Guidance Document

Analytical Methods for Determining VOC Concentrations and VOC Emission Potential for the *Volatile Organic Compound Concentration Limits for Certain Products Regulations*

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Environment and Climate Change Canada
Public Inquiries Centre
12th Floor, Fontaine Building
200 Sacré-Coeur Boulevard
Gatineau QC K1A 0H3
Telephone: 819-938-3860
Toll Free: 1-800-668-6767 (in Canada only)
Email: enviroinfo@ec.gc.ca

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Guidance Document
Analytical Methods for Determining VOC Concentrations and VOC Emission Potential for the *Volatile Organic Compound Concentration Limits for Certain Products Regulations*

This Guidance Document describes the analytical methods that will be used for determining the volatile organic compound (VOC) concentrations and VOC emission potential for the purposes of the *Volatile Organic Compound Concentration Limits for Certain Products Regulations* [1] (the Regulations). The Regulations apply to manufacturers and importers in Canada and establish VOC limits for the import and manufacture of products in approximately 130 product categories and sub-categories including personal care products, automotive and household maintenance products, adhesives, adhesive removers, sealants and caulks as well as other miscellaneous products.

Disclaimer

Mention of any trade names or commercial products in this document does not constitute endorsement or recommendation of this product by Environment and Climate Change Canada (ECCC). Specific brand names, techniques and instrumentation listed here are for information purposes only and describe methods and equipment used by the ECCC testing laboratory. Any functionally equivalent instrumentation and methods are acceptable.

Although care has been taken to ensure that this document reflects the requirements of the *Canadian Environmental Protection Act, 1999* (CEPA) [2] and the *Volatile Organic Compound Concentration Limits for Certain Products Regulations*, the Act and these Regulations prevail over the text of this document in case of any discrepancies or inconsistencies. This document does not supersede or modify the Act or these Regulations. It is ultimately the responsibility of regulatees to be familiar with the full text and application of the Regulations.

The methods described herein were developed, validated and approved by internationally recognized organizations such as: the Canadian Association for Laboratory Accreditation (CALA), the American Society for Testing and Materials (ASTM), the United States Environmental Protection Agency (US EPA) and the California Air Resources Board (CARB). ECCC recognizes these methods as reference methods.

Under section 21 of the Regulations, any analysis performed to determine the VOC concentration or VOC emission potential of a product for the purposes of the Regulations must be performed by a laboratory that is accredited under the International Organization for Standardization standard ISO/IEC 17025 or under the Environmental Quality Act, CQLR, c. Q-2, and the scope of its accreditation includes the parameters that are analyzed or determined. If no method has been recognized by a standards development organization in respect of the analysis performed to determine the VOC concentration or VOC emission potential of a product and the scope of the laboratory's accreditation does not therefore include that analysis, the analysis must be performed in accordance with standards of good scientific practice that are generally accepted at the time that it is performed.

Terms and Definitions

"VOC Concentration" for the purpose of the Regulations [subsection 1(2)] is measured and expressed as a percentage of the product's net weight (% w/w).

"Content" is normally used when dealing with fraction of the product weight, and is used in this guidance in relation to product total volatility, ammonia and water determination. It is usually dimensionless.

"Volatile organic compound" (VOC) means a compound that participates in atmospheric photochemical reactions and that is not excluded under item 65 of Schedule 1 to the *Canadian Environmental Protection Act, 1999*.

"Fragrances" are defined in the Regulations [subsection 1(1)] as a substance or mixture of chemicals, natural essential oils or other components, that has a combined vapour pressure less than or equal to 0.267 kPa at 20 ºC, the sole purpose of which is to impart a scent or to mask an unpleasant odour.

"Low vapour pressure VOC" (LVOC) as it relates to products other than antiperspirant or deodorant for human axilla are defined in the Regulations [subsection 1(1)] as a VOC having one of the following characteristics:

(a) vapour pressure less than 0.013 kPa at 20 ºC
(b) boiling point above 216 ºC, or
(c) contain more than 12 carbon atoms per molecule

"Medium vapour pressure VOC" (MVOC) are defined in subsection 1(1) of the Regulations as a VOC having vapour pressure at 20 °C greater than 0.267 kPa but less than or equal to 10.67 kPa.

"High vapour pressure VOC" (HVOC) are defined in subsection 1(1) of the Regulations as a VOC with vapour pressure at 20 °C greater than 10.67 kPa.

