



Designation: D8267 – 24

# Standard Test Method for Determination of Total Aromatic, Monoaromatic and Diaromatic Content of Aviation Turbine Fuels Using Gas Chromatography with Vacuum Ultraviolet Absorption Spectroscopy Detection (GC-VUV)<sup>1</sup>

This standard is issued under the fixed designation D8267; 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 reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

## 1. Scope\*

1.1 This test method is a standard procedure for the determination of total aromatic, monoaromatic and diaromatic content in aviation turbine fuels using gas chromatography and vacuum ultraviolet detection (GC-VUV).

1.2 Concentrations of compound classes and certain individual compounds are determined by percent mass or percent volume.

1.2.1 This test method is developed for testing aviation turbine engine fuels having concentration test results ranging from 0.487 % to 27.876 % by volume total aromatic compounds, 0.49 % to 27.537 % by volume monoaromatics and 0.027 % to 2.523 % by volume diaromatics.

NOTE 1—Samples with a final boiling point greater than 300 °C that contain triaromatics and higher polyaromatic compounds are not determined by this test method.

1.3 Individual hydrocarbon components are not reported by this test method, however, any individual component determinations are included in the appropriate summation of the total aromatic, monoaromatic or diaromatic groups.

1.3.1 Individual compound peaks are typically not baseline-separated by the procedure described in this test method, that is, some components will coelute. The coelutions are resolved at the detector using VUV absorbance spectra and deconvolution algorithms.

1.4 This test method has been tested for aviation turbine engine fuels including synthetic alternative jet fuels. This test method may apply to other hydrocarbon streams boiling between hexane (68 °C) and heneicosane (356 °C), but has not been extensively tested for such applications.

1.5 *Units*—The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

<sup>1</sup> 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 D02.04.0L on Gas Chromatography Methods.

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1.6 *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.*

1.7 *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:<sup>2</sup>

- D1840 Test Method for Naphthalene Hydrocarbons in Aviation Turbine Fuels by Ultraviolet Spectrophotometry
- D4057 Practice for Manual Sampling of Petroleum and Petroleum Products
- D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants
- D4307 Practice for Preparation of Liquid Blends for Use as Analytical Standards
- D6299 Practice for Applying Statistical Quality Assurance and Control Charting Techniques to Evaluate Analytical Measurement System Performance
- D6300 Practice for Determination of Precision and Bias Data for Use in Test Methods for Petroleum Products, Liquid Fuels, and Lubricants
- D6379 Test Method for Determination of Aromatic Hydrocarbon Types in Aviation Fuels and Petroleum Distillates—High Performance Liquid Chromatography Method with Refractive Index Detection
- D6730 Test Method for Determination of Individual Components in Spark Ignition Engine Fuels by 100-Metre

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto: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

Capillary (with Precolumn) High-Resolution Gas Chromatography

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

D7372 Guide for Analysis and Interpretation of Proficiency Test Program Results

### 3. Terminology

#### 3.1 Definitions:

3.1.1 For definitions of terms used in this test method, refer to Terminology D4175.

#### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *diaromatics, n*—hydrocarbon compounds containing two aromatic rings; this group includes naphthalene, biphenyls, acenaphthene, acenaphthylene and alkylated derivatives of these hydrocarbons.

3.2.1.1 *Discussion*—Aviation turbine fuel specifications limit naphthalenes which includes naphthalene, acenaphthene, and alkylated derivatives of these hydrocarbons. The Test Method D1840 method for naphthalenes states that biphenyls interfere with the analysis. Biphenyls if present in typical aviation turbine fuel would be measured as naphthalenes in Test Method D1840, therefore the terms naphthalenes and diaromatics can be considered synonymous in the context of this test method.

3.2.2 *integration filter, n*—a mathematical operation performed on an absorbance spectrum for the purpose of converting the spectrum to a single-valued response suitable for representation in a two-dimensional chromatogram plot.

3.2.3 *library reference spectrum, n*—an absorbance spectrum representation of a molecular species stored in a library database and used for identification of a compound/compound class or deconvolution of multiple coeluting compounds.

3.2.4 *monoaromatic hydrocarbons, n*—hydrocarbon compounds containing one aromatic ring; including benzene, alkylsubstituted benzenes, indans, tetralins, alkyl-substituted indans, and alkyl-substituted tetralins.

3.2.5 *response area, n*—generally refers to a response summed over a given time interval and has units of absorbance units (AU).

