



Designation: ~~D5059 – 14~~ **D5059 – 14 (Reapproved 2019)**

Standard Test Methods for Lead in Gasoline by X-Ray Spectroscopy¹

This standard is issued under the fixed designation D5059; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*Scope

1.1 These test methods cover the determination of the total lead content of a gasoline within the following concentration ranges:

~~0.010 to 5.0 g Pb/US gal
0.012 to 6.0 g Pb/UK gal
0.0026 to 1.32 g Pb/L~~

0.010 g Pb/US gal to 5.0 g Pb/US gal
0.012 g Pb/UK gal to 6.0 g Pb/UK gal
0.0026 g Pb/L to 1.32 g Pb/L

1.1.1 Test Methods A and B cover the range of ~~0.10 to 10.10 g Pb/US gal to 5.0 g Pb/US gal/US gal~~. Test Method C covers the range of ~~0.010 to 0.10 g Pb/US gal to 0.50 g 0.50 g Pb/US gal/US gal~~.

1.1.2 These test methods compensate for normal variation in gasoline composition and are independent of lead alkyl type.

1.2 *Test Method A* (formerly in withdrawn Test Method D2599)—Sections ~~5 – 9~~.

Test Method B (formerly in withdrawn Test Method D2599)—Sections ~~10 – 14~~.

Test Method C (formerly in withdrawn Test Method D3229)—Sections ~~15 – 19~~.

1.3 The values stated in SI are to be regarded as the standard. For reporting purposes the values stated in grams per U.S. gallon are the preferred units in the United States. Note that in other countries, other units can be preferred.

1.4 *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.* For specific hazard statements, see Sections ~~5, 6, 11, and 18~~.

1.5 *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

~~D3341 Test Method for Lead in Gasoline—Iodine Monochloride Method~~

~~D4057 Practice for Manual Sampling of Petroleum and Petroleum Products~~

~~D6299 Practice for Applying Statistical Quality Assurance and Control Charting Techniques to Evaluate Analytical Measurement System Performance~~

~~D6792 Practice for Quality Management Systems in Petroleum Products, Liquid Fuels, and Lubricants Testing Laboratories~~

3. Summary of Test Method

3.1 There are three alternative test methods, as follows.

3.1.1 *Test Method A (Bismuth Internal Standard Method High Concentration)*—One volume of sample is mixed thoroughly with an equal volume of bismuth internal standard solution. The mixture is placed in the X-ray beam and the intensities of the lead $L\alpha_1$

¹ These test methods are under the jurisdiction of Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and are the direct responsibility of Subcommittee D02.03 on Elemental Analysis.

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Initially published as ~~D2599~~ D2599 – 67 – 67F-T and ~~D3229~~ D3229 – 73 – 73-, now withdrawn.

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.

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

radiation at ~~1.175~~1.175 Å and the bismuth $L\text{-}\alpha_1$ radiation at 1.144 Å are determined. The lead concentration of the sample is measured by comparing the ratio of gross counting rate at ~~1.175~~1.175 Å with the gross counting rate at 1.144 Å to a previous prepared calibration curve of concentration versus the same ratios.

3.1.2 *Test Method B (Scattered Tungsten Radiation Method)*—The ratio of the net X-ray intensity of the lead $L\text{-}\alpha_1$ radiation to the net intensity of the incoherently scattered tungsten $L\text{-}\alpha_1$ radiation is obtained on a portion of the sample. The lead content is determined by multiplying this ratio by a calibration factor obtained with a standard lead solution of known concentration.

