



Designation: D8455 – 22

Standard Test Method for Speciated Siloxane GC-IMS Analyzer Based On-line for Siloxane and Trimethylsilanol Content of Gaseous Fuels¹

This standard is issued under the fixed designation D8455; 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 is for the determination of speciated siloxane concentrations in gaseous fuels using on-line Gas Chromatography Ion-Mobility Spectrometry (GC-IMS).

1.2 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *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

[D3609 Practice for Calibration Techniques Using Permeation Tubes](#)

[D3764 Practice for Validation of the Performance of Process Stream Analyzer Systems](#)

[D4150 Terminology Relating to Gaseous Fuels](#)

[D4298 Guide for Intercomparing Permeation Tubes to Establish Traceability](#)

[D5287 Practice for Automatic Sampling of Gaseous Fuels](#)

[D6299 Practice for Applying Statistical Quality Assurance and Control Charting Techniques to Evaluate Analytical Measurement System Performance](#)

¹ This test method is under the jurisdiction of ASTM Committee D03 on Gaseous Fuels and is the direct responsibility of Subcommittee D03.12 on On-Line/At-Line Analysis of Gaseous 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.

[D6621 Practice for Performance Testing of Process Analyzers for Aromatic Hydrocarbon Materials](#)

3. Terminology

3.1 *Definitions*—For definitions of terms used in D03 Gaseous Fuels standards, refer to Terminology [D4150](#).

3.2 *Definitions of Terms Specific to This Standard*:

3.2.1 *siloxanes, n*—a functional group in organosilicon chemical family with the Si—O—Si linkage.

3.2.1.1 *Discussion*—In this test method, “siloxanes” include both “siloxanes and trimethylsilanol (TMSOL).”

3.3 *Abbreviations*—Several of the following abbreviations are for common siloxanes that can be determined according to this test method. This is not meant to construe that this test method is constrained to determining only these substances.

3.3.1 *D3*—Hexamethylcyclotrisiloxane

3.3.2 *D4*—Octamethylcyclotetrasiloxane

3.3.3 *D5*—Decamethylcyclopentasiloxane

3.3.4 *D6*—Dodecamethylcyclohexasiloxane

3.3.5 *DMS*—data management system

3.3.6 *GC-IMS*—Gas Chromatography Ion-Mobility Spectrometry

3.3.7 *L2*—Hexamethyldisiloxane

3.3.8 *L3*—Octamethyltrisiloxane

3.3.9 *L4*—Decamethyltetrasiloxane

3.3.10 *L5*—Dodecamethylpentasiloxane

3.3.11 *NIST*—National Institute of Standards and Technology

3.3.12 *SOP*—standard operating procedure

3.3.13 *TMSOL*—Trimethylsilanol

4. Summary of Test Method

4.1 A representative sample of a gaseous fuel is extracted from a process pipe or pipeline and is transferred in a timely manner through an appropriately designed sampling system to the inlet of a siloxane analyzer. The sample is conditioned with a minimum, preferably negligible, impact on the siloxane content. The line used to transfer gas from the process pipe or pipeline to the instrument is heated to at least 65 °C to prevent condensation of heavier siloxane species. The analyzer sample loop is filled with a known volume of sample gas, after which the contents of this sample loop are injected into a GC-IMS.

Excess process or pipeline sample is either vented to atmosphere, or returned to the process stream, depending on application, safety concerns, and regulatory requirements. If the analyzer is installed inside a building and excess sample gas is vented to atmosphere, the operator should run a ventilation line to a fume hood or outside.

4.2 Sample gas is introduced to a gas chromatographic column, where the various siloxane species and other gas constituents interact with the column material and are separated.

