

Benchmark Environmental Corp.



Bruce D. Marron
Environmental Chemist

4501 Indian School Road N.E., Suite 105 (505)262-2694
Albuquerque, New Mexico 87110 FAX (505)262-2698

April 9, 1993

Project No. 5007.01
Subcontract No. C90-132787
Document No. L-4144

Ms. Berta Oates
EG&G Idaho, Inc.
Materials Chemistry
P.O. Box 1625
Idaho Falls, ID 83415-4107

**Transmittal, Final Standard Operating Procedure for Flammability Testing
of Vapor Phase Mixtures of Volatile Organic Compounds from Neat Liquids**

Dear Berta:

Enclosed are two hardcopies and one diskette copy of the final standard operating procedure (SOP), "Flammability Testing of Vapor Phase Mixtures of Volatile Organic Compounds from Neat Liquids." The final SOP reflects the new EG&G Idaho, Inc. format and incorporates all comments received on the draft version. The discussion below provides response to the questions posed in your March 19, 1993 letter.

We examined the potential for chemical incompatibility in Binary Mixtures 8 and 11 and found that neither mixture will undergo spontaneous reaction under the conditions of the flammability test. The material safety data sheet (MSDS) listing of incompatibility for Binary Mixture 8 is based on the reaction of acetone with chloroform (nucleophilic addition of a carbanion in the presence of base). Even in the presence of base it is unlikely that methyl chloroform will undergo the reaction. The MSDS incompatibility listing for Binary Mixture 11 is based on methanol's ability to enhance the basic hydrolysis of alkyl halides through solvation. The use of neat compounds in microliter quantities and the lack of base ensure that neither mixture will react spontaneously.

The vacuum inspection requirement given in Method 810.1 (30 ± 1.5 torr for five minutes) also applies to this SOP - the requirement was incorrectly stated in the draft SOP.

Coward and Jones (1952) indicate that ordinary variations in laboratory pressure and temperature have no effect on limits of flammability. Thus, a temperature differential of $\pm 5^\circ\text{C}$ and a pressure differential of ± 100 torr (typical laboratory fluctuations in temperature and pressure) should not adversely affect the flammability limits of the vapors tested with this SOP.

Recalibration of both temperature and pressure measuring systems should be performed with the same frequency as initial calibration of the flame test apparatus; namely, after each set of binary, ternary, or quaternary mixtures is tested or after 20 tests, whichever comes first.

Ms. Berta Oates

Page 2

April 9, 1993

We concur with the proposed preliminary testing program as outlined. If you have any questions or if we can be of further assistance in this matter, please call either one of us.

Sincerely,



Karen Knudsen
Project Manager



Bruce Marron
Task Manager

Encl.

cc: Mike Connolly, EG&G, Idaho (w/Enclosure)
Allen Johnson, EG&G, Idaho (w/Enclosure)
Heidi Johnson, EG&G, Idaho (w/o Enclosure)
Central Files, Albuquerque

EG&G Idaho, Inc.
Analytical Chemistry Unit
Environmental Chemistry Lab
Standard Operating Procedure

Title: FLAMMABILITY TESTING OF VAPOR MIXTURES
ECL SOP No.: OH 2.2
Effective Date:
Revision No.:
Page 1 of 16

Standard Operating Procedure
for

**FLAMMABILITY TESTING OF VAPOR PHASE MIXTURES OF
VOLATILE ORGANIC COMPOUNDS FROM NEAT LIQUIDS**

Applicable Method: Procedure 810.1, Rev. 1, WIPP Waste Characterization Program Sampling and Analysis Guidance Manual

Note: This Standard Operating Procedure has been prepared for the sole use of the Analytical Chemistry Unit's Environmental Laboratory, EG&G Idaho, Inc. and may not be specifically applicable to the activities of other organizations.

