ENFLURANE
HALOTHANE
ISOFLURANE

Method number: 103

Matrix: Air

Target concentration, TC:

	enflurane		halothane		isoflurane	
TC	low	high	low	high	low	high
ppm	1	75	1	50	1	75
mg/m^3	7.5	566	8	403	7.5	566

OSHA PEL: None
ACGIH TLV: 75 ppm (566 mg/m^3) for enflurane
50 ppm (403 mg/m^3) for halothane

Procedure: Samples are collected by drawing a known volume of air through standard size (6-mm o.d., 150/75 mg) Anasorb CMS or (6-mm o.d., 140/70 mg) Anasorb 747 tubes. Samples are desorbed with CS_2 and analyzed by GC using a flame-ionization detector (FID).

Air volume and sampling rate: 12 L at 0.05 L/min

Reliable quantitation limit:

	enflurane		halothane		isoflurane	
Anasorb	CMS	747	CMS	747	CMS	747
ppb	25.0	40.7	24.4	21.3	23.0	23.5
$\mu g/m^3$	189	307	197	172	174	177

Standard error of estimate at the target concentration:

	enflurane		halothane		isoflurane	
Anasorb	CMS	747	CMS	747	CMS	747
low TC	0.072	0.058	0.076	0.054	0.078	0.059
high TC	0.083	0.077	0.070	0.058	0.085	0.061

Special requirements: Samples collected on Anasorb CMS for halothane should be stored at reduced temperature following receipt at the laboratory until analysis.

Status of method: Evaluated method. This method has been subjected to the established evaluation procedures of the Organic Methods Evaluation Branch.

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1. General Discussion

1.1 Background

1.1.1 History

The objective of this method is to eliminate the need to use two adsorbent tubes connected in series as specified for enflurane and halothane in OSHA Method 29 (Ref. 5.1), and to expand the methodology to include the newer anesthetic gases, isoflurane and desflurane. (Desflurane will appear as a separate method because it requires different analytical conditions.) Enflurane, halothane and isoflurane were each evaluated at two target concentrations because NIOSH recommended exposure limits (Refs. 5.2 and 5.3) are considerably lower than the current ACGIH TLVs (Ref. 5.4). For this reason, the method was evaluated at a lower target concentration of 1 ppm for all three analytes. Currently there are no OSHA PELs for these substances. Preliminary studies were performed with the following adsorbents: Anasorb CMS, Anasorb 747, Carbosieve S-III and activated coconut charcoal. Anasorb CMS and Anasorb 747 were both good candidates for an improved sampler as neither adsorbent required two tube in series. Evaluation tests were begun with both adsorbents in the anticipation that one would clearly surpass the other in performance. Since this did not occur, both were evaluated and are presented as sampling options.

ACGIH has recommended a TLV-TWA of 75 ppm for enflurane and 50 ppm for halothane (Ref. 5.4). The TLV for enflurane is based on the assumption enflurane is a safer anesthetic gas than halothane. The TLV for halothane is based on a comparison of toxicity and TLVs of trichloroethylene and chloroform. (Ref. 5.4) The ACGIH recommendations are the basis for setting the higher target concentrations of enflurane and halothane for the evaluation of this method. A higher target concentration of 75 ppm was set for isoflurane because it is a geometric isomer of enflurane. NIOSH has recommended that exposure to these halogenated anesthetic gases should be controlled with a 60-min ceiling value of 2 ppm (Ref. 5.2). The anesthetic gases are usually administered in conjunction with nitrous oxide.

1.1.2 Toxic effects (This section is for information only and should not be taken as the basis of OSHA policy.)

Current scientific evidence obtained from human and animal studies suggest that chronic exposure to anesthetic gases increase the risk of both spontaneous abortion and congenital abnormalities in offspring among female workers and wives of male workers. Risks of hepatic and renal diseases are also increased among exposed workers. (Ref 5.2) IARC states there is inadequate evidence for the carcinogenicity of enflurane, halothane and isoflurane in both animals and humans (Ref. 5.5).

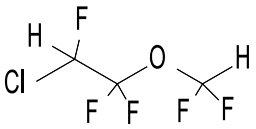
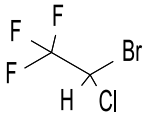
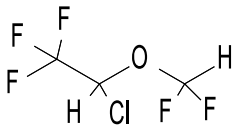
Enflurane and isoflurane have similar health effects for acute exposure. An exposure may cause irritation and redness in eyes, dryness and irritation of skin, and irritation of the mouth and throat. If inhaled, headaches, dizziness, drowsiness, unconsciousness, and death can occur. (Refs. 5.6 and 5.7)

Acute exposures of halothane can cause severe irritation to the eyes, irritation of the skin, reduction of the blood pressure, dizziness, drowsiness, and unconsciousness. Chronic exposures can possibly cause cancer. (Ref. 5.8)

1.1.3 Workplace exposure

Enflurane, halothane and isoflurane are the most commonly used organic anesthetic gases. Occupational exposure may occur whenever anesthetics are used in operating rooms, dental offices and veterinary hospitals. The number of people potentially exposed was estimated to be 215,000 in 1977 (Ref. 5.2). This number is probably much higher today if the increase in the health care industry since 1977 is considered.

1.1.4 Physical properties and other descriptive information (Refs. 5.6 - 5.9)

	enflurane	halothane	isoflurane
CAS number:	13838-16-9	151-67-7	26675-46-7
molecular weight:	184.49	197.39	184.49
boiling point, °C:	56.5	50.2	48.5
color:	colorless	colorless	colorless
specific gravity:	1.52	1.872	1.50
molecular formula:	$C_3H_2OClF_5$	$C_2HBrClF_3$	$C_3H_2OClF_5$
vapor pressure, kPa (mmHg):	25.1 (188.6) @22°C	32.4 (243.3) @20°C	34.9 (261.8) @22°C
odor:	odorless		mild ethereal
flash point, °C:	>200	none	>200
solubility:	miscible with organic solvents	miscible with pet ether and other fat solvents	miscible with organic liquids
synonyms:	Ethrane; 2-chloro-1,1,2-trifluoroethyl difluoromethyl ether; methyl flurether; Efrane; Alyrane	Fluothrane; 2-bromo-2-chloro-1,1,1-trifluoro- ethane; Rhodialothan	Forane; 1-chloro-2,2,2-trifluoroethyl difluoromethyl ether; Aerrane; Forene
structural formulas:			

The analyte air concentrations throughout this method are based on the recommended sampling and analytical parameters. Air concentrations listed in ppm are referenced to 25°C and 101.3 kPa (760 mmHg).

1.2 Limit defining parameters

1.2.1 Detection limit of the analytical procedure

The detection limits of the analytical procedure are 92.8, 87.3 and 44.7 pg for enflurane, halothane and isoflurane respectively. These are the amounts of each analyte that will give a response that is significantly different from the background response of a reagent blank. (Sections 4.1 and 4.2)

1.2.2 Detection limit of the overall procedure

The detection limits of the overall procedure (mass per sample) are listed below. These are the amounts of each analyte spiked on the sampler that will give a response that is significantly different from the background response of a sampler blank. (Sections 4.1 and 4.3)

Table 1.2.2
Detection Limits of the Overall Procedure

adsorbent	enflurane	halothane	isoflurane
Anasorb CMS	0.679 µg	0.709 µg	0.625 µg
	7.50 ppb	7.32 ppb	6.91 ppb
	56.6 µg/m^3	59.1 µg/m^3	52.1 µg/m^3
Anasorb 747	1.105 µg	0.620 µg	0.639 µg
	12.2 ppb	6.40 ppb	7.06 ppb
	92.1 µg/m^3	51.7 µg/m^3	53.3 µg/m^3

1.2.3 Reliable quantitation limit

The reliable quantitation limits (mass per sample) are listed below. These are the amounts of analytes spiked on a sampler that will give a signal that is considered the lower limit for precise quantitative measurements. (Section 4.4)

Table 1.2.3
Reliable Quantitation Limits

adsorbent	enflurane	halothane	isoflurane
Anasorb CMS	2.26 µg	2.36 µg	2.08 µg
	25.0 ppb	24.4 ppb	23.0 ppb
	188 µg/m^3	197 µg/m^3	173 µg/m^3
Anasorb 747	3.68 µg	2.07 µg	2.13 µg
	40.7 ppb	21.4 ppb	23.5 ppb
	307 µg/m^3	172 µg/m^3	178 µg/m^3

1.2.4 Precision (analytical Procedure)

The precisions of the analytical procedure are measured as the pooled relative standard deviation over a concentration range equivalent to the range of 0.5 to 2 times the target concentration. (Section 4.5)

Table 1.2.4
Precisions of the Analytical Procedure, %

target concn	enflurane	halothane	isoflurane
1 ppm	2.77	1.39	3.50
50 ppm		1.37	
75 ppm	2.27		2.83

1.2.5 Precision (overall procedure)

The precisions of the overall procedure at the 95% confidence level for the ambient temperature 15-18 day storage tests (at the target concentration) are listed below. This includes an additional 5% for sampling error. (Section 4.6)

Table 1.2.5.1
Precision of the Overall Procedure on Anasorb CMS, %

target concn	enflurane	halothane	isoflurane
1 ppm	14.1	14.9‡	15.3
50 ppm		13.7	
75 ppm	16.3		16.6

‡ - refrigerated storage test at 4 °C

Table 1.2.5.2
Precision of the Overall Procedure on Anasorb 747, %

target concn	enflurane	halothane	isoflurane
1 ppm	11.3	10.6	11.5
50 ppm		11.4	
75 ppm	15.1		12.0

1.2.6 Recovery

The recoveries of enflurane, halothane and isoflurane from samples used in the 15-18 day storage tests remained above the values listed below when the samples were stored at 22°C. (Section 4.7)

Table 1.2.6.1
Recovery from Anasorb CMS, %

target concn	enflurane	halothane	isoflurane
1 ppm	94.6	97.1‡	93.7
50 ppm		94.5	
75 ppm	96.2		97.2

‡ - refrigerated storage test at 4°C

Table 1.2.6.2
Recovery from Anasorb 747, %

target concn	enflurane	halothane	isoflurane
1 ppm	99.6	99.8	98.7
50 ppm		99.3	
75 ppm	98.0		97.9

1.2.7 Reproducibility

Forty-eight samples collected from controlled test atmospheres, along with a draft copy of this procedure, were submitted for analysis by one of the OSHA Salt Lake Technical Center's service branch laboratories. The samples were analyzed after 17-23 days of storage at 4°C. No individual sample result deviated from its theoretical value by more than the precision reported in Section 1.2.5. (Section 4.8)

2. Sampling Procedure

2.1 Apparatus

2.1.1 Samples are collected using a personal sampling pump calibrated, with the sampling device attached, within ±5% at the recommended flow rate.

2.1.2 Samples are collected with 7-cm × 4-mm i.d. × 6-mm o.d. glass sampling tubes packed with two sections of (150/75 mg) Anasorb CMS or (140/70 mg) Anasorb 747. The sections are held in place with a glass wool plug and two urethane foam plugs. For this evaluation, commercially prepared sampling tubes were purchased from SKC, Inc. (catalog nos. 226-121 and 226-81).

2.2 Reagents

None required.

2.3 Technique

2.3.1 Only properly trained personnel can sample in an operating room or dental office, this is necessary to be in compliance with OSHA's Exposure Control Plan for bloodborne pathogens. (Ref. 5.10)

2.3.2 Immediately before sampling, break off the ends of the sampling tube. All tubes should be from the same lot.

2.3.3 Attach the sampling tube to the sampling pump with flexible, non-crimping tubing. It is desirable to utilize sampling tube holders which have a protective cover to shield the employee from the sharp, jagged end of the sampling tube. Position the tube so that the sampled air first passes through the larger section.

2.3.4 Air being sampled should not pass through any hose or tubing before entering the sampling tube.

2.3.5 To avoid channeling, attach the sampler vertically with the larger section pointing downward, in the worker's breathing zone. Position the sampler so it does not impede work performance or safety.

2.3.6 After sampling for the appropriate time, immediately remove the sampling tube and seal it with plastic end caps.

2.3.7 In order to prevent occupational exposure to SLTC personnel, sampling tubes that may become contaminated with blood or other potentially infectious materials are to be examined prior to shipping and decontaminated (e.g., wiped off with bleach or other disinfectant) as necessary. Contaminated items are not to be placed or stored in areas where food is kept, and decontamination should be accomplished as soon as possible following the inspection where contamination occurred. Decontamination is not to take place in any area where food or drink is consumed. (Ref. 5.10)

2.3.8 Wrap each sample end-to-end with a Form OSHA-21 seal.

2.3.9 Submit at least one blank sample with each set of samples. Handle the blank sampling tube in the same manner as the other samples, except draw no air through it.

2.3.10 Record sample air volumes (in liters) for each sample, along with any potential interferences.

2.3.11 Ship any bulk sample(s) in a container separate from the air samples.

2.3.12 Submit the samples to the laboratory for analysis as soon as possible after sampling. If delay is unavoidable, store the samples at reduced temperature.

2.4 Sampler capacity

Sampler capacity is determined by measuring how much air can be sampled before the analyte breaks through the sampler, i.e., the sampler capacity is exceeded. Breakthrough is considered to occur when the effluent from the sampler contains a concentration of analyte that is 5% of the upstream concentration (5% breakthrough). Testing for breakthrough was performed by using an FID to monitor the effluent from sampling tubes containing only either the 150-mg section of Anasorb CMS or 140-mg section of Anasorb 747. Dynamically generated test atmospheres, which were about two times the higher target concentration of each analyte, were used for the capacity tests. The samples were collected at 0.05 L/min and the relative humidity was about 80% at 25°C. The 5% breakthrough air volumes were calculated from the data of duplicate determinations and are listed below. (Section 4.9)

Table 2.4
Sampler Capacity

analyte	atmospheric concentration	Anasorb CMS	Anasorb 747
enflurane	165 ppm (1247 mg/m^3)	28.8 L	14.2 L
halothane	93 ppm (753 mg/m^3)	15.8 L	19.9 L
isoflurane	165 ppm (1246 mg/m^3)	24.0 L	17.5 L

2.5 Desorption efficiency

2.5.1 The average desorption efficiencies for the analytes from the sampling media over the range of 0.5 to 2.0 times the target concentrations (TC) are listed below. (Section 4.10)

Table 2.5.1
Desorption Efficiencies, %

analyte	Anasorb CMS		Anasorb 747	
	low TC	high TC	low TC	high TC
enflurane	100.3	99.8	103.7	100.5
halothane	99.7	99.5	99.6	99.3
isoflurane	99.4	99.2	100.8	100.2

2.5.2 The desorption efficiencies at 0.05, 0.1 and 0.2 times the target concentrations (TC) were found to be very high and are listed below. (Section 4.10)

Table 2.5.2.1
Desorption Efficiencies at 0.05 to 0.2 times Low TC, %

analyte	Anasorb CMS			Anasorb 747		
	0.05×Tc	0.1×TC	0.2×TC	0.05×TC	0.1×TC	0.2×TC
enflurane	100.2	100.4	99.5	101.3	99.0	99.0
halothane	99.6	100.5	99.8	84.3	92.6	94.7
isoflurane	99.3	98.4	99.9	96.8	100.0	101.1

Table 2.5.2.2
Desorption Efficiencies at 0.05 to 0.2 times High TC, %

analyte	Anasorb CMS			Anasorb 747		
	0.05×Tc	0.1×TC	0.2×TC	0.05×TC	0.1×TC	0.2×TC
enflurane	100.1	99.8	99.8	100.2	100.0	100.3
halothane	99.3	98.9	98.5	99.6	98.6	100.4
isoflurane	100.0	99.3	99.2	98.0	97.2	99.0

2.5.3 Desorbed samples remain stable for at least 22.5 h.

2.6 Recommended air volume and sampling rate

2.6.1 For long-term samples, collect 12 L at 0.05 L/min.

2.6.2 For short-term samples, collect 0.75 L at 0.05 L/min.

2.6.3 When short-term samples are collected, the air concentration equivalent to the reliable quantitation limit becomes larger.

Table 2.6.3
Reliable Quantitation Limits at 0.75 L

adsorbent	enflurane	halothane	isoflurane
Anasorb CMS	2.26 µg	2.36 µg	2.08 µg
	399 ppb	390 ppb	368 ppb
	3013 µg/m^3	3147 µg/m^3	2773 µg/m^3
Anasorb 747	3.68 µg	2.07 µg	2.13 µg
	651 ppb	342 ppb	377 ppb
	4707 µg/m^3	2760 µg/m^3	2840 µg/m^3

2.7 Interferences (sampling)

2.7.1 It is not known if any compounds will severely interfere with the collection of enflurane, halothane and isoflurane on Anasorb CMS or Anasorb 747. In general, the presence of other contaminant vapors in the air will reduce the capacity of Anasorb CMS or Anasorb 747 to collect the three analytes.