3.2.5.1 *Discussion*—A time factor necessary to convert a response area to a true mathematical area cancels out of all critical calculations and is omitted.

#### 3.3 Abbreviations:

3.3.1 *AU*—absorbance units

3.3.2 *GC-VUV*—gas chromatography with vacuum ultraviolet spectroscopy detection

3.3.3 *RI*—retention index

3.3.4 *RRF*—relative response factor

### 4. Summary of Test Method

4.1 An aviation turbine fuel sample is introduced to a gas chromatographic (GC) system. After volatilization, the effluent is introduced onto a GC column for separation, and then detected by a vacuum ultraviolet absorption spectroscopy

detector.<sup>3</sup> The separation is accomplished using a 30 m, non-polar phase capillary column and a moderately fast temperature ramp (typical operating parameters of this test method are given in Table 1). Coelutions are resolved by the detector using vacuum ultraviolet absorbance spectra and deconvolution.

4.2 The calculation of the results is based on the determination of the total response areas of each of the classes of saturate, aromatic and diaromatic compounds. The saturates class includes the summation of the paraffins, isoparaffins, and naphthenes. The total aromatics class includes the summation of monoaromatics and diaromatics. The percent mass concentrations are calculated from the response areas using class-based relative response factors, as appropriate. The volume percent concentrations are calculated from the mass concentrations by applying specific component or class-based density values as appropriate.

### 5. Significance and Use

5.1 The determination of class group composition of aviation turbine fuels is useful for evaluating quality and expected performance, as well as compliance with various industry specifications and governmental regulations.

### 6. Interferences

6.1 Interferences with this test method, if any, have not been determined.

### 7. Apparatus

7.1 *Gas Chromatograph*, equipped with automated oven temperature control and split/splitless inlet.

<sup>3</sup> The sole source of supply of the apparatus known to the committee at this time is VUV-Analytics, Cedar Park, Texas. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,<sup>1</sup> which you may attend.

TABLE 1 Typical Instrument Settings for GC-VUV Aviation Turbine Fuel Measurement

Column Dimensions	Capillary, 30 m × 0.25 mm ID × 0.25 μm film thickness
Column phase <sup>A</sup>	Nonpolar (for example, 100 % dimethyl polysiloxane)
Injector temperature	250 °C
Injection volume <sup>B</sup>	1.0 μL
Split ratio <sup>B</sup>	100:1
Column flow (constant flow mode)	2.0 mL/min
Oven initial temperature	50 °C
Initial hold time	0.1 min
Oven ramp	15 °C/min
Final oven temperature	260 °C
Final hold time	0 min
Detector makeup gas pressure (gauge)	as per manufacturer's instructions
Data scan rate	7.0 Hz
Detector flow cell temperature	275 °C
Transfer line temperature	275 °C

<sup>A</sup> Columns with low bleed phases such as MS grade have been successfully used for this application (see 11.6).

<sup>B</sup> Other injection volumes and split ratios may be used to achieve the required naphthalene response (see 13.2).

7.1.1 *Flow Controllers*—The gas chromatograph must be equipped with mass flow controllers capable of maintaining carrier gas flow constant to  $\pm 1\%$  over the full operating temperature range of the column. The inlet pressure of the carrier gas supplied to the gas chromatograph must be at least 485 kPa. This will ensure that the minimum pressure needed to compensate for the increase in column back-pressure as the column temperature is maintained.

7.1.2 It is highly recommended that the gas chromatograph is equipped with an autosampler. All statistical data were obtained using a GC equipped with an autosampler.

7.2 *Carrier Gas*, for gas chromatograph: helium (see 8.2).

7.3 *Purge/Makeup Gas*, for detector: helium, nitrogen, or argon (see 8.3).

7.4 *Oxygen, Water, Hydrocarbon Filters*, to further purify GC carrier gas and detector purge/makeup gas.

7.5 *Capillary Analytical Column*, nonpolar (for example, dimethyl polysiloxane) phase, dimensions 30 m length, 0.25 mm internal diameter, 0.25  $\mu\text{m}$  film thickness.

7.6 *Vacuum Ultraviolet Absorption Spectroscopy Detector*, capable of measuring 125 nm to 240 nm absorbance spectra with a wavelength resolution of 1 nm or better.

7.6.1 The detector shall be able to interface with a gas chromatographic system and measure an eluent with a scan frequency of at least 5 Hz with a baseline peak-to-peak noise width over a 10 s interval no greater than 0.002 AU when averaged over the following wavelength regions: 125 nm to 240 nm, 170 nm to 200 nm, 125 nm to 160 nm, and 0.001 AU when averaged over the 140 nm to 160 nm wavelength region.