Approved by: _____
David L. Miller, Analytical Chemistry Unit Manager

Reviewed by: _____
Joseph T. Bennett, Ph.D., ECL Technical Leader

Reviewed by: _____
Shelly J. Sailer, ECL Quality Assurance Officer

Reviewed by: _____
Safety and Health

Reviewed by: _____
ERA CFA Environmental Coordinator

Reviewed by: _____
Berta E. Oates, Process Owner

STANDARD OPERATING PROCEDURE

1.0 METHOD SCOPE AND APPLICATION

This standard operating procedure (SOP) provides the necessary instructions to evaluate the flammability of vapor mixtures of volatile organic compounds (VOCs) generated from neat liquids. The evaluation is qualitative and is not designed to obtain quantitative estimates of either upper explosive limit (UEL) values or lower explosive limit (LEL) values. Figure 1 diagrams the specialized flame test apparatus required by this SOP.

The use of this SOP is required when evaluating the vapor mixtures that are part of the Phase I and Phase II experiments sponsored by Idaho National Engineering Laboratory (INEL). These experiments support the U.S. Department of Energy's (DOE's) intent to modify its approach to the determination of the flammability of VOCs in headspace samples. This SOP is based on Procedure 810.1, *Modified ASTM Method E 681-85 for the Evaluation of the Flammability of Waste Container Headspace Using SUMMA® Passivated Canister Sampling* (DOE, 1991).

2.0 METHOD SUMMARY

The flame test apparatus and all connecting lines are flushed with air and then evacuated. Neat compounds are injected into the sample introduction tube with a syringe through a septum. After injection into the tube, the neat compounds are drawn by vacuum into the 5-liter test vessel. Safety precautions are taken and, after the compounds have vaporized and the test apparatus has equilibrated, a spark is delivered to the mixture. If the mixture propagates a flame upward and outward from the ignition source the mixture is considered flammable. If no flame is propagated, the mixture is considered nonflammable.

3.0 DEFINITIONS

- 3.1 Explosive Limit: The concentration range of a flammable gas or vapor in which explosion can occur upon ignition in a confined area. The concentration range is defined by lower and upper explosive limits.
 - 3.1.1 Lower Explosive Limit (LEL): The minimum concentration of a combustible gas or vapor that is capable of propagating a flame on contact with a source of ignition. LEL is synonymous with the lower limit of flammability (LLF).
 - 3.1.2 Upper Explosive Limit (UEL): The maximum concentration of a combustible gas or vapor that is capable of propagating a flame on contact with a source of ignition. UEL is synonymous with the upper limit of flammability (ULF).
- 3.2 Flame Test: The procedure specified for the Waste Isolation Pilot Plant (WIPP) Experimental Test Program for determining the flammability of headspace samples containing concentrations of flammable VOCs greater than 500 ppmv.
- 3.3 Flammable Mixture: (1) A binary mixture with concentrations of hydrogen and methane exceeding 50 percent of the theoretical LEL, or (2) a mixture of flammable VOCs in air that propagates a flame during a flame test.
- 3.4 Flammable VOC: A VOC identified as noncombustible or considered, by EPA, not to be a significant fire hazard under WIPP repository conditions (See Table 1).

- 3.5 Propagation of Flame: As used in this SOP, the upward and outward movement of a flame front from the ignition source to the walls of the flame test vessel. The propagation of flame is determined by visual observation.
- 3.6 SUMMA® Canister: A stainless steel pressure vessel with SUMMA® passivated interior surfaces for the collection and storage of gas samples. The SUMMA® passivation process involves the formation of chromium-nickel oxide on the interior surface of the canister. This type of canister is used for sample storage stability of many specific organic compounds.

4.0 INTERFERENCES

- 4.1 Flame quenching effects of the test vessel walls are mitigated by the diameter of the flame test vessel used. The 5-liter flame test vessel used in this procedure has a sufficient diameter to eliminate the effects of flame quenching for most materials.
- 4.2 The slightest vacuum leak can invalidate the test results. Prior to each flammability determination, the flame test apparatus and all connecting lines must pass a vacuum inspection. The apparatus must be capable of maintaining a vacuum of 30 ± 1.5 torr for five minutes.
- 4.3 The neat compounds used as standards and in experimental mixtures may condense before reaching the test vessel. Applying a gentle heat source to the connections above the test vessel during pressurization will ensure quantitative transfer of all neat compound material.
- 4.4 Normal variations in atmospheric pressure do not appreciably affect flammability limits. However, the effect of large pressure variations is neither simple nor uniform but is specific to each flammable mixture (Coward and Jones, 1952). Flammability testing must be conducted at a pressure not less than 400 torr and not more than 760 torr. All calibrations and subsequent sample evaluations must be performed at the same final pressure.