2.7.2 Nitrous oxide was tested as an interferant to the collection of halothane and it does not interfere. (Section 4.12)

2.7.3 Suspected interferences should be reported to the laboratory with submitted samples.

2.8 Safety precautions (sampling)

2.8.1 The sampling equipment should be attached to the worker in such a manner that it will not interfere with work performance or safety.

2.8.2 All safety practices that apply to the work area being sampled should be followed.

2.8.3 Protective eyewear should be worn when breaking the ends of the glass sampling tubes.

3. Analytical Procedure

3.1 Apparatus

3.1.1 Gas chromatograph equipped with an FID. For this evaluation, a Hewlett-Packard 5890A Gas Chromatograph equipped with a 7673A Automatic Sampler was used. A Forma Scientific Model 2006 refrigerated circulator was used to cool the sample tray of the HP 7673A to 10°C to minimize evaporation.

3.1.2 A GC column capable of separating the analyte of interest from the desorption solvent, internal standard and any interferences. A 60-m × 0.32-mm i.d. fused silica Stabilwax-DB column with a 1-µm df (Restek Corp., Bellefonte, PA) was used in the evaluation.

3.1.3 An electronic integrator or some other suitable means of measuring peak areas. A Waters 860 Networking Computer System was used in this evaluation.

3.1.4 Two-milliliter vials with polytetrafluoroethylene-lined caps.

3.1.5 A dispenser capable of delivering 1.0 mL of desorbing solvent to prepare standards and samples. If a dispenser is not available, a 1.0-mL volumetric pipet may be used.

3.2 Reagents

3.2.1 Enflurane, USP. The enflurane used in this evaluation was manufactured by Anaquest (Madison, WI), and purchased from a local hospital.

3.2.2 Halothane, reagent grade or better. The halothane used in this evaluation was purchased from Aldrich Chemical (Milwaukee, WI).

3.2.3 Isoflurane, USP. The isoflurane used in this evaluation was manufactured by Anaquest (Madison, WI), and purchased from a local hospital.

3.2.4 Carbon disulfide (CS_2), reagent grade or better. The CS_2 used in this evaluation was purchased from JT Baker Chemical (Phillipsburg, NJ).

3.2.5 A suitable internal standard, reagent grade. The n-decane used in this evaluation was purchased from ICN Pharmaceuticals, Inc. (Plainview, NY).

3.2.6 Desorption solvent. The desorption solvent contains 500 µL of *n*-decane per 1 L of CS_2.

3.2.7 GC grade nitrogen, air, and hydrogen.

3.2.8 Toluene, chromatographic grade or better. The toluene used in this evaluation was Optima Grade and was purchased from Fisher Scientific (Fair Lawn, NJ).

3.3 Standard preparation

3.3.1 Prepare concentrated stock standard of enflurane, halothane and isoflurane in toluene. Prepare working analytical standards by injecting microliter amounts of concentrated stock standards into 2-mL vials containing 1.0 mL of desorption solvent delivered from the same dispenser used to desorb samples. For example, to prepare a target level standard of isoflurane, inject 10 µL of a stock solution containing 672 mg/mL of isoflurane in toluene into 1 mL of desorption solvent.

3.3.2 Bracket sample concentrations with working standard concentrations. If samples fall outside the concentration range of prepared standards, prepare and analyze additional standards or dilute the sample.

3.4 Sample preparation

3.4.1 Remove the plastic end caps from the sample tube and carefully transfer each section of the adsorbent to separate 2-mL vials. Discard the glass tube, urethane foam plugs and glass wool plug.

3.4.2 Add 1.0 mL of desorption solvent to each vial using the same dispenser as used for preparation of standards.

3.4.3 Immediately seal the vials with polytetrafluoroethylene-lined caps.

3.4.4 Shake the vials vigorously several times during the next 30 min.

3.5 Analysis

3.5.1 Analytical conditions

GC conditions

zone temperatures:	60°C (column)
	250°C (injector)
	300°C (detector)
run time:	15 min
column gas flow:	1.2 mL/min (hydrogen)
septum purge:	1.5 mL/min (hydrogen)
injection size:	1.0 µL (11.3:1 split)
column:	60-m × 0.32-mm i.d. capillary Stabilwax-DB (1.0-µm df)
retention times:	5.50 min (isoflurane)
	5.97 min (halothane)
	6.51 min (enflurane)
	8.34 min (*n*-decane)

FID conditions

hydrogen flow:	34 mL/min
air flow:	450 mL/min
makeup flow:	33 mL/min (nitrogen)

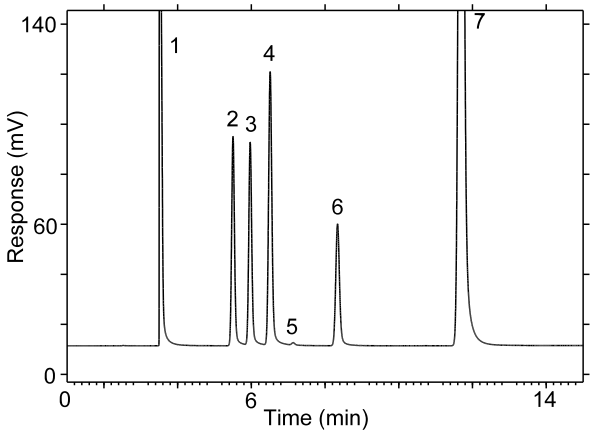


Figure 3.5.1.1. Chromatogram obtained at the high TC with the recommended conditions. Peak identification: (1) carbon disulfide, (2) isoflurane, (3) halothane, (4) enflurane, (5) benzene - contaminant in CS_2, (6) *n*-decane, (7) toluene - from spiking solution.

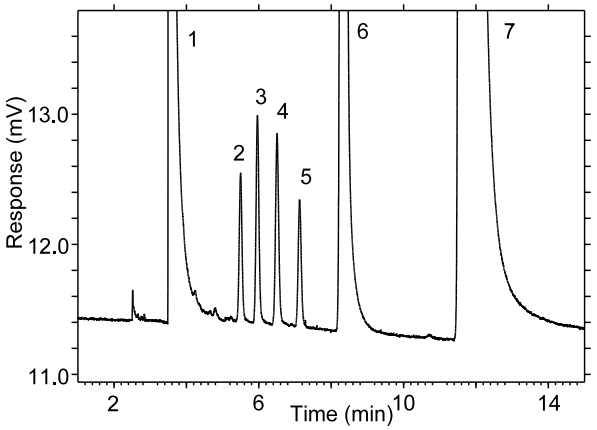


Figure 3.5.1.2. Chromatogram obtained at the low TC with the recommended conditions. Peak identification: (1) carbon disulfide, (2) isoflurane, (3) halothane, (4) enflurane, (5) benzene - contaminant in CS_2, (6) *n*-decane, (7) toluene - from spiking solution.

3.5.2 An internal standard (ISTD) calibration method is used. A calibration curve can be constructed by plotting micrograms of analyte per sample versus ISTD-corrected response of standard injections. Bracket the samples with freshly prepared analytical standards over a range of concentrations.

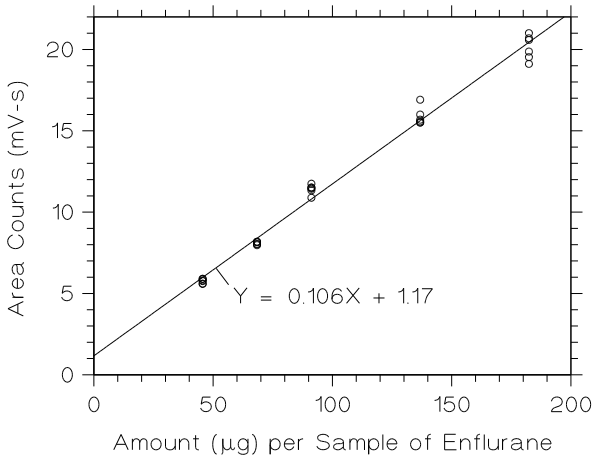


Figure 3.5.2.1. Calibration curve of enflurane at low TC made from data of Table 4.5.1.

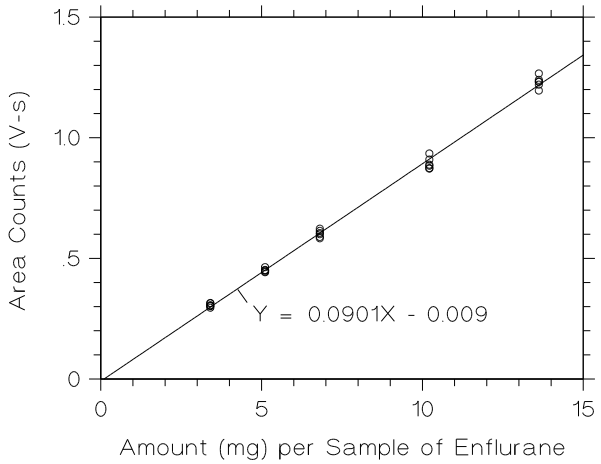


Figure 3.5.2.2. Calibration curve of enflurane at high TC made from data of Table 4.5.2.

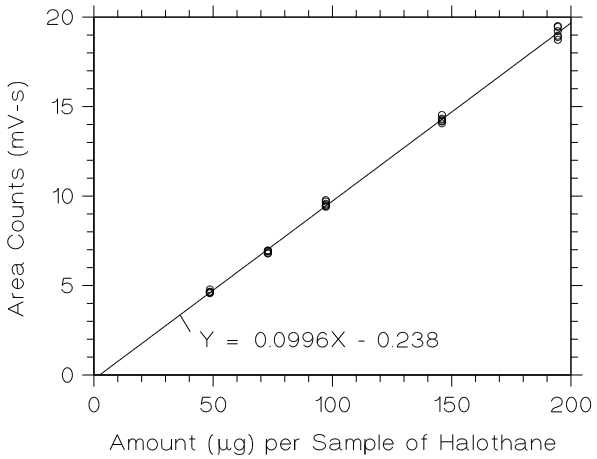


Figure 3.5.2.3. Calibration curve of halothane at low TC made from data of Table 4.5.3.

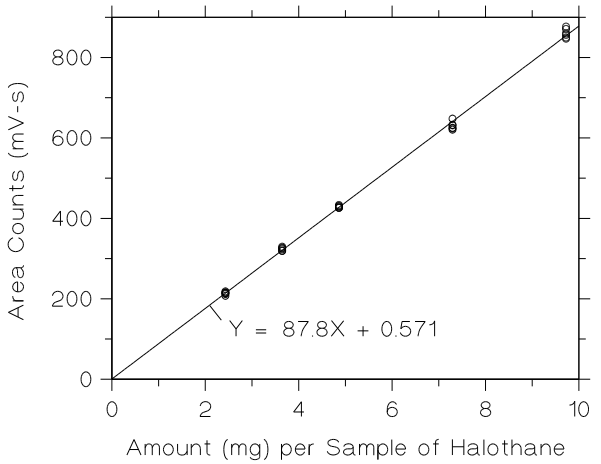


Figure 3.5.2.4. Calibration curve of halothane at high TC made from data of Table 4.5.4.

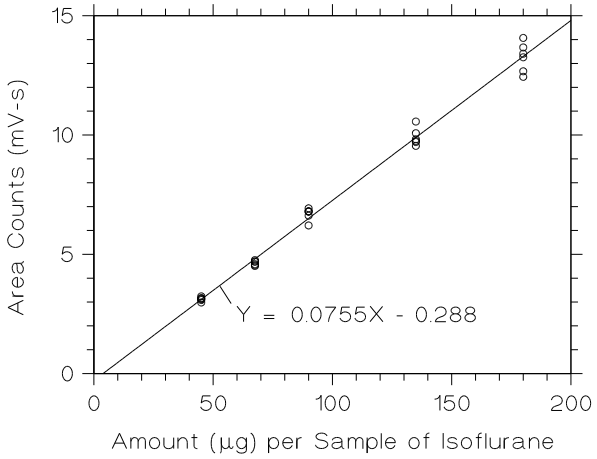


Figure 3.5.2.5. Calibration curve of isoflurane at low TC made from data of Table 4.5.5.

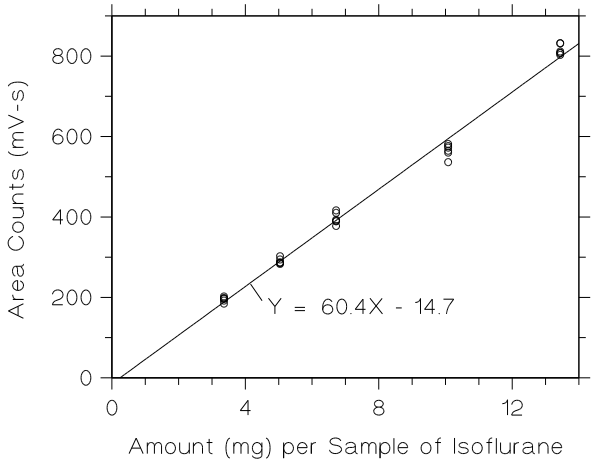


Figure 3.5.2.6. Calibration curve of isoflurane at high TC made from data of Table 4.5.6.

3.6 Interferences (analytical)

3.6.1 Any compound that produces an FID response and has a similar retention time as the analytes or internal standard is a potential interference. If any potential interferences were reported, they should be considered before the samples are desorbed.

3.6.2 Generally, chromatographic conditions can be altered to separate an interference from the analyte.

3.6.3 When necessary, the identity or purity of an analyte peak may be confirmed with additional analytical data. (Section 4.11)

3.7 Calculations

The amount of analyte per sampler is obtained from the appropriate calibration curve in terms of micrograms per sample, uncorrected for desorption efficiency. The back (70-75 mg) section is analyzed primarily to determine if there was any breakthrough from the front (140-150 mg) section during sampling. If a significant amount of analyte is found on the back section (e.g., greater than 25% of the amount found on the front section), this fact should be reported with the sample results. If any analyte is found on the back section, it is added to the amount on the front section. This amount is then corrected by subtracting the total amount (if any) found on the blank. The air concentration is calculated using the following formulae.

$$\text{mg/m}^3 = \frac{\text{micrograms of analyte per sample}}{\text{liters of air sampled} \times \text{desorption efficiency}}$$

$$\text{ppm} = \frac{24.46 \times \text{mg/m}^3}{\text{molecular weight of analyte}}$$

where 24.46 is the molar volume at 25°C and 101.3 kPa (760 mmHg)
184.49 = molecular weight of enflurane and isoflurane
197.39 = molecular weight of halothane

3.8 Safety precautions (analytical)

3.8.1 Adhere to the rules set down in your Chemical Hygiene Plan.

3.8.2 Avoid skin contact and inhalation of all chemicals.

3.8.3 Wear safety glasses, gloves and a lab coat at all times while in the laboratory areas.

4. Backup Data

4.1 Determination of detection limits

Detection limits, in general, are defined as the amount (or concentration) of analyte that gives a response (Y_{DL}) that is significantly different [three standard deviations (SD_{BR})] from the background response (Y_{BR}).

$$Y_{DL} - Y_{BR} = 3(SD_{BR})$$

The measurement of Y_{BR} and SD_{BR} in chromatographic methods is typically inconvenient and difficult because Y_{BR} is usually extremely low. Estimates of these parameters can be made with data obtained from the analysis of a series of analytical standards or samples whose responses are in the vicinity of the background response. The regression curve obtained for a plot of instrument response versus concentration of analyte will usually be linear. Assuming SD_{BR} and the precision of the data about curve are similar, the standard error of estimate (SEE) for the regression curve

can be substituted for SD_{BR} in the above equation. The following calculations derive a formula for DL:

$$SEE = \sqrt{\frac{\sum(Y_{obs} - Y_{est})^2}{n - k}}$$

Y_{obs} = observed response
Y_{est} = estimated response from regression curve
n = total number of data points
k = 2 for linear regression curve

At point Y_{DL} on the regression curve

$$Y_{DL} = A(DL) + Y_{BR}$$

A = analytical sensitivity (slope)

therefore

$$DL = \frac{(Y_{DL} - Y_{BR})}{A}$$

Substituting 3(SEE) + Y_{BR} for Y_{DL} gives

$$DL = \frac{3(SEE)}{A}$$

4.2 Detection limit of the analytical procedure (DLAP)

The DLAP is measured as the mass of analyte actually introduced into the chromatographic columns. Ten analytical standards were prepared in equal descending increments with the highest standard containing 10.02, 10.68 and 9.89 µg/mL of enflurane, halothane and isoflurane respectively. This is the concentration that would produce a peak approximately 10 times the baseline noise of a reagent blank near the elution time of the analyte. These standards, and the reagent blank, were analyzed with the recommended analytical parameters (1-µL injection with a 11.3:1 split), and the data obtained were used to determine the required parameters (A and SEE) for the calculation of the DLAP.