"VOC emission potential" means, for a product that is listed in column 1 of the table at Schedule 2 of the Regulations, the quantity of VOC that can be expected to be released during a single use as specified in column 2 of the table at Schedule 2.

1. Introduction

The design of the Regulations aligns closely with the California Air Resources Board's (CARB) Regulations for Reducing Emissions from Consumer Products and Regulations for Reducing VOC Emissions from Antiperspirants and Deodorants (referred to as the General Consumer Product Regulations). As such, the analytical approach for the Regulations is intended to align with the methodology in CARB Method 310 [3].

2. Overview of required testing

A number of different tests are required to determine whether the VOC concentration of a product meets the applicable maximum VOC concentration in the Regulations. These include:

A/ Net weight – for the determination of the VOC concentration the net weight of the product is needed. The net weight is the weight of the product (in grams) excluding all packaging material and delivery substrates.

B/ Total volatiles – this is everything within the sample that is deemed volatile. As well as including the VOC content of the sample, it could also include water, ammonia and excluded VOCs. The procedure for analysing total VOC content is discussed in section 4B.

C/ Product water content – as the total volatile analysis includes the mass of water, the water content must be analysed and subtracted from the total volatile content. The methodology for water content determination is discussed in section 4C.

D/ Ammonia content – a number of products may contain ammonia in their formulation. Ammonia is not a VOC, however as it is volatile it will be in the 'Total Volatiles' analysis. Therefore, the ammonia content of the product must be quantified and subtracted from the total volatiles. Ammonia analysis is described further in section 4D.

E/ Excluded VOCs – a number of compounds are excluded from the definition of VOC in item 65 of Schedule 1 to CEPA. These compounds do not count towards the VOC concentration limits given in the Regulations. The excluded VOCs must therefore be quantified and subtracted from the 'Total Volatile' content, and is discussed further in 4E.

F/ Other exclusions – as outlined in the Regulations, there may be other exclusions for specific product categories that impact the VOC concentration. These differ depending upon the product category and must be assessed before the determination of the VOC concentration of the product. These can include colourants, fragrances, ethanol and VOCs with vapour pressure equal to or less than 0.267 kPa or containing more than 10 carbon atoms.

In the case the LVOC, MVOC and HVOC concentration of a product cannot be established as described in section 4G, it can be determined from a product formulation.

3.0 Determination of VOC Concentration

As outlined in section 5 of the Regulations, the VOC concentration of a product that belongs to a product category set out in column 1 of the table to Schedule 1 is determined by equation (1):

$$(1) \quad \%VOC = \frac{Ws - Wex}{Wp} \times 100$$

Where:

Ws is the weight in grams of all of the substances contained in the product that volatize when the product is tested to determine its VOC concentration for the purposes of the Regulations;

Wex is the weight in grams of all of the substances to be excluded when determining the VOC concentration, namely, any of the following substances contained in the product that volatize when the product is tested to determine its VOC concentration for the purposes of the Regulations:

(a) water, ammonia and any other inorganic substances;
(b) compounds that are excluded under item 65 of Schedule 1 to the Act;
(c) in the case of an antiperspirant or deodorant for the human axilla referred to in items 2 and 3, respectively, of the table at Schedule 1 of the Regulations,
  (i) VOCs that have a vapour pressure of less than or equal to 0.267 kPa when measured at 20°C or, if the vapour pressure is unknown, that contain more than 10 carbon atoms per molecule,
  (ii) colourants and fragrances that, combined, constitute 2% or less of the product's net weight,
  (iii) ethanol;
(d) in the case of a personal fragrance product referred to in item 11 of the table to Schedule 1 of the Regulations,
  (i) low vapour pressure VOCs
  (ii) fragrances;
(e) in the case of a pressurized gas duster referred to in item 53 of the table to Schedule 1 of the Regulations,
  (i) low vapour pressure VOCs
(f) in the case of a product other than a product referred to in paragraph (c), (d) or (e),
  (i) low vapour pressure VOCs
  (ii) fragrances that, combined, constitute 2% or less of the product's net weight;

Wp is the net weight of the product, expressed in grams.

Alternatively, for 100% volatile products containing LVOCs, the VOC concentration can be determined using equation (2):

$$(2) \quad \%VOC = [(1 - H) \times (1 - L) - E] \times 100$$

Where:

H is the weight fraction of water in the product;
L is the weight fraction of LVOCs in the non-aqueous portion of the product;
E is the weight fraction of all excluded components in the product other than LVOC and water.