5.0 SAFETY PRECAUTIONS

- 5.1 Avoid direct skin contact of neat compounds and inhalation of any mixture vapors. Some compounds are carcinogens or suspect carcinogens (as noted by an asterisk in Table 1) and their handling requires the use of gloves.
- 5.2 The flame test apparatus should never be operated outside of a fully-operational fume hood.
- 5.3 Ensure that all electrical components (including the magnetic stirrer) are turned off, all vacuum and sample transfer lines are closed, all shielding is in place, and the fume hood door is closed prior to activating the ignition source. Failure to do so could endanger the analyst or damage equipment and circuitry.

5.4 Safety Precautions

Based on a completed S&T Hazard Analysis (Exhibit 1), the potential safety, health, and environmental hazards for the activity described by this SOP result in a Hazard

Measure of 2. This SOP does not require S&T Independent Safety Review Group review.

6.0 SAMPLE HANDLING

There are no sample handling or preservation requirements since all vapor phase mixtures are generated inside the test vessel from neat liquids.

7.0 MATERIALS AND APPARATUS

- Flame test apparatus.
- Flame test vessel, Kontes 5 liter, borosilicate glass, long-neck (45/50) round bottom flask (#601000-1045).
- Magnetic stirrer.
- Stir bar, 2 1/2 inch egg-shaped.
- Heat gun.
- Pressure measuring system including pressure transducer and digital process indicator capable of measuring pressures from 5 to 760 torr with an accuracy of 0.2 percent.
- Thermocouples, two digital readout.
- Vacuum pump capable of reducing internal system pressure to less than 30 torr.
- Lantern batteries, two 6-volt.
- Surge protector, 6 plug.
- Syringes, gas-tight, 100-1000 μL capacities.
- Septa.

8.0 REAGENTS, STANDARD SOLUTIONS, AND QUALITY CONTROL SAMPLES

8.1 Calibration standard sources are:

- Methanol, reagent grade or better
- Cyclohexane, reagent grade or better

Calibration standards are prepared by volatilizing and air-diluting neat compounds in the flame test vessel.

8.2 The method described in this SOP can be used to evaluate any vapor phase combination of the analytes listed in Table 1. The method must be used to evaluate the flammability of all of the Phase I binary and ternary mixtures listed in Table 2 and Table 3, as well as all Phase II mixtures. Due to experimental design, Phase II mixtures will not be identified until after completion of the Phase I tests.

9.0 PROCEDURES

9.1 Equipment Calibration and Operational Checks

- 9.1.1 The test vessel volume must be accurately determined. Weigh the clean, dry test vessel to within ± 1 gram. Fill the flask with distilled water and insert all components (thermocouple, ignition rods, tubing) allowing the excess water to overflow. Remove the components, dry the outside of the vessel, and reweigh. Record the net volume in milliliters as the difference in grams between the dry test vessel measurement and the water-filled vessel measurement. The volume

measurement will need to be performed once on every 5-liter flask used as a test vessel.

9.1.2 Prior to each calibration or analysis procedure, the following operational checks shall be performed:

- Examine the flame test vessel for structural integrity (no cracks or deformations).
- Examine the flame test vessel for cleanliness (no residual material or soot from previous testing).
- Inspect the ignition source power output (clearly visible spark produced between the electrodes).
- Verify the pressure stability of the test vessel and all connecting lines (apparatus capable of maintaining a vacuum of 30 ± 1.5 torr for five minutes).
- Verify that the magnetic stirrer and stirring bar are operating properly.

9.2 Testing of Calibration Standards

9.2.1 Attach a septum to the end of the sample line and then close the bleed-air valve. Turn the vacuum pump on and open vacuum system Valves 1 and 2. Evacuate the sample-inlet line and the test vessel to a pressure of 30 torr. Close vacuum system Valve 2 and then turn off the vacuum pump. Turn on the magnetic stirrer.

