Designation: D6021 – 12

Standard Test Method for Measurement of Total Hydrogen Sulfide in Residual Fuels by Multiple Headspace Extraction and Sulfur Specific Detection[1]

1. Scope*

1.1 This test method covers a method suitable for measuring the total amount of hydrogen sulfide (H_2S) in heavy distillates, heavy distillate/residual fuel blends, or residual fuels as defined in Specification D396 Grade 4, 5 (Light), 5 (Heavy), and 6, when the H_2S concentration in the fuel is in the 0.01 to 100 µg/g (ppmw) range.

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

1.3 *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.* For specific warning statements, see 7.5, 8.2, 9.2, 10.1.4, and 11.1.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D396 Specification for Fuel Oils

D1193 Specification for Reagent Water

D2420 Test Method for Hydrogen Sulfide in Liquefied Petroleum (LP) Gases (Lead Acetate Method)

D3609 Practice for Calibration Techniques Using Permeation Tubes

D4057 Practice for Manual Sampling of Petroleum and Petroleum Products

D4084 Test Method for Analysis of Hydrogen Sulfide in Gaseous Fuels (Lead Acetate Reaction Rate Method)

D4323 Test Method for Hydrogen Sulfide in the Atmosphere by Rate of Change of Reflectance

D5504 Test Method for Determination of Sulfur Compounds in Natural Gas and Gaseous Fuels by Gas Chromatography and Chemiluminescence

D5705 Test Method for Measurement of Hydrogen Sulfide in the Vapor Phase Above Residual Fuel Oils

D7621 Test Method for Determination of Hydrogen Sulfide in Fuel Oils by Rapid Liquid Phase Extraction

3. Terminology

3.1 *Definitions:*

3.1.1 *heavy distillate, n*—a fuel produced from the distillation of crude oil which has a kinematic viscosity at 40°C between 5.5 and 24.0 mm^2/s, inclusive.

3.1.2 *heavy distillate/residual fuel blend, n*—a blend of heavy distillate and residual fuel oil having a viscosity at 40°C between 5.5 and 24.0 mm^2/s, inclusive.

3.1.3 *multiple headspace extraction, n*—a technique to determine the total concentration of a gas trapped in a liquid by analysis of successive gas extractions from the vapor space of a closed vessel containing a known amount of the sample.

3.1.4 *residual fuel oil, n*—any liquid or liquefiable petroleum product having a kinematic viscosity at 100°C between 5.0 and 50.0 mm^2/s, inclusive, burned for the generation of heat in a furnace or firebox or for the generation of power in an engine.

4. Summary of Test Method

4.1 A representative sample of residual fuel oil is obtained in sufficient quantity to completely fill the sample container. The sample is taken to the laboratory preferably within one to 4 h, within 24 h maximum and placed in a refrigerator until the hydrogen sulfide analysis can be run. At that time, the sample is removed from the refrigerator and allowed to sit at ambient temperature until it flows freely.

4.2 A 0.05 to 5.0 g test specimen (aliquot) is placed in a headspace vial and heated in an oven at 60°C for more than five but less than 15 min. The headspace gas is sampled and injected into either of two types of apparatus capable of measuring the hydrogen sulfide concentration in the gaseous

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[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 D02.14 on Stability and Cleanliness of Liquid Fuels.

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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.

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

sample.[3] The two types of apparatus are those using the reaction of lead acetate with H_2S (see Test Method D4084 or Test Method D4323) and those based on chemiluminescence (see Test Method D5504).

4.3 The remaining contents of the headspace vial are cooled for 5 min, then again heated in the oven. The headspace contents are again transferred to the hydrogen sulfide measuring instrument. The procedure is repeated for a third time. This is known as multiple headspace extraction procedure (MHE).

4.4 A linear plot of the natural logarithm of the area or peak height difference of the instrument reading against the number of injections is indicative of the correctness of the extraction procedure. The difference in area or peak height of the first two injections is used to calculate a total area or total peak height difference. The total area or total peak height difference is multiplied by a response factor determined from a direct gas calibration mixture and divided by the weight of the test specimen to determine the concentration of H_2S in the residual fuel in µg/g (ppmw).