7.6.2 The detector shall be equipped with a shutter or equivalent mechanism that allows the detector array to be blocked from the light source in order to perform a “dark” measurement of electronic noise level.

7.6.3 The detector shall be equipped with a flow cell capable of being heated to at least 275 °C.

7.6.4 The detector shall have an independently controlled makeup gas capability, capable of providing up to 5 mL/min additional flow of nitrogen, helium, or argon to the flow cell.

7.7 *Data Processing System*, capable of storing and processing absorbance scan data and corresponding time.

7.7.1 Data processing system shall include a database library of vacuum ultraviolet reference spectra, compound class information, carbon number, density, and approximate retention index values. Data processing system shall also store relative response factors for each hydrocarbon class in addition to relative response factors for individually reported compounds.

7.7.2 Data processing system shall be capable of implementing equations and fit procedures that result in deconvolution of absorbance spectra that contain contributions from multiple species.

7.7.3 Data processing system shall be capable of binning and storing response contributions from each deconvolution analysis and reporting a combined total response at the end of the analysis.

7.7.4 Data processing system shall be capable of implementing equations to convert response areas to percent mass and further convert percent mass to percent volume.

## 8. Reagents and Materials

8.1 *Purity of Reagents*—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 where such specifications are available.<sup>4</sup> 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 Helium carrier gas for gas chromatograph, 99.999 % pure.

8.3 Nitrogen, helium, or argon purge/makeup gas for vacuum ultraviolet detector, 99.999 % pure.

8.4 Methylene chloride, reagent grade, used as a solvent test sample and GC rinse solvent. (**Warning**—Toxic material. May be combustible at high temperatures.)

8.5 A system validation mixture that complies with Practice D4307, having the components and approximate concentrations given in Table 2. The concentrations of the prepared system validation mixture should be close to those in Table 2 and shall otherwise be accurately known.

8.5.1 The components of the system validation mixture may be modified to include other components of particular relevance to this test method.

8.5.2 The components of the system validation mixture must include linear alkanes in a continuous series from C6 to C21 at the nominal concentrations in Table 2.

<sup>4</sup> ACS Reagent Chemicals, Specifications and Procedures for Reagents and Standard-Grade Reference Materials, 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.

**TABLE 2 System Validation Mixture**

Component	Concentration (percent mass)
Hexane	0.25
Heptane	0.25
Octane	0.25
Nonane	0.25
Decane	0.25
Undecane	0.25
Dodecane	0.25
Tridecane	0.25
Tetradecane	0.25
Pentadecane	0.25
Hexadecane	0.25
Heptadecane	0.25
Octadecane	0.25
Nonadecane	0.25
Eicosane	0.25
Heneicosane	0.25
Naphthalene	0.25
2-Methylnaphthalene	0.25
1,2,4-Trimethylbenzene	0.25
Methylene Chloride	Balance

8.5.2.1 The system validation mixture is used to determine a retention time marker list (see 12.1 and 12.2).

8.5.2.2 The system validation mixture is used to determine splitter linearity (see 13.3.2).

8.6 A quality control (QC) sample, similar in characteristics to samples that are to be routinely analyzed such as aviation turbine engine fuel. See Section 18 on Quality Control Monitoring.

## 9. Hazards

9.1 Many of the compounds in aviation turbine engine fuel or other test samples used in this test method are toxic, flammable, or both. Safety and sample-handling procedures appropriate for working with such materials shall be in place before attempting to use this test method.

## 10. Sampling

10.1 Refer to Practice D4057 for guidelines on obtaining aviation turbine engine fuel samples for analysis.

## 11. Preparation of Apparatus

11.1 Ensure that all gas connections are properly made, without leaks.

11.2 Install oxygen, moisture, and hydrocarbon filters in gas lines upstream of GC and detector. Maintain gas filters as instructed by manufacturer.

11.3 Install the 30 m column in the GC inlet. Condition the column according to the column manufacturer's recommendations prior to installation in the detector.

11.4 Perform maintenance on the GC as suggested by manufacturer, such as replacing septum and liner.

11.5 Configure the injector, carrier gas, and other GC parameters according to Table 1.

11.6 Inject the solvent test sample defined in 8.4 and run the GC-VUV apparatus through a full oven ramp and cool-down cycle. Repeat.