9.2.2 Take up the calculated volume of liquid standard with an appropriately-sized microliter syringe, and inject the liquid standard into the sample line through the septum. For routine operating conditions of 295 K and 400 torr, 8 percent (v/v) methanol = 387 μ L, 15 percent (v/v) methanol = 726 μ L, and 1 percent (v/v) cyclohexane = 129 μ L. Allow the needle and syringe to remain in the injection port while carefully heating the connecting compounds with the heat gun and watching the pressure reading. As the increasing pressure stabilizes, unscrew the needle from the syringe and allow air to bleed through the needle into the vessel.

WARNING:

AVOID INHALATION OF CHEMICALS AND CONTACT WITH SKIN

9.2.3 Continue gentle heating of the lines to eliminate any condensation and to ensure the quantitative transfer of the neat compound. As the pressure either stabilizes again or approaches 250 torr, remove the needle from the injection port and slowly open the bleed-air valve to bring the pressure within the test vessel to 400 torr. Pressurization of the vessel should take 5 to 9 minutes.

9.2.4 Close the bleed-air valve. Record the final pressure within the apparatus, the temperature within the test vessel, and the temperature within the enclosure.

Close the vacuum system Valve 1. Ensure that all lines leading to the vessel are closed.

- 9.2.5 Turn off the stirrer, both internal and external temperature-measurement devices and the pressure-measurement device. Disconnect the internal temperature-measuring leads. Ensure that all electrical circuits attached to the apparatus are off. Turn off the surge protector.

WARNING:

FAILURE TO ENSURE THAT
ALL ELECTRICAL COMPONENTS ARE TURNED OFF,
ALL TRANSFER LINES ARE CLOSED, AND ALL SHIELDING IS IN PLACE
PRIOR TO ACTIVATING THE IGNITION SOURCE COULD ENDANGER
THE ANALYST OR DAMAGE EQUIPMENT AND/OR CIRCUITRY.

- 9.2.6 Take appropriate safety precautions (don safety goggles, close sash of the fume hood, close and latch the flame test apparatus enclosure door, and disconnect all electrical devices). Darken the viewing area and activate the ignition source.
- 9.2.7 If the mixture is flammable, a flame is generated with enough explosive force to propagate to the test vessel walls and lift the rubber stopper off the top of the flask.
- 9.2.8 Record the test results for each calibration standard in a bound and numbered laboratory notebook.

9.3 Testing of Analytes

- 9.3.1 Perform all operational checks as outlined in 9.1.2.
- 9.3.2 Follow procedure described in 9.2.1 through 9.2.8 using volumes listed in Table 2 and Table 3.

10.0 QUALITY CONTROL REQUIREMENTS

- 10.1 The accuracy of the flame test apparatus will be assessed and qualified through the initial calibration process prior to the analysis of experimental mixtures and thereafter, after each set of binary, ternary, or quaternary mixtures. The flame test apparatus will be considered qualified when it successfully evaluates the flammability of the mixtures listed in Table 4. The flame test apparatus will have an accuracy of 100 percent. Accuracy is expressed as, (number of test mixtures whose flammability is correctly evaluated / total number of test mixtures whose flammability is evaluated) * 100.
- 10.2 The flammability test apparatus must be qualified for accuracy prior to the evaluation of Phase I and Phase II mixtures. Initial calibration of the flame test apparatus shall be performed by testing the flammability of 8 percent (v/v) methanol, 15 percent (v/v) methanol, and 1 percent (v/v) cyclohexane. Calibration is achieved when the 8 percent (v/v) methanol and the 15 percent (v/v) methanol standards are evaluated as flammable, and the 1 percent (v/v) cyclohexane standard is evaluated as nonflammable. An initial calibration must be performed after each set of binary, ternary, or quaternary mixtures is tested or after 20 tests, whichever comes first.

- 10.3 Continuing calibration of the flame test apparatus shall be maintained on a daily basis with 8 percent (v/v) methanol. Calibration is achieved when the 8 percent (v/v) methanol standard is evaluated as flammable.
- 10.4 Laboratory duplicates will be evaluated at a minimum frequency of one per ten mixture evaluations.
- 10.5 The 1 percent (v/v) cyclohexane serves as a functional blank and no other blank is required.
- 10.6 Operators must successfully complete all applicable laboratory training program requirements. Each complete set of mixtures must be analyzed by the same operator who performed the initial and continuing calibrations associated with that set of mixtures.