4.3 Siloxanes and other gas constituents elute from the GC column, where they are introduced to the IMS drift chamber. A low-radiation tritium source generates reactant ions $H^+(H_2O)_n$. These reactant ions chemically ionize compounds entering the IMS cell, producing specific analyte ions. These ions are released into the drift chamber at a defined frequency (generally every 30 ms), then forced through the chamber via an applied electric field. Simultaneously, nitrogen gas flows through the drift cell in the opposite direction. As ions are forced against the flow of nitrogen, they are separated by charge and geometry, until they strike a detector at the opposite end of the drift cell. This produces a change in electric potential (analyzer response) proportional to the quantity of ions striking the detector. This two-stage separation produces a 3-dimensional chromatogram, as illustrated in the example below. (See Fig. 1.)

NOTE 1—This illustration is meant for conceptual demonstration of a 3D chromatogram; real chromatograms may include more analyte species (such as TMSOL and D6) as well as non-target compounds.

4.4 A GC-IMS configured to measure siloxanes in gaseous fuels may measure silicon concentration down to the concentrations indicated in Table 1 using a 1 mL sample loop. This is the maximum recommended sample loop volume.

4.5 Calibration, maintenance, quality assurance, and performance protocols provide a means to validate the analyzer operation and the generated results.

4.6 The siloxane species analyzed by the GC-IMS include TMSOL, L2, L3, L4, L5, D3, D4, D5, and D6.

5. Significance and Use

5.1 Combustion of gaseous fuel containing significant siloxane concentrations results in conversion of these siloxanes to silicon dioxide (SiO_2). This SiO_2 accumulates on downstream equipment such as the interior of reciprocating engine cylinders (used for electricity generation and transportation applications), flame sensors, and condenser coils in residential/commercial furnaces, or post-combustion catalysts used for the removal of NO and NO_2 . In each of these cases, SiO_2 compromises the performance of the equipment and may lead to eventual failure. Continuous measurement of siloxane concentrations enables a fuel producer to ensure their gas quality meets contractual obligations, regulatory requirements, pipeline injection tariff limits, and internal performance requirements. This method is intended to provide procedures for standardized start-up procedures, operating procedures, and quality assurance practices for on-line analysis of siloxanes using a GC-IMS analyzer.

6. Apparatus

6.1 *Instrument (GC-IMS)*—A gas chromatography column coupled to an ion mobility spectrometer drift cell and electrometer. Table 2 summarizes the recommended analytical parameters for a GC-IMS configured to analyze siloxanes. Some GC-IMS analyzers or configurations may require different settings.

6.1.1 The analyzer is typically configured to log IMS temperature data and flag data as invalid (or prevent the measurement altogether) if temperature is measured outside the acceptable range. The shutter releases ions into the drift cell every 30 ms, during which time the electrometer records the spectrum change in electric potential.

6.2 *Sample Extraction*—The location and orientation of sampling components are critical for ensuring that a representative sample is analyzed. The locations and orientation of sampling components is expected to be selected based upon sound analytic and engineering considerations. Sampling practices for gaseous fuels can be found in Practice D5287. It is of critical importance that the sampling system be heated to at