3.1 Determination of VOC emission potentials

The VOC emission potential of a product that belongs to a product category set out in column 1 of the table at Schedule 2 of the Regulations is determined by one of the following methods:

a) For charcoal lighter material the determination of maximum VOC emission potential shall be performed using the procedures specified in the South Coast Air Quality Management District Rule 1174 Ignition Method Compliance Certification Protocol. Testing to

determine distillation points of petroleum distillate-based charcoal lighter material shall be performed using ASTM D86 [14].

b) For single-use dryer products, the VOC emission potential shall be determined by cutting a disc shaped subsample from a fresh sheet, or equivalent delivery substrate impregnated with the product, with a diameter slightly smaller than the diameter of weighing dish. The volatile fraction of the subsample is established following the procedure described in US EPA Method 24 and the result is multiplied by the weight of the appropriate quantity of sheets (or equivalent delivery substrate) according to the manufacturer's instructions, to obtain VOC emission potential in grams per use. The appropriate quantity will be based on the recommended quantity for a single use, as specified on the product packaging or label. A similar approach can be applied to water determination when using KF titration with a sample drying oven. In the case of excluded VOCs, a subsample of the product needs to be extracted with solvent prior to analysis. For single-use dryer products, the emissions potential shall be calculated as per equation 3:

$$(3)\ Emission\ potential\ = \frac{Ws - Wex}{Wd} \times Wper\ use$$

Where:

Ws is the weight in grams of all of the substances contained in the product that volatize when the product is tested to determine its VOC emission potential for the purposes of the Regulations;

Wex is the weight in grams of all of the substances to be excluded when determining the VOC emission potential;

Wd is the weight of the sample of the sheet (or equivalent delivery substrate)

Wper use is the weight of the appropriate quantity of sheets (or equivalent substrate), based on the recommended quantity for a single use as specified on the product packaging or label.

4. Testing procedures

The product testing procedure is divided into separate determinations:

A. Determination of the net weight of a representative sample
B. Determination of product total volatile material
C. Determination of product water content
D. Determination of ammonia content
E. Determination of ethanol and excluded VOCs
F. Determination of fragrances
G. Determination of:
  (i) LVOC
  (ii) MVOC and HVOC
H. Aerosol samples

I. Samples with atypical matrices

A. Establishing the net weight of the product sample

The sample net weight is established using an analytical balance. Typically, a balance needs to be accurate to 0.01% of a sample net weight, e.g. when dealing with sample net weight in the range of 1 to 10 grams, the determination should be accurate within 0.0001g or 0.1 mg.

B .Determining the weight of product total volatiles (Ws)

The weight of total volatiles of a non-aerosol sample and non-propellant portion of an aerosol product sample is determined gravimetrically. The analytical approach is based on US EPA Method 24/24A [4, 5] and ASTM D2369 [6]. Typically, a portion of a sample (usually 0.3 to 1.0 g) is dispensed with a syringe into a preconditioned aluminum weighing dish (Al-dishes). Preconditioning is achieved by heating the Al-dishes for 30 minutes at 110 ± 5ºC, after which they are transferred and stored in a desiccator prior to use (see ASTM D2369-07, section 5.2 for details). If the sample interacts with the aluminium dish, a Teflon dish may be used. A small volume of an appropriate solvent, typically water, toluene or methanol is used to facilitate its dispersion. The solvent evaporates fully during sample heating and does not contribute to sample non-volatile weight, which is used to determine sample total volatiles. If the sample in the dish does not disperse well it may interfere with sample volatilization.

The sample is then heated at 110 ± 5ºC for 60 minutes. The volatile content is calculated from the difference in the sample weight before and after heating. A desiccator is used for cooling samples to ambient temperature before weighing and for vial conditioning to avoid absorption of water vapour from air.

Thick oven cleaners containing sodium hydroxide and/or entrained propellant can be difficult to analyse. Even when using Teflon weighing dishes, the sample can forcibly eject residue during the oven drying process and affect sample analysis. To mitigate contamination and retain any ejected residue, the Teflon weighing dish containing the sample is placed in a larger Petri dish and covered with a Teflon bowl. This system of Teflon dishes and bowl comprise a containment unit, which needs to be used in place of the single weighing dish prescribed in the Method 24/24A [4, 5].

