Standard Test Method for Ignitable Liquid Residues in Extracts from Fire Debris Samples by Gas Chromatography-Mass Spectrometry[1]

This standard is issued under the fixed designation E1618; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the identification of residues of ignitable liquids in extracts from fire debris samples. Extraction procedures are described in the referenced documents.

1.2 Although this test method is suitable for all samples, it is especially appropriate for extracts that contain high background levels of substrate materials or pyrolysis and combustion products. This test method is also suitable for the identification of single compounds, simple mixtures, or non-petroleum based ignitable liquids.

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

1.4 This practice cannot replace knowledge, skill, or ability acquired through appropriate education, training, and experience and should be used in conjunction with sound professional judgment.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E1386 Practice for Separation of Ignitable Liquid Residues from Fire Debris Samples by Solvent Extraction
E1388 Practice for Sampling of Headspace Vapors from Fire Debris Samples
E1412 Practice for Separation of Ignitable Liquid Residues from Fire Debris Samples by Passive Headspace Concentration With Activated Charcoal
E1413 Practice for Separation of Ignitable Liquid Residues from Fire Debris Samples by Dynamic Headspace Concentration
E2154 Practice for Separation and Concentration of Ignitable Liquid Residues from Fire Debris Samples by Passive Headspace Concentration with Solid Phase Microextraction (SPME)
E2451 Practice for Preserving Ignitable Liquids and Ignitable Liquid Residue Extracts from Fire Debris Samples

3. Summary of Test Method

3.1 The sample is analyzed with a gas chromatograph (GC) which is interfaced to a mass spectrometer (MS) and a data system (DS) capable of storing and manipulating chromatographic and mass spectral data.

3.2 Post-run data analysis generates extracted ion profiles (mass chromatograms) characteristic of the chemical compound types commonly found in ignitable liquids. Additionally, specific chemical components (target compounds) may be identified by their mass spectra and retention times. Semi-quantitative determination of target compounds which are identified by mass spectra and retention time may be used to develop target compound chromatograms (TCCs).

3.2.1 The total ion chromatogram (TIC), extracted ion profiles (EIP) for the alkane, alkene, alcohol, aromatic, cycloalkane, ester, ketone and polynuclear aromatic compound types, or TCCs, or combination thereof, are evaluated by visual pattern matching against known reference ignitable liquids.

3.2.2 Ignitable liquids may be grouped into one of seven major classifications or one miscellaneous class, as described in this test method.

4. Significance and Use

4.1 The identification of an ignitable liquid residue in samples from a fire scene can support the field investigator's opinion regarding the origin, fuel load, and incendiary nature of the fire.

4.1.1 The identification of an ignitable liquid residue in a fire scene does not necessarily lead to the conclusion that a fire was incendiary in nature. Further investigation may reveal a legitimate reason for the presence of ignitable liquid residues.

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[1] This test method is under the jurisdiction of ASTM Committee E30 on Forensic Sciences and is the direct responsibility of Subcommittee E30.01 on Criminalistics.

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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.

4.1.2 Because of the volatility of ignitable liquids and variations in sampling techniques, the absence of detectable quantities of ignitable liquid residues does not necessarily lead to the conclusion that ignitable liquids were not present at the fire scene.

4.2 Materials normally found in a building, upon exposure to the heat of a fire, will form pyrolysis and combustion products. Extracted ion profiling and target compound identification techniques described herein may facilitate the identification of an ignitable liquid in the extract by reducing interference by components generated as products of pyrolysis.

5. Apparatus

5.1 *Gas Chromatograph*—A chromatograph capable of using capillary columns and being interfaced to a mass spectrometer.

5.1.1 *Sample Inlet System*—A sample inlet system that can be operated in either split or splitless mode with capillary columns; the inlet system may use on-column technology.

5.1.2 *Column*—A capillary, bonded phase, methylsilicone or phenylmethylsilicone column or equivalent. Any column length or temperature program conditions may be used provided that each component of the test mixture (see 6.4) is adequately separated.

5.1.3 *GC Oven*—A column oven capable of reproducible temperature program operation in the range from 50 to 300°C.

5.2 *Mass Spectrometer*—Capable of acquiring mass spectra from m/z 40 to m/z 400 with unit resolution or better, with continuous data output. Values above m/z 40 may not be sufficient to detect or identify some lower molecular weight compounds; for example, methanol, ethanol, acetone.

5.2.1 *Sensitivity*—The system shall be capable of detecting each component of the test mixture (see 6.4) and providing sufficient ion intensity data to identify each component, either by computer library search or by comparison with reference spectra.

5.3 *Data Station*—A computerized data station, capable of storing time sequenced mass spectral data from sample runs.

5.3.1 *Data Handling*—The data system shall be capable of performing, either through its operating system or by user programming, various data handling functions, including input and storage of sample data files, generation of extracted ion profiles, searching data files for selected compounds, and qualitative and semi-quantitative compound analysis.

5.3.2 *Mass Spectral Libraries*—The system shall be capable of retrieving a specified mass spectrum from a data file and comparing it against a library of mass spectra available to the data system. This capability is considered an aid to the analyst, who will use it in conjunction with chromatographic data and known reference materials to identify unknown components.

5.4 *Syringes:*

5.4.1 *For liquid samples,* a syringe capable of introducing a sample size in the range from 0.1 to 10.0 µL.

5.4.2 *For gas samples,* a gas-tight syringe capable of introducing a sample size in the range of 0.5 to 5 mL.

6. Chemicals, Reagents, and Reference Materials

6.1 *Purity of Reagents*—Reagent grade or better 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 such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

6.2 *Solvent/Diluent*—Carbon disulfide, diethyl ether, pentane, or other solvent that will not interfere with the analysis. It is generally desirable to use a solvent whose volatility greatly exceeds that of the solute to facilitate sample concentration by evaporation, if necessary.

6.2.1 Use of a heavier solvent, such as toluene or tetrachloroethylene, is sometimes necessary when the compounds of interest have low molecular weights.

6.3 *Carrier Gas*—Helium or hydrogen of purity 99.995 % or higher.

6.4 *Test Mixture*—The test mixture shall consist of a minimum of the even-numbered normal alkanes (ranging from *n*-octane through *n*-eicosane), methylbenzene (toluene), 1,4-dimethylbenzene (*p*-xylene), 1-methyl-2-ethylbenzene (*o*-ethyltoluene), 1-methyl-3-ethylbenzene (*m*-ethyltoluene), and 1,2,4-trimethylbenzene (pseudocumene). Additional compounds may be included at the discretion of the analyst. The final test solution is prepared by diluting the above mixture such that the concentration of each component is 0.005 % volume/volume (0.05 microliters/milliliter) in the chosen solvent (see 6.2). A typical chromatogram of the test mixture is shown in Fig. 1.

6.5 *Reference Ignitable Liquids*—Ignitable liquids shall be available for the various ignitable liquids represented in Table 1.

6.5.1 Typically, reference ignitable liquids are diluted 1:1000 in an appropriate solvent. Depending on the column capacity and injection technique, ignitable liquid solutions can be made somewhat more concentrated to ensure detection of minor compounds.

6.5.2 Certified ignitable liquid standards are not necessary. Most reference ignitable liquids can be obtained from commercial and retail sources.

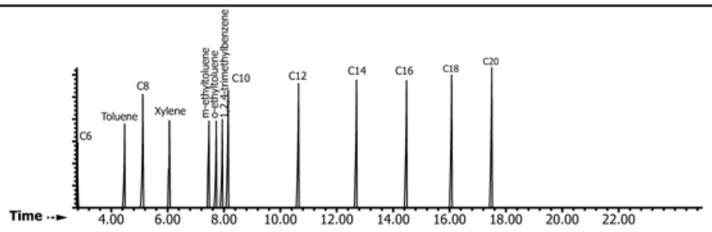
7. Equipment Calibration and Maintenance

7.1 Verify the consistent performance of the chromatographic instrument by using blanks and known concentrations of either prepared test mixture or other known ignitable liquids. Optimize gas flows periodically.

7.2 Tune and calibrate mass spectrometer.

7.2.1 Tune the mass spectrometer using perfluorotributylamine (PFTBA), or another appropriate calibration standard, according to the instrument manufacturer's specifications, prior to use. This should be done at least every day that the instrument is used or per manufacturer's recommendations.