Table 4.2.1
DLAP Data for Enflurane
A = 3.81 SEE = 117.9

concentration (µg/mL)	mass on column (pg)	area counts (µV-s)
0	0	0
0.956	84.4	455
1.90	168	840
2.84	251	1002
3.77	333	1145
5.60	494	2090
6.50	574	2105
7.39	653	2610
8.28	731	2869
9.15	808	3041
10.02	884	3519

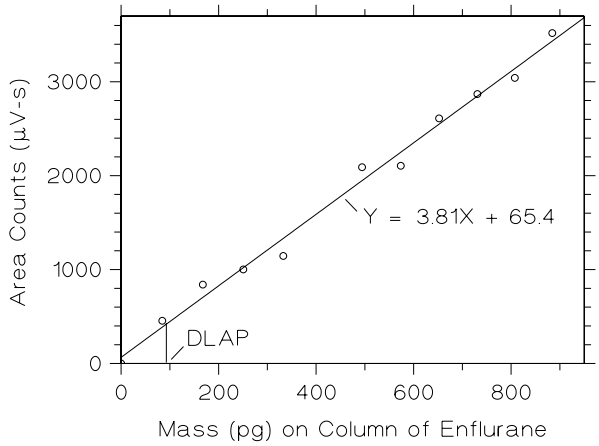


Figure 4.2.1. Plot of the data from Table 4.2.1 to determine the DLAP of enflurane, DLAP = 92.8 pg.

Table 4.2.2
DLAP Data for Halothane
A = 4.08 SEE = 118.7

concentration (µg/mL)	mass on column (pg)	area counts (µV-s)
0	0	0
1.02	90	413
2.03	179	916
3.03	267	1219
4.02	355	1326
5.97	527	2366
6.93	612	2501
7.88	696	2907
8.82	779	3219
9.76	861	3416
10.68	943	4035

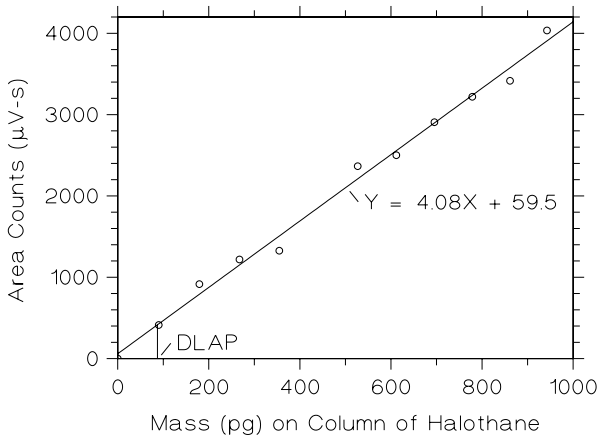


Figure 4.2.2. Plot of the data from Table 4.2.2 to determine the DLAP of halothane, DLAP = 87.3 pg.

Table 4.2.3
DLAP Data for Isoflurane
A = 2.34 SEE = 34.90

concentration (µg/mL)	mass on column (pg)	area counts (µV-s)
0	0	0
0.944	83	288
1.88	166	421
2.80	247	627
3.72	328	794
5.53	488	1230
6.41	566	1307
7.30	644	1537
8.17	721	1711
9.03	797	1921
9.89	873	2090

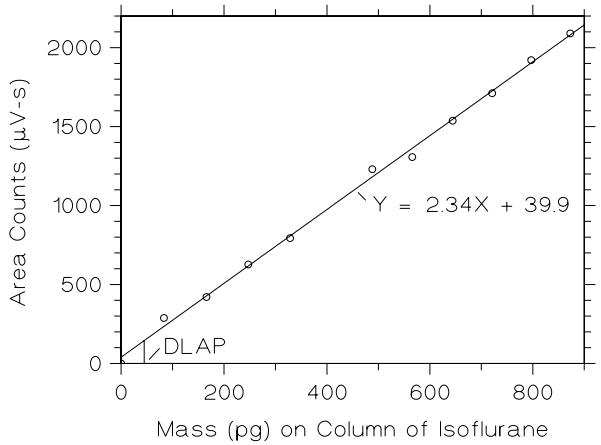


Figure 4.2.3. Plot of the data from Table 4.2.3 to determine the DLAP of isoflurane, DLAP = 44.7 pg.

4.3 Detection limit of the overall procedure (DLOP)

The DLOP is measured as mass per sample and expressed as equivalent air concentration, based on the recommended sampling parameters. Ten samplers were spiked with equal descending increments of analyte, such that the highest sampler loading was 9.15, 9.76 and 9.03 µg/sample of enflurane, halothane and isoflurane respectively. This is the amount, when spiked on a sampler, that would produce a peak approximately 10 times the baseline noise for a sample blank. These spiked samplers, plus a sample blank, were analyzed with the recommended analytical parameters, and the data obtained used to calculate the required parameters (A and SEE) for the calculation of the DLOP.

Table 4.3.1
DLOP Data for Enflurane

mass per sample (µg)	area counts on Anasorb CMS (µV-s)	area counts on Anasorb 747 (µV-s)
0	0	0
0.956	441	292
1.90	651	735
2.84	1042	1109
3.77	1423	1449
4.69	1618	1690
5.60	1858	1786
6.50	2084	2430
7.39	2378	2393
8.28	2635	2749
9.15	3035	3238

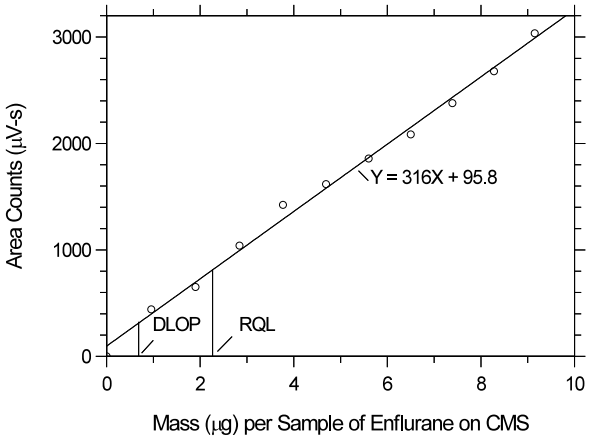


Figure 4.3.1.1. Plot of the data to determine the DLOP of enflurane on Anasorb CMS, (SEE = 71.55).

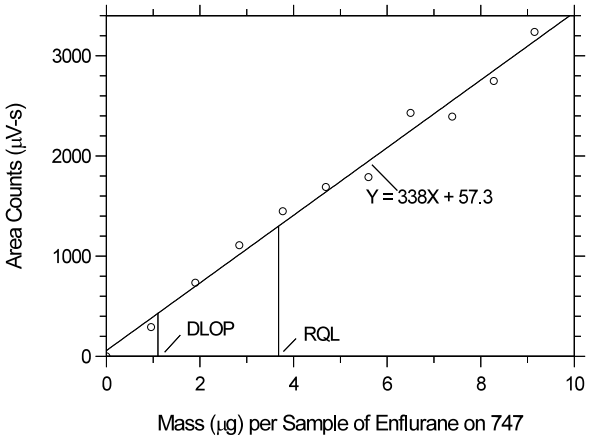


Figure 4.3.1.2. Plot of the data to determine the DLOP of enflurane on Anasorb 747, (SEE = 124.5).

Table 4.3.2
DLOP Data for Halothane

mass per sample (µg)	area counts on Anasorb CMS (µV-s)	area counts on Anasorb 747 (µV-s)
0	0	0
1.02	512	382
2.03	761	812
3.03	1224	1263
4.02	1554	1670
5.00	1870	1999
5.97	2192	2481
6.93	2526	2795
7.88	2721	3059
8.82	3288	3319
9.76	3677	3761

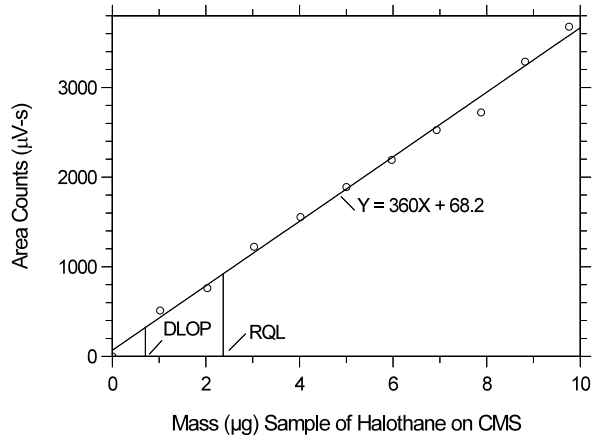


Figure 4.3.2.1. Plot of the data to determine the DLOP of halothane on Anasorb CMS, (SEE = 85.02).

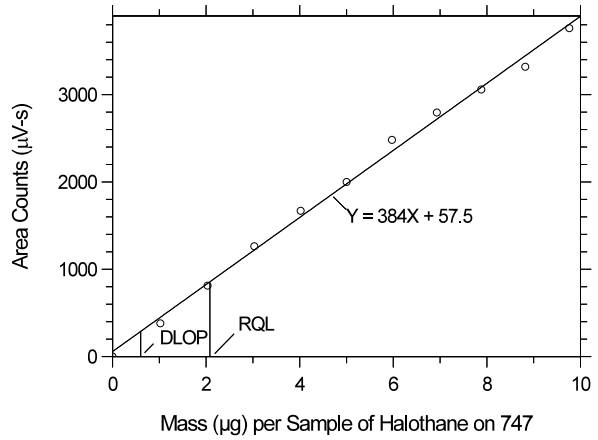


Figure 4.3.2.2. Plot of the data to determine the DLOP of halothane on Anasorb 747, (SEE = 79.37).

Table 4.3.3
DLOP Data for Isoflurane

mass per sample (µg)	area counts on Anasorb CMS (µV-s)	area counts on Anasorb 747 (µV-s)
0	0	0
0.944	274	245
1.88	444	442
2.80	654	630
3.72	845	813
4.63	963	1041
5.53	1195	1088
6.41	1349	1326
7.30	1564	1488
8.17	1622	1615
9.03	1877	1825

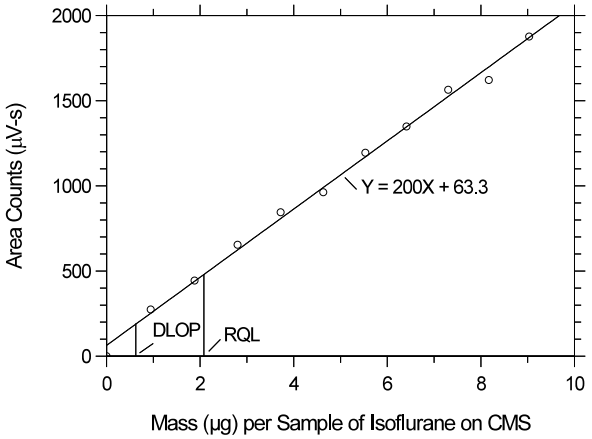


Figure 4.3.3.1. Plot of the data to determine the DLOP of isoflurane on Anasorb CMS, (SEE = 41.65).

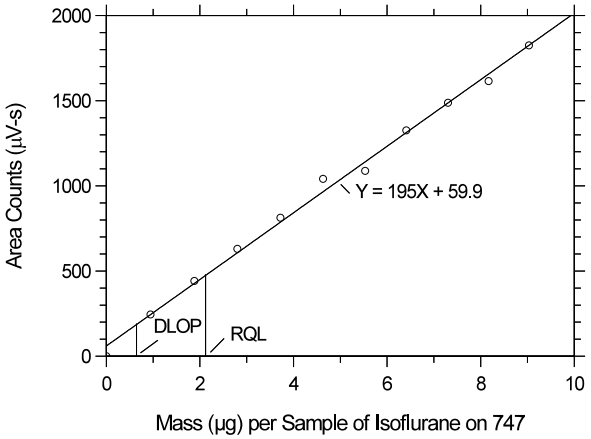


Figure 4.3.3.2. Plot of the data to determine the DLOP of isoflurane on Anasorb 747, (SEE = 41.51).

4.4 Reliable quantitation limit (RQL)

The RQL is considered the lower limit for precise quantitative measurements. It is determined from the regression line parameters obtained for the calculations of the DLOP (Section 4.3), providing at least 75% of the analyte is recovered. The RQL is defined as the amount of analyte that gives a response (Y_{RQL}) such that

$$Y_{RQL} - Y_{BR} = 10(SD_{BR})$$

therefore

$$RQL = \frac{10(SEE)}{A}$$

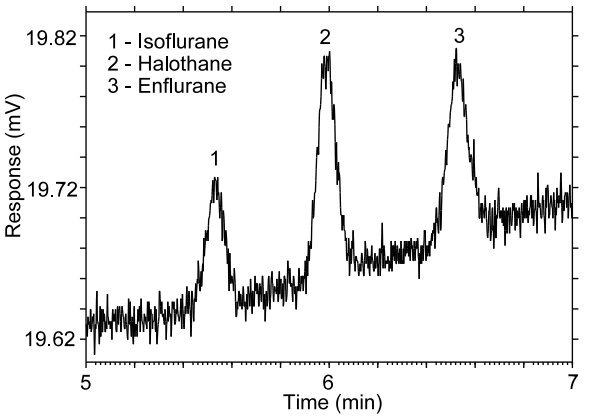


Figure 4.4.1. Chromatogram of the RQL for all three analytes on Anasorb CMS.

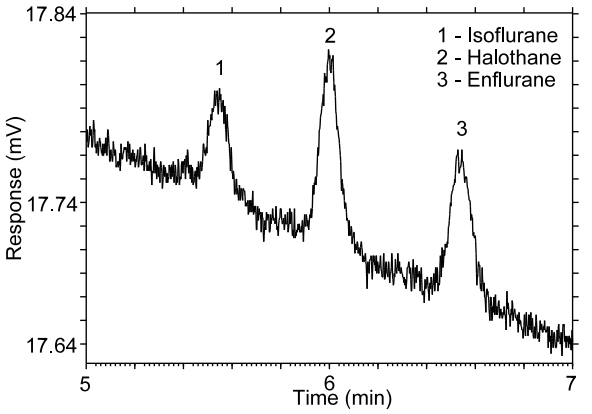


Figure 4.4.2. Chromatogram of the RQL for halothane and isoflurane on Anasorb 747.

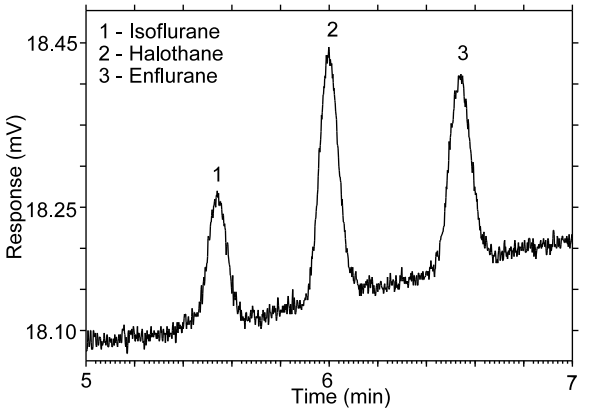


Figure 4.4.3. Chromatogram of the RQL for enflurane on Anasorb 747.

Table 4.4
Reliable Quantitation Limits

adsorbent	enflurane	halothane	isoflurane
Anasorb CMS	2.26 µg	2.36 µg	2.08 µg
	225 ppb	219 ppb	207 ppb
	1695 µg/m^3	1770 µg/m^3	1560 µg/m^3
	91.7%	95.9%	104.1%
Anasorb 747	3.68 µg	2.07 µg	2.13 µg
	366 ppb	192 ppb	212 ppb
	2760 µg/m^3	1553 µg/m^3	1598 µg/m^3
	109.2%	102.9%	103.6%

The RQL for each analyte was calculated and listed above along with the recovery of the analyte peak near the RQL.

4.5 Precision (analytical method)

The precision of the analytical procedure is measured as the pooled relative standard deviation (RSD_P). Relative standard deviations are determined from six replicate injections of analyte standards at 0.5, 0.75, 1, 1.5 and 2 times the target concentration. After assuring that the RSDs satisfy the Cochran test for homogeneity at the 95% confidence level, RSD_P was calculated.