3.1.3 *Test Method C (Bismuth Internal Standard Method, Low Concentration)*—Twenty millilitres of sample is mixed thoroughly with two ~~milliliters~~millilitres of bismuth internal standard solution. The mixture is placed in the X-ray beam of a spectrometer and the intensities of the lead $L\text{-}\alpha_1$ radiation at ~~1.175~~1.175 Å, the bismuth $L\text{-}\alpha_1$ radiation at ~~1.144~~1.144 Å, and a background at ~~1.194~~1.194 Å are determined. A blank, made with *iso*-octane and bismuth internal standard, is run using the same procedure. The lead concentration is measured by determining the ratio of the net counting rate at ~~1.175~~1.175 Å to the gross counting rate at ~~1.144~~1.144 Å for the sample, subtracting the comparable ratio found for the blank, and comparing to a previously prepared calibration curve of concentration versus the same ratios.

4. Significance and Use

4.1 These test methods determine the concentration of lead (from alkyl addition) in gasoline. These alkyl additives improve the antiknock properties.

4.2 Test Method C is used to ensure compliance of trace lead as required by federal regulations for lead-free gasoline (40 CFR part 80).

TEST METHOD A (BISMUTH INTERNAL STANDARD)

5. Apparatus

5.1 *X-ray Spectrometer*, capable of measuring radiations mentioned in 3.1.1 and of being operated under the following instrumental conditions or other giving equivalent results:

Tube Voltage Tube Voltage Tube Current Tube Current Analyzing Crystal Optical Path	50 kV 50 kV 20 to 45 mA 20 mA to 45 mA Lithium Fluoride (LiF) Air, Helium (Warning —Compressed gas under pressure) Air, Helium (Warning —Compressed gas under pressure) Proportional or Scintillation
Optical Path	Air, Helium (Warning —Compressed gas under pressure)
Detector	Proportional or Scintillation

NOTE 1—The X-ray spectrometer and manner of use should comply with the regulations governing the use of ionizing radiation or recommendations of the International Commission of Radiological Protection, or both.

6. Reagents and Materials

6.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society where such specifications are available.³ Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determinations.

6.2 Hydrocarbon-Soluble Bismuth.

NOTE 2—Bismuth 2-Ethylhexoate has been found suitable to use. Other bismuth containing materials that are hydrocarbon-soluble may also be used when they are certified to conform to 6.1.

6.3 *Bismuth Internal Standard Solution*—*Solution*—Dilute the hydrocarbon-soluble bismuth with a suitable solvent. If bismuth 2-ethylhexoate is used, add 2-ethylhexanoic acid as a stabilizer (see Note 3) to obtain a solution containing the following:

- ~~3.00 g Bi/US gal at 15.5°C (60°F) or~~
- ~~3.60 g Bi/UK gal at 15.5°C (60°F) or~~
- ~~0.793 g Bi/L at 15°C~~
- 3.00 g Bi/US gal at 15.5 °C (60 °F) or
- 3.60 g Bi/UK gal at 15.5 °C (60 °F) or
- 0.793 g Bi/L at 15 °C

³ *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For Suggestions on the testing of reagents not listed by the American Chemical Society, see *Annual Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

NOTE 3—Some stability difficulties have been experienced with bismuth 2-ethylhexoate internal standard solution. If the standard is blended to contain 5 % 2-ethylhexanoic acid, the standard has been found to last almost indefinitely. The 2-ethylhexanoic acid stabilizes *iso*-octane, toluene, and benzene solutions of the bismuth 2-ethylhexoate which are otherwise stable for only a day or two. Normal octanoic acid does *not* stabilize solution.

6.4 *Iso-octane*. (**Warning**—Extremely flammable.)

6.5 *Solvent*, capable of dissolving the bismuth internal standard. Mixed xylenes and dodecane have been found suitable to use.

6.6 *Hydrocarbon-Soluble Lead*—Either tetraethyllead (TEL) or a lead-containing compound (for example, lead naphthenate) with a certifiable lead concentration.