11.0 CALCULATIONS, DATA REDUCTION, AND DATA RECORDING METHODS

- 11.1 The volume of liquid standard required to produce a calibration concentration in the test vessel is calculated as:

$$\mu L = \frac{(MW)(P)(V\%)(0.8820)}{(d)(T)} \quad (1)$$

where,

- μL = Volume of liquid standard to be injected into the test vessel
- MW = Molecular weight of liquid standard, g mol⁻¹
(methanol = 32.04 g mol⁻¹; cyclohexane = 84.16 g mol⁻¹)
- P = Final test pressure, torr
- V% = Concentration of volatilized standard in test vessel, v/v%
- d = Density of liquid standard at 20°C, g mL⁻¹
(methanol = 0.7915 g mL⁻¹; cyclohexane = 0.7781 g mL⁻¹)
- T = Temperature within test vessel, K

- 11.1.1 Equation (1) above is specifically derived for this SOP by combining physical constants with the test vessel volume (5.5 L). The more general equation is shown below as equation (2). The volume of liquid standard required to produce a calibration concentration in the test vessel is calculated by the following:

$$\mu L = \frac{(MW)(P)(V\%)(V)(T_0)(1000)}{(d)(T)(V_0)(P_0)(100\%)} \quad (2)$$

where,

μL	=	Volume of liquid standard to be injected into the test vessel
MW	=	Molecular weight of liquid standard, g mol ⁻¹
P	=	Final test vessel pressure, torr
$V\%$	=	Concentration of volatilized standard in test vessel, v/v%
d	=	Density of liquid standard at 20°C, g mL ⁻¹
T	=	Temperature within test vessel, K
V_0	=	Standard molar volume, 22.4 L mol ⁻¹
P_0	=	Standard pressure, 760 torr
V	=	Volume of test vessel, L
T_0	=	Standard temperature, 273 K

For example, in a 5.0 liter test vessel at 25° C and 400 torr, the required volume for the 8.0 percent (v/v) methanol calibration standard is 348 μL .

- 11.2 The qualitative results from this flammability testing require no data reduction; there are no calculations required in order to evaluate the flame test results.
- 11.3 The flammability testing data shall be recorded in a bound and numbered laboratory notebook. Data shall include:
 - Flammability test date and time
 - Initial calibration data
 - Continuing calibration data
 - Evaluation of mixture flammability
- 11.4 The results from the evaluation of all Phase I and Phase II mixtures must be reported to Mr. Allen Johnson, Materials Chemistry, MS-2280.

12.0 METHOD PERFORMANCE

Flammability test results are considered qualitative. Since qualitative evaluations do not lend themselves to statistical analysis, precision will be enhanced by the use of standardized flame test apparatus and a standardized analytical method in conjunction with operator training. The accuracy of the method is expressed as,

$$\text{Method accuracy} = \frac{N_c}{N_T} * 100 \quad (3)$$

where,

N_c = Number of test mixtures where flammability correctly evaluated.
 N_T = Total number of test mixtures evaluated by the analyst.

13.0 RECORDS MANAGEMENT

Records generated as a result of implementing this SOP and associated management activities are as follows:

13.1 ECL Analytical Method OH2.2

13.1.1 Document Description: ECL Analytical Method SOP OH2.2 - Flammability Testing of Vapor Phase Mixtures of Volatile Organic Compounds from Neat Liquids

13.1.2 Form Number: Not applicable

13.1.3 Records Status/Vital Records (DOE 1324.2A): Record

13.1.4 Filing Location/Distribution: ECL Central Files, SOPs; OH2.2; Project Files, WIPP - ECL Analytical Method SOPs; Controlled Copies of ECL SOP Manual

