant into a surface acoustic wave (SAW) sensor. The fuel dilution apparatus measures the concentration of contaminating fuel vapor present in the air “headspace” over the lubricant. The fuel dilution apparatus assumes that this headspace fuel vapor concentration is directly proportional to the fuel present in the

*A Summary of Changes section appears at the end of this standard

oil. This relationship is based on Henry's Law. As fuel contamination builds up, a vapor concentration will be established in the headspace that is directly proportional to the concentration dissolved in the oil. The fuel dilution apparatus uses a SAW sensor to make these measurements.

3.2.6 *SAW sensor, n*—consists of a piezoelectric substrate that has an interdigitated electrode lithographically patterned on its surface. The surface of the SAW sensor has a polymer coating that is chosen to offer specific solubility to fuel vapors. The mechanism of detection is a reversible absorption of the fuel component into the polymer. When this device is excited by external RF (radio frequency) voltage, a synchronous Rayleigh wave is generated on the surface of the device. When fuel contamination comes in contact with the SAW sensor surface, it will absorb into the polymer coating. This absorption into the polymer causes a mass change, which produces a corresponding change in the amplitude and velocity of the surface wave. When used in a self-resonant oscillator circuit, the change in Rayleigh wave velocity resulting from vapor absorption into the polymer coating causes a corresponding change in oscillator frequency. This change in frequency is the basis of detection of the fuel dilution apparatus.

3.2.7 *surface acoustic wave (SAW), n*—a mechanical deformation travelling on the surface of a material; such a deformation may be converted into electrical signals using a piezoelectric material, which generates a voltage in response to a mechanical deformation.

4. Summary of Test Method

4.1 A liquid sample is placed into the fuel dilution sample holder of the SAW fuel dilution apparatus and fuel dilution (percent by mass) is determined.

4.2 The vapor headspace of the sample, equilibrated at room temperature, is drawn into the SAW sensor by means of a diaphragm pump, which draws the vapor into the chamber of the SAW sensor.

4.3 The SAW sensor registers the buildup of mass on its polymer absorbent coating over a period of approximately one minute.

4.4 Based on this mass buildup and a calibration, fuel dilution (percent by mass) for the sample is determined.

5. Significance and Use

5.1 This test method provides a means for a reliable field determination of fuel dilution that is quick and preparation-free. Results are obtained in approximately 1 min. Such a method is used, for example, at remote railroad depots where it is impractical to carry out a standard laboratory method for determination of fuel dilution, such as described in Test Method **D7593**, but it is a critical need to determine if fuel has contaminated the lubricant. If fuel has contaminated the lubricant, this is significantly detrimental to the machinery and it is typically serviced immediately. Further, the fuel can ignite at the high temperatures encountered in machinery lubricant paths.

6. Interferences

6.1 Departures in temperature between the sample under test and the sample which was used in the calibration by more than 2 °C will affect the precision of the results. This is due to the fact that the fuel vapor pressure is temperature dependent. For example, if calibration was performed with the fuel standard at 20 °C and the measured samples that are at 30 °C, the fuel dilution determination would be approximately 50 % high.

6.2 Creating a standard using fresh, rather than aged, fuel will cause the method to underreport actual measured values.

6.3 Possible interferences include the introduction of biodiesel variations or other additives in the fuel after it has been calibrated on the SAW fuel dilution meter. If the sample is calibrated with fuel containing the expected amount of biodiesel or additive, no error in the measurement should occur. If measured with an unexpected amount of biodiesel higher than that calibrated with, the apparent reading will be lower. This is because the biodiesel is typically less volatile than the fuel being measured. For example, if a calibration was performed on a 5.0 % fuel sample with no biodiesel, then a sample of that same fuel containing 10 % biodiesel (B10) is diluted into the lubricant at a 5.0 % level, the reading will be approximately 4.5 %. Thus, unexpected additional amounts of biodiesel can lead to false negative indications of fuel contamination if the apparatus is not calibrated with that same fuel. Similarly, unexpected lesser amounts of biodiesel can lead to false positive indications of fuel content when the apparatus is not calibrated with that fuel.

6.4 Other interferences include the possibility of the calibration not being performed with the source fuel and lubricant material under test. This can significantly reduce the precision of the method.

6.5 Other interferences can arise from fuel dilution sample holders that are not completely dry or with a cleaning compound residue.

6.6 Samples that have very high water content (>1.0 % by mass) may also degrade the precision of the measurement.

7. Apparatus

7.1 The SAW fuel dilution apparatus consists of the following components:

7.1.1 *SAW Sensor Module, Fuel Dilution Sample Stand, Sample Inlet, and Seal*—These components work in conjunction to extract a sealed vapor headspace from the sample being analyzed, and gauge fuel contamination in the in-service lubricant sample.

7.1.2 *Fuel Dilution Sample Stand Holder*—This is a disposable bottle into which the in-service lubricant is added and placed into the apparatus.

7.2 *Optional*—A *thermometer*, for example a thermocouple, which allows for the determination of the lubricant temperature. A thermometer is not required because users may elect to calibrate the instrument each time before a series of measurements, minimizing the temperature effects discussed in 6.1.