



Test Method for Total Sulfur in Liquid Aromatic Hydrocarbons and Their Derivatives by Oxidative Combustion and Electrochemical Detection¹

This standard is issued under the fixed designation D 6428; 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 covers the determination of the total sulfur naturally found in liquid aromatic hydrocarbons, their derivatives and related chemicals.

1.2 This test method is applicable for samples containing sulfur from 0.05 to 100 mgS/kg.

1.3 The detector response for this technique within the scope of this test method is linear with sulfur concentration.

1.4 The following applies to all specified limits in this test method for purposes of determining conformance with this test method, an observed value or a calculated value shall be rounded off “to the nearest unit” in the last right-hand digit used in expressing the specification limit, in accordance with the rounding-off method of Practice E 29.

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 and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Section 9, and Notes 2-4 and Note 7.

2. Referenced Documents

2.1 ASTM Standards:

D 3437 Practice for Sampling and Handling Liquid Cyclic Products²

D 3852 Practice for Sampling and Handling Phenol and Cresylic Acid

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications³

2.2 Other Documents

OSHA Regulations, 29 CFR, paragraphs 1910.1000 and 1910.1200⁴

3. Terminology

3.1 Definitions:

3.1.1 *oxidative combustion, n*—process in which a sample under goes combustion in an oxygen rich environment at temperatures greater than of 650°C and compounds decompose to carbon dioxide, water, and elemental oxides.

3.1.2 *quartz combustion tube devitrification, n*—the suggested maximum temperature for a quartz combustion tube is 1200°C.

3.1.2.1 *Discussion*—Samples containing alkali-metals (elements from the Periodic Group IA (that is, sodium, potassium, etc.)) or alkaline earth (elements from the Periodic Group IIA (that is, calcium, magnesium, etc.)) will cause quartz to devitrify (that is, become milky white and brittle).

4. Summary of Test Method

4.1 The sample of liquid aromatic hydrocarbon is injected, at a controlled rate, into a stream of inert gas (helium or argon) or inert gas mixed with oxygen. The sample is vaporized and carried into a high temperature zone (>900°C) where oxygen is introduced. Sulfur compounds, present in the specimen are converted to sulfur dioxide (SO₂). Sulfur dioxide is reacted with the sensing electrode in a 3-electrode electrochemical cell. This reaction produces a measurable current that is directly proportional to the amount of sulfur in the original sample material. The reaction that occurs is as follows:

Combustion: R-S + O₂ > 900°C +> CO₂ + H₂O + SO₂ + oxides
Detection: SO₂ + 2 H₂O electrolyte H₂SO₄ + (2H⁺) + (2e⁻)

5. Significance and Use

5.1 Some process catalysts used in petroleum and chemical refining may be poisoned when even trace amounts of sulfurous materials are contained in the feedstocks. This test method can be used to determine total sulfur in process feeds and may also be used to control sulfur compounds in finished products which fall within the scope of this test method.

NOTE 1—Virtually all sulfur compounds will be detected by this technique.

¹ This test method is under the jurisdiction of ASTM Committee D16 on Aromatic Hydrocarbons and Related Chemicals and is the direct responsibility of Subcommittee D16.04 on Instrumental Analysis.

Current edition approved June 10, 1999. Published August 1999.

² *Annual Book of ASTM Standards*, Vol 06.04.

³ *Annual Book of ASTM Standards*, Vol 14.02.

⁴ Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

6. Interferences

6.1 Moisture produced during the combustion step can interfere if not removed prior to the detector.

7. Apparatus

7.1 *Pyrolysis Furnace*—a furnace capable of maintaining a temperature sufficient to volatilize and combust all of the sample and oxidize the sulfur to SO₂. The furnace temperatures for petroleum substances shall be as recommended by the manufacturer.

7.2 *Quartz Combustion Tube*—capable of withstanding 900 to 1200°C. The inlet end of the tube holds a septum for syringe entry of the sample and has inlet fittings or side arms for the introduction of oxygen (O₂) and inert gas. The construction is such that the inert gas (or inert gas and oxygen mixture) sweeps the inlet zone transporting all of the volatilized sample into a high temperature oxidation zone. The oxidation section shall be large enough to ensure complete oxidation of the sample.

7.2.1 *Quartz Combustion Tube*—The suggested maximum temperature for a quartz combustion tube is 1200°C. Samples containing alkali-metals (that is, calcium, magnesium, etc.) will cause quartz to devitrify (that is, become milky white and brittle).

7.3 *Drier Tube*—The reaction products include water vapor that must be removed prior to measurement by the electrochemical detector. This can be accomplished with a magnesium perchlorate Mg(ClO₄)₂ scrubber or a membrane drying tube (permeation drier), or both.

7.4 *Electrochemical Detector*—capable of measuring SO₂ in the combustion gas stream.

7.5 *Data Reduction System*—having the capability of measuring, amplifying, and integrating the current from the electrochemical detector. The amplified or integrated output signal shall be applied to a digital display or some other data reporting device.