13.1.5 Disposition Authority (DOE 1324.2A): U1-8-A-2

13.1.6 Retention Period (DOE 1324.2A): Five years or destroy after analysis results accepted.

13.2 Raw Data Reports

13.3 S&T Hazard Analysis

13.3.1 Document Description: S&T Hazard Analysis

13.3.2 Form Number: EG&G Form 1245

13.3.3 Records Status/Vital Records (DOE 1324.2A): Record

13.3.4 Filing Location/Distribution: ECL Central Files, SH - S&T Hazard Analysis, Exhibit in ECL Analytical Method SOP OH2.2

13.3.5 Disposition Authority (DOE 1324.2A): U2-9-A-1

13.3.6 Retention Period (DOE 1324.2A): Destroy when superseded.

14.0 REFERENCES

- 4.1 U.S. Department of Energy (DOE), 1991, "WIPP Waste Characterization Program Sampling and Analysis Guidance Manual, Method 810.1" [DOE/WIPP 91-043](#), Current Revision, Waste Isolation Pilot Plant, Carlsbad, New Mexico.
- 4.2 American Society for Testing and Materials, 1989, Method E 681-85, "Standard Method for Concentration Limits of Flammability of Chemicals", 1916 Race St., Philadelphia, Pennsylvania
- 4.3 Coward, H.F. and Jones, G.W., 1952, *Limits of Flammability of Gases and Vapors*, NTIS No. AD-701 575, U.S. Dept. of Commerce, Springfield, Virginia