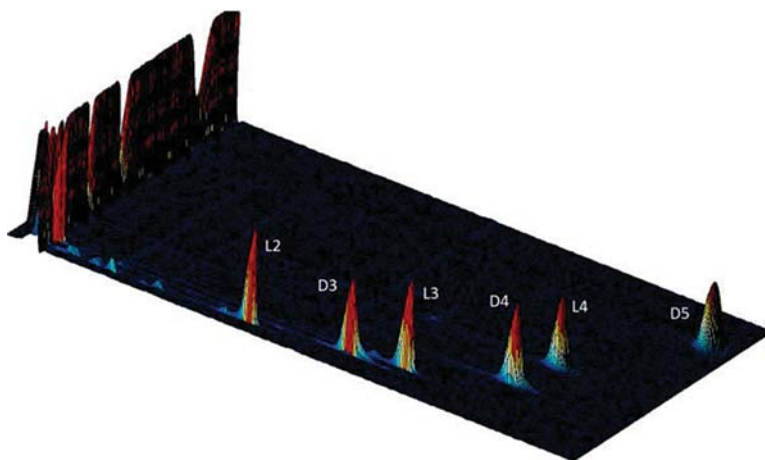


FIG. 1 Conceptual Illustration of a 3D Chromatogram

TABLE 1 Siloxanes Limits of Quantification

Species	Siloxanes and Silanols <i>Limits of Quantification (LOQ)</i> [1 mL Loop]		CAS#
	Silicon (Si) (mg/m ³)	Silicon (Si) (ppb)	
(TMSOL) Trimethylsilanol	0.006	1.6	1066-40-6
(L2) Hexamethyldisiloxane	0.007	1	107-46-0
(L3) Octamethyltrisiloxane	0.007	0.7	107-51-7
(L4) Decamethyltetrasiloxane	0.007	0.5	141-62-8
(L5) Dodecamethylpentasiloxane	0.018	1.1	141-63-9
(D3) Hexamethylcyclotrisiloxane	0.008	0.9	541-05-9
(D4) Octamethylcyclotetrasiloxane	0.008	0.7	556-67-2
(D5) Decamethylcyclopentasiloxane	0.008	0.5	541-02-6
(D6) Dodecamethylcyclohexasiloxane	0.019	1	540-97-64

TABLE 2 Recommended GC-IMS Operating Parameters

Parameter/Component	Value/Details
Drift gas flow rate	150 mL/min during analysis, 10 mL/min in idle mode
Carrier gas flow rate	5 mL/min until t=2 min, ramp to 15 mL/min over 30 sec, maintain 15 mL for remainder
GC Column temperature	Isothermal - 80 °C ±0.1 °C
GC Column	Low polarity, 30 m length x 0.32 mm ID
Injection	Splitless; loop volume varies but 1 mL is suitable for most applications
IMS drift chamber length	98 mm
Electrical field strength	500 V/cm
Scan collection time	30 ms
IMS temperature	65 °C ±1 °C
Ionization source	Tritium
Drift chamber pressure	Atmospheric (1 atm)

least 65 °C to prevent condensation of siloxane species, and all sampling system components must be free of silicon-based materials, such as lubricants. Sample gas should be passed through a membrane separator to remove any liquids and solids present in the gas stream before the gas is delivered to the instrument. Excess sample gas may either be returned to the process or vented to atmosphere, dependent on safety concerns and application requirements. If the sample gas pressure exceeds 5 psig, it is recommended that a pressure regulator be installed to reduce the pressure to 5 psig or less.

6.3 Sample Inlet System—The siting and installation of an on-line monitor is critical for collecting representative information on siloxanes content. Factors that should be considered in siting an instrument include ease of access for repair or maintenance, sample uniformity at the sampling point, appropriateness of samples from a sampling location, ambient conditions, and of course safety issues. All sampling system components in contact with the fuel stream must be constructed of inert and organosilicon-free materials. Care should be taken to ensure that the extracted sample is maintained as a particulate and condensate free gas, which can be accomplished with the use of an appropriately selected membrane filter. Heat tracing along the sample line to the analyzer is required to ensure that higher molecular weight siloxane species are kept in the gas phase. If a membrane filter is included in the sampling system, or any other components between the sampling connection and the analyzer inlet, they must also be heated. It is recommended that all heated components maintain a temperature of at least 65 °C. Sample gas should be brought to the analyzer continuously and conveyed through a bypass loop that either vents to atmosphere or is returned to the source gas pipe. If venting to atmosphere, an appropriately designed scrubber or control device may be used. Although sample gas

is delivered to the analyzer continuously, the analyzer only withdraws a small subsample of the gas immediately before a measurement begins. This subsample is delivered to the GC column through a sample loop with a known volume. The volume selected for the sample loop is based on application requirements and expected concentrations of siloxane species. The sampling frequency relative to the process bandwidth is critical to ensuring that the reported analytical results adequately represent the process being monitored. The Nyquist-Shannon sampling criterion of a sampling frequency that exceeds twice the process bandwidth can be used to establish a minimum analytical cycle time.^{3,4} Typical measurement frequency is 2-3 times per day, but measurements may be acquired up to once per hour.