Table 4.5.1
Instrument Response to Enflurane at Low TC

× target concn	0.5×	0.75×	1×	1.5×	2×
(µg/mL)	45.6	68.4	91.2	136.8	182.4
area counts	5802	8044	11502	15685	21003
(µV-s)	5762	7971	11748	15514	20685
	5592	8178	11513	15995	19527
	5604	8024	10887	16911	20585
	5898	8173	11441	15579	19114
	5902	8146	11336	15502	19871
$\bar{X}$	5760	8089	11405	15864	20131
SD	136.8	87.6	287.4	544.1	740.3
RSD (%)	2.37	1.08	2.52	3.42	3.67

Table 4.5.2
Instrument Response to Enflurane at High TC

× target concn	0.5×	0.75×	1×	1.5×	2×
(µg/mL)	3405	5108	6810	10215	13620
area counts	313768	442725	588885	909618	1266303
(µV-s)	295385	449118	614061	884040	1231585
	306119	444388	600184	888369	1239847
	302927	452003	605174	873998	1195472
	302101	463954	583097	872158	1232590
	315239	450679	623083	934700	1220325
$\bar{X}$	305923	450478	602414	893814	1231020
SD	7523.3	7523.5	15044.1	24117.5	23253.5
RSD (%)	2.45	1.67	2.48	2.69	1.88

Table 4.5.3
Instrument Response to Halothane at Low TC

× target concn	0.5×	0.75×	1×	1.5×	2×
(µg/mL)	48.62	72.93	97.24	145.9	194.5
area counts	4652	6892	9563	14067	19459
(µV-s)	4572	6936	9438	14324	18888
	4781	6802	9773	14181	18732
	4625	6931	9501	14180	19216
	4630	6802	9694	14534	18964
	4609	6960	9404	14271	19499
$\bar{X}$	4645	6887	9562	14260	19126
SD	71.8	69.5	145.6	160.7	315.0
RSD (%)	1.54	1.00	1.52	1.12	1.64

Table 4.5.4
Instrument Response to Halothane at High TC

× target concn	0.5×	0.75×	1×	1.5×	2×
(µg/mL)	2431	3646	4862	7293	9724
area counts	214963	319204	427008	631533	876733
(µV-s)	211987	326882	426550	625176	856581
	218236	322866	430225	620733	870877
	215433	325338	429946	632545	849740
	214585	329467	436427	647793	860103
	207597	319337	433215	623791	847012
$\bar{X}$	213800	323849	430562	630262	860174
SD	3635.3	4144.4	3759.2	9723.2	11694.2
RSD (%)	1.70	1.27	0.87	1.54	1.35

Table 4.5.5
Instrument Response to Isoflurane at Low TC

× target concn	0.5×	0.75×	1×	1.5×	2×
(µg/mL)	45.0	67.5	90.0	135.0	180.0
area counts	3164	4584	6793	9544	14068
(µV-s)	3083	4690	6928	9750	13672
	3239	4700	6791	10564	13408
	2983	4510	6209	10076	12670
	3120	4546	6809	9707	13257
	3147	4757	6621	9820	12437
$\bar{X}$	3123	4631	6692	9910	13252
SD	85.9	98.2	256.0	364.5	611.5
RSD (%)	2.75	2.11	3.82	3.67	4.61

Table 4.5.6
Instrument Response to Isoflurane at High TC

× target concn	0.5×	0.75×	1×	1.5×	2×
(µg/mL)	3360	5040	6720	10080	13440
area counts	192010	285648	377707	560192	831803
(µV-s)	198666	302263	389365	536323	808032
	196337	286004	390013	576197	832183
	197101	283263	392882	581411	807540
	184540	294184	416447	572522	811381
	202374	287224	410104	564809	803188
$\bar{X}$	195171	289764	396086	565242	815688
SD	6199.9	7149.2	14430.4	16102.5	12896.4
RSD (%)	3.17	2.46	3.64	2.84	1.58

The Cochran test for homogeneity:

$$g = \frac{\text{largest } RSD^2}{RSD_{0.5\times}^2 + RSD_{0.75\times}^2 + RSD_{1\times}^2 + RSD_{1.5\times}^2 + RSD_{2\times}^2}$$

The critical value of the *g*-statistic, at the 95% confidence level, for five variances, each associated with six observations is 0.5065. Because the *g*-statistic does not exceed this value, the RSDs can be considered equal and they can be pooled (RSD_P) to give an estimated RSD for the concentration range studied.

$$RSD_P = \sqrt{\frac{5(RSD_{0.5\times}^2 + RSD_{0.75\times}^2 + RSD_{1\times}^2 + RSD_{1.5\times}^2 + RSD_{2\times}^2)}{5+5+5+5+5}}$$

Table 4.5.7
Cochran Test Results and Pooled Relative Standard Deviations

	enflurane		halothane		isoflurane	
TC	low	high	low	high	low	high
g	0.3515	0.2808	0.2785	0.3058	0.3465	0.3317
RSD_P, %	2.77	2.27	1.39	1.37	3.50	2.83

4.6 Precision (overall procedure)

The precision of the overall procedure is determined from the storage data in Section 4.7. The determination of the standard error of estimate (SEE_R) for a regression line plotted through the graphed storage data allows the inclusion of storage time as one of the factors affecting overall precision. The SEE_R is similar to the standard deviation, except it is a measure of the dispersion of data about a regression line instead of about a mean. It is determined with the following equation:

$$SEE_R = \sqrt{\frac{\sum(Y_{obs} - Y_{est})^2}{n - k}}$$

Y_{obs} = observed % recovery at a given time
Y_{est} = estimated % recovery from the regression line at the same given time
n = total number of data points
k = 2 for linear regression
k = 3 for quadratic regression

An additional 5% for pump error (SP) is added to the SEE_R by the addition of variances to obtain the total standard error of the estimate.

$$SEE = \sqrt{(SEE_R)^2 + (SP)^2}$$

The precision at the 95% confidence level is obtained by multiplying the standard error of estimate (with pump error included) by 1.96 (the *z*-statistic from the standard normal distribution at the 95% confidence level). The 95% confidence intervals are drawn about their respective regression lines in the storage graphs, as shown in Figures 4.7.1.1.1 through 4.7.2.6.2. The precisions of the overall procedure and the associated figures are listed below.

Table 4.6.1
Precision of the Overall Procedure on Anasorb CMS, %

target concn	enflurane	halothane	isoflurane
1 ppm	14.1	14.9	15.3
	Fig. 4.7.2.1.1	Fig. 4.7.2.3.2	Fig. 4.7.2.5.1
50 ppm		13.7	
		Fig. 4.7.1.3.1	
75 ppm	16.3		16.6
	Fig. 4.7.1.1.1		Fig. 4.7.1.5.1

Table 4.6.2
Precision of the Overall Procedure on Anasorb 747, %

target concn	enflurane	halothane	isoflurane
1 ppm	11.3	10.6	11.5
	Fig. 4.7.2.2.1	Fig. 4.7.2.4.1	Fig. 4.7.2.6.1
50 ppm		11.4	
		Fig. 4.7.1.4.1	
75 ppm	15.1		12.0
	Fig. 4.7.1.2.1		Fig. 4.7.1.6.1

4.7 Storage test

4.7.1 Analyte storage at high target concentration

Storage samples were generated by sampling from a controlled test atmosphere containing 2120 mg/m^3 of enflurane, about 3.7 times the 75-ppm target concentration. Anasorb CMS tubes were used to sample for 60 min at 0.05 L/min, the relative humidity was about 80% at 22°C. Thirty-six storage samples were prepared. Six samples were analyzed immediately after generation, fifteen tubes were stored at reduced temperature (4°C) and the other fifteen were stored in a closed drawer at ambient temperature (about 22°C). At 2-4 day intervals, three samples were selected from each of the two sets and analyzed.

Table 4.7.1.1
Storage Test for Enflurane on Anasorb CMS

time (days)	ambient storage recovery (%)			refrigerated storage recovery (%)		
0	90.0	101.5	98.0	90.0	101.5	98.0
	101.9	103.4	95.3	101.9	103.5	95.3
3	101.0	101.6	94.6	90.9	88.3	95.6
6	102.1	105.1	107.3	111.1	103.6	98.7
9	101.8	104.1	95.4	90.7	97.0	100.5
13	97.8	88.4	91.9	98.3	112.7	103.3
15	91.1	102.7	90.7	92.0	100.2	102.3

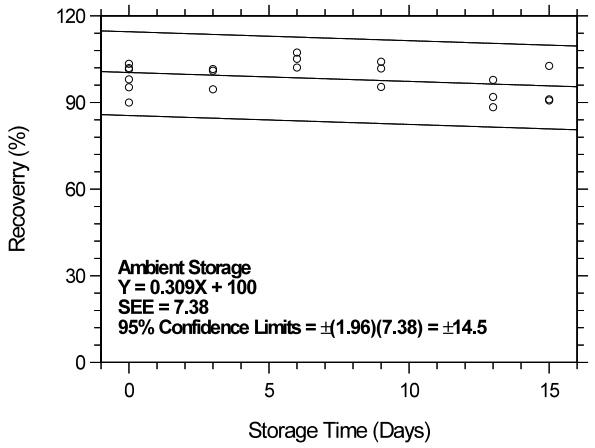


Figure 4.7.1.1.1. Ambient storage test for enflurane on Anasorb CMS.

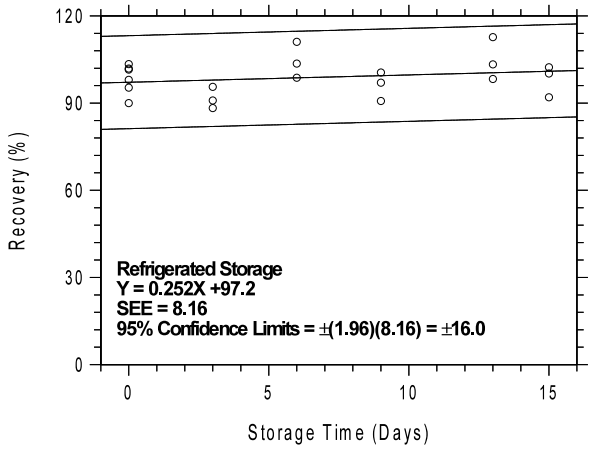


Figure 4.7.1.1.2. Refrigerated storage test for enflurane on Anasorb CMS.

Storage samples were generated by sampling from a controlled test atmosphere containing 2118 mg/m^3 of enflurane, about 3.7 times the 75-ppm target concentration. Anasorb 747 tubes were used to sample for 60 min at 0.05 L/min, the relative humidity was about 80% at 22°C. Thirty-six storage samples were prepared. Six samples were analyzed immediately after generation, fifteen tubes were stored at reduced temperature (4°C) and the other fifteen were stored in a closed drawer at ambient temperature (about 22°C). At 2-4 day intervals, three samples were selected from each of the two sets and analyzed.

Table 4.7.1.2
Storage Test for Enflurane on Anasorb 747

time (days)	ambient storage recovery (%)			refrigerated storage recovery (%)		
0	96.3	97.4	106.9	96.3	97.4	106.9
	102.1	101.7	102.5	102.1	101.7	102.5
2	92.4	84.7	100.8	96.9	101.4	98.2
6	92.0	104.1	97.6	95.1	96.9	99.6
9	102.2	96.7	106.3	93.1	104.2	99.0
12	97.2	112.2	105.2	102.1	103.0	105.6
16	102.0	102.6	105.7	99.1	112.2	106.9

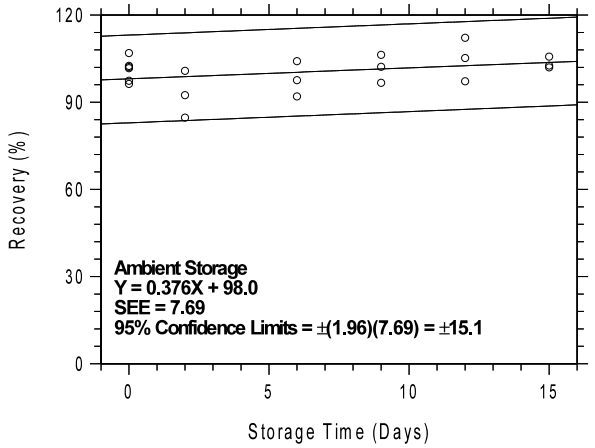


Figure 4.7.1.2.1. Ambient storage test for enflurane on Anasorb 747.

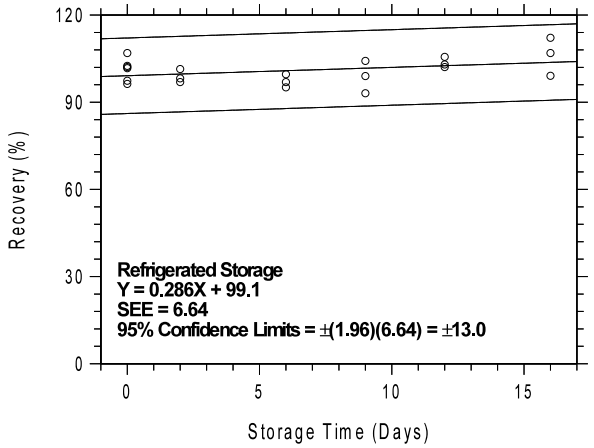


Figure 4.7.1.2.2. Refrigerated storage test for enflurane on Anasorb 747.

Storage samples were generated by sampling from a controlled test atmosphere containing 2146 mg/m^3 of halothane, about 5.3 times the 50-ppm target concentration. Anasorb CMS tubes were used to sample for 60 min at 0.05 L/min, the relative humidity was about 80%

at 22°C. Thirty-six storage samples were prepared. Six samples were analyzed immediately after generation, fifteen tubes were stored at reduced temperature (4°C) and the other fifteen were stored in a closed drawer at ambient temperature (about 22°C). At 2-4 day intervals, three samples were selected from each of the two sets and analyzed.

Table 4.7.1.3
Storage Test for Halothane on Anasorb CMS

time (days)	ambient storage recovery (%)			refrigerated storage recovery (%)		
0	103.3	104.3	90.8	103.3	104.3	90.8
	98.3	95.5	98.7	98.3	95.5	98.7
4	101.5	95.4	96.9	106.6	91.4	99.6
6	103.2	88.7	96.0	99.1	95.8	98.8
8	103.5	101.1	97.7	108.3	92.9	100.4
12	106.0	91.0	94.5	108.7	102.0	102.3
15	96.0	91.1	93.6	103.6	90.6	101.1

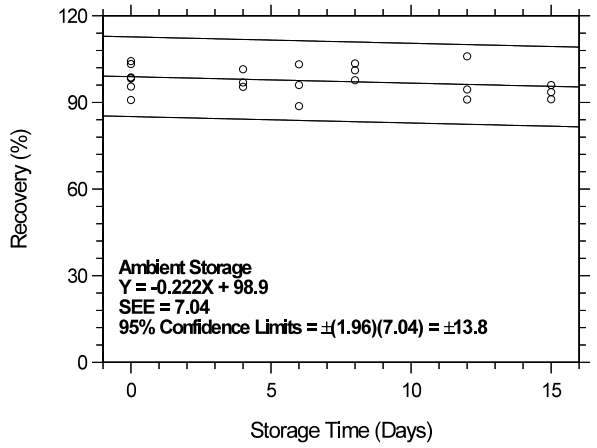


Figure 4.7.1.3.1. Ambient storage test for halothane on Anasorb CMS.

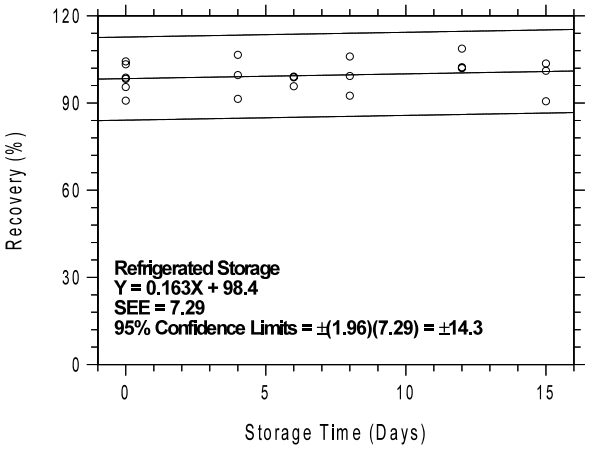


Figure 4.7.1.3.2. Refrigerated storage test for halothane on Anasorb CMS.

Storage samples were generated by sampling from a controlled test atmosphere containing 2305 mg/m^3 of halothane, about 5.7 times the 50-ppm target concentration. Anasorb 747 tubes were used to sample for 60 min at 0.05 L/min, the relative humidity was about 80% at 22°C. Thirty-six storage samples were prepared. Six samples were analyzed immediately after generation, fifteen tubes were stored at reduced temperature (4°C) and the other fifteen were stored in a closed drawer at ambient temperature (about 22°C). At 3-4 day intervals, three samples were selected from each of the two sets and analyzed.

Table 4.7.1.4
Storage Test for Halothane on Anasorb 747

time (days)	ambient storage recovery (%)			refrigerated storage recovery (%)		
0	99.1	100.0	103.9	99.1	100.0	103.9
	100.5	99.7	96.9	100.5	99.7	96.9
3	99.4	99.2	96.2	98.6	104.2	98.9
6	98.8	104.2	98.8	101.5	100.1	97.3
10	99.1	103.5	94.9	100.9	105.0	101.3
13	95.8	104.5	98.7	101.3	95.7	95.5
17	103.8	104.8	99.6	102.7	105.9	99.2

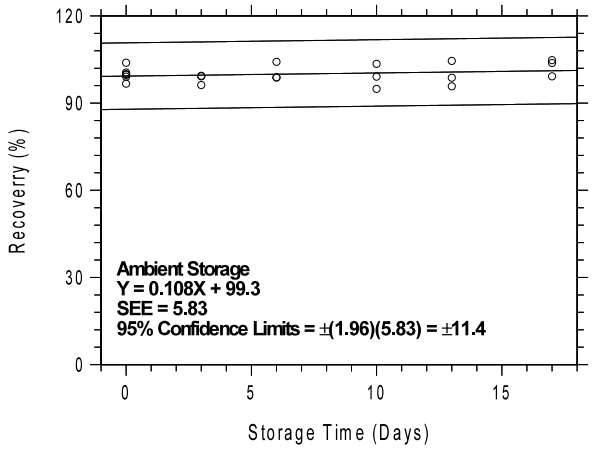


Figure 4.7.1.4.1. Ambient storage test for halothane on Anasorb 747.