7.2.2 Maintain tuning documentation as a portion of the quality control documentation.



Chromatographic Conditions

Instrument: HP 5890 Gas Chromatograph
Detector: HP 5970 Mass Selective Detector
Column: 30 meter, Rtx-1 (polymethylsiloxane)
0.25 mm ID, 0.25 micron film thickness
Sample: 1.0 microliter of 1% solution in pentane

Initial Temperature: 50 C, 2.5 minutes
Rate: 15 C/min
Final Temperature: 300 C, 5.83 minutes
Total Run Time: 25.00 minutes
Split 20:1

NOTE: This is a typical chromatogram, provided for illustration only. Each laboratory is likely to obtain slightly different retention times and relative abundance of individual components, depending on sample history, separation procedure, and chromatographic conditions.

FIG. 1 Test Mixture Containing C8-C20 Normal Hydrocarbons, toluene, *p*-xylene, *o*-ethyltoluene, *m*-ethyltoluene, and 1,2,4-trimethylbenzene

TABLE 1 Ignitable Liquid Classification Scheme[A]

Class	Light (C_4-C_9)	Medium (C_8-C_{13})	Heavy (C_9-C_{20+})
Gasoline-all brands, including gasohol and E85	Fresh gasoline is typically in the range C_4-C_{12}		
Petroleum Distillates (including De-Aromatized)	Petroleum Ether Some Cigarette Lighter Fluids Some Camping Fuels	Some Charcoal Starters[B] Some Paint Thinners Some Dry Cleaning Solvents	Kerosene Diesel Fuel Some Jet Fuels Some Charcoal Starters
Isoparaffinic Products	Aviation Gas Some Specialty Solvents	Some Charcoal Starters Some Paint Thinners Some Copier Toners	Some Commercial Specialty Solvents
Aromatic Products	Some Paint and Varnish Removers Some Automotive Parts Cleaners Xylenes, Toluene-based products.	Some Automotive Parts Cleaners Specialty Cleaning Solvents Some Insecticide Vehicles Fuel Additives	Some Insecticide Vehicles Industrial Cleaning Solvents
Naphthenic- Paraffinic Products	Cyclohexane based solvents/products	Some Charcoal Starters Some Insecticide Vehicles Some Lamp Oils	Some Insecticide Vehicles Some Lamp Oils Industrial Solvents
Normal-Alkanes Products	Solvents Pentane Hexane Heptane	Some Candle Oils Some Copier Toners	Some Candle Oils Carbonless Forms Some Copier Toners
Oxygenated Solvents	Alcohols Ketones Some Lacquer Thinners Fuel Additives Surface Preparation Solvents	Some Lacquer Thinners Some Industrial Solvents Metal Cleaners/Gloss Removers	
Others-Miscellaneous	Single Component Products Some Blended Products Some Enamel Reducers	Turpentine Products Some Blended Products Some Specialty Products	Some Blended Products Some Specialty Products

[A] The products listed in the various classes of Table 1 are examples of known commercial uses of these ignitable liquids. These examples are not intended to be all-inclusive. Reference literature materials may be used to provide more specific examples of each classification.

[B] Many of the examples can be prefaced by the word "some," as in "some charcoal starters."

7.3 Cleaning the equipment.

7.3.1 Change septa and clean or replace injector liners on a periodic basis to avoid sample contamination by carryover of residual material from previous sample injections.

8. Sample Handling Procedure

8.1 Only samples of appropriate dilution should be analyzed on a GC-MS system.

8.2 Methods for isolating ignitable liquid residues from fire debris for analysis by this test method are described in Practices E1386, E1388, E1412, E1413, and E2154.

8.3 Because of the volatility of solvents and analytes, care must be taken to ensure that samples do not evaporate or otherwise change composition prior to analysis. Septum seal vials may be used for short term storage of any solvents or extracts. See Annex A1 for sample and extract storage guidance.

8.3.1 Avoid the use of water as a sealant.

8.4 Analyze solvent blanks at least once each day that the instrument is used; maintain these analysis records. This will verify the purity of the solvent and potentially detect carryover or contamination.

8.5 Clean syringes thoroughly between injections to ensure no carryover.

8.5.1 Conduct carryover studies periodically, and maintain records that demonstrate the adequacy of laboratory procedures to prevent carryover.

8.5.2 Running a solvent blank between samples is recommended but is not necessary if studies demonstrate that the cleaning procedure is adequate to prevent carryover.

8.6 Maintain reference files of known ignitable liquids that have been analyzed in the same manner as the questioned samples.

8.7 *Chromatogram Evaluation*—An adequate chromatogram with sufficient data for comparison work is one in which the peaks of interest are 50 to 100 % of full scale. Re-print the chromatogram, using different parameters (amplitude or presentation of data) to achieve an adequately scaled chromatogram in the targeted area of investigation.

9. Data Analysis

9.1 Initial data analysis consists of a visual comparison of the total ion chromatograms to reference ignitable liquid chromatograms as described below.

9.1.1 The essential requirement for making a classification using this procedure is the matching of the sample chromatogram with a reference ignitable liquid chromatogram obtained under similar conditions, noting points of correlation or similarities. Make all comparisons using adequate chromatograms as described in 8.7 and interpretation criteria described in Section 11, Interpretation of Results.

9.1.2 The use of externally generated libraries of chromatograms is not sufficient for identification of an ignitable liquid. Such libraries are intended only to give guidance for selection of reference ignitable liquids.

9.1.3 Pattern matching requires that the entire pattern used for comparison be displayed at the same sensitivity.

9.1.3.1 To provide sufficient detail for some comparisons, different amplitudes or presentations of the data may be necessary.

9.1.4 The carbon number range is determined by comparing the chromatogram to a reference or test mixture containing known normal alkanes.

9.1.5 Additional data analysis may be carried out using extracted ion profiling (mass chromatography), target compound analysis, or both.

9.1.6 Store the reference chromatogram(s) in the case file, along with the sample chromatogram(s).

9.1.7 The compounds that comprise ignitable liquids consist of six major types: normal alkane, branched alkane, cycloalkane, aromatic, polynuclear aromatic, and oxygenates. Other compounds may be present, but are not considered significant for the purposes of this method.

9.1.8 Compounds of each type produce characteristic major ion fragments. These ions are listed in Table 2.

9.2 *Extracted ion Profiling (EIP):*

9.2.1 A data station is used to extract and draw extracted ion profiles (mass chromatograms) for major ions characteristic of each compound type. Individual extracted ion profiles for two or more characteristic ions of the same functional groups or of similar magnitude may be summed to enhance the signal-to-noise ratio and to decrease interference by extraneous compounds that contain only one of the ions or to create summed profiles characteristic of specific classes of hydrocarbons.

TABLE 2 Major Ions Present in Mass Spectra of Common Ignitable Liquids[A,B,C,D,E]

Compound Type	m/z
Alkane	43, 57, 71, 85, 99
Cycloalkane and alkene	55, 69
n-Alkylcyclohexanes	82, 83
Aromatic—alkylbenzenes	91, 105, 119, 92, 106, 120, 134
Indanes	117, 118, 131, 132
Alkylnaphthalenes (Condensed Ring Aromatics)	128, 142, 156, 170
Alkylstyrenes	104, 117, 118, 132, 146
Alkylanthracenes	178, 192, 206
Alkylbiphenyls/acenaphthenes	154, 168, 182, 196
Monoterpenes	93, 136
Ketones	43, 58, 72, 86
Alcohols	31, 45

[A] Smith, R.M., “Arson Analysis by Mass Chromatography”*Analytical Chemistry*, Vol 54, No. 13, November 1982, pp. 1399A–1409A.

[B] Kelly, R.L., and Martz, R.M., “Accelerant Identification in Fire Debris by Gas Chromatography/Mass Spectrometry Techniques”, *Journal of Forensic Sciences*, Vol 29, No. 3, 1984, pp. 714–722.

[C] Keto, R.O., and Wineman, P.L., “Detection of Petroleum-Based Accelerants in Fire Debris by Target Compound Gas Chromatography/Mass Spectrometry”, *Analytical Chemistry*, Vol 63, No. 18, September 15, 1991, pp. 1964–1971.

[D] Keto, R.O., “GC/MS Data Interpretation for Petroleum Distillate Identification in Contaminated Arson Debris”, *Journal of Forensic Sciences*, Vol 40, No. 3, 1995, pp. 412–423.

[E] McLafferty, F.W., and Turecek, F., Interpretation of Mass Spectra, 4th Edition, University Science Books, Sausalito, California, 1993, pp. 233 and 247.

9.2.1.1 Many data stations scale chromatograms so that the tallest peak is 100 % of full scale. It may be misleading to use a relative intensity display for ions of significantly different abundance. It is best to overlay these mass chromatograms or use an absolute intensity output.