6.3.1 Carrier and Drift Gas Control—Constant flow control of carrier and IMS drift gases is critical for optimum and consistent analytical performance. For the specific GC-IMS analyzer described in this method, ultra-high-purity nitrogen is used for both carrier gas and IMS drift gas. Flow rates and pressures are maintained by use of electronic pressure controllers. Depending on the application and site-specific requirements, rotameters may be used to control gas flow downstream of the analyzer, whether the gas is being directed back to the source pipe or is vented to atmosphere. Plumbing should be designed to ensure the pressure of gas within the analyzer's sample loop is as close to one atmosphere pressure as possible. Temperature control is vital for ensuring consistent operation of the instrument. Carrier/Drift gas pressure must not exceed 6 bar(600 kPa) at the inlet to the analyzer. (See Fig. 2.)

³ Nyquist, H., "Certain Topics in Telegraph Transmission Theory," *Trans. AIEE*, Vol 47, Apr. 1928, pp. 617-644.

⁴ Shannon, C. E., "Communication in the Presence of Noise," *Proc. Institute of Radio Engineers*, Vol 37, No. 1, Jan. 1949, pp. 10-21.

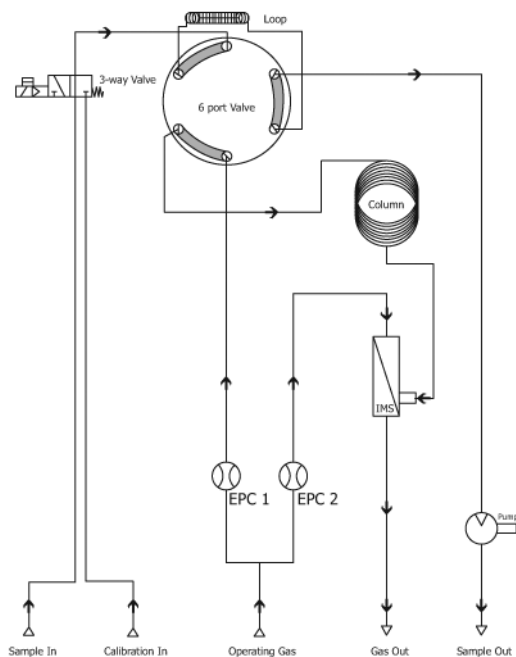


FIG. 2 GC-IMS Siloxane Analyzer Flow Diagram

6.3.2 *Detector*—The GC-IMS detector is an electrometer, which measures a change in electric potential when ionized siloxanes (or any other compounds susceptible to ionization through the tritium-hydronium pathway) pass through the IMS drift cell and strike the detector. The magnitude of induced electric potential is proportional to the number of ions (and therefore concentration of the analyte) striking the detector at any given moment in time. The correlation between ion concentration and change in potential is non-linear, and therefore any calibration curve generated will necessarily also be non-linear. GC-IMS calibrations for this application typically utilize a Boltzmann curve fit, where peak height is used as the dependent variable. Calibration curves are created for each species measured, and should include a minimum of five concentration levels spanning the full calibration range. Calibration ranges are given in [Table 3](#).

NOTE 2—Lower limits may vary by instrument and smaller sample loop volumes may be used to increase the upper limits of calibration ranges.