7.6 *Microlitre Syringe*—of 5, 10, 25, 50, or 100 µL capacity capable of accurately delivering microlitre quantities is required. The needle should be long enough to reach the hottest portion of inlet section of the furnace when injecting the sample.

7.7 *Recorder (Optional)*.

7.8 *Constant Rate Injector or Automatic Sampler System(s) (Optional)*—capable of delivering a sample at a precisely controlled rate.

8. Reagents

8.1 *Purity of Chemicals*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society,⁴ where such specifications are available. 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 determination.

8.2 *Magnesium Perchlorate* Mg(ClO₄)₂—for drying products of the combustion (if a permeation drier is not used).

NOTE 2—**Warning:** Magnesium perchlorate is a strong oxidizer, and is an irritant.

8.3 *Inert Gas*—Either argon (Ar) or helium (He) may be used. The purity should be no less than 99.99 mol %.

8.4 *Oxygen*—The purity should be no less than 99.99 mol %.

NOTE 3—**Warning:** Oxygen of this purity will vigorously accelerate combustion.

8.5 *Solvent*—The solvent chosen should be capable of dissolving the sulfur-containing compound used to prepare the standard and if necessary the samples. The solvent of choice should have a boiling point similar to the samples being analyzed and it should contain less sulfur than the lowest sample to be analyzed. Suggested possibilities include, but are not limited to: toluene, *iso*-octane, methanol, cetane, or other solvent similar to the compound present in the sample to be analyzed.

NOTE 4—**Warning:** Flammable solvents.

NOTE 5—A quick screening can be conducted by injecting the solvent and sample once or twice and comparing relative integral response.

8.6 *Sulfur Stock Solution, 1000 µgN/mL*—Prepare a stock solution by accurately weighing to the nearest 0.1 mg, 0.576 g of dibenzothiophene into a tared 100-mL volumetric flask. Dilute to volume with selected solvent. This stock may be further diluted to desired sulfur concentrations.

$$\frac{\mu\text{gS/L} = \text{exact weight of dibenzothiophene (mg)} \times 32.06 \times 1000 (\mu\text{g/mg})}{100 \text{ mL} \times \text{the molecular weight of the reference material weighed}}$$

NOTE 6—Dibenzothiophene may be used for calibration throughout the boiling range of this test method.

8.7 *Dibenzothiophene (C₁₂H₈S)*—having a molecular weight of 184.27.

NOTE 7—**Warning:** Dibenzothiophene is an irritant.

8.8 *Sulfur Working Standard Solutions, 0.1, 1.0, 10.0 and 100.0 µg S/mL*—The working standards are prepared by accurately pipetting and diluting each to volume with solvent. To obtain the following concentrations 100.0, 10.0, 1.0, and 0.1 µg S/mL see Table 1.

NOTE 8—**Caution:** Working standards should be remixed on a regular basis depending upon frequency of use and age. Typically, standards have a useful life of about three months.

9. Hazards

9.1 Consult current OSHA regulations, suppliers' Materials Safety Data Sheets, and local regulations for all materials used in this test method.

9.2 High temperature is employed in this test method. *Extra* care must be exercised when using flammable materials near the high temperature furnace.

10. Sample Handling

10.1 Collect the samples in accordance with Practice D 3437 or Practice D 3852 as appropriate.

TABLE 1 Dilutions for Working Standards

Desired µg S/mL	mL to pipet	From µg/mL	Dilution volume, mL
100.0	10.0	1000.0	100.0
10.9	10.0	100.0	100.0
1.0	10.0	10.0	100.0
0.1	10.0	1.0	100.0

10.2 To preserve sample integrity (consistency) and prevent the loss of volatile components, which may be in some samples, do not uncover samples any longer than necessary. Analyze samples as soon as possible after taking from the bulk supplies to prevent loss of sulfur or contamination.

10.3 Since this procedure is intended for trace level contamination, care must be taken to ensure the containers used for the sample, the specimen, and the working standards do not alter the sample result.

11. Preparation of Apparatus

11.1 Assemble the apparatus in accordance with manufacturer's instructions.

11.2 Adjust the gas flows and the combustion temperature to the desired operating conditions.

12. Calibration and Standardization

12.1 Prepare a series of calibration standards using a stock solution covering the range of operation as described in 8.6-8.8, and consisting of sulfur type and matrix similar to samples to be analyzed.

12.2 Volumetric measurement of the injected sample can be obtained by filling the syringe to the 80 % level, retracting the plunger so that the lower liquid meniscus falls on the 10 % scale mark, and recording volume of liquid in the syringe. After the sample has been injected, again retract the plunger so that the lower liquid meniscus falls on the 10 % scale mark, and record the volume of liquid in the syringe. The difference between the two volume readings is the volume of sample injected.

12.3 Alternatively, the sample injection device may be weighed before and after injection to determine the amount of sample injected. This test method provides greater precision than the volume delivery method, provided a balance with a precision of ± 0.01 mg is used.