9.2.2 Extracted ion profiles for an unknown sample are compared against the corresponding extracted ion profiles from reference ignitable liquids. This is generally done by visual pattern recognition as described in 9.1. Computerized pattern recognition techniques are also acceptable, provided the analyst visually verifies the results.

9.2.3 Major peaks in the extracted ion profiles should be identified by searching their mass spectra against a suitable library. The final identification shall be made by the analyst on the basis of the mass spectra and relative retention times of the components in question by comparison to reference ignitable liquids.

9.3 *Target Compound Analysis (TCA):*

9.3.1 Target compound analysis uses key specific compounds to characterize an ignitable liquid. These target compounds are listed in Table 3, Table 4, and Table 5.

9.3.2 Semi-quantitative ratios for the target compounds shall be derived and compared against standards to ensure not only their presence but also that their chromatographic patterns match. Computerized pattern matching techniques are acceptable, provided the analyst visually verifies results.

9.3.2.1 Target compound pattern recognition may be improved by the production of target compound chromatograms,

TABLE 3 Gasoline Target Compounds

Compound	CAS Number
1. 1,3,5-Trimethylbenzene	108–67–8
2. 1,2,4-Trimethylbenzene	95–36–3
3. 1,2,3-Trimethylbenzene	526–73– 8
4. Indane	496– 11– 7
5. 1,2,4,5-Tetramethylbenzene	95– 93– 2
6. 1,2,3,5-Tetramethylbenzene	527– 53–7
7. 5-Methylindane	874– 35– 1
8. 4-Methylindane	824– 22– 6
9. Dodecane	112–40– 3
10. 4,7-Dimethylindane	6682– 71– 9
11. 2-Methylnaphthalene	91– 57– 6
12. 1-Methylnaphthalene	90–12– 0
13. Ethylnaphthalenes (mixed)	1127–76– 0
14. 1,3-Dimethylnaphthalene	575– 41– 7
15. 2,3-Dimethylnaphthalene	581–40–8

TABLE 4 Medium Petroleum Distillate (MPD) Target Compounds

Compound	CAS Number
1. Nonane	111–84– 2
2. Propylcyclohexane	1678–92–8
3. 1,3,5-Trimethylbenzene	108– 67–8
4. 1,2,4-Trimethylbenzene	95–36–3
5. Decane	124–18– 5
6. 1,2,3-Trimethylbenzene	526– 7–8
7. *n*-Butylcyclohexane	1678– 93– 9
8. Trans-decalin	493– 02– 7
9. Undecane	1120– 21– 4
10. 1,2,3,5-Tetramethylbenzene	527– 53–7
11. *n*-Pentylcyclohexane	4292– 92– 6
12. Dodecane	112– 40– 3
13. *n*-Hexylcyclohexane	4292– 75– 5

TABLE 5 Heavy Petroleum Distillate (HPD) Target Compounds

Compound	CAS Number
1. Decane	124–18–5
2. *n*-Butylcyclohexane	1678–93–9
3. Trans-decalin	493–02–7
4. Undecane	1120–21–4
5. 1,2,3,5-Tetramethylbenzene	527–53–7
6. *n*-Pentylcyclohexane	4292–92–6
7. Dodecane	112–40–3
8. *n*-Hexylcyclohexane	4292–75–5
9. 2-Methylnaphthalene	91–57–6
10. 1-Methylnaphthalene	90–12–0
11. Tridecane	629–50–5
12. *n*-Heptylcyclohexane	005617–41–4
13. 1,3-Dimethylnaphthalene	575–41–7
14. Tetradecane	629–59–4
15. *n*-Octylcyclohexane	1795–15–9
16. 2,3,5-Trimethylnaphthalene	2245–38–7
17. Pentadecane	629–62–9
18. *n*-Nonylcyclohexane	2883–02–5
19. Hexadecane	544–76–3
20. Heptadecane	629–78–7
21. Pristane	1921–70–6
22. Octadecane	593–45–3
23. Phytane	638–36–8
24. Nonadecane	629–92–5
25. Eicosane	112–95–8
26. Heneicosane	629–94–7

which are graphical representations of semi-quantitative peak areas for the target compounds. Target compound data may be plotted as a bar graph, with the x-axis representing retention time and the y-axis representing peak area. A single bar on the graph depicts each target compound.

9.3.2.2 Target compound chromatograms for unknown samples are compared to those generated for reference samples. The same pattern matching criteria for mass chromatography apply to target compound chromatography.

9.3.2.3 Major peaks in the TIC that are not accounted for by one of the target compound types may be identified by searching their mass spectra against a suitable library. The final identification shall be made by the analyst on the basis of the mass spectra and relative retention times of the components in question by comparison to reference materials.

9.3.2.4 While TCCs provide much useful information, a TCA should not be the sole basis for the identification of an ignitable liquid residue.

10. Ignitable Liquid Classification Scheme

10.1 Seven major classes of ignitable liquids may be identified by gas chromatography, mass spectrometry, extracted ion profiling (or extracted ion profile analysis), or a combination thereof, when recovered from fire debris. These classes are outlined in 10.2. Typical total ion chromatograms of many of these classes are shown in Figs. 2-10.

10.1.1 This test method is intended to allow identified ignitable liquids to be characterized as belonging to one of the classifications. Distinguishing between examples within any class may be possible, but such further characterization is not within the scope of this test method.

10.1.2 A miscellaneous category is included for those ignitable liquids that do not fall into one of the first seven major ignitable liquid classifications.

10.1.3 With the exception of the gasoline class, the major ignitable liquid classes may be divided into three subclasses based on boiling (n-alkane) range: light, medium and heavy.

10.1.3.1 *Light product range*—n-C$_4$-n-C$_9$; the majority of the pattern occurs in the range n-C$_4$-n-C$_9$, no major peaks associated with the ignitable liquid exist above n-C$_{11}$.

10.1.3.2 *Medium product range*—n-C$_8$-n-C$_{13}$; narrow range products, the majority of the pattern occurs in the range of n-C$_8$-n-C$_{13}$, no major peaks associated with the ignitable liquid below n-C$_7$ or above n-C$_{14}$.

10.1.3.3 *Heavy product range*—n-C$_9$-n-C$_{20+}$, typically broad range products, the majority of the pattern occurs in the range C$_9$–C$_{23}$, with a continuous pattern spanning at least 5 consecutive n-alkanes. Also included in the subclass are narrow range (encompassing less than five n-alkanes) ignitable liquid products starting above n-C$_{11}$.

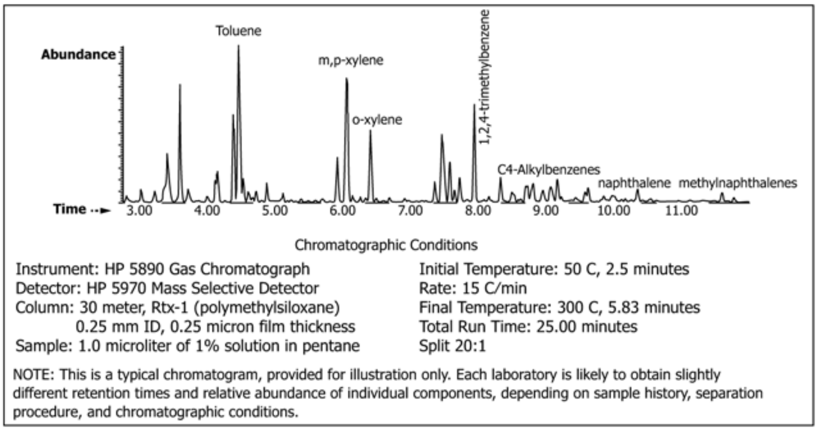
10.1.3.4 It may be necessary to characterize a product as "light to medium," or "medium to heavy," when the carbon number range does not fit neatly into one of the above categories. In such instances, the carbon number range should be reported.

10.2 In order for an extract to be characterized as containing a particular class, the following minimum criteria shall be met:

10.2.1 *Criteria for the Identification of Gasoline:*

10.2.1.1 *General*—All brands of gasoline including gasohol and E85. Pattern characterized by abundant aromatics in a specific pattern.

10.2.1.2 *Alkanes*—Present. Pattern may vary by brand, grade, and lot.