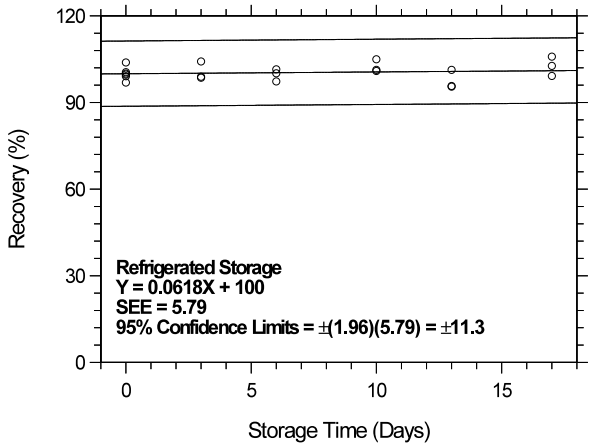


Figure 4.7.1.4.2. Refrigerated storage test for halothane on Anasorb 747.

Storage samples were generated by sampling from a controlled test atmosphere containing 3050 mg/m^3 of isoflurane, about 5.4 times the 75-ppm target concentration. Anasorb CMS tubes were used to sample for 60 min at 0.05 L/min, the relative humidity was about 80% at 22°C. Thirty-six storage samples were prepared. Six samples were analyzed immediately after generation, fifteen tubes were stored at reduced temperature (4°C) and the other fifteen were stored in a closed drawer at ambient temperature (about 22°C). At 2-4 day intervals, three samples were selected from each of the two sets and analyzed.

Table 4.7.1.5
Storage Test for Isoflurane on Anasorb CMS

time (days)	ambient storage recovery (%)			refrigerated storage recovery (%)		
0	99.7	103.6	93.9	99.7	103.6	93.6
	99.0	85.4	97.8	99.0	85.4	97.8
4	111.9	104.8	97.5	106.7	91.7	92.1
7	99.2	94.2	90.2	108.8	103.0	100.6
11	113.1	102.9	102.3	106.5	99.1	91.4
13	103.9	96.4	92.0	108.0	105.3	103.6
15	108.0	105.1	106.1	105.0	100.3	96.8

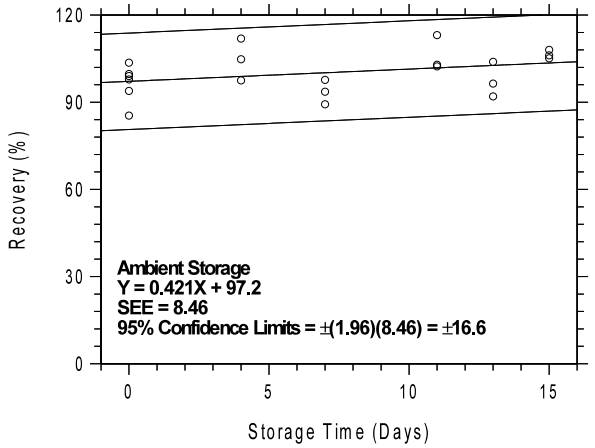


Figure 4.7.1.5.1. Ambient storage test for isoflurane on Anasorb CMS.

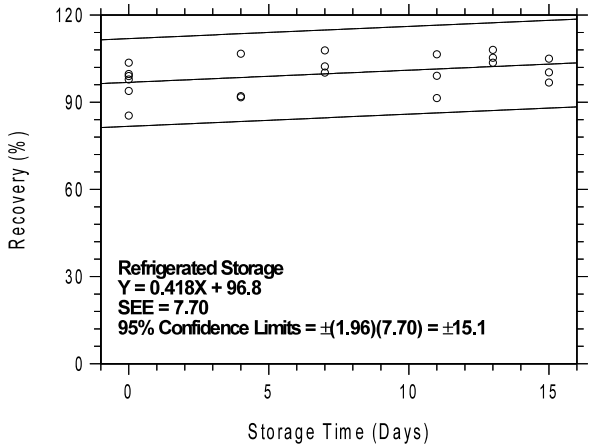


Figure 4.7.1.5.2. Refrigerated storage test for isoflurane on Anasorb CMS.

Storage samples were generated by sampling from a controlled test atmosphere containing 2992 mg/m^3 of isoflurane, about 5.3 times the 75-ppm target concentration. Anasorb 747 tubes were used to sample for 60 min at 0.05 L/min, the relative humidity was about 80%

at 22°C. Thirty-six storage samples were prepared. Six samples were analyzed immediately after generation, fifteen tubes were stored at reduced temperature (4°C) and the other fifteen were stored in a closed drawer at ambient temperature (about 22°C). At 3-4 day intervals, three samples were selected from each of the two sets and analyzed.

Table 4.7.1.6
Storage Test for Isoflurane on Anasorb 747

time (days)	ambient storage recovery (%)			refrigerated storage recovery (%)		
0	92.3	99.3	99.1	92.3	99.3	99.1
	99.6	100.6	101.5	99.6	100.6	101.5
4	99.6	97.4	102.6	97.0	92.1	98.2
7	92.5	94.9	101.0	103.2	102.8	103.5
10	100.5	103.2	102.5	98.0	97.0	100.7
14	103.1	100.6	108.3	106.8	102.4	105.9
18	107.7	100.1	105.1	103.1	100.5	104.1

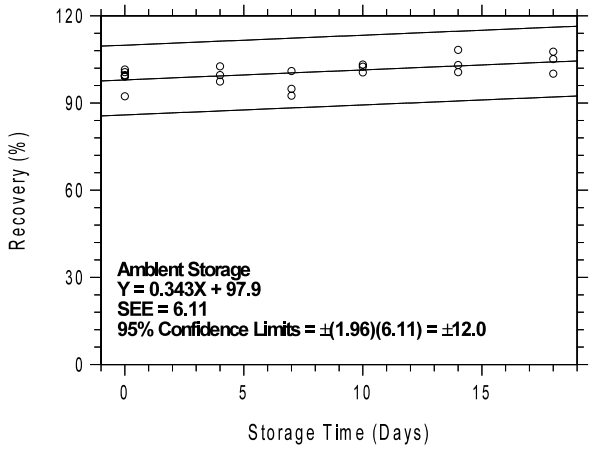


Figure 4.7.1.6.1. Ambient storage test for isoflurane on Anasorb 747.

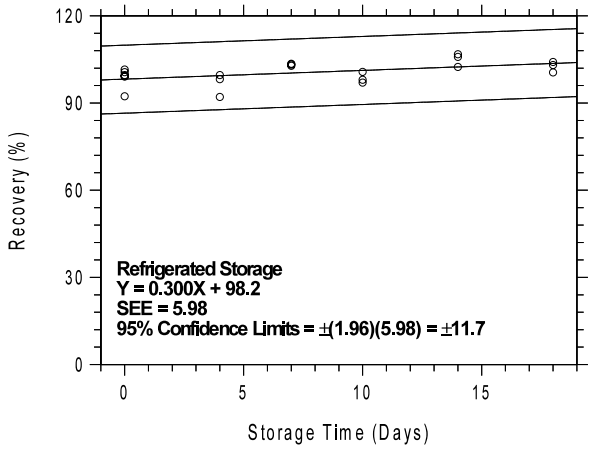


Figure 4.7.1.6.2. Refrigerated storage test for isoflurane on Anasorb 747.

4.7.2 Analyte storage at low target concentration

Storage samples were generated by sampling from a controlled test atmosphere containing 58.2 mg/m^3 of enflurane, about 7.7 times the 1-ppm target concentration. Anasorb CMS tubes were used to sample for 30 min at 0.05 L/min, the relative humidity was about 80% at 22°C. Thirty-six storage samples were prepared. Six samples were analyzed immediately after generation, fifteen tubes were stored at reduced temperature (4°C) and the other fifteen were stored in a closed drawer at ambient temperature (about 22°C). At 2-4 day intervals, three samples were selected from each of the two sets and analyzed.

Table 4.7.2.1
Storage Test for Enflurane on Anasorb CMS

time (days)	ambient storage recovery (%)			refrigerated storage recovery (%)		
0	82.6	88.7	94.1	82.6	88.7	94.1
	98.8	98.3	102.9	98.8	98.3	102.9
4	90.1	92.9	97.0	90.4	101.0	101.7
7	91.6	99.9	102.2	96.6	103.9	99.0
11	99.1	96.6	100.9	90.0	100.8	96.9
13	88.3	95.9	97.3	104.9	97.7	98.1
15	96.3	92.1	95.6	86.6	93.0	102.0

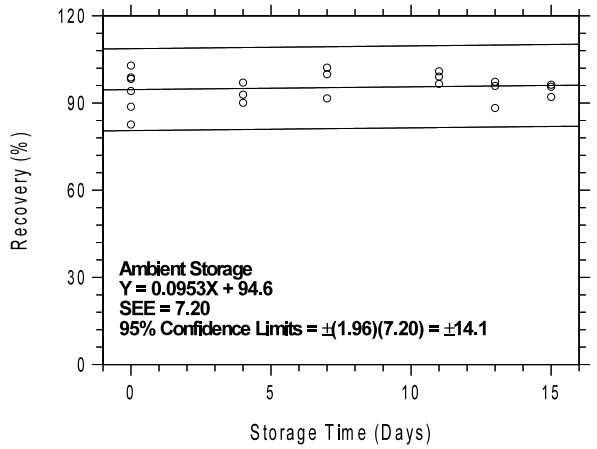


Figure 4.7.2.1.1. Ambient storage test for enflurane on Anasorb CMS.

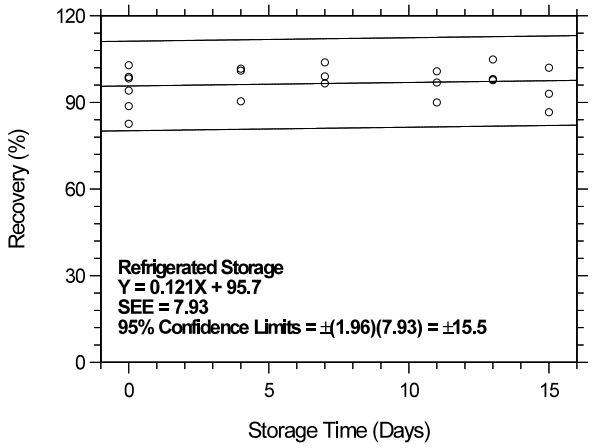


Figure 4.7.2.1.2. Refrigerated storage test for enflurane on Anasorb CMS.

Storage samples were generated by sampling from a controlled test atmosphere containing 59.4 mg/m^3 of enflurane, about 7.9 times the 1-ppm target concentration. Anasorb 747 tubes were used to sample for 30 min at 0.05 L/min, the relative humidity was about 80% at 22°C. Thirty-six storage samples were prepared. Six samples were analyzed immediately after generation, fifteen tubes were stored at reduced temperature (4°C) and the other fifteen were stored in a closed drawer at ambient temperature (about 22°C). At 2-6 day intervals, three samples were selected from each of the two sets and analyzed.

Table 4.7.2.2
Storage Test for Enflurane on Anasorb 747

time (days)	ambient storage recovery (%)			refrigerated storage recovery (%)		
0	101.8	93.4	96.5	101.8	93.4	96.5
	100.0	103.4	98.3	100.0	103.4	98.3
3	102.3	98.9	97.3	99.0	96.3	101.1
6	101.7	104.0	102.9	98.8	101.8	100.3
12	98.3	100.2	96.4	98.0	98.2	101.3
14	101.1	101.3	102.7	102.2	104.2	96.7
18	98.6	99.0	95.8	106.9	100.7	103.0

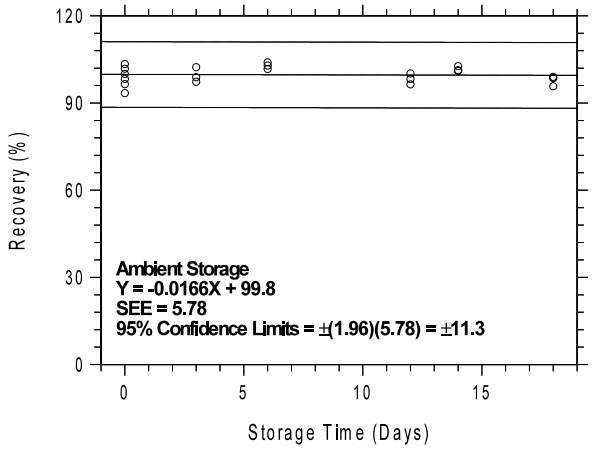


Figure 4.7.2.2.1. Ambient storage test for enflurane on Anasorb 747.

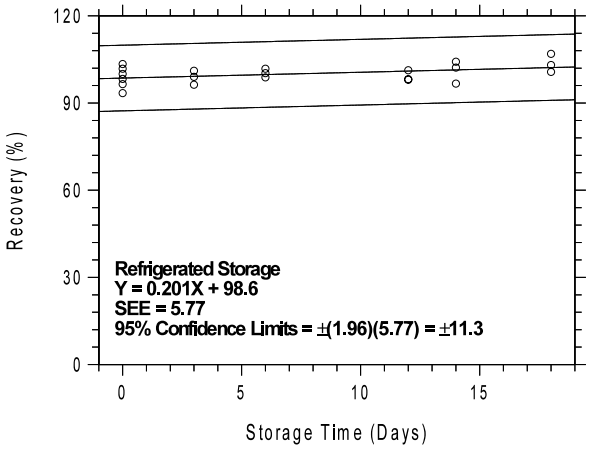


Figure 4.7.2.2.2. Refrigerated storage test for enflurane on Anasorb 747.

Storage samples were generated by sampling from a controlled test atmosphere containing 70.1 mg/m^3 of halothane, about 8.7 times the 1-ppm target concentration. Anasorb CMS tubes were used to sample for 30 min at 0.05 L/min, the relative humidity was about 80% at 22°C. Thirty-six storage samples were prepared. Six samples were analyzed immediately after generation, fifteen tubes were stored at reduced temperature (4°C) and the other fifteen were stored in a closed drawer at ambient temperature (about 22°C). At 2-5 day intervals, three samples were selected from each of the two sets and analyzed.

Table 4.7.2.3
Storage Test for Halothane on Anasorb CMS

time (days)	ambient storage recovery (%)			refrigerated storage recovery (%)		
0	91.7	93.8	98.7	91.7	93.8	98.7
	101.1	103.6	106.9	101.1	103.6	106.9
3	80.6	88.4	95.5	89.3	95.4	105.5
8	78.8	85.6	90.1	92.6	99.3	100.5
12	79.2	85.3	92.4	86.5	107.4	100.0
14	77.2	86.9	98.0	97.0	98.6	101.2
16	73.4	80.0	92.0	92.5	94.4	100.2

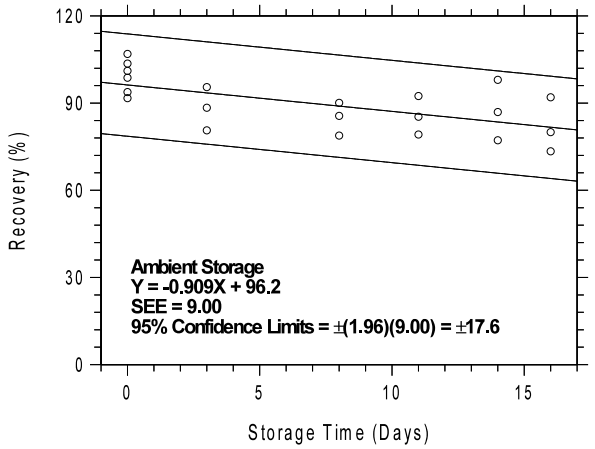


Figure 4.7.2.3.1. Ambient storage test for halothane on Anasorb CMS.

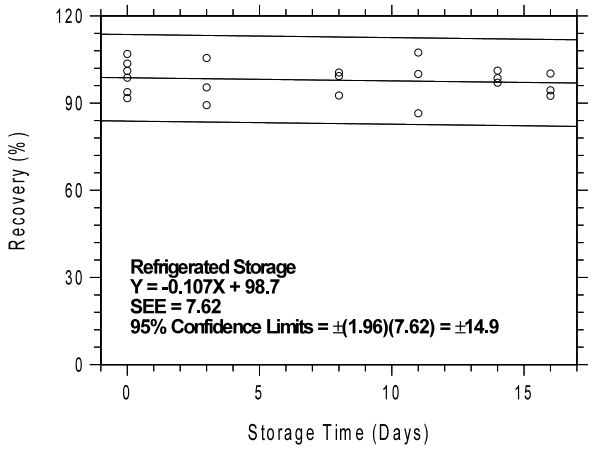


Figure 4.7.2.3.2. Refrigerated storage test for halothane on Anasorb CMS.