6.7 *Lead (Pb) Standard Solution*—~~Solution~~—Dissolve tetraethyllead (TEL) (**Warning**—TEL is toxic by ingestion), lead naphthenate (see ~~ingestion~~ **Note 4**), or other suitable lead containing compound in *iso*-octane), lead naphthenate (see **Note 4**), or other suitable lead containing compound in *iso*-octane (**Warning**—Extremely flammable), toluene, or a mixture of these two solvents. This standard solution shall contain an accurately known lead concentration of approximately the following magnitude: flammable), toluene, or a mixture of these two solvents. This standard solution shall contain an accurately known lead concentration of approximately the following magnitude:

~~5 g Pb/US gal at 15.5°C (60°F) or
6 g Pb/UK gal at 15.5°C (60°F) or
1.3 g Pb/L at 15.5°C~~

~~5 g Pb/US gal at 15.5 °C (60 °F) or
6 g Pb/UK gal at 15.5 °C (60 °F) or
1.3 g Pb/L at 15.5 °C~~

6.7.1 Keep the standard solution refrigerated when not in use.

NOTE 4—A lead naphthenate solution of same lead concentration has also proven satisfactory as a calibration material. Concentrated TEL is not used to make up standard solutions. The concentrated solution is too acutely toxic to be handled safely under normal laboratory conditions.

NOTE 5—When this lead standard solution is prepared with TEL, the lead concentration can be determined with Test Method **D3341**.

6.8 *Toluene*. (**Warning**—Flammable. Vapor harmful.)

7. Calibration

7.1 Make dilutions of the lead (Pb) standard solution to give ~~0.10, 0.10 g Pb 1.00/US gal, 1.00 g Pb 2.00/US gal, 2.00 g Pb 3.00/US gal, 3.00 g Pb 4.00/US gal, 4.00 g Pb/US gal and 5.005.00 g Pb g Pb/US gal at 15.5°C (60°F) or 0.10/US gal at 15.5 °C (60 °F) or 0.10 g Pb 1.00/UK gal, 1.00 g Pb 2.50/UK gal, 2.50 g Pb 3.50/UK gal, 3.50 g Pb 5.00/UK gal, 5.00 g Pb/UK gal, and 6.006.00 g Pb g Pb/UK gal at 15.5°C (60°F) or 0.025/UK gal at 15.5 °C (60 °F) or 0.025 g Pb 0.264/L, 0.264 g Pb 0.529/L, 0.529 g Pb 0.793/L, 0.793 g Pb 1.057/L, 1.057 g Pb 1.322/L, 1.322 g Pb g Pb/L at 15°C/L at 15 °C~~ in toluene, *iso*-octane, or a mixture of these solvents.

7.2 Allow the lead standards and bismuth internal standard solutions to come to room temperature.

7.3 Pipet accurately ~~10 mL~~ 10 mL of each standard into separate glass-stoppered bottles or flasks and add an equal, accurately measured volume of the bismuth internal standard solution to each one. Mix thoroughly.

7.4 Place one of these solutions in the sample cell using techniques consistent with good operating practice for the spectrometer employed. Place the cell in the instrument, allow the spectrometer atmosphere to reach equilibrium (if appropriate), and determine the counting rate at the lead $L\text{-}\alpha_1$ line (~~1.175~~ (1.175 Å) and at the bismuth $L\text{-}\alpha_1$ line (~~1.144~~ (1.144 Å).

NOTE 6—When possible, collect at least 100 000 counts at each line. When sensitivity or concentration, or both, makes it impractical to collect this many counts, the technique that allows the greatest statistical precision in the time allotted for each analysis should be used. Sample stability should also be considered in determining counting rate. Variation in counting rates should be observed and if the counting rate tends to go in one direction only, the sample is probably decomposing. If this occurs, shorter counting times should be used consistent with acceptable statistical precision.

7.5 Determine the ratio, R , for each standard as follows:

$$R = A/B \quad (1)$$

where:

A = counting rate at 1.175 Å, and
 B = counting rate at 1.144 Å.

A = counting rate at 1.175 Å, and
 B = counting rate at 1.144 Å.

7.6 Plot a calibration curve relating R to the grams of lead per gallon.

NOTE 7—Many modern X-ray spectrometer instruments will plot and store the calibration curve, slope, and related information in the instrument computer system, as an alternative to hand-plotting this information.