5. Significance and Use

5.1 Residual fuel oils can contain H_2S in the liquid phase, and this can result in hazardous vapor phase levels of H_2S in storage tank headspaces. The vapor phase levels can vary significantly according to the headspace volume, fuel temperature, and agitation. Measurement of H_2S levels in the liquid phase provides a useful indication of the residual fuel oil's propensity to form high vapor phase levels, and lower levels in the residual fuel oil will directly reduce risk of H_2S exposure. It is critical, however, that anyone involved in handling fuel oil, such as vessel owners and operators, continue to maintain appropriate safety practices designed to protect the crew, tank farm operators and others who can be exposed to H_2S.

5.1.1 The measurement of H_2S in the liquid phase is appropriate for product quality control, while the measurement of H_2S in the vapor phase is appropriate for health and safety purposes.

5.2 This test method was developed so refiners, fuel terminal operators and independent testing laboratory personnel can analytically measure the amount of H_2S in the liquid phase of residual fuel oils.

NOTE 1—Test Method D6021 is one of three test methods for quantitatively measuring H_2S in residual fuels:
1) Test Method D5705 is a simple field test method for determining H_2S levels in the vapor phase.
2) Test Method D7621 is a rapid test method to determine H_2S levels in the liquid phase.

5.3 H_2S concentrations in the liquid and vapor phase attempt to reach equilibrium in a static system. However, this equilibrium and the related liquid and vapor concentrations can vary greatly depending on temperature and the chemical composition of the liquid phase. A concentration of 1 mg/kg (µg/g) (ppmw) of H_2S in the liquid phase of a residual fuel can typically generate an actual gas concentration of >50 to 100 µL/L(ppmv) of H_2S in the vapor phase, but the equilibrium of the vapor phase is disrupted the moment a vent or access point is opened to collect a sample.

NOTE 2—Because of the reactivity, absorptivity, and volatility of H_2S any measurement method only provides an H_2S concentration at a given moment in time.

6. Apparatus

6.1 A schematic of the headspace sampling system required for this analysis is shown in Fig. 1. It consists of:

6.1.1 *Sampling On/Off Valve,* with 3.2 mm o.d. connector (Valve 1).

6.1.2 *Six-Port External Loop Injection Valve,* made with 316 stainless steel, resistant to attack by sulfur compounds and having 3.2 mm o.d. tubing from each port (Valve 2).

6.1.3 *Polytetrafluoroethylene (PTFE) Sample Loops,* of 0.5, 2.5, and 10 mL are used for H_2S content of 1 to 100, 0.1 to 50, and 0.01 to 10 ppmw, respectively.

6.1.4 *Pressure/Vacuum Gage,* 6.3 mm diameter dial type with range of −100 to 200 kPag, 5 kPa divisions from −100 to 0 and 10 kPa divisions from 0 to 200 kPag.

6.1.5 *Vacuum On/Off Valve,* 3.2 mm o.d. connector (Valve 3).

6.1.6 *Sulfur Selective Detector,* any H_2S specific detector capable of measuring H_2S in the gas from 1 to 10 000 ppmv with a repeatability of ±2 % of full scale.

NOTE 3—Good performance has been obtained with a lead acetate tape detector and a sulfur chemiluminescence detector.

6.1.7 *Fluorocarbon Tubing,* 0.6 m long by 3.2 mm o.d. to connect components together.

6.2 *Vacuum pump,* 3.2 mm o.d. outlet, capable of achieving a 0.2 kPa vacuum and with a capacity of 100 mL/min.

6.3 *Headspace Oven,* capable of operating at 60 ± 0.5°C with internal dimensions of 30 by 30 by 30 cm. An optional vent line is recommended in case a vial leaks.

6.4 *Analytical Balance,* sensitivity of 0.01 mg, maximum weight of 250 g.

6.5 *Data Handling System,* such as electronic integrator or any computer unit that can work with a chromatographic signal.

6.6 If sulfur specific detectors are used instead of an H_2S analyzer then a chromatographic system equipped with a suitable column and oven is required to separate H_2S from other sulfur compounds (see Test Method D5504).

6.7 *Hand Crimper,* to crimp 20 mm diameter aluminum seals.

7. Reagents and Materials

7.1 *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

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[3] Determination of H_2S in Residual Fuel Oils by Multiple Headspace Extraction: A Critical Evaluation of Available Analytical Methods. Silva, B., Carvajal, N., Gonzalez, A., Eastern Analytical Symposium, sponsored by American Chemical Society and the American Microchemical Society, November 16–20, 1992, Somerset, N.J.