6.4 *Data Acquisition*—Following a measurement, the GC-IMS analyzer produces a measurement file and a report. The measurement file contains data related to analyzer conditions during the measurement, such as temperatures, electronic pressure controller pressures and flow rates, as well as sample duration. The measurement file also includes the complete three-dimensional chromatographic data for the analysis (the three axes being signal current, IMS drift time, and GC

retention time). The report includes essential information such as device ID, timestamp, and the name of the associated measurement file. The report also includes concentration data for each individual measured species, as well as the total siloxane concentration, the total SiO₂ concentration, and the total Si concentration (the latter two are mathematically derived from the total siloxane concentration, as explained in [11.1](#)).

6.4.1 Data is typically stored locally on the GC-IMS computer, but it may also be retrieved via USB connection. The analyzer may also be configured to automatically send data via communication with a TFTP server to a data management system (DMS), or an operator may retrieve data from a remote location via SSH connection.

7. Reagents and Materials

Warning—Compressed gas cylinders should only be handled in well ventilated locations away from sparks and flames. Improper handling of compressed gas cylinders can result in explosion. Rapid release of nitrogen can result in asphyxiation.

7.1 *Standards*—Accurate siloxane standards are required for the accurate calibration of GC-IMS analyzers. Calibration may be performed either with permeation tubes or a calibration gas delivery apparatus. All standards shall have a certified concentration traceable to NIST or similar standard reference material source.

7.2 *Prepared Standards*—Compressed gas standards should be stable as defined by the manufacturer’s certification, of the highest available accuracy and purity and used in accordance with the manufacturer’s recommendations. The matrix components in the reference standard are ideally representative of the monitored gas. Alternatively, a simplified matrix can be used if

TABLE 3 Typical GC-IMS Calibration Ranges

Typical GC-IMS Calibration Ranges; 1 mL Sample Loop	
Species	Range (mg/m ³)
TMSOL	0.03-1.5
L2,L3,L4,D3,D4	0.02-1.5
D5,L5	0.05-4.5
D6	0.1-9.0

the analyzer can be calibrated in accordance with the manufacturer's specifications. Siloxane concentrations are dependent on the detector linearity and are typically selected between one half and twice their expected concentration in the monitored gas. Alternatively, a critical value of siloxane concentration, such as an alarm limit, can be used to identify the desired total siloxane concentration of the standard. Standards must be maintained within the temperature range specified by the manufacturer to ensure accuracy and stability. Standards prepared for use in the procedure described in 7.4 must use a solvent free of siloxanes.

7.3 Permeation Devices—Permeation devices contain an aliquot of a specific compound that continuously diffuses at a determined rate through a permeable medium. A dry inert carrier gas flows at a constant rate across the medium at a constant temperature consistent with the manufacturer's recommendations to create a calibration gas that then flows to the analyzer. Proper storage, in accordance with the manufacturer's recommendations, is required to prevent damage to the membrane. A sufficiently long equilibration time is required when the permeation device temperature is changed to ensure the reestablishment of a constant permeation rate. Calibration devices using permeation tubes contain a temperature-controlled oven and employ flow control to maintain a constant diluent flow rate. Practice **D3609** and Guide **D4298** contain additional information on permeation tubes.

7.4 Nebulizer Calibration Apparatus—In lieu of permeation devices, the GC-IMS may be calibrated using a synthesized gas mixture containing known concentrations of siloxanes. A liquid standard of siloxanes is created using accurately measured amounts of pure siloxane standards added to a solvent, such as hexane. The liquid calibration standard is mixed with a gas (such as zero air) in a nebulizer. The nebulizer delivers a fine spray of standard liquid/gas mixture into a heated mixing chamber, where the standard is mixed with diluent gas at a precise ratio. The diluted gas mixture is then delivered to the analyzer and the concentrations of each siloxane species are quantified. To change the concentration of the calibration gas, both the standard solution concentration and the gas dilution ratio can be adjusted.

7.4.1 Metering Pump—A metering pump is used to deliver a precisely measured volumetric flow rate of liquid standard to the nebulizer. The metering pump's accuracy must be verified by a secondary method such as gravimetric analysis or a NIST-traceable or similar reference liquid flow meter. The metering pump's specific set-point must be defined by the operator and is based on the concentration of the liquid standard as well as the ratio of gas and liquid brought into the nebulizer.