11.6.1 Assess the baseline on either a solvent test sample or a system validation mixture (see 8.5) run. The average absorbance value (125 nm to 240 nm) of at least a 0.1 min section of the baseline near the end of the oven ramp shall be no more than  $\pm 0.0035$  AU of the average value (125 nm to 240 nm) of the initial 0.5 min to 1.0 min range.

## 12. Calibration and Standardization

12.1 On installation of GC-VUV apparatus, after significant maintenance of GC-VUV apparatus, or after a significant method change, establish a retention index file. Run the system validation mixture (see 8.5) using the same flow conditions and oven ramp profile as measured samples (see Table 1 for recommended run conditions). Record the retention times of C6 through C21 linear alkanes. These will serve as retention time markers.

12.1.1 Significant method changes include changing the GC, column type, make-up gas pressure, or oven ramp profile. Significant maintenance of the GC-VUV apparatus includes changing or trimming the analytical column.

12.2 A list of retention times and retention indices for the linear alkanes is used to estimate elution times of other compounds in the VUV library according to an interpolation scheme. The retention index scheme sets the linear alkane retention indices to multiples of 100 according to carbon number: nonane RI = 900, decane RI = 1000, etc.

12.2.1 Once updated, the same retention time marker list is used for all subsequent aviation turbine fuel measurements until the next modification or maintenance of the GC-VUV instrumentation.

12.3 The conversion from response areas to percent mass uses class-based relative response factors. The relative response factors account for the differing areal response per unit mass for the various hydrocarbon classes.

12.4 For the purpose of this calculation, the response at a given elution time refers to the absorbance averaged over the 125 nm to 240 nm wavelength region. The response area refers to the sum of the response over all detector scans within a given time region. A true area can be generated by multiplying this quantity by the time interval between scans. However, this step is unnecessary when the scan rate is kept constant throughout a given measurement. For the purposes of this test method, the response area is taken to be a sum having units of absorbance units.

12.5 The response factors are relative to the response of methane, which is taken to have a relative response factor of 1.

12.6 Relative response factors used to obtain the precision data in this test method are given in Table 3 and Table 4, and are suitable for use with this test method.

12.7 Relative response factors may alternatively be refined or determined as described in Appendix X1.

## 13. Pre-Measurement Validation

13.1 Before proceeding with measurements or after a significant change or maintenance of the GC-VUV system, the procedures in Section 11 should have been completed, and a retention index file generated or verified following the procedure in 12.1 and 12.2.

13.2 Verify that the total response for naphthalene is  $3.25 \pm 0.25$  in the system validation mixture (see 8.5).

13.2.1 Otherwise adjust the detector make-up gas pressure in 0.14 kPa increments and reanalyze the system validation mixture, checking the naphthalene response until it is in the specified range. Increasing the detector make-up gas pressure will decrease the naphthalene response.

**TABLE 3 Relative Response Factors for Bulk Hydrocarbon Classes**

Hydrocarbon Class	Relative Response Factor C6 to C21 <sup>A</sup>
Saturates	0.811 to 0.683
Monoaromatics	0.258 to 0.422
Diaromatics	0.198 to 0.213

<sup>A</sup>A compound's relative response factor is a function of the type and number of chemical bonds.

**TABLE 4 Relative Response Factors for Specific Individual Compounds and Compound Groups**

Compound	Relative Response Factor
Benzene	0.258
Toluene	0.267
Ethylbenzene	0.284
Xylenes	0.284
1,2,4-trimethylbenzene	0.279
Naphthalene	0.198
Methylnaphthalenes	0.202

13.2.2 If the detector make-up gas pressure has been changed, reanalyze the retention index sample (see 12.1 and 12.2) and establish a new retention index file. Adjusting the detector make-up gas pressure will change retention times. Reanalyze the system validation mixture (see 8.5) and verify the total response for naphthalene (see 13.2).

13.3 The system validation mixture (see 8.5) serves as a verification of the analytical system.

13.3.1 *System Accuracy*—The system validation mixture percent by mass results for individual paraffins, aromatics, and diaromatics shall be within  $\pm 10\%$  relative of the certified concentration values.

13.3.2 *Split Linearity*—The experimentally determined percent by mass ratio of C21 to C7 shall be within 10 % relative of the ratio of the certified percent by mass in the system validation mixture.

13.3.2.1 If the split linearity results are unacceptable, verify that the inlet seals, liner, and column position are designed to minimize split inlet mass discrimination. A GC inlet liner packed with deactivated glass wool is recommended.