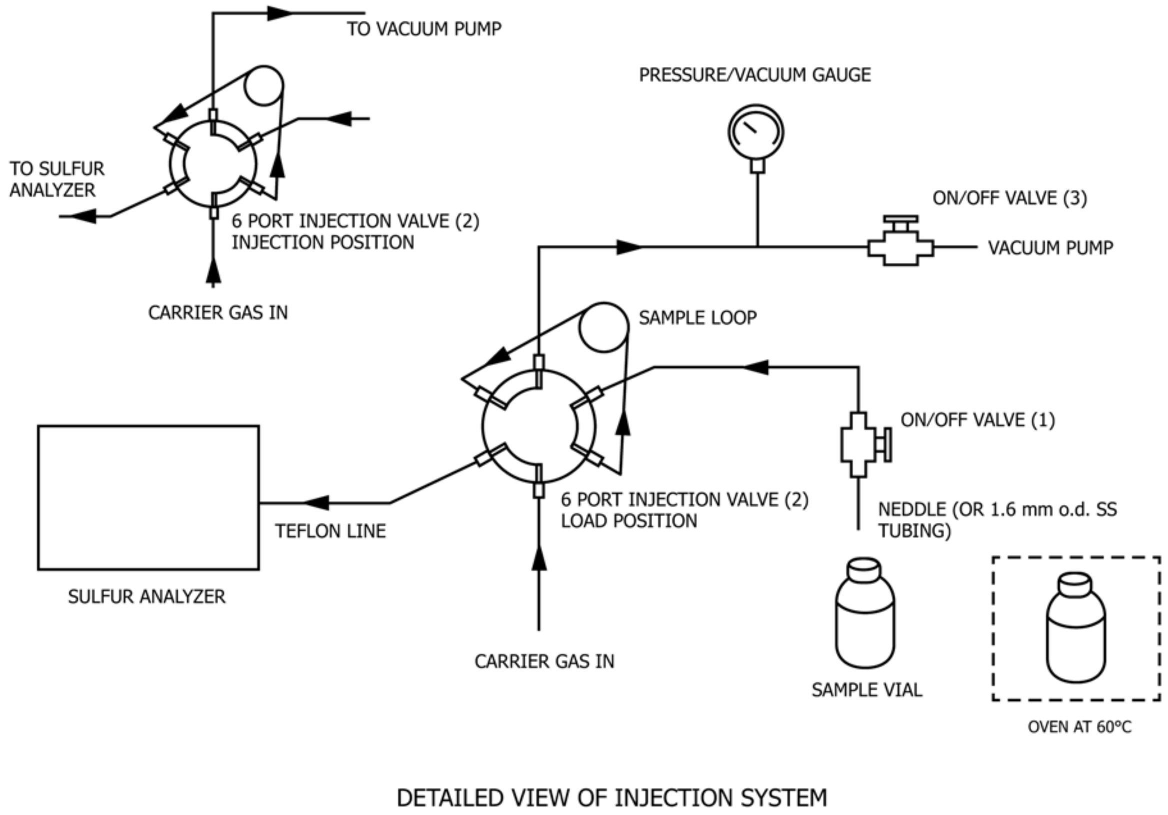

FIG. 1 Schematic of Headspace Analysis System

such specifications are available.[4] 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.

7.2 *Acetic Acid Solution*—Add 50 mL of glacial acetic acid (CH_3COOH) to a 1-L volumetric flask and then add Type II distilled water, as specified in Specification D1193, to the 1-L mark to make a 5 % acetic acid solution.

7.3 *Aluminum Seals,* 20 mm diameter to seal septas to headspace sample vials.

7.4 *Headspace Vials,* 30-, 60-, or 120-mL borosilicate glass vials with 20 mm mouth diameter.

7.5 *Hydrogen Sulfide Gas Calibration Standard,* 1, 10, and 100 µL/L H_2S in helium or nitrogen high pressure cylinders (obtain from gas supply company). (**Warning—**Hydrogen sulfide is an extremely toxic gas.)

7.6 *Gases,* helium or nitrogen (H_2S free), chemically pure grade or purified, as carrier gas to sweep sample into the detector.

7.7 *Lead Acetate Sensing Paper*—Prepare in accordance with Test Method D2420, using appropriate size strips and drying in an H_2S-free environment. Commercially available test paper has been found satisfactory.