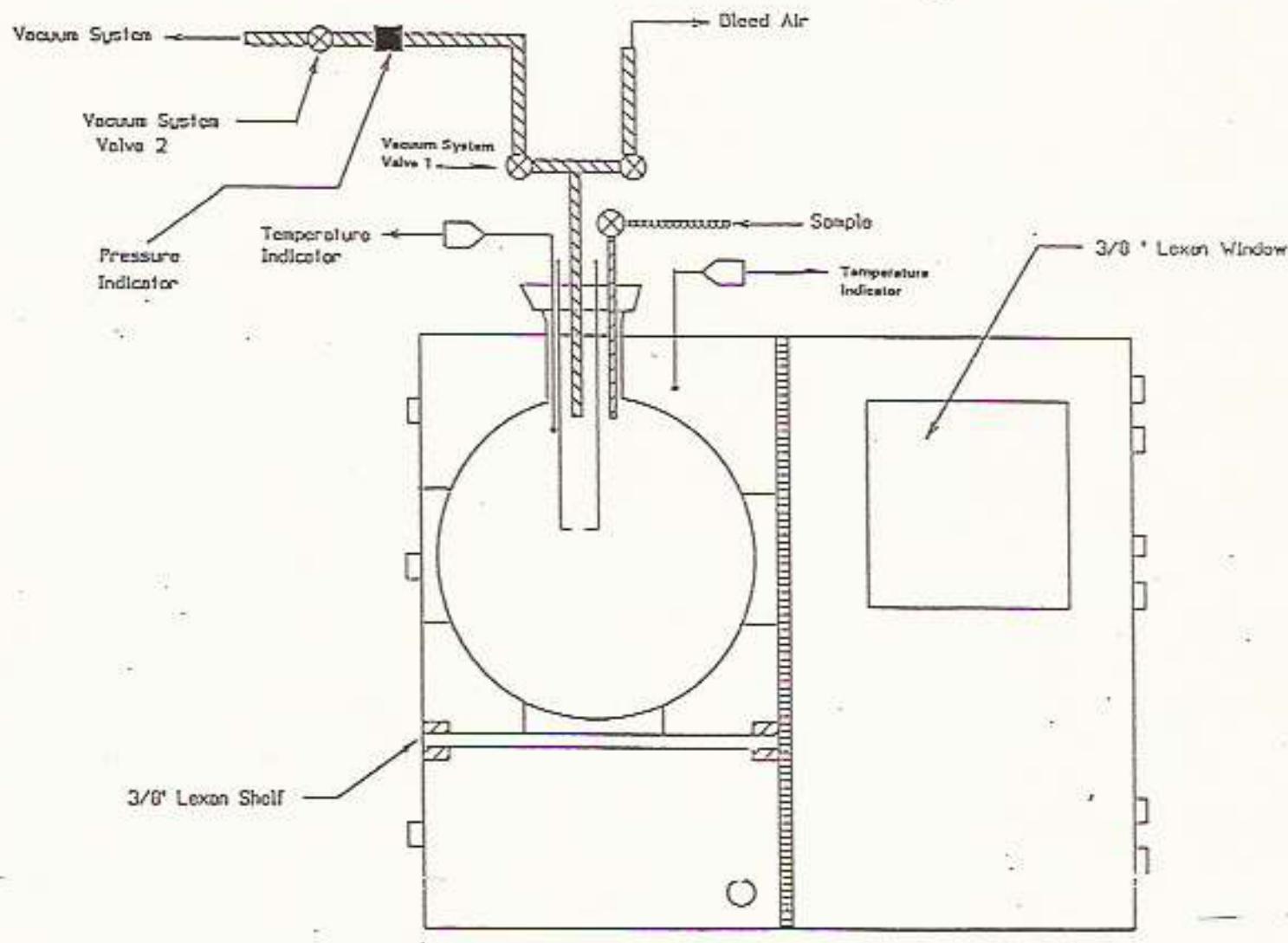


FIGURE 1 Flame Test Apparatus

TABLE 1
 Volatile Organic Compounds Used in Flammability Experiments

Compound	CAS No.	Lower Explosive Limit (v/v%)	Flammability Group
1,2,4-Trimethylbenzene	95-63-6	0.9	High
2-Ethoxyethanol	110-80-5	1.7	High
Cyclohexane	110-82-7	1.3	High
Ethyl acetate	141-78-6	2.0	High
Acetone	67-64-1	2.5	High
1,2-Dichloroethene	mixed isomers	5.6	Moderate
Methanol	67-56-1	6.0	Moderate
1,2-Dichloroethane*	107-06-2	6.2	Moderate
1,1,1-Trichloroethane	71-55-6	8.0	Low
Methylene chloride*	75-09-2	12.0	Low
Tetrachloroethylene*	127-18-4	(16.0) ^a	Low

* Although listed as nonflammable, an LEL of 16.0 is arbitrarily assigned for experimental purposes.

^a Indicates carcinogen or suspect carcinogen according to Material Safety Data Sheets.

TABLE 2
 Binary Mixtures for Phase I Flammability Experiments*

Mixture Number	Compounds	Flammability Group	Compound Concentration (v/v %)	Required Amount of Compound ^b (g/L)	Total Mixture Concentration (w/v %)
1	Ethyl acetate 1,2-Dichloroethylene	H M	1.62 1.62	172 133	3.24
2	1,2,4-Trimethylbenzene 1,2-Dichloroethane	H M	0.71 0.71	162 60	1.42
3	Acetone Methanol	H M	1.58 1.58	127 70	3.18
4	2-Ethoxyethanol Methanol	H M	1.46 1.46	163 84	2.82
5	Cyclohexane 1,2-Dichloroethylene	H M	0.95 0.95	112 78	1.90
6	2-Ethoxyethanol Methylene chloride	H L	1.84 1.84	172 114	3.28
7	Ethyl Acetate Tetrachloroethylene ^c	H L	1.80 1.80	170 178	3.20
8	Acetone 1,1,1-Trichloroethane	H L	1.71 1.71	137 186	3.43
9	1,2,4-Trimethylbenzene 1,1,1-Trichloroethane	H L	0.89 0.89	203 96	1.78
10	Cyclohexane Tetrachloroethylene	H L	1.08 1.08	127 120	2.16
11	Methanol Methylene chloride	M L	3.80 3.80	158 251	7.20
12	1,2-Dichloroethane 1,1,1-Trichloroethane	M L	3.84 3.84	328 417	7.68
13	1,2-Dichloroethylene Tetrachloroethylene	M L	4.56 4.56	376 607	9.13

* Based on the output from the dBase IV program FLMDSN1B run 4/07/93 at 2:47 gm. Date and time are referenced because FLMDSN1B uses a random number generator for determining whether or not a given mixture will exceed its theoretical LEL.

^b Assumes a 5.0 L test vessel operating at a temperature of 22 °C and a pressure of 400 torr.