Storage samples were generated by sampling from a controlled test atmosphere containing 71.2 mg/m^3 of halothane, about 8.8 times the 1-ppm target concentration. Anasorb 747 tubes were used to sample for 30 min at 0.05 L/min, the relative humidity was about 80% at 22°C. Thirty-six storage samples were prepared. Six samples were analyzed immediately after generation, fifteen tubes were stored at reduced temperature (4°C) and the other fifteen were stored in a closed drawer at ambient temperature (about 22°C). At 2-4 day intervals, three samples were selected from each of the two sets and analyzed.

Table 4.7.2.4
Storage Test for Halothane on Anasorb 747

time (days)	ambient storage recovery (%)			refrigerated storage recovery (%)		
0	97.8	104.5	97.5	97.8	104.5	97.5
	99.4	101.0	99.8	99.4	101.0	99.8
3	99.2	102.0	98.0	97.3	99.0	103.4
6	--	100.2	100.8	98.4	105.3	97.1
9	104.5	103.7	101.0	98.9	111.2	102.6
13	101.0	102.7	100.6	106.0	102.3	99.7
15	105.7	103.0	101.4	113.3	101.0	101.1

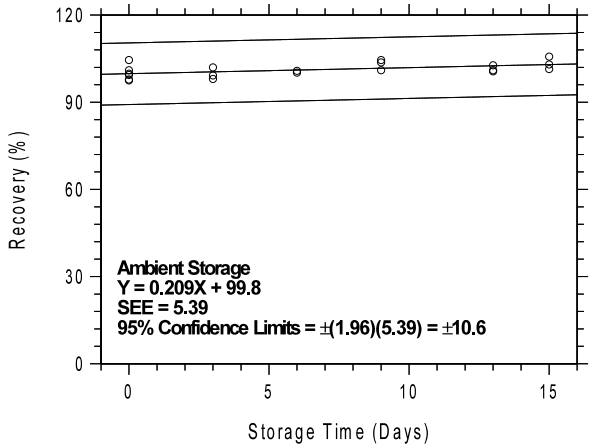


Figure 4.7.2.4.1. Ambient storage test for halothane on Anasorb 747.

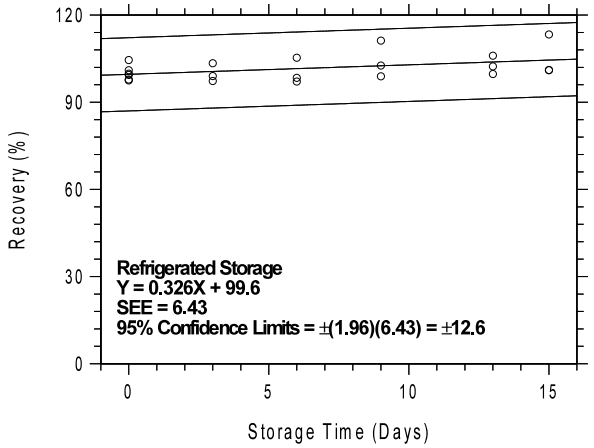


Figure 4.7.2.4.2. Refrigerated storage test for halothane on Anasorb 747.

Storage samples were generated by sampling from a controlled test atmosphere containing 50.4 mg/m^3 of isoflurane, about 6.7 times the 1-ppm target concentration. Anasorb CMS tubes were used to sample for 30 min at 0.05 L/min, the relative humidity was about 80%

at 22°C. Thirty-six storage samples were prepared. Six samples were analyzed immediately after generation, fifteen tubes were stored at reduced temperature (4°C) and the other fifteen were stored in a closed drawer at ambient temperature (about 22°C). At 2-4 day intervals, three samples were selected from each of the two sets and analyzed.

Table 4.7.2.5
Storage Test for Isoflurane on Anasorb CMS

time (days)	ambient storage recovery (%)			refrigerated storage recovery (%)		
0	79.1	88.1	91.8	79.1	88.1	91.8
	98.9	98.0	103.2	98.9	98.0	103.2
4	97.8	96.5	101.7	90.7	101.8	105.7
7	91.5	97.4	102.2	94.5	103.7	100.8
11	97.6	94.0	98.7	89.3	102.3	100.0
13	85.4	95.1	98.0	105.3	98.9	96.1
15	92.1	87.4	92.7	85.0	89.4	99.4

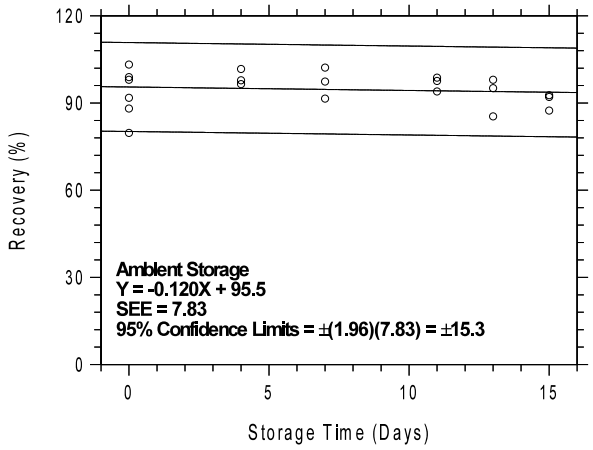


Figure 4.7.2.5.1. Ambient storage test for isoflurane on Anasorb CMS.

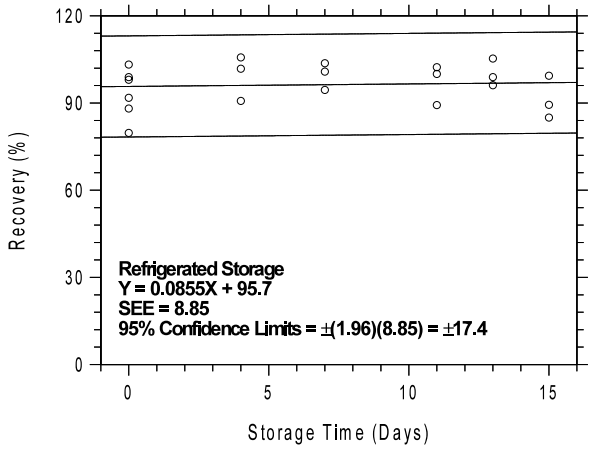


Figure 4.7.2.5.2. Refrigerated storage test for isoflurane on Anasorb CMS.

Storage samples were generated by sampling from a controlled test atmosphere containing 52.7 mg/m^3 of isoflurane, about 7 times the 1-ppm target concentration. Anasorb 747 tubes were used to sample for 30 min at 0.05 L/min, the relative humidity was about 80% at 22°C. Thirty-six storage samples were prepared. Six samples were analyzed immediately after generation, fifteen tubes were stored at reduced temperature (4°C) and the other fifteen were stored in a closed drawer at ambient temperature (about 22°C). At 2-6 day intervals, three samples were selected from each of the two sets and analyzed.

Table 4.7.2.6
Storage Test for Isoflurane on Anasorb 747

time (days)	ambient storage recovery (%)			refrigerated storage recovery (%)		
0	102.3	90.5	96.7	102.3	90.5	96.7
	100.0	104.2	96.8	100.0	104.2	96.8
3	101.8	98.0	98.4	100.7	97.4	102.0
6	102.5	102.6	101.2	98.4	102.3	100.6
12	97.7	98.5	96.7	99.9	100.5	102.3
14	99.5	99.5	100.9	102.8	101.6	96.0
16	98.4	96.9	97.0	107.6	101.8	103.2

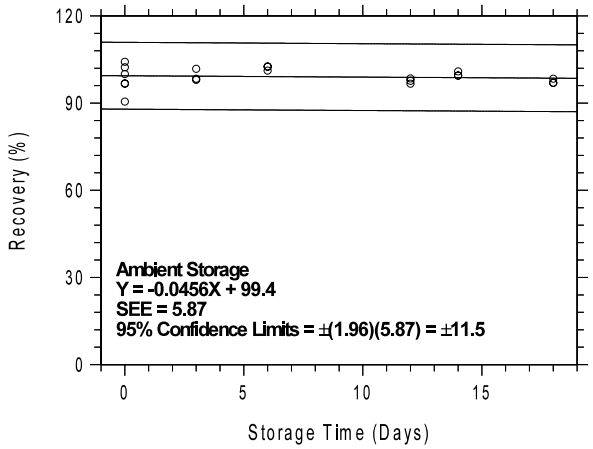


Figure 4.7.2.6.1. Ambient storage test for isoflurane on Anasorb 747.

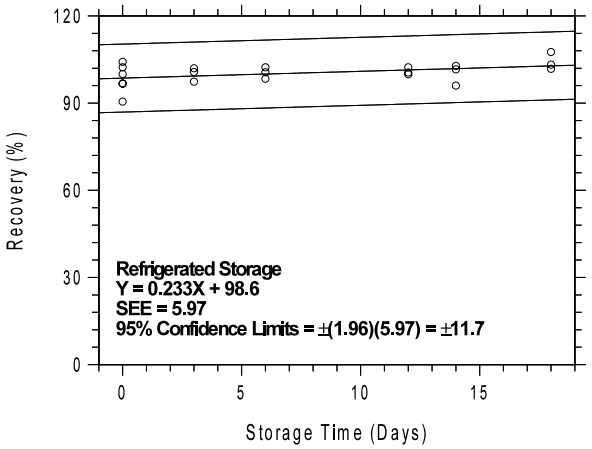


Figure 4.7.2.6.2. Refrigerated storage test for isoflurane on Anasorb 747.

4.8 Reproducibility

4.8.1 Analyte reproducibility at high target concentration

Six samples for each adsorbent were prepared by collecting them from a 75-ppm controlled test atmosphere containing enflurane and isoflurane for 4 h at 0.05 L/min. The samples were submitted to an OSHA Salt Lake Technical Center service branch. The samples were analyzed after being stored for 21 days at 4°C. Sample results were corrected for desorption efficiency. No sample result for enflurane or isoflurane had a deviation greater than the precision of the overall procedure determined in Section 4.6.

Table 4.8.1.1.1
Reproducibility Data for Enflurane

		Anasorb CMS			Anasorb 747		
sample	expected (mg/m^3)	reported (mg/m^3)	recovery (%)	deviation (%)	reported (mg/m^3)	recovery (%)	deviation (%)
1	570	546.3	95.9	-4.1	517.6	90.8	-9.2
2	570	517.3	90.9	-9.1	533.1	93.5	-6.5
3	570	544.1	95.5	-4.5	520.3	91.3	-8.7
4	570	556.9	97.7	-2.3	532.1	93.4	-6.6
5	570	518.7	91.0	-9.0	499.6	87.7	-12.3
6	570	536.9	94.2	-5.8	524.0	91.9	-8.1

Table 4.8.1.1.2
Reproducibility Data for Isoflurane

		Anasorb CMS			Anasorb 747		
sample	expected (mg/m^3)	reported (mg/m^3)	recovery (%)	deviation (%)	reported (mg/m^3)	recovery (%)	deviation (%)
1	562.5	596.6	106.1	+6.1	562.3	100.0	0
2	562.5	550.2	97.8	-2.2	576.6	102.5	+2.5
3	562.5	591.1	105.1	+5.1	564.0	100.3	+0.3
4	562.5	609.0	108.3	+8.3	578.1	102.8	+2.8
5	562.5	564.8	100.3	+0.3	540.3	96.1	-3.9
6	562.5	587.4	104.4	+4.4	569.2	101.2	+1.2

Six samples for each adsorbent were prepared by collecting them from a 50-ppm controlled test atmosphere containing halothane for 4 h at 0.05 L/min. The samples were submitted to an OSHA Salt Lake Technical Center service branch. The samples were analyzed after being stored for 17 days at 4°C. Sample results were corrected for desorption efficiency. No sample result for halothane had a deviation greater than the precision of the overall procedure determined in Section 4.6.

Table 4.8.1.2
Reproducibility Data for Halothane

		Anasorb CMS			Anasorb 747		
sample	expected (mg/m^3)	reported (mg/m^3)	recovery (%)	deviation (%)	reported (mg/m^3)	recovery (%)	deviation (%)
1	408	411.0	100.7	+0.7	406.2	99.6	-0.4
2	408	406.6	99.7	-0.3	411.1	100.8	+0.8
3	408	402.8	98.7	-1.3	411.5	100.8	+0.8
4	408	409.8	100.4	+0.4	410.6	100.6	+0.6
5	408	399.7	98.0	-2.0	401.7	98.5	-1.5
6	408	406.4	99.6	-0.4	408.1	100.0	0

4.8.2 Analyte reproducibility at low target concentration

Six samples for each adsorbent were prepared by collecting them from a 1-ppm controlled test atmosphere containing enflurane and isoflurane for 4 h at 0.05 L/min. The samples were submitted to an OSHA Salt Lake Technical Center service branch. The samples were analyzed after being stored for 22 days at 4°C. Sample results were corrected for desorption efficiency. No sample result for enflurane and isoflurane had a deviation greater than the precision of the overall procedure determined in Section 4.6.

Table 4.8.2.1.1
Reproducibility Data for Enflurane

		Anasorb CMS			Anasorb 747		
sample	expected (mg/m^3)	reported (mg/m^3)	recovery (%)	deviation (%)	reported (mg/m^3)	recovery (%)	deviation (%)
1	7.62	8.02	105.2	+5.2	7.81	102.5	+2.5
2	7.62	7.58	99.5	-0.5	7.82	102.6	+2.6
3	7.62	7.62	100.0	0	7.82	102.6	+2.6
4	7.62	6.55	86.0	-14.0	6.95	91.2	-8.8
5	7.62	7.58	99.5	-0.5	7.73	101.4	+1.4
6	7.62	7.65	100.4	+0.4	8.48	111.3	+11.3

Table 4.8.2.3
Reproducibility Data for Isoflurane

		Anasorb CMS			Anasorb 747		
sample	expected (mg/m^3)	reported (mg/m^3)	recovery (%)	deviation (%)	reported (mg/m^3)	recovery (%)	deviation (%)
1	7.52	7.74	102.9	+2.9	7.91	105.2	+5.2
2	7.52	7.47	99.3	-0.7	8.22	109.3	+9.3
3	7.52	7.65	101.7	+1.7	8.32	110.6	+10.6
4	7.52	6.58	87.5	-12.5	7.09	94.3	-5.7
5	7.52	7.15	95.1	-4.9	8.22	109.3	+9.3
6	7.52	7.59	100.9	+0.9	7.70	102.4	+2.4

Six samples for each adsorbent were prepared by collecting them from a 1-ppm controlled test atmosphere containing halothane for 4 h at 0.05 L/min. The samples were submitted to an OSHA Salt Lake Technical Center service branch. The samples were analyzed after being stored for 23 days at 4°C. Sample results were corrected for desorption efficiency. No sample result for halothane had a deviation greater than the precision of the overall procedure determined in Section 4.6.

Table 4.8.2.2
Reproducibility Data for Halothane

		Anasorb CMS			Anasorb 747		
sample	expected (mg/m^3)	reported (mg/m^3)	recovery (%)	deviation (%)	reported (mg/m^3)	recovery (%)	deviation (%)
1	8.40	7.38	87.9	-12.1	8.79	104.6	+4.6
2	8.40	7.80	92.9	-7.1	8.53	101.5	+1.5
3	8.40	8.32	99.0	-1.0	9.03	107.5	+7.5
4	8.40	7.93	94.4	-5.6	8.81	104.9	+4.9
5	8.40	8.20	97.6	-2.4	8.70	103.6	+3.6
6	8.40	8.67	103.2	+3.2	8.93	106.3	+6.3

4.9 Sampler capacity

4.9.1 Anasorb CMS

The sampling capacity of the front section of an Anasorb CMS sampling tube was tested by sampling from a dynamically generated test atmosphere of enflurane (1247 mg/m^3 or 165 ppm). The samples were collected at 0.05 L/min and the relative humidity was about 80% at 22°C. A GC with a gas sampling valve was placed in-line behind the 150-mg front test section. The valve was rotated to measure the amount of enflurane passing through the sampler at the time of rotation. The 5% breakthrough air volume was determined to be 28.8 L.