NOTE 4—Reagents from 7.2 and 7.7 are only needed if using an H_2S lead acetate tape detector.

7.8 *Nuts and Ferrules,* Polytetrafluoroethylene (PTFE) and stainless steel (3.2 mm).

7.9 *Septas,* 20 mm diameter PTFE silicone/fluorocarbon to seal headspace sample vials.

7.10 *Side Port Needles,* for pressure lock, A-gas series (with reduction union 3.2 mm to 1.6 mm).

7.11 *Syringe Needles,* common dischargeable (dosing needle).

8. Sampling

8.1 Using a suitable H_2S inert container of 250 to 500 mL, collect a representative sample by Practice D4057. Suitable containers can be made of borosilicate glass or aluminum. If the sample temperature is below 60°C then a high density polyethylene bottle can be used.

8.2 Fill the container completely to the top so that there is no headspace in the container. Cap immediately. (**Warning—**At no time should the container temperature be allowed to exceed the temperature of the sample at the time.)

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[4] *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 *Analar 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.

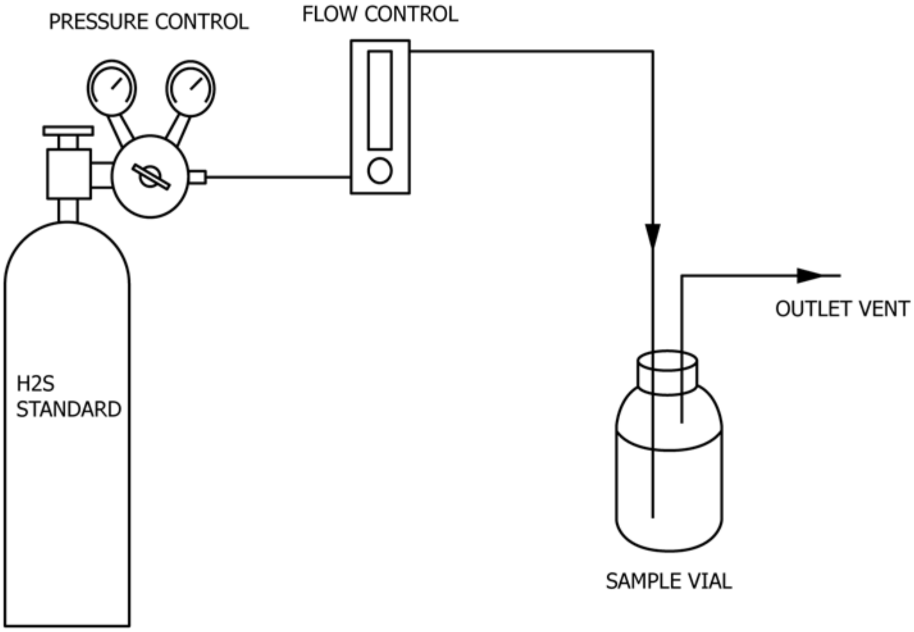

FIG. 2 Gas Calibration Standard Preparation

8.3 Take the samples to the laboratory preferably within one to four hours, within 24 h maximum. Place the samples in refrigerated storage. Store samples until analysis time but not more than three days.

9. Preparation of Apparatus

9.1 Assemble the headspace sampling system as shown in Fig. 1.

9.2 Because of the chemical activity and adsorptive properties of H_2S, it is highly desirable to connect the components of the test apparatus together using minimum lengths of aluminum or fluorocarbon sample lines. (**Warning—**To preclude the formation of mercaptide gels and to reduce problems associated with corrosion do not use brass or copper flow system parts.)

10. Calibration and Standardization

10.1 *Filling Head Space Vial With Gas Calibration Standard:*

10.1.1 Depending on the expected concentration use, a 1 µL/L (≤0.1µ g/g) in a 120-mL headspace vial, 10 µL/L (~1 µg/g) in a 60-mL headspace vial, or 100 µL/L (~10 µg/g) in a 30-mL headspace vial, H_2S gas standard to calibrate the headspace sampling system.

NOTE 5—Parts per million by volume units (µL/L), equivalent to micro moles per mole, are used because of the convenience in use of volume measurements rather than weight for a gas standard.