C. Water

i) Determination of water by Karl Fisher titration

This method is applicable over a wide range of water content including very low (below 1%) and very high (above 80%) concentrations and is the preferred method for analysing samples. Water content can be determined using commercially available Karl Fischer (KF) volumetric titrators integrated with automated drying oven. The procedure is based on ASTM D 4017 [10]. The use of a KF drying oven in connection with the KF titrator is necessary. In this procedure, a pre-weighed aliquot of a product sample is diluted with 1-Methoxy-2-propanol (MPA) and sealed in a preparation vial. The solvent (MPA) is completely miscible with water forming an azeotrope boiling at 97.5 °C. The sample vial is then heated in the oven until all moisture is removed from the vial headspace with a stream of dry inert gas, typically nitrogen. After passing through the vial

the gas is directed to the KF titrator where water vapour is retained by the KF reagent. This technique avoids the interference between the sample matrix, KF reagent and electrode, and in most cases is preferable over the direct injection of the sample to the KF titrator.

ii) Determination of water content by Gas Chromatography

Alternatively, the water content may be established by direct injection gas chromatography following the approach described in ASTM D 3792 [11]. This method was originally developed for determination of water content in water-reducible paints. This gives the best results for products with water content between 15%-75%. For samples with either a very low and/or very high water concentration, the Karl Fisher (KF) method is more accurate.

The ASTM D 3792-05 method is often applied with some modifications to solvent type and/or column packing material. Such modifications are acceptable, assuming that the modified method is properly validated before use. When applied to commercial/certain products, samples can be diluted in a 1:10 ratio (weight/volume) with 1-Methoxy-2-propanol (MPA) or other compatible solvents. Some samples, particularly gels, may require using the homogenizer to obtain sufficient surface area for a solvent to extract the water. After thorough mixing, the solution often requires filtering to remove any remaining insoluble material. A small aliquot (1-2 µL) of the mixture is injected into a gas chromatograph equipped with a thermal conductivity detector (TCD) with a 4 to 6 ft long column, 1/8" outside diameter (O.D.) stainless steel, lined with TFE-fluorocarbon coating and packed with 60-80 mesh (180 to 250 µm) porous polymer packing material (HayeSep R, C or similar). Calibration standards are prepared by diluting a known amount of ASTM type I water in solvent used for sample dilution.

D. Ammonia

Since ammonia volatilizes but is not a VOC, its weight needs to be excluded when determining the product's VOC concentration. For example, ammonium hydroxide, with a vapour pressure of 115 mmHg at 20 °C, is present in some glass and general-purpose cleaners and can cause an overestimation in the VOC determination. Procedures for the measurements of ammonium ions in aqueous products are based on ASTM D 1426 [12] and/or US EPA Method 300.7 [13].

In this method, ion chromatography with a conductivity detector is used to analyze ammonium ions. An aliquot of the product is diluted in water and introduced into the ion chromatograph via an autosampler. The ion chromatographic system is a modular unit comprised of a gradient pump, an automated sampler and a conductivity detector. The eluent is typically 20mM methanesulfonic acid.

Interferences can be caused by analytes with retention times that overlap with the NH_4^+ cation. Large amounts of any given cation may influence peak resolution. Interferences may also be caused by contaminants in the reagent water, the reagents, glassware and other sample processing apparatus that could lead to detectable concentrations of ions or an elevated baseline. A water blank should be run at the beginning of each analytical batch to ascertain possible contamination from reagents or sample vials used.

E. Excluded VOCs

If present in a sample, any organic compounds excluded from VOC definition in item 65 of CEPA Schedule 1 [6] must be excluded when determining the VOC concentration of a product. To determine the concentration of such compounds, ECCC uses its own reference method based on ASTM D 6133 [7]:

Product samples are prepared as weight/volume dilutions in an organic solvent, most commonly toluene or 1-methoxy-2-propanol (MPA). After the initial extraction, the sample is further diluted to a level appropriate for MS detection and filtered through a 0.2µm pore size filter to remove any insoluble material that would interfere with analysis before introduction to the GC-MS system. A small aliquot of filtered sample is injected onto a 60m × 0.25mm internal diameter (I.D.) DB-624 capillary column, which offers good retention and separation of analyzed compounds. The data are reported as the weight fraction of analyte in the product. This method can analyze relatively large suites of VOCs including ethanol, acetone, methyl acetate, dichloromethane, t-butyl acetate, parachlorobenzotrifluoride (PCBTF) and others. It is also capable of separating and analysing common volatile methyl siloxanes (VMS) such as D4, D5, L3, L4 and L5.