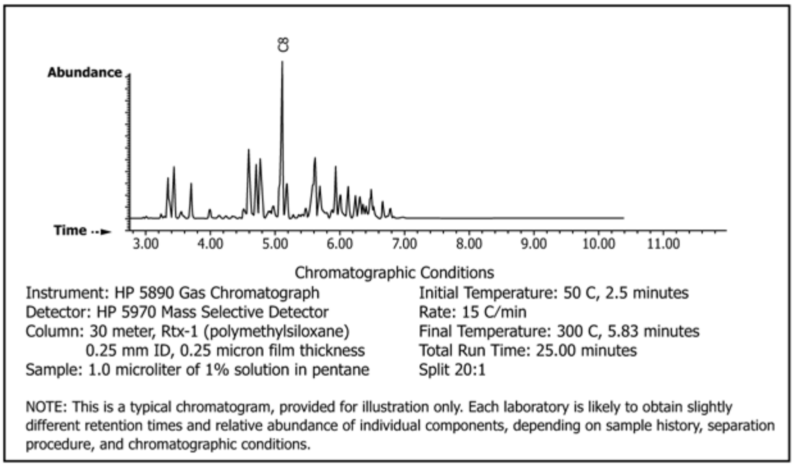
Chromatographic Conditions

Instrument: HP 5890 Gas Chromatograph
Detector: HP 5970 Mass Selective Detector
Column: 30 meter, Rtx-1 (polymethylsiloxane)
0.25 mm ID, 0.25 micron film thickness
Sample: 1.0 microliter of 1% solution in pentane

Initial Temperature: 50 C, 2.5 minutes
Rate: 15 C/min
Final Temperature: 300 C, 5.83 minutes
Total Run Time: 25.00 minutes
Split 20:1

NOTE: This is a typical chromatogram, provided for illustration only. Each laboratory is likely to obtain slightly different retention times and relative abundance of individual components, depending on sample history, separation procedure, and chromatographic conditions.

FIG. 2 Example of a Gasoline Pattern; 50 % Evaporated Gasoline



Chromatographic Conditions

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Column: 30 meter, Rtx-1 (polymethylsiloxane)
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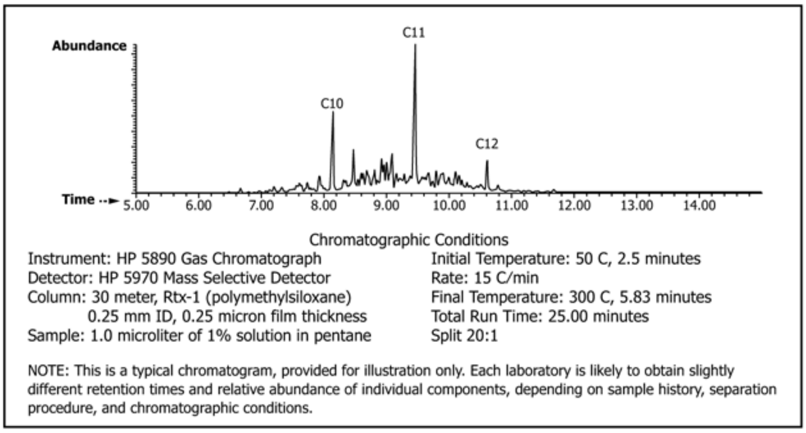
Sample: 1.0 microliter of 1% solution in pentane

Initial Temperature: 50 C, 2.5 minutes
Rate: 15 C/min
Final Temperature: 300 C, 5.83 minutes
Total Run Time: 25.00 minutes
Split 20:1

NOTE: This is a typical chromatogram, provided for illustration only. Each laboratory is likely to obtain slightly different retention times and relative abundance of individual components, depending on sample history, separation procedure, and chromatographic conditions.

FIG. 3 Example of a Light Petroleum Distillate; Cigarette Lighter Fluid



Chromatographic Conditions

Instrument: HP 5890 Gas Chromatograph
Detector: HP 5970 Mass Selective Detector
Column: 30 meter, Rtx-1 (polymethylsiloxane)
0.25 mm ID, 0.25 micron film thickness
Sample: 1.0 microliter of 1% solution in pentane

Initial Temperature: 50 C, 2.5 minutes
Rate: 15 C/min
Final Temperature: 300 C, 5.83 minutes
Total Run Time: 25.00 minutes
Split 20:1

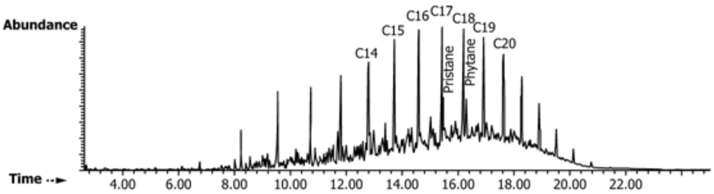
NOTE: This is a typical chromatogram, provided for illustration only. Each laboratory is likely to obtain slightly different retention times and relative abundance of individual components, depending on sample history, separation procedure, and chromatographic conditions.

FIG. 4 Example of a Medium Petroleum Distillate Pattern; 50 % Evaporated Mineral Spirits

10.2.1.3 *Cycoloalkanes*—Not present in significant amounts.

10.2.1.4 *Aromatics*—Petroleum pattern comparable to that of the reference ignitable liquids; 1-methyl-3-ethylbenzene (*m*-ethyltoluene), 1-methyl-4-ethylbenzene (*p*-ethyltoluene), 1,3,5-trimethylbenzene, 1-methyl-2-ethylbenzene (*o*-ethyltoluene), and 1,2,4-trimethylbenzene shall be present; above *n*-C_7, the aromatic concentration is generally substantially higher than the alkane concentration.

10.2.1.5 *Condensed Ring Aromatics*—Pattern comparable to known standard is usually present, including naphthalene, 1- and 2-methylnaphthalenes. These compounds may be absent in some gasolines. Indan (dihydroindene) and methyl indans are usually present.



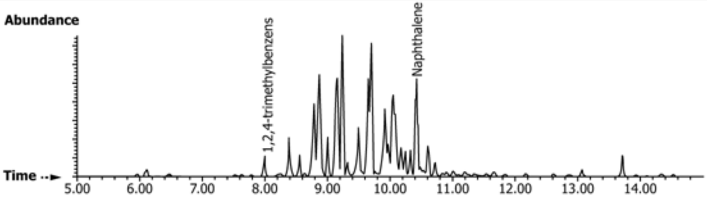
Chromatographic Conditions

Instrument: HP 5890 Gas Chromatograph
Detector: HP 5970 Mass Selective Detector
Column: 30 meter, Rtx-1 (polymethylsiloxane)
0.25 mm ID, 0.25 micron film thickness
Sample: 1.0 microliter of 1% solution in pentane

Initial Temperature: 50 C, 2.5 minutes
Rate: 15 C/min
Final Temperature: 300 C, 5.83 minutes
Total Run Time: 25.00 minutes
Split 20:1

NOTE: This is a typical chromatogram, provided for illustration only. Each laboratory is likely to obtain slightly different retention times and relative abundance of individual components, depending on sample history, separation procedure, and chromatographic conditions.

FIG. 5 Example of Heavy Petroleum Distillate; Diesel Fuel



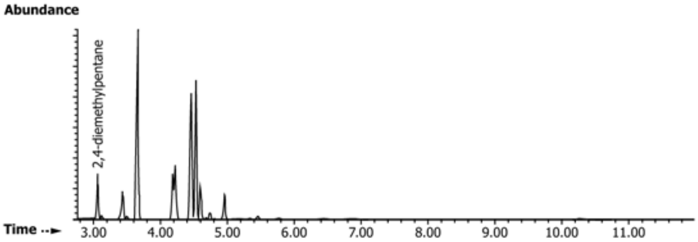
Chromatographic Conditions

Instrument: HP 5890 Gas Chromatograph
Detector: HP 5970 Mass Selective Detector
Column: 30 meter, Rtx-1 (polymethylsiloxane)
0.25 mm ID, 0.25 micron film thickness
Sample: 1.0 microliter of 1% solution in pentane

Initial Temperature: 50 C, 2.5 minutes
Rate: 15 C/min
Final Temperature: 300 C, 5.83 minutes
Total Run Time: 25.00 minutes
Split 20:1

NOTE: This is a typical chromatogram, provided for illustration only. Each laboratory is likely to obtain slightly different retention times and relative abundance of individual components, depending on sample history, separation procedure, and chromatographic conditions.