10.1.2 Insert a silicone/fluorocarbon septum, with the PTFE side pointing inwards, into the headspace vial, cover it with an aluminum seal, and crimp the aluminum seal with the hand crimper.

10.1.3 Insert the inlet needle attached to the H_2S calibration cylinder (see Fig. 2) through the septum with the flow control set to zero. Also insert an open syringe needle into the septum as an outlet vent.

10.1.4 Set the pressure of the H_2S calibration cylinder to 105 kPa, and open the flow control to purge the vial as follows: (**Warning—**Because of the toxicity of H_2S the vial should be in a hood during the purging operation.)

30-mL vial—purge for 3 min at a flow of 100 mL/min.
60-mL vial—purge for 6 min at a flow of 100 mL/min.
120-mL vial—purge for 10 min at a flow of 120 mL/min.

10.1.5 Turn the flow control to zero flow and remove the inlet needle, leaving the outlet vent in the vial.

10.1.6 Allow the vial to equilibrate to atmospheric pressure for 1.0 min, then remove the outlet vent.

10.1.7 Record the laboratory ambient temperature in °C and the laboratory barometric pressure in kPa.

10.1.8 Immediately after preparing a calibration standard obtain its analyzer response as shown in 10.2.1 – 10.2.7.

NOTE 6—Alternative methods for preparing a calibration standard include: heating a solid to generate H_2S and then using a permeation tube as discussed in Practice D3609 or using pure H_2S and a movable piston as discussed in Test Method D4084.

10.2 *Calibration of Analyzer:*

10.2.1 Place the headspace vial in a 60°C oven for at least 5 min but for no more than 15 min. Install an 0.5-mL sample loop if using the 100 µL/L H_2S standard, a 2.5 mL sample loop if using the 10 µL/L H_2S standard, and a 10-mL sample loop if using the 1 µL/L H_2S standard. With Valve 2 in the load position, see Fig. 1 and Valve 1 closed, evacuate the sample loop by opening Valve 3. When a vacuum of at least −70 kPag is achieved, then close Valve 3.

10.2.2 Immediately insert the sampling needle (Fig. 1) through the septum of the headspace vial containing the calibration gas mixture.

10.2.3 Open Valve 1 and let the sample fill the injection loop until a reading of 0 kPag is achieved on the pressure/vacuum gauge. Close Valve 1.

10.2.4 Place Valve 2 in the *Inject* position (see Fig. 1) for 10 s to allow the carrier gas to sweep the sample to the H_2S analyzer. Return Valve 2 to the load position. Remove sampling needle from the vial. Record reading from the analyzer as reading A_1.

10.2.5 After the injection step, insert needle connected to a line containing nitrogen at atmospheric pressure into the septum to reestablish atmospheric pressure within the vial.

10.2.6 Repeat steps 10.2.1 – 10.2.5 with the same headspace vial but record the reading from the analyzer as reading A_2.

10.2.7 Repeat steps 10.2.1 – 10.2.5 with the same headspace vial but record the reading from the analyzer as reading A_3. Two injections are sufficient for the required calculations, but three are required to verify the correctness of the calibration procedure.

10.2.8 Regress the natural log (ln) of readings A_1, A_2 , and A_3 against the number of injections one, two, and three. A linear correlation (correlation coefficient $R^2 > 0.95$) must exist to insure the correctness of the calibration procedure. If R^2 is not greater than 0.95, then repeat the calibration.

10.3 *Analyzer Response Factor:*

10.3.1 Calculate the total area difference (or total height difference) using Eq 1:[5]

$$A_T = \sum A_n = \frac{A_1^2}{A_1 - A_2} \quad (1)$$

where:

A_T = total area difference (or total height difference),
A_1 = area (or height) obtained from the first injection, and
A_2 = area (or height) obtained from the second injection.

10.3.2 Assuming the ideal gas law, calculate the weight of H_2S in the calibration standard by Eq 2:

$$W_{(H_2S)_S} = \frac{PV_vC_{(H_2S)_S}(34.0759)\,(\mathrm{g/g \times mole})10^{-6}(\mu\mathrm{L/L})\;10^{6}(\mu\mathrm{g/g})}{(8313.7162)(\mathrm{mL \times kPa/g \times mole \times {}^\circ}K)T} \quad (2)$$

where:

$W_{(H_2S)_S}$ = weight of H_2S in calibration standard, µg,
P = laboratory barometric pressure, kPa,
V_v = volume of headspace vial, mL,
$C_{(H_2S)_S}$ = concentration of H_2S in calibration standard, µL/L,
34.0759 = molecular weight of H_2S, g/g × mole,
8313.7162 = (mL × kPa)/(g × mole × °K) = R = ideal gas constant, and
T = laboratory ambient temperature,°K.