Table 4.9.1.1
Capacity of Enflurane on Anasorb CMS

first test		second test	
air volume (L)	breakthrough (%)	air volume (L)	breakthrough (%)
17.54	0	16.39	0
18.24	0.79	17.11	0.27
19.62	1.57	20.76	0.69
21.93	2.07	20.97	1.04
23.18	2.50	22.18	1.34
24.19	2.87	22.90	1.57
25.06	3.23	24.20	1.98
26.12	3.93	25.55	2.38
26.99	4.41	26.46	2.83
28.48	5.03	27.57	3.33
29.23	5.59	27.72	3.81
29.99	6.25	28.44	4.24

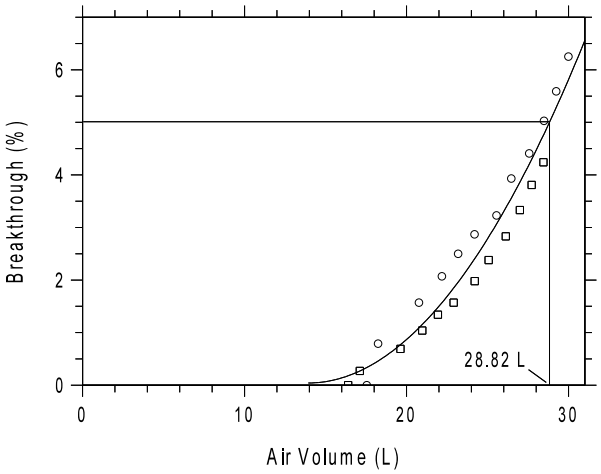


Figure 4.9.1.1. Five percent breakthrough air volume for enflurane on Anasorb CMS.

The sampling capacity of the front section of an Anasorb CMS sampling tube was tested by sampling from a dynamically generated test atmosphere of halothane (753 mg/m^3 or 93.3 ppm). The samples were collected at 0.05 L/min and the relative humidity was about 80% at 22°C. A GC with a gas sampling valve was placed in-line behind the 150-mg front test section. The valve was rotated to measure the amount of halothane passing through the sampler at the time of rotation. The 5% breakthrough air volume was determined to be 15.8 L.

Table 4.9.1.2
Capacity of Halothane on Anasorb CMS

first test		second test	
air volume (L)	breakthrough (%)	air volume (L)	breakthrough (%)
5.88	0	6.06	0
7.10	0	7.26	0
8.37	0	8.52	0
12.42	3.11	12.53	3.08
12.93	3.28	13.03	3.21
13.44	3.71	13.53	3.65
13.94	4.11	14.03	4.00
14.55	4.53	14.63	4.29
15.06	4.64	15.13	4.47
15.56	4.97	15.63	4.72
16.07	5.26	16.13	4.96
16.58	5.74	16.63	5.19
17.09	5.83	17.13	5.58
17.59	6.24	17.64	5.87
18.10	6.32		

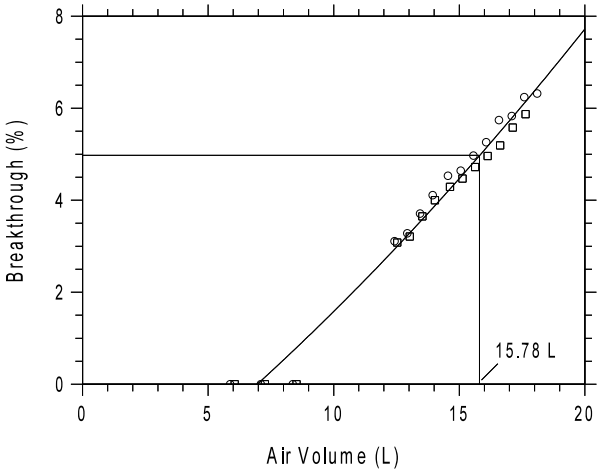


Figure 4.9.1.2. Five percent breakthrough air volume for halothane on Anasorb CMS.

The sampling capacity of the front section of an Anasorb CMS sampling tube was tested by sampling from a dynamically generated test atmosphere of isoflurane (1246 mg/m^3 or 165 ppm). The samples were collected at 0.05 L/min and the relative humidity was about 80% at 22°C. A GC with a gas sampling valve was placed in-line behind the 150-mg front test section. The valve was rotated to measure the amount of isoflurane passing through the sampler at the time of rotation. The 5% breakthrough air volume was determined to be 24.0 L.

Table 4.9.1.3
Capacity of Isoflurane on Anasorb CMS

first test		second test	
air volume (L)	breakthrough (%)	air volume (L)	breakthrough (%)
9.10	0	9.93	0
13.48	0.42	14.11	0.96
14.51	0.73	15.12	1.42
15.50	1.03	16.13	1.76
16.48	1.39	17.14	1.96
17.76	1.75	18.50	2.42
19.19	2.36	20.06	3.15
20.41	2.86	21.17	3.74
21.50	3.24	22.27	4.24
22.68	3.67	23.49	5.21
23.86	4.32	24.70	6.16
24.85	4.65	25.70	6.89

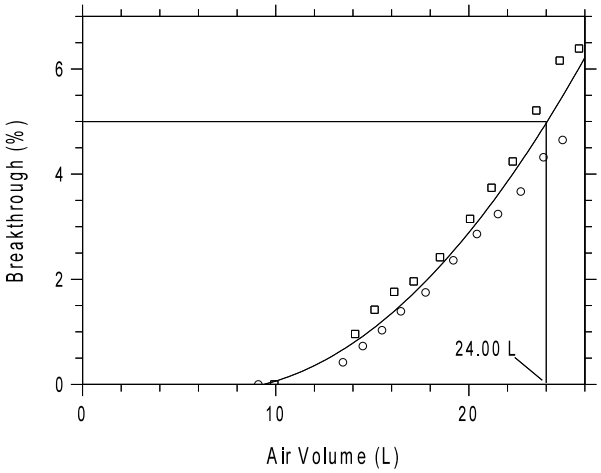


Figure 4.9.1.3. Five percent breakthrough air volume for isoflurane on Anasorb CMS.

4.9.2 Anasorb 747

The sampling capacity of the front section of an Anasorb 747 sampling tube was tested by sampling from a dynamically generated test atmosphere of enflurane (1247 mg/m^3 or 165 ppm). The samples were collected at 0.05 L/min and the relative humidity was about 80% at 22°C. A GC with a gas sampling valve was placed in-line behind the 140-mg front test section. The valve was rotated to measure the amount of enflurane passing through the sampler at the time of rotation. The 5% breakthrough air volume was determined to be 14.2 L.

Table 4.9.2.1
Capacity of Enflurane on Anasorb 747

first test		second test	
air volume (L)	breakthrough (%)	air volume (L)	breakthrough (%)
9.85	0	10.10	0
13.13	1.40	13.43	2.22
13.69	3.12	13.94	3.98
14.24	5.61	14.49	6.29
14.75	7.77	15.00	8.12
15.25	9.13	15.50	9.95

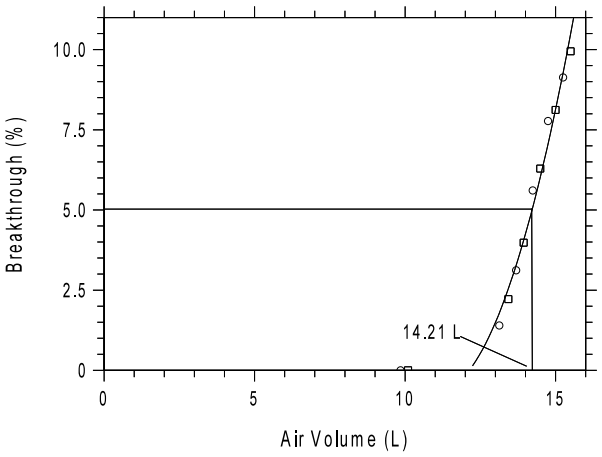


Figure 4.9.2.1. Five percent breakthrough air volume for enflurane on Anasorb 747.

The sampling capacity of the front section of an Anasorb 747 sampling tube was tested by sampling from a dynamically generated test atmosphere of halothane (753 mg/m^3 or 93.3 ppm). The samples were collected at 0.05 L/min and the relative humidity was about 80% at 22°C. A GC with a gas sampling valve was placed in-line behind the 140-mg front test section. The valve was rotated to measure the amount of halothane passing through the sampler at the time of rotation. The 5% breakthrough air volume was determined to be 19.9 L.

Table 4.9.2.2
Capacity of Halothane on Anasorb 747

first test		second test	
air volume (L)	breakthrough (%)	air volume (L)	breakthrough (%)
16.07	0	16.13	0
17.34	0	17.38	0
18.86	0.52	18.89	0.45
19.87	2.56	19.94	2.37
20.18	5.06	20.19	4.86
20.43	8.67	20.44	8.70
20.69	12.58	20.69	12.70

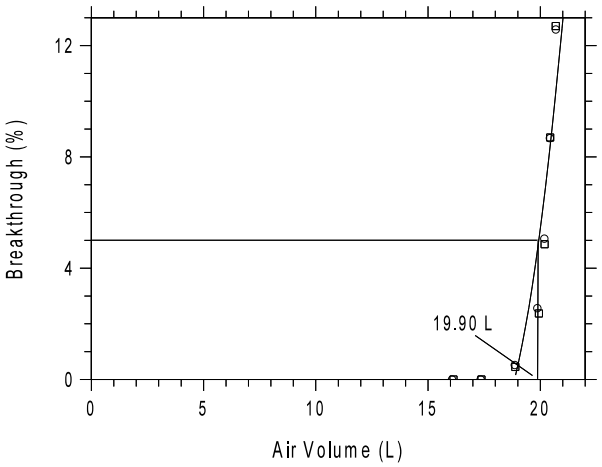


Figure 4.9.2.2. Five percent breakthrough air volume for halothane on Anasorb 747.

The sampling capacity of the front section of an Anasorb 747 sampling tube was tested by sampling from a dynamically generated test atmosphere of isoflurane (1246 mg/m^3 or 165 ppm). The samples were collected at 0.05 L/min and the relative humidity was about 80% at 22°C. A GC with a gas sampling valve was placed in-line behind the 140-mg front test section. The valve was rotated to measure the amount of isoflurane passing through the sampler at the time of rotation. The 5% breakthrough air volume was determined to be 17.5 L.

Table 4.9.2.3
Capacity of Isoflurane on Anasorb 747

first test		second test	
air volume (L)	breakthrough (%)	air volume (L)	breakthrough (%)
11.21	0	10.66	0
12.20	0	11.62	0
13.20	0.18	12.68	0.12
13.94	0.35	13.64	0.61
14.44	0.59	14.39	1.12
14.94	0.93	14.90	1.59
15.44	1.36	15.40	2.13
15.94	1.94	15.91	2.86
16.43	2.50	16.41	3.72
16.93	3.29	16.92	4.62
17.43	4.07	17.42	5.56
17.93	4.85	17.93	6.69
18.43	5.73	18.43	7.69
		18.94	8.76

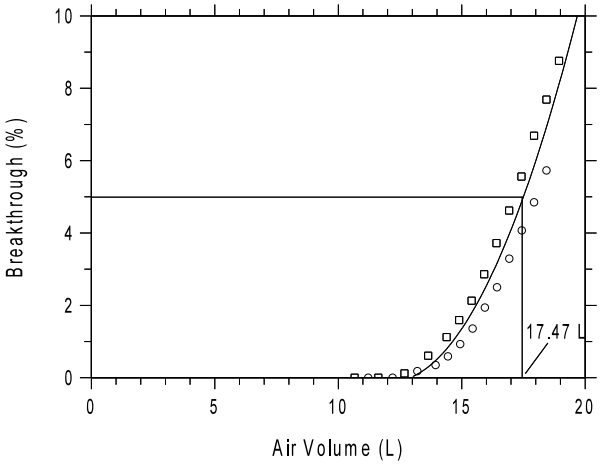


Figure 4.9.2.3. Five percent breakthrough air volume for isoflurane on Anasorb 747.

4.10 Desorption efficiency and stability of desorbed samples

4.10.1 Anasorb CMS at high target concentration (TC)

Enflurane

The desorption efficiencies (DE) of enflurane were determined by liquid-spiking 150-mg portions of Anasorb CMS with amounts equivalent to 0.05 to 2 times the 75-ppm target concentration. These samples were stored overnight at ambient temperature and then desorbed and analyzed. The average desorption efficiency over the working range of 0.5 to 2 times the target concentration is 99.8%.

Table 4.10.1.1.1
Desorption Efficiency of Enflurane from Anasorb CMS at High TC

× target concn (µg/sample)	0.05× 340.5	0.1× 681	0.2× 1362	0.5× 3403	1.0× 6810	2.0× 13620
DE (%)	101.4	98.5	100.2	100.2	99.8	99.3
	98.7	98.3	97.2	99.6	98.2	98.9
	100.5	100.3	100.1	99.9	100.6	98.9
	98.9	100.7	101.6	101.2	100.7	100.1
	100.8	100.0	99.6	100.3	99.7	97.8
	100.1	100.7	100.2	101.0	101.0	99.2
$\bar{X}$	100.1	99.8	99.8	100.4	100.0	99.0

The stability of desorbed samples was investigated by reanalyzing the target concentration samples 22.5 h after initial analysis. After the original analysis was performed, three vials were recapped with new septa while the remaining three retained their punctured septa. The samples vials were stored in the refrigerated sampling tray for the GC injector. The samples were reanalyzed with fresh standards. The average percent change was −2.0% for samples that were resealed with new septa, and −4.2% for those that retained their punctured septa.

Table 4.10.1.1.2
Stability of Desorbed Samples for Enflurane from Anasorb CMS

punctured septa replaced			punctured septa retained		
initial DE (%)	DE after one day (%)	difference	initial DE (%)	DE after one day (%)	difference
99.8	97.3	−2.5	100.7	98.7	−2.0
98.2	96.7	−1.5	99.7	95.4	−4.3
100.6	98.6	−2.0	101.0	94.8	−6.2
	(averages)			(averages)	
99.5	97.5	−2.0	100.5	96.3	−4.2

Halothane

The desorption efficiencies (DE) of halothane were determined by liquid-spiking 150-mg portions of Anasorb CMS with amounts equivalent to 0.05 to 2 times the 50-ppm target concentration. These samples were stored overnight at ambient temperature and then desorbed and analyzed. The average desorption efficiency over the working range of 0.5 to 2 times the target concentration is 99.5%.

Table 4.10.1.2.1
Desorption Efficiency of Halothane from Anasorb CMS at High TC

× target concn (µg/sample)	0.05× 243.1	0.1× 486.2	0.2× 972.4	0.5× 2431	1.0× 4862	2.0× 9724
DE (%)	99.4	98.6	98.9	99.1	99.8	99.6
	99.6	98.5	96.5	98.8	98.0	99.9
	97.4	99.1	98.5	101.8	100.0	99.4
	101.0	99.3	99.5	99.6	99.7	100.1
	99.0	98.9	98.3	99.5	99.2	98.6
	99.2	99.0	99.1	99.8	99.9	98.5
$\bar{X}$	99.3	98.9	98.5	99.8	99.4	99.4

The stability of desorbed samples was investigated by reanalyzing the target concentration samples 22.5 h after initial analysis. After the original analysis was performed, three vials were recapped with new septa while the remaining three retained their punctured septa. The samples vials were stored in the refrigerated sampling tray for the GC injector. The samples were reanalyzed with fresh standards. The average percent change was −1.5% for samples that were resealed with new septa, and −3.4% for those that retained their punctured septa.

Table 4.10.1.2.2
Stability of Desorbed Samples for Halothane from Anasorb CMS

punctured septa replaced			punctured septa retained		
initial DE (%)	DE after one day (%)	difference	initial DE (%)	DE after one day (%)	difference
99.8	97.4	−2.4	99.7	97.7	−2.0
98.0	97.1	−0.9	99.2	96.1	−3.1
100.0	98.8	−1.2	99.9	94.8	−5.1
	(averages)			(averages)	
99.3	97.8	−1.5	99.6	96.2	−3.4

Isoflurane

The desorption efficiencies (DE) of isoflurane were determined by liquid-spiking 150-mg portions of Anasorb CMS with amounts equivalent to 0.05 to 2 times the 75-ppm target concentration. These samples were stored overnight at ambient temperature and then desorbed and analyzed. The average desorption efficiency over the working range of 0.5 to 2 times the target concentration is 99.2%.

Table 4.10.1.3.1
Desorption Efficiency of Isoflurane from Anasorb CMS at High TC

× target concn (µg/sample)	0.05× 336	0.1× 672	0.2× 1344	0.5× 3360	1.0× 6720	2.0× 13440
DE (%)	100.2	97.3	99.6	99.8	99.1	97.6
	99.2	99.3	99.4	99.3	97.6	97.3
	98.7	99.9	100.9	99.4	99.7	97.8
	101.3	100.2	99.3	100.7	99.7	98.5
	100.9	99.1	99.5	100.2	103.3	96.8
	99.9	99.9	96.5	100.8	99.5	98.1
$\bar{X}$	100.0	99.3	99.2	100.0	99.8	97.7

The stability of desorbed samples was investigated by reanalyzing the target concentration samples 22.5 h after initial analysis. After the original analysis was performed, three vials were recapped with new septa while the remaining three retained their punctured septa. The samples vials were stored in the refrigerated sampling tray for the GC injector. The samples were reanalyzed with fresh standards. The average percent change was −2.3% for samples that were resealed with new septa, and −4.1% for those that retained their punctured septa.