FIG. 6 Example of a Medium Aromatic Solvent; Fuel Additive



Chromatographic Conditions

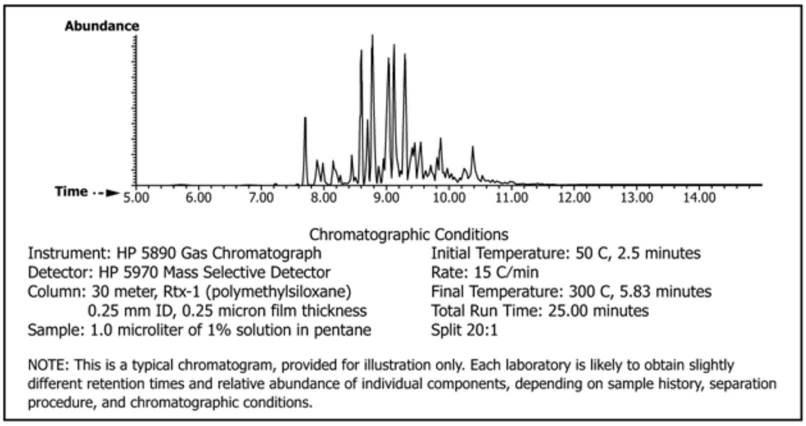
Instrument: HP 5890 Gas Chromatograph
Detector: HP 5970 Mass Selective Detector
Column: 30 meter, Rtx-1 (polymethylsiloxane)
0.25 mm ID, 0.25 micron film thickness
Sample: 1.0 microliter of 1% solution in pentane

Initial Temperature: 50 C, 2.5 minutes
Rate: 15 C/min
Final Temperature: 300 C, 5.83 minutes
Total Run Time: 25.00 minutes
Split 20:1

NOTE: This is a typical chromatogram, provided for illustration only. Each laboratory is likely to obtain slightly different retention times and relative abundance of individual components, depending on sample history, separation procedure, and chromatographic conditions.

FIG. 7 Example of Light Isoparaffinic Product; Aviation Gas

10.2.1.6 **Warning—**The mere presence of alkylbenzenes does not justify an identification of gasoline. These compounds shall be present at approximately the same relative concentrations as are observed in samples of known gasoline. Many carpet samples that have been exposed to fire conditions contain these compounds in some concentrations. Benzene, toluene, ethylbenzene, xylenes, cumenes, ethyltoluenes, and naphthalenes, which are present in gasoline, are also sometimes found in fire debris samples containing no foreign ignitable liquid residues. The presence of high levels of alkenes and oxygenates may indicate significant pyrolysis of the matrix and should make the recovery suspect. The presence of high levels of aromatics without the appropriate levels of alkanes may indicate an aromatic product.



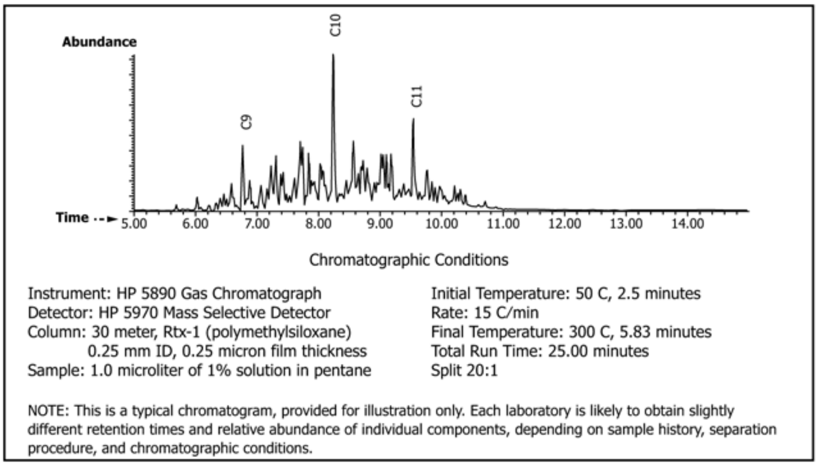
Chromatographic Conditions

Instrument: HP 5890 Gas Chromatograph
Detector: HP 5970 Mass Selective Detector
Column: 30 meter, Rtx-1 (polymethylsiloxane)
0.25 mm ID, 0.25 micron film thickness
Sample: 1.0 microliter of 1% solution in pentane

Initial Temperature: 50 C, 2.5 minutes
Rate: 15 C/min
Final Temperature: 300 C, 5.83 minutes
Total Run Time: 25.00 minutes
Split 20:1

NOTE: This is a typical chromatogram, provided for illustration only. Each laboratory is likely to obtain slightly different retention times and relative abundance of individual components, depending on sample history, separation procedure, and chromatographic conditions.

FIG. 8 Example of Medium Isoparaffinic Product; Charcoal Starter



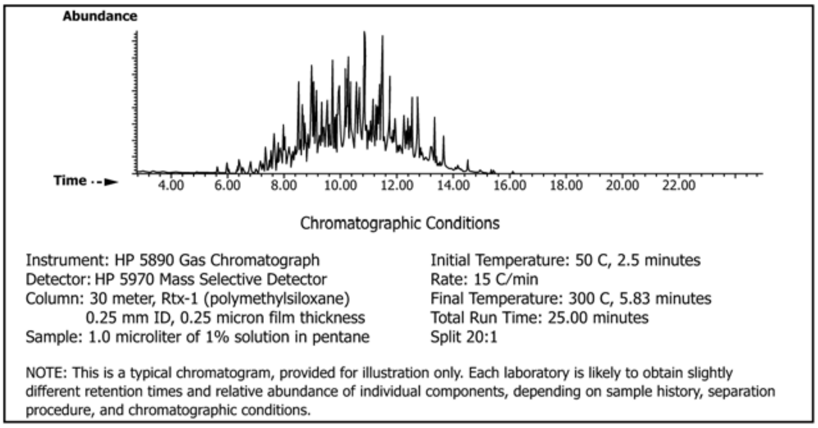
Chromatographic Conditions

Instrument: HP 5890 Gas Chromatograph
Detector: HP 5970 Mass Selective Detector
Column: 30 meter, Rtx-1 (polymethylsiloxane)
0.25 mm ID, 0.25 micron film thickness
Sample: 1.0 microliter of 1% solution in pentane

Initial Temperature: 50 C, 2.5 minutes
Rate: 15 C/min
Final Temperature: 300 C, 5.83 minutes
Total Run Time: 25.00 minutes
Split 20:1

NOTE: This is a typical chromatogram, provided for illustration only. Each laboratory is likely to obtain slightly different retention times and relative abundance of individual components, depending on sample history, separation procedure, and chromatographic conditions.

FIG. 9 Example of Medium De-aromatized Distillate; Odorless Paint Thinner



Chromatographic Conditions

Instrument: HP 5890 Gas Chromatograph
Detector: HP 5970 Mass Selective Detector
Column: 30 meter, Rtx-1 (polymethylsiloxane)
0.25 mm ID, 0.25 micron film thickness
Sample: 1.0 microliter of 1% solution in pentane

Initial Temperature: 50 C, 2.5 minutes
Rate: 15 C/min
Final Temperature: 300 C, 5.83 minutes
Total Run Time: 25.00 minutes
Split 20:1

NOTE: This is a typical chromatogram, provided for illustration only. Each laboratory is likely to obtain slightly different retention times and relative abundance of individual components, depending on sample history, separation procedure, and chromatographic conditions.

FIG. 10 Example of a Heavy Naphthenic Paraffinic Product; Lamp Oil

10.2.2 *Criteria for the Identification of Distillates:*

10.2.2.1 *General*—Traditional distillates and de-aromatized distillates; Predominant pattern associated with a homologous series of *n*-alkanes in a Gaussian distribution of peaks. Light distillates may not exhibit a recognizable pattern and may contain only one or two of the *n*-alkanes.

10.2.2.2 *Alkanes*—Abundant. Predominant normal alkanes present with isoparaffinic compounds present.

10.2.2.3 *Cycoloalkanes*—Present, less abundant than alkanes. Pattern varies by boiling range and peak spread.

10.2.2.4 *Aromatics*—Always present in traditional medium and heavy distillates; less abundant than alkanes; pattern and abundance varies by boiling range and peak spread; may be present in light distillates. In some products, the aromatic composition may be significantly reduced or completely absent (de-aromatized).

10.2.2.5 *Condensed Ring Aromatics*—May be present based on boiling range and peak spread.

10.2.3 *Criteria for the Identification of Isoparaffinic Products:*

10.2.3.1 *General*—Product comprised almost exclusively of branched chain aliphatic compounds (isoparaffins). The boiling range and pattern are dependent on the specific formulation.

10.2.3.2 *Alkanes*—Abundant. Pattern comparable to known isoparaffinic formulation. Characteristic isoparaffin product patterns present with no or insignificant levels of *n*-alkanes. The boiling range and component pattern are dependent on the specific formulation.

10.2.3.3 *Aromatics*—Absent, or not present in significant concentrations.

10.2.3.4 *Cycloalkanes*—Absent, or not present in significant concentrations. Note: Ions indicative of cycloparaffins are also present in smaller amounts in isoparaffinic compounds. "Cycloalkane" pattern representing isoparaffins maybe be present, but significantly less abundant than the alkane pattern.