If P = 101 325 kPa, V_v = 120 mL, $C_{(H2S)S}$ = 10 µL/L and T = 298.15 °K then:

$$W_{(H_2S)_S} = \frac{(101\,325)(\mathrm{kPa})(120)(\mathrm{mL})(10)(\mu\mathrm{L/L})(34.0759)(\mathrm{g/g \times mole})10^{-6}(\mathrm{L}/\mu\mathrm{L})10^{6}(\mu\mathrm{g/g})}{(8313.7162)(\mathrm{mL \times kPa/g \times mole \times {}^\circ}K)(298.15)({}^\circ K)} = 1.67\ \mu\mathrm{g} \quad (3)$$

10.3.3 Calculate the response factor from the weight of the H_2S in the calibration standard divided by the total area difference obtained for the standard, Eq 3:

$$R_{F_{H_2S}} = \frac{W_{(H_2S)_S}}{A_{T_S}} \frac{\mu\mathrm{g}}{\mathrm{area}} \quad (4)$$

where:

$R_{F_{H_2S}}$ = H_2S response factor, µg/area, and
A_{T_S} = total area or peak height difference from H_2S calibration standard analysis.

11. Procedure

11.1 Remove a sample from refrigerated storage and allow it to stand in the laboratory until it flows freely. A sample can be analyzed as soon as it flows freely. A sample that is still not free flowing after sitting at laboratory ambient for 1 h should be heated gently just until it flows freely. (**Warning**—At no time should the container temperature be allowed to exceed the temperature of the sample at the time.)

11.2 To avoid possible loss of H_2S in the headspace vial by reaction with oxygen, displace the air in the vial with nitrogen prior to transferring a sample into it. Weigh the nitrogen flushed headspace vial and septum seal to the nearest 0.1 mg and then transfer, by any suitable means, as quickly as possible to minimize losses, between 0.05 and 5.0 g of residual fuel oil sample directly into the nitrogen filled headspace vial, and seal the vial immediately with the septum seal to avoid H_2S losses PTFE side of the septum in contact with sample. Reweigh the filled headspace vial to the nearest 0.1 mg. Cover the septum seal with an aluminum seal, and crimp the aluminum seal with the hand crimper.

11.3 Place the headspace vial in a 60°C oven for at least 5 min but for no more than 15 min.

11.4 Install an 0.5-mL sample loop if the anticipated H_2S concentration is between 1 and 100 ppmw, a 2.5-mL sample loop if the anticipated H_2S concentration is between 0.1 and 50 ppmw, and a 10-mL sample loop if the anticipated H_2S concentration is between 0.01 and 10 ppmw. With Valve 2 in. the load position (see Fig. 1) and Valve 1 closed, evacuate the sample loop by opening Valve 3. When a vacuum of at least −70 kPag is achieved, then close Valve 3.

11.5 Take the headspace vial from the oven, and immediately insert the sampling needle (see Fig. 1) through the septum of the headspace vial containing the residual fuel oil sample.

11.6 Open Valve 1, and let the sample fill the injection loop until a reading of 0 kPa is achieved on the pressure/vacuum gauge. Close Valve 1.

11.7 Place Valve 2 in the *Inject* position (see Fig. 1) for 10 s to allow the carrier gas to sweep the sample to the H_2S

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[5] This is one standard formula used in headspace analysis. For the derivation of this formula see Ioffe, B. V., and Vitenberg, A. G.,“ Head-Space Analysis and Related Method in Gas Chromatography,” Wiley-Interscience, John Wiley & Sons, New York, 1984, pp. 131–142.

analyzer. Return Valve 2 to the load position. Remove sampling needle from the vial. Record reading from the analyzer as reading A_1.

11.8 After the injection step, insert a needle connected to a line containing nitrogen at atmospheric pressure into the septum to reestablish atmospheric pressure within the vial.