13.4 Analyze the quality control sample defined in 8.6.

13.5 If the specifications in 13.3 or control limits in 13.4 are not met, verify the functionality of all GC-VUV components, validity of retention time marker list, and validity/quality of the QC or system validation mixture, or both. Repeat setup methodology in Sections 11, 12, and 13 as necessary to ensure specifications in 13.3 and 13.4 are met before proceeding.

13.6 It is strongly recommended that the system validation mixture and or the QC sample be run with every subsequent batch of 20 samples.

## 14. Procedure

14.1 Inject the sample into the GC injector port. Typical GC method and detector conditions are given in Table 1.

14.2 The system shall record a dark scan immediately after start.

14.3 The system shall record a reference scan immediately after the dark scan.

14.3.1 The reference scan refers to an initial detector scan used as a reference to convert subsequent detector scans to absorbance scans, and is defined in Annex A1. It is not a library reference spectrum.

14.4 The system shall record 125 nm to 240 nm absorbance spectra and time of scan for each detector scan. Conversion of recorded intensity data to absorbance is given in Annex A1.

14.5 At the end of the GC run, the data collection shall automatically stop, and the recorded absorbance spectra processed in order to obtain response areas for each of the hydrocarbon classes and individual compounds being monitored.

14.5.1 Calculate percent mass for each hydrocarbon group; saturates, aromatics, and diaromatics.

14.5.2 Calculate percent volume results from the percent mass results and class/compound densities.

## 15. Calculation

NOTE 2—See pertinent information on modeling absorbance data in Annex A2.

15.1 Divide the measured chromatogram into time slices of a given width,  $\Delta t$ . Define the following parameters:

15.1.1 A retention index (RI) window,

15.1.2 A chi-squared iteration threshold, expressed as a percentage,

15.1.3 An  $R^2$  threshold,

15.1.4 A saturation threshold, and

15.1.5 An initial background time region (optional).

15.2 If an initial background time region is defined, calculate a background spectrum from the average of the absorbance scans over the background time region.

15.3 Analyze each time slice using the following algorithm:

15.3.1 Calculate the total absorbance from the sum of the absorbance scans within the time slice.

15.3.1.1 If a background spectrum is defined, subtract the background spectrum from each of the individual absorbance spectra within the time slice. Sum the resulting background-subtracted spectra to obtain the total absorbance spectrum for the time slice.

15.3.1.2 If the absorbance value at a given wavelength exceeds the saturation threshold for any of the absorbance scans within the time slice, remove the data at that wavelength value from the total absorbance and library reference spectra used in subsequent fits for that time slice.

15.3.2 Calculate the average retention index of the time slice using the average elution time of the time slice and the list of retention time markers. A linear interpolation scheme is sufficient.

15.3.3 Construct a list consisting of all compounds in the VUV reference library within  $\pm$ RI window of the average retention index of the time slice.

15.3.4 Perform a tiered search on the total absorbance spectrum, drawing from the constructed list of compounds:

15.3.4.1 Construct Eq A2.1 (see Annex A2) assuming a single component contributes to the total absorbance. Select a compound from the list and assign its library reference spectrum to  $A_{i,ref}$  in Eq A2.1. Fit the total absorbance to Eq A2.1 using general linear least squares. Calculate a metric, such as the chi-squared statistic:

$$x^2 = \frac{1}{N} \sum_{i=1}^N \frac{1}{\sigma_i^2} (A_{i,meas} - A_{i,calc})^2 \quad (1)$$

where:

$N$  = the number of data points in an absorbance spectrum fit,

$A_{i,meas}$  = the measured total absorbance at data point  $i$ ,  
 $A_{i,calc}$  = the calculated total absorbance at data point  $i$ , and  
 $\sigma_i$  = the uncertainty of measured data point  $i$ , expressed as a standard deviation.

If the uncertainty in the measured data have not been estimated, the  $\sigma_i$  may be set to 1. Normalization by the number of data points,  $N$ , is also optional.

15.3.4.2 Repeat the fit for each compound in the list and retain the fit yielding the best chi-square value, along with the best-fit compound's fit value  $f_j$ .

15.3.4.3 Construct Eq A2.1 assuming two compounds contribute to the total absorbance spectrum. Populate  $A_{1,ref}$  and  $A_{2,ref}$  in Eq A2.1 with library reference spectra for each possible pair of compounds from the compound list. Fit the total absorbance to Eq A2.1 for each pair. Retain the pair resulting in the best chi-squared value along with their fit values,  $f_1$  and  $f_2$ . Compare the chi-squared value from the best two-component fit to the chi-squared value from the best one-component fit. If the percent improvement of the chi-squared value for the best two-component fit over the best one-component fit is greater than the chi-squared iteration threshold, retain the two-component result. Otherwise, reject the two-component result and retain the one-component result.