10.2.3.5 *Condensed Ring Aromatics*—Not present.

10.2.4 *Criteria for the Identification of Aromatic Products:*

10.2.4.1 *General*—Products comprised almost exclusively of aromatic or condensed ring aromatic compounds, or both. The boiling range and pattern are dependent on the specific formulation.

10.2.4.2 *Alkanes*—Not present in significant amounts.

10.2.4.3 *Cycloalkanes*—Not present in significant amounts.

10.2.4.4 *Aromatics*—Abundant. Pattern comparable to known aromatic products. Pattern depends on formulation.

10.2.4.5 *Condensed Ring Aromatics*—May be present, pattern depends on formulation. Pattern comparable to known aromatic product.

NOTE 1—Light aromatic products may consist of single or few components. These compounds shall be identified by both GC retention time and mass spectral identification.

10.2.4.6 **Warning—**The relative intragroup ratios of the isomers of xylenes and C_3-alkylbenzenes do not vary significantly among petroleum products. Therefore, the relative ratios of these compounds should match, or nearly match, the ratios found in petroleum products, if they are to be reported. Further, in the presence of styrene at a concentration significantly higher than that of toluene or xylenes, the finding of toluene or xylenes should not be considered significant.

10.2.5 *Criteria for the Identification of Naphthenic-Paraffinic Products:*

10.2.5.1 *General*—Products comprised mainly of branched chain (isoparaffinic) and cyclic (naphthenic) alkanes. The boiling range and pattern are dependent on the specific formulation.

10.2.5.2 *Alkanes*—Abundant. Branched alkanes present while normal alkanes may be notably absent or at diminished levels compared to distillate products. Pattern comparable to known naphthenic-paraffinic products.

10.2.5.3 *Cycloalkanes*—Abundant. Pattern comparable to known naphthenic-paraffinic products.

10.2.5.4 *Aromatics*—Not present in significant amounts.

10.2.5.5 *Condensed Ring Aromatics*—Not present in significant amounts.

10.2.6 *Criteria for the Identification of Normal Alkane Products:*

10.2.6.1 *General*—Products comprised exclusively of *n*-alkanes. The boiling range and pattern are dependent on the specific formulation.

10.2.6.2 *Alkanes*—Normal alkane product pattern present with no isoparaffins or only minor levels of isoparaffins. The boiling range and pattern are dependent on the specific formulation.

10.2.6.3 *Cycloalkanes*—Not present in significant amounts.

10.2.6.4 *Aromatics*—Not present in significant amounts.

10.2.6.5 *Condensed Ring Aromatics*—Not present in significant amounts.

NOTE 2—All major chromatographic peaks for this class shall be identified by both GC retention times and mass spectral characteristics.

10.2.7 *Criteria for the Identification of Oxygenated Solvents:*

10.2.7.1 *General*—Products containing major oxygenated components may include mixtures of oxygenated compounds and other compounds or products. Major oxygenated compounds typically present before C8; major compound(s) may include alcohols, esters, and ketones. Other major compounds including toluene, xylene, and distillate formulations may also be present.

10.2.7.2 *Alkanes*—If in a mixture, may contain characteristic petroleum distillate pattern; pattern depends on formulation.

10.2.7.3 *Cycloalkanes*—Pattern depends on formulation.

10.2.7.4 *Aromatics*—Pattern depends on formulation.

10.2.7.5 *Condensed Ring Aromatics*—Not significant.

NOTE 3—All major oxygenated compounds shall be identified by GC retention times and mass spectral characteristics.

10.2.7.6 **Warning—**The mere presence of oxygenated solvents such as alcohols or acetone does not necessarily indicate that a foreign ignitable liquid is present in the sample. There should be a large excess of the compound (at least one order of magnitude above the matrix peaks in the chromatogram) before the analyst should consider the finding of an oxygenated product significant.

10.2.8 *Miscellaneous/Other*—No classification system is likely to describe all possible ignitable liquids. There are numerous commercial and industrial products which are ignitable but which fall into more than one category or do not fall into any of the above categories other than miscellaneous. Many of these are synthetic mixtures consisting of only a few compounds, rather than distillation fractions; GC retention times and mass spectra of the components are required in order to achieve identification.

11. Interpretation of Results

11.1 Pattern matching of extracted ion profiles or target compound chromatograms rarely gives perfect correlation with reference ignitable liquids. In general, the unknown pattern (if positive) will be skewed towards less volatile compounds for weathered samples or skewed towards more volatile compounds for incompletely recovered samples. Compounds may be missing from either the light end, the heavy end, or both.

Under certain conditions, selective loss of classes of compounds may result from microbiological degradation. Compounds may also be added to the pattern when the pyrolysis or combustion of materials at the fire scene yields target compounds or compounds of the same type as those being compared. All of these circumstances shall be taken into account by the analyst during visual pattern evaluation. Therefore, it is imperative that the analyst has a sufficient library of reference ignitable liquids, in successive stages of evaporation. A library of extracts from common substrate materials containing no foreign ignitable liquids should also be maintained.

11.2 *Interferences:*

11.2.1 *Extraneous Components*—Burned material from which the sample has been extracted usually contributes extraneous components to extract. The amount and type of pyrolysis and combustion products formed during a fire depend on the substrate material and its fire history. They can consist of oxygenated compounds, paraffinic, cycloparaffinic, aromatic, or condensed ring aromatic hydrocarbons, all of which will appear in the extracted ion profiles. Only those pyrolysis products that are themselves target compounds listed in Tables 3-5 will appear on the target compound chromatograms. The presence of these extraneous product components is acceptable when sufficient ignitable liquid product compounds remain to allow proper classification of the sample. When the pattern becomes overwhelmed by extraneous components, identification is not possible by this method.

11.2.2 Extracts that meet the criteria for heavy petroleum distillates should be reviewed carefully for "extraneous components" that elute near *n*-alkanes and are the result of polyolefin or high molecular weight hydrocarbon (asphalt) decomposition. Peaks representing the corresponding 1-alkene or 1, (*n*-1) diene, and having an abundance near the concentration (within one-half an order of magnitude when viewed in the alkene profile) of the alkane, should be considered as indicating the presence of polyolefin or asphalt decomposition products rather than fuel oil products. Polyolefin decomposition products typically do not exhibit the same pattern of branched alkanes as fuel oils.

11.3 *Missing Components*—Exposure of the ignitable liquid to heat usually results in the preferential loss of lighter components, thereby enhancing the chromatographic pattern at the heavy end. Some sample preparation techniques may result in the preferential recovery of either the lighter or heavier components, resulting in the "loss" in the opposite end. Neither of these factors will cause the selective loss of intermediate components. The unexplainable absence of components from the middle of a pattern is generally sufficient grounds for a negative finding. Possible explanations for missing intermediate compounds include low sample concentration (compound below detection limit), compound did not meet target compound identification criteria (due to distortion of mass spectrum by co-eluting extraneous compound), and, in rare cases, selective loss due to digestion by microbes. Any such explanation for loss of compounds in the middle of a pattern shall be scientifically supportable, and efforts should be made, if possible, to retrieve evidence of their existence from the data file or by reanalyzing the sample.

11.4 The presence of small quantities of some components common to a particular class of ignitable liquid product does not necessarily indicate the presence of that liquid in the debris at the time of the fire.

11.4.1 For example, the pyrolyzates of some polymers may include toluene and xylenes. The pyrolyzates of polyolefin plastic may include a homologous series of normal alkanes.

11.5 Certain ignitable liquid components may be found in some substrates common to fire scenes.

11.5.1 Examples include: normal alkane products found in linoleum and in carbonless paper forms; distillates found in some printed materials; and solvents used in some adhesives and coatings.

11.5.2 If there is suspicion that an ignitable liquid found might be indigenous to the substrate, the testing of an appropriate comparison sample, if available, may aid in determining whether an ignitable liquid is foreign to the substrate.

12. Report

12.1 This test method does not require a specific format for a forensic laboratory report for fire debris samples, but does indicate what specific information to include in a report.

12.1.1 Regardless of the format, a report shall include the following information:

(1) Unique case reference number.
(2) Identity of the laboratory issuing the report and the report date.
(3) Submitting agency's (requestor's) information.
(4) Date of submission to the laboratory.
(5) Itemized list of the submitted items.
(6) Description of the separation/extraction technique(s) employed.
(7) Description of the analytical technique(s) employed.
(8) Conclusion stating the result(s) of the laboratory examination(s).
(9) Name and signature of the individual(s) responsible for the analysis.