11.9 Repeat steps 11.3 – 11.9 with the same headspace vial but record the reading from the analyzer as reading A_2.

11.10 Repeat steps 11.3 – 11.9 with the same headspace vial but record the reading from the analyzer as reading A_3. Two injections are sufficient for the required calculations but three are required to verify the correctness of the multiple extraction procedure.

12. Calculation

12.1 Regress the natural log (ln) of readings A_1, A_2 , and A_3 against the number of injections one, two, and three. A linear correlation (correlation coefficient $R^2 > 0.95$) must exist to insure the correctness of the multiple extraction procedure. If R^2 is not greater than 0.95, then repeat the procedure with a new sample from a different container.

12.2 Calculate the concentration of H_2S as outlined below.

12.3 Calculate the total area difference (or total height difference) using Eq 1.

12.4 Calculate the concentration of H_2S in the sample (μg/g) by multiplying the total area difference obtained for the residual fuel sample times the H_2S response factor and dividing by the weight of the residual fuel oil sample in (g), Eq 4:

$$C_{(H_2S)_F} = \frac{R_{F_{H_2S}}\left(\frac{\mu\text{g}}{\text{area}}\right) \times A_{T_F}\,(\text{area})}{W_F\,(\text{g})} \tag{5}$$

where:

$R_{F_{H_2S}}$ = response factor from Eq 3,

$C_{(H_2S)_F}$ = concentration of H_2S in the residual fuel oil, μg/g,

A_{T_F} = total area or peak height difference from H_2S residual fuel oil analysis, and

W_F = weight of residual fuel oil sample, g.

12.5 See Appendix X1 for an example calculation.

13. Precision and Bias

13.1 *Precision*—Based on limited information from one laboratory, the 95 % repeatability limits when using a lead acetate paper detector are:

Average $C_{(H_2S)_F}$, μg/g	Repeatability
0.022	0.004
0.24	0.07
37.3	1.9

NOTE 7—These repeatability numbers were obtained by Beatriz A. Silva, Intevep, SA, Apdo 76343, Caracas 1070A Venezuela.

13.2 It is not possible to specify the precision of the procedure in this test method beyond what appears in 13.1, since generating the reproducibility data is not practical.

13.3 *Bias*—Bias cannot be determined because there is no reference material suitable for determining the bias of the procedure in this test method.

14. Keywords

14.1 heavy distillates; heavy distillate/residual fuel blends; hydrogen sulfide; multiple headspace extraction; residual fuels; sulfur specific detection

APPENDIX

(Nonmandatory Information)

X1. CALCULATION EXAMPLE

TABLE X1.1 Example of Calibration Information

Wt	A_1	A_2	A_3	Correlation Coefficient, R^2
H_2S std 10 μL/L (ppmv) 1.67 μg	1.6508×10^8	1.431×10^8	1.2166×10^8	0.999
Fuel sample 0.0792 (g)	1.7327×10^7	1.4242×10^7	1.2539×10^7	0.985

X1.1 See Table X1.1 information for an H_2S calibration standard and an analysis of a residual fuel oil. Using the information in Table X1.1 the following equations are applicable.

$$A_{T_S} = \frac{(1.6508 \times 10^8)^2}{1.6508 \times 10^8 - 1.431 \times 10^8} = 1.240 \times 10^9 \ \text{area} \tag{X1.1}$$

$$R_{F_{H_2S}} = \frac{1.67\ \mu\text{g}}{1.240 \times 10^9\ \text{area}} = 1.3468 \times 10^{-9}\ \mu\text{g/area} \tag{X1.2}$$

$$A_{T_F} = \frac{(1.7327 \times 10^7)^2}{1.7327 \times 10^7 - 1.4242 \times 10^7} = 9.7318 \times 10^7 \ \text{area} \tag{X1.3}$$

$$C_{(H_2S)_F} = \frac{1.3468 \times 10^{-9}\ \frac{\mu\text{g}}{\text{area}} \times 9.7318 \times 10^7\ \text{area}}{0.0792\ \text{g}} = 1.66\ \mu\text{g/g} \tag{X1.4}$$

SUMMARY OF CHANGES

Subcommittee D02.E0 has identified the location of selected changes to this standard since the last issue (D6021–06) that may impact the use of this standard.

(1) Revised 5.1, 5.2, and 5.3.
(2) New Note 1.
(3) Added Test Methods D5705 and D7621 to Referenced Documents and standard text.
(4) Added keywords.

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