7.4.2 Nebulizer—This is a device used for delivering a fine spray of liquid standard at a precise flow rate. It may take many forms, but the simplest approach is to use a durable glass tee with an input for liquid, an input for gas, and a fine nozzle. The nozzle is inserted into the heated mixing chamber, and the volumetric flow rate of both the liquid and gaseous inputs are independently controlled.

7.4.3 Mass Flow Controllers—These devices are used to precisely control the amount of gas flowing into the nebulizer

and the heated mixing chamber. Mass flow controllers are verified against a NIST-traceable reference gas flow meter prior to use.

8. Equipment Siting and Installation

8.1 A sample inlet system capable of operating continuously and delivering a gas phase sample to the analyzer is necessary. The location of the sample inlet to the analyzer relative to the sample extraction point is critical to obtaining timely analytical results. Ideally, the analyzer is closely coupled to the sample extraction point. Normally, the analyzer is mounted a short distance from the sample extraction point. A fast loop sweep is used to eliminate the problem of lag time by creating a bypass loop that flows sample from the process to the analyzer and is then returned to the process or is vented.

8.2 The sample must flow continuously without impediment through the instrument sampling system to ensure collection and analysis of a representative aliquot from the gas stream. The sampling system should be capable of delivering a sample to the detection system in 10 min or less.

8.3 A monitoring system pretest of both sampling and analysis functions is critical to determining monitoring system characteristics, identify unforeseen factors affecting measurement and to determine optimal operating conditions for the intended use. This pretest is performed before the system is placed in continuous service.

9. Performance Tests

9.1 The following performance tests could be carried out as part of an overall QA program. This list is not all-inclusive. The user's local, regional, state, and federal regulations, as well as the user's judgement and the manufacturer's recommendations as well as the application may stipulate use of some or all of these performance tests as well as tests not listed.

9.2 7-Day Calibration Error Test—If appropriate for the installation, periodically evaluate the system performance over seven consecutive days. The calibration drift should not exceed 10 % of the full-scale range or detector area counts. This may only be possible for siloxane species that are stable in a gas cylinder, and only if the GC-IMS is configured to operate with an attached calibration cylinder.

9.3 Maintain a current Standard Operating Procedure (SOP) and maintenance log.

9.4 Analyzer calibration verification should be performed at least annually. If the analyzer is configured to operate with an attached calibration cylinder, this can be done with a select number of siloxane species. Otherwise, the analyzer can be verified by the manufacturer according to their specific verification procedure. When performing a calibration verification using calibration gas, the following procedure may be followed:

9.4.1 Perform consecutive triplicate analyses using the calibration gas.

9.4.2 Discard the first analysis as a conditioning and purging step.

9.4.3 Record the second analysis as the initial data point.

9.4.4 Compare the third analysis against the second analysis. The results of the third analysis should agree with the results of the initial data point to within 20 %.

9.4.5 If the third analysis satisfies criteria under 9.4.4, record the result of the third analysis.

9.4.6 If the third analysis does not satisfy criteria under 9.4.4, initiate investigation and corrective action as appropriate.

9.5 The carrier and drift flow rates should be verified on an as needed basis and at least annually. Nitrogen pressure should be checked frequently.

9.6 Calibration, precision, calibration error, and performance audit tests are conducted to determine performance of the monitor at least annually. Periodic calibration and maintenance methodology are also performed as needed and according to manufacturer’s instructions.

9.7 General practices for validation of a process analyzer is covered in Practices D3764 and D6621. Application of statistical quality assurance techniques to the performance evaluation of an analytical measurement system is covered in Practice D6299.