12.1.2 A report may include the following information:

(1) Statement of the analysis performed.
(2) Incident summary.
(3) Manner of submission to the laboratory.
(4) Disposition of the submitted items.
(5) Qualifying statements.
(6) Additional information or remarks.

NOTE 4—A sample report is provided as Annex A2.

12.2 *Criteria for Report Contents:*

12.2.1 *Unique Case Reference Number*—The report shall contain a case identifying number, such as a laboratory case number or agency case file number, which is unique to the submitted items.

12.2.1.1 In a report that contains multiple submissions (multiple case reference numbers), items shall be referenced by their item number and unique case reference number.

12.2.2 *Identity of the Laboratory Issuing the Report and the Report Date*—The report shall contain the name of the laboratory responsible for issuing the report and the date of the report. The report may also include the address and phone number of the issuing laboratory. The information may appear in the letterhead.

12.2.3 *Submitting Agency's (or Requestor's) Information*—The report shall contain the submitting agency's (or requestor's) name and may also include the agency's (or requestor's) case identifier, address, and investigator information.

12.2.4 *Date of Submission to the Laboratory*—The report shall contain the date the evidence was received by the laboratory.

12.2.5 *Itemized List of the Submitted Items*—The report shall include an itemized list describing the items received.

12.2.5.1 Each item shall be uniquely identified and include a brief description of the container type and its contents.

12.2.5.2 Each item shall be described as observed by the analyst, not simply as it appears on container labels or within the submitting paperwork.

12.2.5.3 The report shall describe the contents of each container as observed by the analyst or as the contents would appear to the court. Some contents may be unrecognizable and described in only general terms. For example: broken glass and burned carpet, clear yellow liquid, or charred unidentified debris.

12.2.5.4 The item description may reflect information based upon the submitter's description but shall be qualified by adding a statement such as "reported as" or "labeled as." The analyst's personal observations and descriptions of the evidence shall be easily distinguishable from the submitter's information, such as using quotation marks to identify the submitter's remarks.

12.2.6 *Description of the Separation/Extraction and Analytical Techniques Employed*—The report shall contain a brief description of the separation, extraction, concentration, and analytical techniques used. The appropriate ASTM standard(s) may be cited in lieu of a description.

12.2.7 *Conclusion Stating the Result(s) of the Laboratory Examination(s)*—The report shall contain a conclusion which clearly states the result(s) of the examination(s) in terms understandable to an investigator or lay person.

12.2.7.1 The results/conclusions section shall state the analyst's opinion as to whether or not an ignitable liquid or residue was identified/classified in the sample and the identity/classification of the liquid/residue.

12.2.7.2 A single results/conclusions section of the report may serve as the opinion in the report. A separate opinion section may appear in a report; however, restating the results in an opinion section is not necessary.

12.2.7.3 There is no universally accepted set of terms used in fire debris analysis conclusions. The results shall be scientifically accurate and convey the proper significance of the conclusions. Refer to Section 12.3 for acceptable terminology and phrases used in results/conclusions.

12.2.8 *Name and Signature of the Individual(s) Responsible for the Analysis*—The report shall contain the name and signature of the individual(s) responsible for the results, conclusions, or opinions within the report. The signature(s) may be electronic.

12.2.8.1 The signature(s) of the technical reviewer(s) may also appear on the report.

12.2.9 Reports may include the following:

12.2.9.1 *Statement of the Analysis Performed*—The report may include a statement or title reflecting the type of analysis conducted as per the request of the submitting agency or contributor. For example: Fire Debris Analysis Report, Chemical Analysis Report, Ignitable Liquid Tests, or Results of Fire Debris Analysis.

12.2.9.2 *Incident Summary*—Information such as date, location, victim(s), or subject(s) may be included to identify or associate the submitted items to an incident.

12.2.9.3 *Manner of Submission to the Laboratory*—The report may contain the method of delivery, such as personal delivery or registered mail.

12.2.9.4 *Disposition of the Submitted Items*—The report may contain the disposition of the submitted items. Examples of disposition are: returned to contributor, preserved, destroyed, and destroyed in 30 days unless otherwise notified.

12.2.9.5 *Qualifying Statements*—The laboratory/author may include an appropriate note, qualifier, or disclaimer in the report, examples of which appear in Section 12.3.

12.2.9.6 *Additional Information*—Remarks, special instructions, requests, or additional information may appear within a remarks section of the report. Example comments include: references to commercial products, requests for comparison samples, additional testing that may or can be performed upon receipt of additional items, and the description of secondary evidence.

12.2.9.7 Requested examinations by the submitting agency (requestor) that were not conducted may be noted with a reason for not performing the examination.

12.3 *Terminology Used in Reporting Results/Conclusions and Opinions*—There are many appropriate phrases and words that may be used to describe the results and conclusions of a fire debris or ignitable liquid analysis. The analyst has many options in reporting a positive or negative finding of an ignitable liquid or residue.

12.3.1 *Reporting Positive Results of an Ignitable Liquid or Residue:*

12.3.1.1 Some possible phrases include: was present in, was detected on, was identified in, was recovered from, and was found in. The meaning of all these phrases are interchangeable and represent a positive result or identification/classification of an ignitable liquid or ignitable liquid residue using the methods described in Sections 9, 10, and 11.

NOTE 5—Regardless of the choice of phrases used, there is no implied difference in the perceived level of confidence for a positive result.

12.3.1.2 The reporting of a positive result does not preclude the contribution of ignitable liquids from the matrix of other material present in the debris. In general, the source of the ignitable liquid cannot be determined and therefore shall not be stated. It may be appropriate to add a qualifying statement to the report finding. Refer to 12.3.6.

12.3.1.3 The results section may list examples of commercial products or substrates, or both, that might contain the ignitable liquid identified. Examples of positive results are:

> A medium petroleum distillate (MPD) was detected in Item #1. Examples of commercial products that contain MPDs include some charcoal lighters and paint thinners.
>
> Gasoline was identified on Item #2.

12.3.2 *Report Terminology Using the Ignitable Liquid Classification Scheme (Table 1):*

12.3.2.1 *Gasoline* is a distinct class of ignitable liquid and shall be named as such in the report.

12.3.2.2 *Petroleum Distillates*—These products are distilled from petroleum (crude oil) and are consequently named petroleum distillates. They are further characterized by their *n* -alkane range. Table 1 classifies distillates into light, medium, and heavy distillates based upon their n-alkane range. Some distillates may not fit clearly into a single category, so it may be necessary to describe the ignitable liquid as "light to medium," "medium to heavy," or simply state the *n* -alkane range of the material.

(1) The report may list examples of commercial products or substrates that may contain such liquids. For example:

> A heavy petroleum distillate (HPD) was recovered from Item #22. Examples of HPDs include kerosene, diesel fuel, and some charcoal starters.
>
> A medium petroleum distillate in the range of C10 to C13 was detected in Item #4. Examples of this distillate include some paint thinners and some specialty solvents. Medium petroleum distillates are also found in some shoe polish, wood staining products, insecticides, and automotive cleaner products.

12.3.2.3 *Other Ignitable Liquids*—Commercial products can be variations of petroleum products or derived from non-petroleum sources. These include: isoparaffinic products, aromatic products, naphthenic-paraffinic products, *n*-alkane products, oxygenated products, and miscellaneous products.

(1) These products may also be reported by assigning an *n*-alkane range, or may be classified as light, medium, or heavy. For example:

> A medium isoparaffinic product like that found in some lamp oils or toner solvents was present on Item #7.

12.3.2.4 *Single Compounds or Simple Mixtures*—Some commercial products contain a single compound or mixture of a few compounds. These ignitable liquids shall be reported based upon identification of the compounds rather than classification. For example:

> Isopropyl alcohol and methyl alcohol were identified in Item #7 (plastic bottle of clear liquid).

12.3.2.5 *Terminology for Residues of Ignitable Liquids*—In many cases components of an ignitable liquid may be reduced or lost due to evaporation or other environmental condition, such as microbial degradation. The terms "residue," "weathered," or "evaporated" may be used to refer to recovered products. However, do not use a term such as "fire-aged" as it implies that fire was the only reason for the recovered condition of the ignitable liquid.

12.3.3 *Special Materials and Matrices:*

12.3.3.1 Debris and matrices of the submitted items sent in for fire debris analysis may contain ignitable liquids. Some commercial products that are ignitable liquids, such as turpentine, toluene, polish removers, rubbing alcohol, and some cleaning solvents are also common to items submitted for analysis, such as wood (terpenes), shoes (toluene), and clothing (alcohols).