^c There is no published LEL for tetrachloroethylene. An LEL estimate of 16.0 is used for calculation purposes.

TABLE 3
 Ternary Mixtures for Phase I Flammability Experiments*

Mixture Number	Compounds	Flammability Group	Compound Concentration (w/v%)	Required Amount of Compound (µL)	Total Mixture Concentration (v/v%)
1	Acetone Methanol Tetrachloroethylene ^a	H M L	1.43 1.43 1.43	116 63 159	4.29
2	Ethyl acetate 1,2-Dichloroethane Methylene chloride	H M L	1.48 1.48 1.48	157 126 103	4.43
3	2-Ethoxyethanol 1,2-Dichloroethylene 1,1,1-Trichloroethane	H M L	1.01 1.01 1.01	106 83 109	3.03
4	Cyclohexane 1,2-Dichloroethane Tetrachloroethylene	H M L	1.11 1.11 1.11	130 95 123	3.32
5	1,2,4-Trimethylbenzene 1,2-Dichloroethylene 1,1,1-Trichloroethane	H M L	0.64 0.64 0.64	145 62 69	1.91
6	Acetone 1,2-Dichloroethylene 1,2-Dichloroethane	H M M	1.22 1.22 1.22	97 100 104	3.65
7	2-Ethoxyethanol 1,2-Dichloroethane 1,2-Dichloroethane	H M M	1.21 1.21 1.21	127 103 103	3.62
8	Cyclohexane Methanol 1,2-Dichloroethane	H M M	0.82 0.82 0.82	96 36 70	2.46
9	Ethyl acetate 1,2-Dichloroethylene Methanol	H M M	1.30 1.30 1.30	138 107 67	3.90

* Based on the output from the dBBase IV program FLIMDSN2B run 4/7/93 at 3:02 pm. Date and time are referenced because FLIMDSN2B uses a random number generator for determining whether or not a given mixture will exceed its theoretical LEL.

^a Assumes a 6.0 L test vessel operating at a temperature of 22 °C and a pressure of 400 torr.

^b There is no published LEL for tetrachloroethylene. An LEL estimate of 16.0 is used for calculation purposes.

TABLE 3
 (continued)

Ternary Mixtures for Phase I Flammability Experiments^a

Mixture Number	Compounds	Flammability Group	Compound Concentration (v/v %)	Required Amount of Compound (μ L)	Total Mixture Concentration (v/v %)
10	1,2,4-Trimethylbenzene Methanol	H M	0.82 0.82	141 27	1.86
	1,2-Dichloroethylene	M	0.82	51	
11	2-Ethoxyethanol Methylene chloride Tetrachloroethylene	H L L	1.60 1.60 1.60	158 104 188	4.80
12	Acetone Tetrachloroethylene 1,1,1-Trichloroethane	H L L	1.63 1.63 1.63	123 170 166	4.80
13	1,2,4-Trimethylbenzene Tetrachloroethylene 1,1,1-Trichloroethane	H L L	0.85 0.85 0.85	193 94 92	2.54
14	Ethyl acetate Tetrachloroethylene 1,1,1-Trichloroethane	H L L	1.80 1.80 1.80	170 178 174	7.80
15	Cyclohexane Methylene chloride 1,1,1-Trichloroethane	H L L	1.13 1.13 1.13	132 78 122	3.28

^a Based on the output from the dBase IV program FLMDSN2B run 11/08/93 at 12:08 pm. Date and time are referenced because FLMDSN2B uses a random number generator for determining whether or not a given mixture will exceed its theoretical LEI.

^b Assumes a 6.0 L test vessel operating at a temperature of 22 °C and a pressure of 400 torr.

^c There is no published LEI for tetrachloroethylene. An LEI estimate of 16.0 is used for calculation purposes.

TABLE 4
Flammability Testing Calibration Requirements

Procedure	Frequency	Acceptance Criteria	
3-point initial calibration	Initially and after each set of binary, ternary, or quaternary mixtures	8.0% Methanol 15.0% Methanol 1.0% Cyclohexane	- Flammable - Flammable - Not Flammable
Continuing calibration	Beginning of each working day	8.0% Methanol	- Flammable