Other exclusions

Sections 4(2), 5(1) and 6 of the Regulations specify other exclusions, such as fragrances or LVOC, depending on the product category. Where applicable, their weight can be determined as follows:

F. Fragrances

There is currently no method for determination of colourants and/or fragrances for the Regulations. Instead, where applicable, up to 2% of the product's net weight may be excluded from the determination of VOC concentration based on the manufacturer's claimed composition.

G. LVOC, MVOC and HVOC

LVOC, MVOC and HVOC concentrations can be determined using similar procedures.

i) *LVOC*

Where applicable, LVOC are excluded from the determination of VOC concentration limits and can be analyzed by either automated distillation or simulated distillation techniques.

To determine the LVOC, MVOC and HVOC status by automated distillation, an aliquot of sample up to 100 mL is accurately measured. The sample is then placed into a round bottomed flask with some anti-bumping granules and run according to the appropriate ASTM method (ASTM D 86 [14], ASTM D 850 [15], ASTM D 1078 [16], ASTM D 2879 [17] and ASTM E 1719 [18]).

The requirements for the simulated distillation procedure are described in ASTM D2887 [19]. In this procedure, the Gas Chromatography Mass Spectrometry (GC-MS) or Gas Chromatography Flame Ionisation Detector (GC-FID) system is calibrated using accurately weighed mixtures of n-hydrocarbons (C6-C44) dissolved in a known amount of volatile solvent. The sample is then injected into the GC-MS or GC-FID system and analyzed.

ii) MVOC and HVOC

In some product categories the concentration of MVOCs and HVOCs are limited and must each be determined separately.

Automated distillation and simulated distillation techniques are commonly used for determination of boiling points distribution of LVOC, MVOC and HVOC containing mixtures. Requirements for both of these methods are described in section 4G(i).

For analysis by GC simulated distillation, compounds eluting after the retention time corresponding to a hydrocarbon standard with boiling point at the LVOC cut-off are quantified. The VOC concentration of products containing LVOCs are then determined following the equation (2) in section (3).

Automated distillation techniques allow for separation and collection of fractions of a product boiling at different temperature ranges, and consequently precise determination of weight distribution of distilled fractions. This enables direct calculations of the percentage of LVOC/MVOC/HVOC in a product. Typical reference methods include ASTM D 86 [14], ASTM D 850 [15], ASTM D 1078 [16], ASTM D 2879 [17] and ASTM E 1719 [18]

If LVOC compounds cannot be positively identified and quantified but it is claimed that the product contains LVOC, or there is a disagreement between laboratory and manufacturer/importer VOC estimates, the Enforcement Officer may request and consider formulation data to determine product compliance.

H. Aerosol samples

Aerosol products contain a propellant that is used to eject and disperse a liquid or solid portion of the product from its container. The propellant and non-propellant portions need to be treated separately. Attention needs to be paid to minimizing potential air leaks and interferences before the analysis is conducted, considering the type of containers used to collect the propellant. For example, if Tedlar bags are employed it is important to remember that Tedlar bags are semi-permeable and propellant analysis should be completed within three days of collection.

Prior to analysis, the aerosol container is vented under controlled conditions and the propellant is quantitatively collected in an evacuated container by ASTM D 3074 [8] or ASTM D 3063 [9].

The propellant fraction of the sample needs to be separated from the non-propellant phase. Both fractions are determined separately then the results are added together. Propellant fractions are normally completely volatile while the volatility of the non-propellant fraction needs to be established.

A propellant sample collected in the container is analyzed (screened) for identification of propellant composition using GC-MS. Once all the compounds are identified, the quantification can often be carried out using a thermal conductivity detector (TCD) instead of a mass selective detector (MSD). Inorganic propellants such as air, nitrogen and CO_2 could be used in aerosol products and if present, their weight needs to be subtracted from the weight of propellant for

percentage VOC calculations. Other compounds often found in aerosol propellants include 1,1-difluoroethane (HCF-152a), 1,1,1,2-tetrafluoroethane (HFC-134a), propane, dimethyl ether (DME), isobutane, and *n*-butane.