12.4 Insert the syringe needle through the inlet septum up to the syringe barrel and inject the sample or standard at a uniform rate of 0.2 to 1.0 $\mu\text{L/s}$. Rate of injection is dependent on such factors as viscosity, hydrocarbon type, and sulfur concentration. Each user must adopt a method whereby a consistent and uniform injection rate is ensured.

NOTE 9—For the most consistent injection rate and best analytical results, a constant rate injection system or automatic sampling system may be helpful. Consult manufacturer for recommendations.

NOTE 10—With direct injection below 2 mg/kg of sulfur, the needle-septum blank may become increasingly important. Error due to this can be avoided by inserting the syringe needle into the hot inlet and allowing the needle-septum blank to dissipate before injecting the sample.

12.5 For the method blank, rinse the syringe thoroughly with the solvent blank, Then inject the same amount of solvent blank as utilized with standards and obtain the reading. Measure the blank a second time and average the results. The solvent blank should contain less than 0.05 mg/kg of sulfur.

12.6 If the system features an automatic calibration procedure, repeat the measurement of each calibration standard three times. All calibration points shall be used to construct a calibration curve. System performance shall be checked with suitable calibration standard each day and when changing concentration ranges.

12.7 For those analyzers not equipped with an automatic calibration procedure, construct a standard curve as follows: Repeat the determination of each calibration standard and the blank three times to determine the average net response for each standard. Construct a curve plotting milligrams of sulfur injected versus detector response (integration count). The response curve should be linear and shall be checked at least once per week.

13. Procedure

13.1 Sample sizes ranging from 3 to 40 μL are acceptable. It is advisable that the size of injected sample shall be similar to the size of injected standard.

13.2 Experience dictates the best sample size. Typical sample sizes have been used in the following ranges, (see Table 2).

13.3 Flush the microlitre syringe several times with the unknown sample. Determine the sample size as described in 13.2 and inject it at an even rate as described in 12.4.

14. Calculation

14.1 For analyzers equipped with an automatic calibration, calculate the sulfur content of the sample in parts per million by weight (mg/kg) as follows:

$$\text{Sulfur, mg/kg} = (I - B) \times K/V \times D \quad (1)$$

$$\text{Sulfur, mg/kg} = (I - B) \times K/M \quad (2)$$

where:

D = density of sample, g/mL,

K = dilution factor,

V = volume of sample, μL ,

M = mass of sample, mg,

I = visual display reading of sample, and

B = average of visual display readings of blank.

14.2 For analyzers not equipped with automatic calibration, calculate the sulfur content of the sample in parts per million by weight (mg/kg) as follows:

$$\text{Sulfur, mg/kg} = I \times S \times K/V \times D \quad (3)$$

where:

D = density of sample, g/mL,

S = slope of standard curve, mg S/count,

V = volume of sample, μL ,

I = detector response, integration counts, and

K = dilution factor (when applicable).

15. Precision and Bias

15.1 *Precision*—Based on limited information (10 analyses by one operator, two samples), from one laboratory, the absolute standard deviation of 0.02 mg/kg at the 1.01 mg/kg level of sulfur and the absolute standard deviation of 2.76 mg/kg at the 80.0 mg/kg level of sulfur were obtained.

15.1.1 *Intermediate Precision*—Within laboratory results by a single operator should not be considered suspect unless they

TABLE 2 Concentrations for Suggested Sample Size

Sulfur, mg/kg	Sample Size, μL
1 and less	up to 20
10	up to 10
100	up to 5

differ by more than the amount shown in Table 3.

15.1.2 *Reproducibility*—The data of this test method is being determined.

15.2 *Bias*—Since there is no accepted reference material suitable for determining the bias in this test method for measuring sulfur in aromatic hydrocarbons, bias has not been determined.

16. Keywords

16.1 aromatic hydrocarbons; catalyst; electrochemical; nitrogen content; oxidative combustion; oxygenated aromatics; petroleum hydrocarbons; poison

TABLE 3 Intermediate Precision

<u>Sulfur Concentration,</u> mg/kg	<u>Intermediate</u> <u>Precision</u>
1.01	0.06
80.0	7.64

Intermediate Precision Determined at the 95 % Confidence Level

<u>Analysis Number</u>	<u>Integral Response</u>	<u>Concentration, ppm</u>
1	144 375	0.98
2	153 342	1.04
3	148 555	1.01
4	151 272	1.02
5	144 399	0.98
6	144 551	0.98
7	144 610	0.98
8	153 330	1.04
9	149 805	1.02
10	148 001	1.01
Average	148 202	1.01
Standard Deviation	3653	0.02

<u>Analysis Number</u>	<u>Integral Response, K</u>	<u>Concentration, ppm</u>
1	11 856	81.9
2	11 097	76.7
3	11 741	81.1
4	11 357	78.5
5	11 538	79.7
6	12 377	85.5
7	11 554	79.9
8	11 099	76.7
9	11 892	82.1
10	11 242	77.7
Average	11 575K	80.0
Standard Deviation	403 306	2.76

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