10. System Maintenance

10.1 System maintenance is critical for ensuring accuracy and consistency in measurements. A maintenance program following but not limited to manufacturer’s guidelines is a good practice. After performing maintenance or after an analyzer shut down exceeding several hours, a prudent practice is to re-perform the monitoring system pretest procedure stated in 8.3 to ensure the system is performing acceptably.

11. Calculations

11.1 When the GC-IMS analyzer is calibrated, a calibration curve is generated for each species. This calibration curve represents the correlation between analyzer signal (generated by ions striking the faraday plate at the end of the IMS drift chamber) and the concentration of the individual analyte

expressed in mg/m^3 . The reports generated by the analyzer include these raw concentration data, as well as a total silicon concentration and total SiO_2 concentration. Neither silicon nor SiO_2 are directly measured by the analyzer, but these are useful concentrations for operators and can easily be calculated given the concentrations of all species. The content of silicon of each siloxane molecule differs and is determined by M = molecular mass in g/mol . It is calculated as follows, using L2 as an example:

- $M(\text{L2}) = 162.38 \text{ g/mol}$
 - $M(\text{Si}) = 28.09 \text{ g/mol}$
 - L2 contains 2 silicon atoms
 Percent silicon content by mass = $F(\text{Si}) = 2xM(\text{Si})/M(\text{L2}) = 2x28.09/162.38 = 0.346 = 34.6 \%$.

11.1.1 By repeating this calculation for every siloxane species and calculating the sum of all silicon fractions, one may determine the total silicon content of the sample gas. Similarly, the concentration of SiO_2 that will ultimately result from gas combustion can be calculated by multiplying the silicon concentrations by the molar ratio of SiO_2 to Si (2.139). Consider the example in Table 4.

12. Precision and Bias

12.1 *Precision*—The repeatability standard deviation from a single operator has been determined for each of the 9 measured species, at three separate concentrations and using a GC-IMS with a standard 1 mL sample loop. These data are given in Table 5.

12.1.1 An interlaboratory study of this test method is being conducted and a complete precision statement is expected to be available on or before 2026.

12.2 *Bias*—No information can be presented on the bias of the procedure in Test Method D8455 because no material having an accepted reference value is available.

13. Keywords

13.1 at-line monitor; continuous fuel monitor; on-line monitor; siloxanes

TABLE 4 Concentration Calculations

Species	Measured Concentration (mg/m^3)	%Silicon Mass	Calculated Silicon Concentration ($\text{mg Si}/\text{m}^3$)	Calculated SiO_2 Concentration ($\text{mg SiO}_2/\text{m}^3$)
TMSOL	0.93	31.14 %	0.29	0.62
L2	1.27	34.60 %	0.44	0.94
L3	0.29	35.63 %	0.10	0.22
L4	0.63	36.16 %	0.23	0.49
L5	0.42	36.54 %	0.15	0.33
D3	0.88	37.88 %	0.33	0.71
D4	1.05	37.88 %	0.40	0.85
D5	0.92	37.88 %	0.35	0.75
D6	0.65	37.88 %	0.25	0.53
TOTAL	7.04		2.54	5.43

TABLE 5 Precision Data From A Single Operator

	L2	D3	L3	D4	L4	D5	L5	D6	TMSOL
RSD at LOQ [%]	5.57 %	0.00 %	3.57 %	2.09 %	10.87 %	12.01%	22.30 %	8.51 %	8.72 %
RSD at 3x LOQ [%]	8.04 %	1.00 %	1.53 %	1.52 %	2.20 %	3.46%	5.63 %	5.80 %	2.60 %
RSD for Maximum Reported Level [%]	4.01 %	2.55 %	2.88 %	2.33 %	3.15 %	4.19%	3.53 %	1.56 %	8.20 %
LOQ [mg/m ³]	0.02	0.02	0.02	0.02	0.02	0.05	0.05	0.1	0.03
Max Reporting Level [mg/m ³]	1.5	1.5	1.5	1.5	1.5	4.5	4.5	9	1.5

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