15.3.4.4 Construct Eq A2.1 assuming three compounds contribute to the total absorbance spectrum. Populate  $A_{1,ref}$ ,  $A_{2,ref}$ , and  $A_{3,ref}$  with library reference spectra for each possible triplet of compounds from the compound list. Fit the total absorbance to Eq A2.1 for each triplet. Retain the triplet resulting in the best chi-squared value along with the fit values,  $f_1$ ,  $f_2$ , and  $f_3$ . Compare the chi-squared value from the best three-component fit to the chi-squared value from the best two-component fit. If the percentage improvement of the chi-squared value for the best three-component fit over the best two-component fit is greater than the chi-squared iteration threshold, retain the best three-component result. Otherwise, reject the three-component result and retain the best two-component result, unless the best two-component result was also rejected, in which case retain the best one-component result.

15.3.5 The result of the tiered search procedure is a prediction of the number of compounds that contribute to the total absorbance spectrum, their likely identities, as well as the best-fit values. "Integrate" the library reference spectra of the best-fit compounds by averaging them over the 125 nm to 240 nm region, generating an integration factor for each compound. Multiply the best-fit values,  $f_i$ , by the corresponding integration factors. These are the compounds' contributions to the response area of the time slice.

15.3.6 If the  $R^2$  value, determined from

$$R^2 = 1 - \frac{\sum_{i=1}^N (A_{i,meas} - A_{i,calc})^2}{\sum_{i=1}^N (A_{i,meas} - \bar{A})^2} \quad (2)$$

is less than the  $R^2$  threshold value, reject the analysis results for the time slice (optional). Otherwise, add the compound contributions to the total class response areas according to their class, or to an individual compound's response area if a

compound is one of the speciated compounds given in Table 4. If an individual compound in Table 4 also belongs to a compound class in Table 3 (for example, naphthalene), add its response to the individual compound response area and not to the class response area. In Eq 2,  $\bar{A}$  is the wavelength average of the measured total absorbance spectrum.

15.3.7 Iterate the algorithm until all of the time slices have been analyzed.

15.4 Implementation of an analysis criterion for determining whether to analyze a time slice and a background subtraction is permissible. If a background subtraction is used, a criterion for automatically determining that a time region should be used as a background spectrum may be defined.

15.4.1 *Absorbance Check 1*—Compare the change of a response filter over a time slice. If the response filter changes by more than the absorbance threshold, then analyze the time slice. Otherwise, skip the time slice.

15.4.1.1 If a time slice is skipped, the background threshold may be checked and if the response change over the time slice is less than the background threshold, update the background spectrum using the average absorbance spectrum over the time slice.

15.4.2 *Absorbance Check 2*—If the maximum response of the four filters consisting of average 125 nm to 240 nm absorbance, average 170 nm to 200 nm absorbance, average 125 nm to 160 nm absorbance, and average 140 nm to 160 nm absorbance exceeds the maximum response of the same four filters applied to the current background spectrum by more than three times the absorbance threshold, then analyze the time slice (and do not update the background spectrum) regardless of the outcome of Absorbance Check 1.

15.4.3 Other threshold criteria may be used, provided it is first determined that use of alternate threshold criteria does not lessen the accuracy or precision of the test method.

15.5 Due to the similarities of absorbance spectra of compounds belonging to the same class, as well as the similarities of relative response factors among compounds belonging to the same class, it is not necessary to have an explicit representation of all compounds in the VUV reference library. The following substitutions for an uncharacterized compound are permissible and will generally automatically be made by the algorithm:

15.5.1 Library reference spectra of similar compound class and similar carbon number.

15.5.2 Linear combinations of spectra of similar compound class and similar carbon number.

15.6 If an  $R^2$  threshold is applied, record the amount of response area rejected by implementation of the  $R^2$  threshold. Compare the rejected amount to the total response area at the end of the analysis. If more than 3 % of the response area was rejected, the analysis should be flagged, and the measurement data and GC-VUV instrumentation should be inspected.

15.7 Table 5 lists values for analysis parameters used in the statistical study given in Section 17, and are suitable for use with this test method.

15.8 The result of the measurement and analysis procedure are total response areas for each of the hydrocarbon classes and