The GC propellant data are volume based; however, the Regulations require data be reported on a percent of mass basis, therefore density measurements are necessary for data conversion. A densitometer capable of measuring density to five decimal places (0.00001 g/mL) is recommended.

For the non-propellant portion of a product, the VOC content is determined following the procedures of US EPA Method 24/24A [4, 5] and ASTM D 2369 [6], similar to that described for non-aerosol products at the beginning of this section.

I. Samples with atypical matrices

Product-impregnated materials where the separation of the sample from the delivery system is possible

The VOC limit for product-impregnated materials such as wipes for cleaning hands or car surfaces applies to its liquid phase only (the substrate, such as tissue, is considered a delivery system and, like packaging, is excluded from the net weight of the product). The liquid needs to be separated from the substrate. The determination is carried out as described in general testing procedure for non-aerosol samples.

Product-impregnated materials where the separation of the sample from the delivery system is not possible.

Procedure in such case calls for cutting a disc shaped subsample from the product with a diameter slightly smaller than the diameter of the weighing dish. The volatile fraction of the subsample is established following the procedure described in US EPA Method 24 [4]. A similar approach can be applied to water determination when using Karl Fisher titration with a sample drying oven. In the case of excluded VOCs, a subsample of the product needs to be extracted with solvent prior to analysis.

References

[1] Volatile Organic Compound Concentration Limits for Certain Products Regulations.

[2] Canadian Environmental Protection Act, 1999

[3] CARB Method 310 – Determination of Volatile Organic Compounds (VOC) in Consumer Products and Reactive Organic Compounds in Aerosol Coating Products, California Environmental Protection Agency, Air Resources Board, https://ww2.arb.ca.gov/our-work/programs/consumer-products-program/consumer-products-laboratory-sops-test-methods .

[4] US EPA Method 24, Determination of Volatile Matter Content, Water Content, Density, Volume Solids and Weight Solids of Surface Coatings, Appendix A-7, Part 60, Chapter 1 of Title 40 of the Code of Federal Regulations of the United States.

[5] US EPA Method 24A, Determination of Volatile Matter Content of Publication Rotogravure Inks and Related Publication Rotogravure Coatings, https://www.epa.gov/emc/method24-A.

[6] ASTM D 2369, Standard Test Method for Volatile Content of Coatings, https://www.astm.org

[7] ASTM D 6133 Standard Test Method for Acetone, p-Chlorobenzotrifluoride, Methyl Acetate, or t-Butyl Acetate Content of Solventborne and Waterborne Paints, Coatings, Resins and Raw Material by Direct Injection into a Gas Chromatograph, https://www.astm.org

[8] ASTM D 3074 Standard Test Method for Pressure in Metal Aerosol Containers, https://www.astm.org

[9] ASTM D 3063 Standard Test Method for Pressure in Glass Aerosol Bottles, https://www.astm.org

[10] ASTM D 4017 Standard Test Method for Water in Paints and Paint Materials by Karl Fischer Method, https://www.astm.org

[11] ASTM D 3792 Standard Test Method for Water Content of Coatings by Direct Injection Into a Gas Chromatograph, https://www.astm.org

[12] ASTM D 1426, Standard Test Method for Ammonia Nitrogen in Water, https://www.astm.org

[13] US EPA Method 300.7, Dissolved Sodium, Ammonium, Potassium and Calcium in Wet Deposition by Chemically Suppressed Ion Chromatography, https://www.epa.gov

[14] ASTM D 86 Standard Test Method for Distillation of Petroleum Products, https://www.astm.org

[15] ASTM D 850 Standard Test Method for Distillation of Industrial Aromatic Hydrocarbons and Related Materials, https://www.astm.org

[16] ASTM D 1078 Standard Test Method for Distillation Range of Volatile Liquids, https://www.astm.org

[17] ASTM D 2879 Standard Test Method for Vapor-Pressure-Temperature Relationship and Initial Decomposition Temperature of Liquids by Isoteniscope, https://www.astm.org

[18] ASTM E 1719 Standard Test method for Vapor Pressure of Liquids by Ebulliometry, https://www.astm.org

[19] ASTM D 2887 Standard Test method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography, https://www.astm.org

[20] South Coast Air Quality Management District Rule 1174 Ignition Method Compliance Certification Protocol, https://www.aqmd.gov/docs/default-source/laboratory-procedures/methods-procedures/r1174_protocol.pdf