12.3.3.2 The analyst shall use caution and not report positive results if the submitted items may contain a matrix which is known to contain an ignitable liquid of the type detected. If the laboratory elects to report matrix compounds, such as terpenes in wood and alcohols in clothing, the report shall reflect the nature of the ignitable liquid. Examples of report conclusions for items with matrices that contain known ignitable liquids include:

> No ignitable liquids were detected on Items #7 and #8 (sneakers) other than compounds associated with the items.
>
> Toluene was identified on Items #3 and #4 (sneakers). Toluene is found in glue commonly used in the manufacturing of shoes.
>
> No ignitable liquids were detected on Item #11 (pine studs) except for terpenes which are common to softwoods.

12.3.4 *Reporting Negative Findings of an Ignitable Liquid:*

12.3.4.1 Several phrases may be used when no ignitable liquid was identified on an item. The word "detected" could be used to describe no response great enough to be identified by gas chromatography-mass spectrometry, while the word "identified" may be used when compounds are detected but are not associated with an ignitable liquid and most likely correspond to interfering products. Examples include:

> No ignitable liquids were detected in Item #18.
>
> No ignitable liquids were identified on Item #6.

12.3.4.2 The use of the phrase "No ignitable liquids were present" is not recommended as an ignitable liquid may be present below the detectable limits of the method.

12.3.4.3 For clarification purposes, the analyst may elect to report to the submitter that something other than an ignitable liquid was detected or identified. For example:

> The analysis identified volatile compounds consistent with the interfering products associated with a variety of synthetic materials. These compounds may be responsible for the positive alert on the investigator's monitoring equipment at the scene.

12.3.5 *Misleading Terminology:*

12.3.5.1 Certain words shall not appear without explanation within the report. All extracts from organic materials are likely to contain "hydrocarbons." The word "hydrocarbon" shall not appear in a report unless those hydrocarbons can be specifically identified and classified. The phrase "hydrocarbons from an unknown source" is expressly prohibited. Similarly, words such as "consistent with," "in the boiling range of," "similar to," or "characteristic of" a particular ignitable liquid shall not be used unless that liquid has been positively identified and classified using the methods described in Sections 9, 10, and 11. Examples of misleading terminology include:

> Item #22 contained hydrocarbons in the range of gasoline.
>
> Hydrocarbons from an unknown source were detected in Item #12.
>
> Flammable compounds were present on Item #6.
>
> Some components consistent with gasoline were identified on Item #9.

12.3.5.2 Common interfering compounds resulting from pyrolysis, combustion, or distillation of a substrate at the fire scene are not normally reported except when a significant quantity of an unexplainable product is detected.

12.3.5.3 The analyst cannot determine the source or intended use of an ignitable liquid residue. For this reason, residues shall not be characterized as "accelerants" by the analyst.

12.3.6 *Qualifying Statements:*

12.3.6.1 A finding of either a positive or negative result/conclusion shall be scientifically accurate and supported by the analytical data. Positive and negative results often cannot be reported in simple terms because of the presence of matrix and interfering compounds. The analyst may use qualifiers or disclaimers to convey the proper significance of both positive and negative results.

12.3.6.2 Qualifying statements shall be used when necessary and not routinely.

12.3.6.3 Examples of qualifying statements that may be used with positive findings when the matrix cannot be ruled out as a contributor of an ignitable liquid:

> The identification of an ignitable liquid residue in a fire scene does not necessarily lead to the conclusion that a fire was incendiary in nature. Further investigation may reveal a legitimate reason for the presence of ignitable liquid residues.

(1) If the analyst or laboratory elects to report a positive ignitable liquid finding of a known matrix component, a qualifying statement shall be used. For example:

> A medium isoparaffinic product like that found in some lamp oils or toner solvents was present on Item #7.Toluene was identified on Item #5 (tennis shoes). Toluene is an ignitable liquid but is a component of some glues used in the manufacturing of shoes.
>
> Terpenes were identified in Item #8 (charred wood and debris). Terpenes are a natural component in some softwoods and are also found in turpentine solvents and pine-based cleaners.

12.3.6.4 An example of a qualifying statement that may be used with negative findings:

> The absence of an ignitable liquid residue does not preclude the possibility that ignitable liquids were present at the fire scene. Ignitable liquids are volatile compounds that may have evaporated, been totally consumed in a fire, environmentally altered or removed, or otherwise indistinguishable from background materials.

(1) A qualifying statement shall only include remarks appropriate for the specimen(s) analyzed. For example, if an item was not burned or involved in a fire, the qualifying statement shall not reference having "been totally consumed in a fire."

12.3.7 *Additional Remarks:*

12.3.7.1 Additional information may be included in a report for further clarification. For example, if a distinctive set of compounds were identified in a sample, the following additional investigative information could be given:

> Examples of commercial products that contain methyl alcohol, acetone, toluene, and methylene chloride include some paint and varnish removers.
>
> The ignitable liquid and components identified in Item #2 are consistent with the ingredients found in "John Smith's Oven Cleaner" or similar product.

12.3.7.2 Other information or comments that may appear in the remarks section include contact information of the analyst (phone number), websites and references to product information, additional testing, testing that could not be conducted, and damage to the submitted items during shipment/delivery. Examples include:

> The liquid in Item #6 (bottle) contained a mixture of gasoline and a medium petroleum distillate. The request to determine the flashpoint of the liquid was not conducted as this laboratory does not have the required equipment to conduct the requested test.
>
> Items #1 through #5 were not examined for the presence of ignitable liquids because they were improperly packaged. Samples from fire scenes to be tested for ignitable liquids should be packaged in metal paint cans, heat-sealable arson bags, or glass jars.
>
> Item #3 was not examined as the glass container was broken upon receipt by the laboratory.

13. Precision and Bias

13.1 Since this is a qualitative test method, the terms precision and bias do not apply.

14. Keywords

14.1 fire debris samples; forensic sciences; gas chromatography; ignitable liquid residues; mass spectrometry

ANNEXES

(Mandatory Information)

A1. SAMPLE AND EXTRACT STORAGE

A1.1 After extraction, store the original sample using appropriate procedures for handling and documentation.

A1.1.1 *Extract Storage Short-Term*—Extracts, liquid samples, or solvents may be stored in septum seal or screw cap glass vials with PTFE-lined seals to prevent evaporation.

A1.1.2 *Extract Storage Long-Term*—Follow the procedures set forth in Practice E2451 for long-term storage of extracts or liquid samples.

A2. SAMPLE LABORATORY REPORT

A2.1 See Table A2.1.

TABLE A2.1 Sample Laboratory Report

[Laboratory Name and address if not already in a letterhead]
[Laboratory or Case file number]
[Date of report]

[Report recipient]
[Agency or Requestor]
[Address]
[City, State, Zip]

Subject (Incident Summary)
[Case Identifier]
[Fire Date]
[Fire Location]
Analysis of Fire Evidence

Background
The following items were received on [Date received] via [method of delivery].

Item 1. [Size of container] [description of container, that is, can, jar, bag] containing [description of material, *that is, charred wood, burned carpet, debris, etc. as determined by the individual who analyzed the sample*] labeled as "removed from [Post-fire location of the sample as *described by the person who collected the sample.*]"

(Example: one-gallon can containing burned carpet labeled as "removed from the master bedroom.")

Continue to describe additional samples.

[Agency/*Laboratory Name*] was requested to analyze the samples to check for the presence of ignitable liquid residues.

Test Methods and Results
The sample was (samples were) separated according to [describe separation procedure(s) or cite ASTM method(s), for example, Practices E1386 – yy, E1412 – yy, E2154 – yy], and analyzed by [describe analytical procedure(s) or cite ASTM method(s), for example, Test Method E1618 – yy].

For a Positive Sample:
Gas chromatography-mass spectrometry (GC-MS) of [a solvent extract, or concentrated headspace vapors] from the sample detected [identify the class of materials identified] (*optional*) having a carbon number range of [C_X through C_Y.]

Examples of ignitable liquids in this class include [provide examples of the class of materials.]

For a Negative Sample:
Gas chromatography-mass spectrometry (GC-MS) of [a solvent extract, or concentrated headspace vapors] from the sample failed to detect any ignitable liquid residues.

Qualifying Statements

Conclusion
[Ignitable liquid residue] was detected in item(s) [ ].

Evidence Disposition
The sample has (samples have) [been returned to the submitting agency, via method of delivery] [been placed in the laboratory storage facility].

Prepared by [signature and printed name of the individual who is responsible for the analysis].

(*optional*) Reviewed by [*signature and printed name of the individual who reviewed the analysis*].