8. Quality Control Checks

8.1 Confirm the calibration of the instrument each day it is in use by analyzing a quality control (QC) sample containing a quantifiable concentration of lead, that is, independent of the calibration curve. It is advisable to analyze additional QC samples as appropriate, such as at the beginning and end of a batch of samples or after a fixed number of samples, to ensure the quality of the results. Analysis of result(s) from these QC samples can be carried out using control chart techniques.⁴ When the QC sample result causes the laboratory to be in an out-of-control situation, such as exceeding the laboratory's control limits, instrument re-calibration may be required. An ample supply of QC sample material shall be available for the intended period of use, and shall be homogeneous and stable under the anticipated storage conditions. If possible, the QC sample shall be representative of samples typically analyzed and the average and control limits of the QC sample shall be determined prior to monitoring the measurement process. The QC sample precision shall be checked against the ASTM method precision to ensure data quality. Further guidance on quality control can be found in Practices [D6299](#) and [D6792](#).

9. Procedure

9.1 Obtain sample in accordance with Practice [D4057](#).

9.2 Prepare the samples to be analyzed as described in [7.3](#) and [7.4](#) for the standard lead solutions and determine the ratio, R , as described in [7.5](#).

9.3 Determine the lead content of the samples by relating the R values obtained to the previously determined calibration curve.

10. Report

10.1 Report the lead content obtained as g Pb/US gal at $\pm 5.5^\circ\text{C}$ (60°F) ± 0.01 g, or g Pb/UK gal at $\pm 5.5^\circ\text{C}$ (60°F) ± 0.01 g, or g Pb/L at $\pm 5.5^\circ\text{C}$ (60°F) ± 0.003 g, as appropriate.

NOTE 8—To convert grams per US gallon at $\pm 5.5^\circ\text{C}$ (60°F) ± 0.01 g to: (a) grams per UK gallon at $\pm 5.5^\circ\text{C}$ (60°F) ± 0.01 g multiply by 1.200 and (b) grams per litre at $\pm 5.5^\circ\text{C}$ (60°F) ± 0.003 g, multiply by 0.2642.

TEST METHOD B (SCATTERED TUNGSTEN RADIATION)

11. Apparatus

11.1 *X-ray Spectrometer*, capable of measuring radiations mentioned in [3.1.2](#) and of being operated under the following instrumental conditions or others giving equivalent results:

Tube Voltage	50 kV
Tube Voltage	50 kV
Tube Current	20 to 45 mA
Tube Current	20 mA to 45 mA
Tube Target	Tungsten
Analyzing Crystal	Lithium Fluoride (LiF)
Optical Path	Air, Helium (Warning—Compressed gas under pressure)
Optical Path	Air, Helium (Warning—Compressed gas under pressure)
Collimation	Fine
Pulse Height Analyzer	Threshold discrimination set as low as possible consistent with the removal of noise with respect to the detector employed. Proportional or Scintillation Fixed Time
Detector	
Counting Technique	

11.1.1 Two restrictions are imposed upon the period of the fixed time: namely, that it is ≥ 30 s or greater, and that it is such that the count on the position of minimum intensity (background at $A = 1.211 \text{ \AA}$) should exceed 200 000.

NOTE 9—The X-ray spectrometer and manner of use should comply with the regulations governing the use of ionizing radiation or recommendations of the International Commission of Radiological Protection, or both.

12. Reagents and Materials

12.1 *Iso-octane*. (Warning—Extremely flammable.)

12.2 *Lead (Pb) Standard Solution*—Dissolve tetraethyllead (TEL) (Warning—TEL is toxic by ingestion) lead naphthenate (see [Note 4](#)), or other suitable lead containing compound in *iso*-octane (Warning—Extremely

⁴ ASTM MNL 7, *Manual on Presentation of Data Control Chart Analysis*, "Section 3, Control Charts for Individuals," 6th ed., ASTM International, W. Conshohocken, PA.