Table 4.10.1.3.2
Stability of Desorbed Samples for Isoflurane from Anasorb CMS

punctured septa replaced			punctured septa retained		
initial DE (%)	DE after one day (%)	difference	initial DE (%)	DE after one day (%)	difference
99.1	96.2	−2.9	99.7	98.0	−1.7
97.6	95.5	−2.1	103.3	98.1	−5.2
99.7	97.8	−1.9	99.5	93.9	−5.4
	(averages)			(averages)	
98.8	96.5	−2.3	100.8	96.7	−4.1

4.10.2 Anasorb 747 at high target concentration (TC)

Enflurane

The desorption efficiencies (DE) of enflurane were determined by liquid-spiking 140-mg portions of Anasorb 747 with amounts equivalent to 0.05 to 2 times the 75-ppm target concentration. These samples were stored overnight at ambient temperature and then desorbed and analyzed. The average desorption efficiency over the working range of 0.5 to 2 times the target concentration is 100.5%.

Table 4.10.2.1.1
Desorption Efficiency of Enflurane from Anasorb 747 at High TC

× target concn (µg/sample)	0.05× 340.5	0.1× 681	0.2× 1362	0.5× 3405	1.0× 6810	2.0× 13620
DE (%)	100.9	100.6	101.4	98.9	103.9	99.5
	99.1	99.1	98.0	100.0	100.9	100.3
	101.1	99.5	98.4	98.9	105.3	102.6
	101.7	99.6	102.5	98.3	99.5	101.0
	99.9	101.8	102.0	100.6	100.2	102.3
	98.6	99.6	99.7	97.6	100.5	97.5
$\bar{X}$	100.2	100.0	100.3	99.1	101.8	100.5

The stability of desorbed samples was investigated by reanalyzing the target concentration samples 22.5 h after initial analysis. After the original analysis was performed, three vials were recapped with new septa while the remaining three retained their punctured septa. The samples vials were stored in the refrigerated sampling tray for the GC injector. The samples were reanalyzed with fresh standards. The average percent change was −0.5% for samples that were resealed with new septa, and −3.7% for those that retained their punctured septa.

Table 4.10.2.1.2
Stability of Desorbed Samples for Enflurane from Anasorb 747

punctured septa replaced			punctured septa retained		
initial DE (%)	DE after one day (%)	difference	initial DE (%)	DE after one day (%)	difference
99.5	99.4	−0.1	105.3	99.3	−6.0
100.2	98.9	−1.3	103.9	99.8	−4.1
100.5	100.3	−0.2	100.9	99.8	−1.1
	(averages)			(averages)	
100.1	99.5	−0.5	103.4	99.6	−3.7

Halothane

The desorption efficiencies (DE) of halothane were determined by liquid-spiking 140-mg portions of Anasorb 747 with amounts equivalent to 0.05 to 2 times the 50-ppm target concentration. These samples were stored overnight at ambient temperature and then desorbed and analyzed. The average desorption efficiency over the working range of 0.5 to 2 times the target concentration is 99.3%.

Table 4.10.2.2.1
Desorption Efficiency of Halothane from Anasorb 747 at High TC

× target concn (µg/sample)	0.05× 243.5	0.1× 486.2	0.2× 972.4	0.5× 2431	1.0× 4862	2.0× 9724
DE (%)	98.9	98.9	100.0	99.9	99.3	99.1
	98.7	98.2	98.1	100.1	100.6	98.4
	100.4	98.2	101.5	100.2	100.1	100.7
	100.6	98.3	100.4	100.5	96.5	99.6
	100.4	98.1	101.3	99.3	96.6	101.1
	98.7	99.9	100.8	100.7	97.0	97.1
$\bar{X}$	99.6	98.6	100.4	100.1	98.4	99.3

The stability of desorbed samples was investigated by reanalyzing the target concentration samples 22.5 h after initial analysis. After the original analysis was performed, three vials were recapped with new septa while the remaining three retained their punctured septa. The samples vials were stored in the refrigerated sampling tray for the GC injector. The samples were reanalyzed with fresh standards. The average percent change was +1.5% for samples that were resealed with new septa, and −1.6% for those that retained their punctured septa.

Table 4.10.2.2.2
Stability of Desorbed Samples for Halothane from Anasorb 747

punctured septa replaced			punctured septa retained		
initial DE (%)	DE after one day (%)	difference	initial DE (%)	DE after one day (%)	difference
96.5	96.6	+0.1	99.3	98.0	−1.3
96.6	98.6	+2.0	100.6	99.0	−1.6
97.0	99.3	+2.3	100.1	98.3	−1.8
	(averages)			(averages)	
96.7	98.2	+1.5	100.0	98.4	−1.6

Isoflurane

The desorption efficiencies (DE) of isoflurane were determined by liquid-spiking 140-mg portions of Anasorb 747 with amounts equivalent to 0.05 to 2 times the 75-ppm target concentration. These samples were stored overnight at ambient temperature and then desorbed and analyzed. The average desorption efficiency over the working range of 0.5 to 2 times the target concentration is 100.2%.

Table 4.10.2.3.1
Desorption Efficiency of Isoflurane from Anasorb 747 at High TC

× target concn (µg/sample)	0.05× 336	0.1× 672	0.2× 1344	0.5× 3360	1.0× 6720	2.0× 13440
DE (%)	97.9	97.7	99.3	100.3	102.8	98.3
	98.5	96.6	96.4	101.5	104.0	99.5
	99.3	97.1	100.2	98.2	99.6	101.7
	98.9	96.7	99.9	100.4	100.1	100.2
	96.9	98.6	101.3	100.3	99.5	101.3
	96.7	96.6	97.1	99.6	99.1	96.5
$\bar{X}$	98.0	97.2	99.0	100.1	100.9	99.6

The stability of desorbed samples was investigated by reanalyzing the target concentration samples 22.5 h after initial analysis. After the original analysis was performed, three vials were recapped with new septa while the remaining three retained their punctured septa. The samples vials were stored in the refrigerated sampling tray for the GC injector. The samples were reanalyzed with fresh standards. The average percent change was −3.4% for samples that were resealed with new septa, and −4.8% for those that retained their punctured septa.

Table 4.10.2.3.2
Stability of Desorbed Samples for Isoflurane from Anasorb 747

punctured septa replaced			punctured septa retained		
initial DE (%)	DE after one day (%)	difference	initial DE (%)	DE after one day (%)	difference
100.1	94.0	−6.1	102.8	97.2	−5.6
99.5	96.4	−3.1	104.0	97.2	−6.8
99.1	98.1	−1.0	99.6	97.6	−2.0
	(averages)			(averages)	
99.6	96.2	−3.4	102.1	97.3	−4.8

4.10.3 Anasorb CMS at low target concentration (TC)

Enflurane

The desorption efficiencies (DE) of enflurane were determined by liquid-spiking 150-mg portions of Anasorb CMS with amounts equivalent to 0.05 to 2 times the 1-ppm target concentration. These samples were stored overnight at ambient temperature and then desorbed and analyzed. The average desorption efficiency over the working range of 0.5 to 2 times the target concentration is 100.3%.

Table 4.10.3.1.1
Desorption Efficiency of Enflurane from Anasorb CMS at Low TC

× target concn	0.05×	0.1×	0.2×	0.5×	1.0×	2.0×
(µg/sample)	4.56	9.12	18.24	45.6	91.2	182.4
DE (%)	99.4	100.2	99.5	101.0	98.7	99.1
	99.2	98.7	99.3	102.2	98.7	100.2
	101.4	101.2	97.7	101.1	97.7	101.8
	101.5	100.0	99.0	101.3	98.7	100.4
	99.4	101.6	100.0	99.4	99.4	102.8
	99.4	100.5	101.7	100.9	100.3	101.8
$\bar{X}$	100.2	100.4	99.5	101.0	98.9	101.0

The stability of desorbed samples was investigated by reanalyzing the target concentration samples 22.5 h after initial analysis. After the original analysis was performed, three vials were recapped with new septa while the remaining three retained their punctured septa. The samples vials were stored in the refrigerated sampling tray for the GC injector. The samples were reanalyzed with fresh standards. The average percent change was +3.3% for samples that were resealed with new septa, and +0.9% for those that retained their punctured septa.

Table 4.10.3.1.2
Stability of Desorbed Samples for Enflurane from Anasorb CMS

punctured septa replaced			punctured septa retained		
initial DE (%)	DE after one day (%)	difference	initial DE (%)	DE after one day (%)	difference
98.7	101.4	+2.7	98.7	98.7	0
98.7	101.9	+3.2	99.4	99.8	+0.4
97.7	101.7	+4.0	100.3	102.8	+2.5
	(averages)			(averages)	
98.4	101.7	+3.3	99.5	100.4	+0.9

Halothane

The desorption efficiencies (DE) of enflurane were determined by liquid-spiking 150-mg portions of Anasorb CMS with amounts equivalent to 0.05 to 2 times the 1-ppm target concentration. These samples were stored overnight at ambient temperature and the

desorbed and analyzed. The average desorption efficiency over the working range of 0.5 to 2 times the target concentration is 99.7%.

Table 4.10.3.2.1
Desorption Efficiency of Halothane from Anasorb CMS at Low TC

× target concn (µg/sample)	0.05× 4.862	0.1× 9.724	0.2× 19.45	0.5× 48.62	1.0× 97.24	2.0× 194.5
DE (%)	101.1	100.3	100.8	99.1	98.7	98.2
	99.7	103.2	99.1	98.3	99.5	98.7
	98.8	99.5	100.8	100.3	99.1	100.1
	99.7	100.0	98.5	100.0	100.2	100.5
	99.5	100.5	99.4	98.9	102.4	100.1
	98.9	99.7	100.2	97.5	101.1	101.7
$\bar{X}$	99.6	100.5	99.8	99.0	100.2	99.9

The stability of desorbed samples was investigated by reanalyzing the target concentration samples 22.5 h after initial analysis. After the original analysis was performed, three vials were recapped with new septa while the remaining three retained their punctured septa. The samples vials were stored in the refrigerated sampling tray for the GC injector. The samples were reanalyzed with fresh standards. The average percent change was +1.1% for samples that were resealed with new septa, and −1.6% for those that retained their punctured septa.

Table 4.10.3.2.2
Stability of Desorbed Samples for Halothane from Anasorb CMS

punctured septa replaced			punctured septa retained		
initial DE (%)	DE after one day (%)	difference	initial DE (%)	DE after one day (%)	difference
98.7	100.9	+2.2	100.2	99.3	−0.9
99.5	99.5	0	102.4	99.2	−3.2
99.1	100.1	+1.0	101.1	100.4	−0.7
	(averages)			(averages)	
99.1	100.2	+1.1	101.2	99.6	−1.6

Isoflurane

The desorption efficiencies (DE) of isoflurane were determined by liquid-spiking 150-mg portions of Anasorb CMS with amounts equivalent to 0.05 to 2 times the 1-ppm target concentration. These samples were stored overnight at ambient temperature and then desorbed and analyzed. The average desorption efficiency over the working range of 0.5 to 2 times the target concentration is 99.4%.

Table 4.10.3.3.1
Desorption Efficiency of Enflurane from Anasorb CMS at Low TC

× target concn (µg/sample)	0.05× 4.50	0.1× 9.00	0.2× 18.0	0.5× 45.0	1.0× 90.0	2.0× 183.0
DE (%)	98.7	99.3	100.2	100.3	96.9	98.6
	99.3	98.1	98.1	98.9	97.6	100.2
	99.1	98.5	101.1	101.3	97.1	101.5
	99.0	98.3	100.1	99.6	97.9	98.7
	100.1	97.2	98.5	100.2	98.5	101.6
	99.5	99.0	101.4	100.6	98.4	100.4
$\bar{X}$	99.3	98.4	99.9	100.2	97.7	100.2

The stability of desorbed samples was investigated by reanalyzing the target concentration samples 22.5 h after initial analysis. After the original analysis was performed, three vials were recapped with new septa while the remaining three retained their punctured septa. The samples vials were stored in the refrigerated sampling tray for the GC injector. The samples were reanalyzed with fresh standards. The average percent change was +3.6%

for samples that were resealed with new septa, and +1.9% for those that retained their punctured septa.

Table 4.10.3.3.2
Stability of Desorbed Samples for Enflurane from Anasorb CMS

punctured septa replaced			punctured septa retained		
initial DE (%)	DE after one day (%)	difference	initial DE (%)	DE after one day (%)	difference
96.9	101.6	+4.7	97.9	97.1	−0.8
97.6	99.8	+2.2	98.5	101.1	+2.6
97.1	101.1	+4.0	98.4	102.5	+4.1
	(averages)			(averages)	
97.2	100.8	+3.6	98.3	100.2	+1.9

4.10.4 Anasorb 747 at low target concentration (TC)

Enflurane

The desorption efficiencies (DE) of enflurane were determined by liquid-spiking 140-mg portions of Anasorb 747 with amounts equivalent to 0.05 to 2 times the 1-ppm target concentration. These samples were stored overnight at ambient temperature and then desorbed and analyzed. The average desorption efficiency over the working range of 0.5 to 2 times the target concentration is 103.7%.

Table 4.10.4.1.1
Desorption Efficiency of Enflurane from Anasorb 747 at Low TC

× target concn (µg/sample)	0.05× 4.56	0.1× 9.12	0.2× 18.24	0.5× 45.6	1.0× 91.2	2.0× 182.4
DE (%)	102.0	100.5	99.1	103.2	102.3	101.9
	102.2	100.2	98.4	102.3	104.2	105.3
	96.9	97.9	99.6	102.2	101.6	103.7
	102.4	98.2	98.2	100.9	104.6	103.8
	101.2	97.7	99.7	107.8	106.3	103.6
	102.9	99.4	99.0	107.4	100.6	104.6
$\bar{X}$	101.3	99.0	99.0	104.0	103.3	103.8

The stability of desorbed samples was investigated by reanalyzing the target concentration samples 22.5 h after initial analysis. After the original analysis was performed, three vials were recapped with new septa while the remaining three retained their punctured septa. The samples vials were stored in the refrigerated sampling tray for the GC injector. The samples were reanalyzed with fresh standards. The average percent change was −2.1% for samples that were resealed with new septa, and −2.9% for those that retained their punctured septa.

Table 4.10.4.1.2
Stability of Desorbed Samples for Enflurane from Anasorb 747

punctured septa replaced			punctured septa retained		
initial DE (%)	DE after one day (%)	difference	initial DE (%)	DE after one day (%)	difference
102.3	98.4	−3.9	104.6	99.4	−5.2
104.2	100.9	−3.3	106.3	101.9	−4.4
101.6	102.6	+1.0	100.6	101.4	+0.8
	(averages)			(averages)	
102.7	100.6	−2.1	103.8	100.9	−2.9

Halothane

The desorption efficiencies (DE) of halothane were determined by liquid-spiking 140-mg portions of Anasorb 747 with amounts equivalent to 0.05 to 2 times the 1-ppm target concentration. These samples were stored overnight at ambient temperature and then desorbed and analyzed. The average desorption efficiency over the working range of 0.5 to 2 times the target concentration is 99.6%.

Table 4.10.4.2.1
Desorption Efficiency of Halothane from Anasorb 747 at Low TC

× target concn	0.05×	0.1×	0.2×	0.5×	1.0×	2.0×
(µg/sample)	4.862	9.724	19.45	48.62	97.24	194.5
DE (%)	85.2	95.7	94.8	98.0	98.3	101.0
	84.5	93.3	97.2	98.3	100.2	100.9
	85.2	92.7	94.3	99.7	97.9	99.0
	83.1	91.7	94.2	99.8	100.9	98.9
	84.5	90.7	93.7	99.7	101.6	99.1
	83.5	91.4	94.2	98.9	100.7	100.5
$\bar{X}$	84.3	92.6	94.7	99.1	99.9	99.9

The stability of desorbed samples was investigated by reanalyzing the target concentration samples 22.5 h after initial analysis. After the original analysis was performed, three vials were recapped with new septa while the remaining three retained their punctured septa. The samples vials were stored in the refrigerated sampling tray for the GC injector. The samples were reanalyzed with fresh standards. The average percent change was ±0% for samples that were resealed with new septa, and −3.0% for those that retained their punctured septa.

Table 4.10.4.2.2
Stability of Desorbed Samples for Halothane from Anasorb 747

punctured septa replaced			punctured septa retained		
initial DE (%)	DE after one day (%)	difference	initial DE (%)	DE after one day (%)	difference
98.3	98.4	+0.1	100.9	97.6	−3.3
100.2	98.1	−2.1	101.6	97.8	−3.8
97.9	99.9	+2.0	100.7	98.9	−1.8
	(averages)			(averages)	
98.8	98.8	±0	101.1	98.1	−3.0

Isoflurane

The desorption efficiencies (DE) of isoflurane were determined by liquid-spiking 140-mg portions of Anasorb 747 with amounts equivalent to 0.05 to 2 times the 1-ppm target concentration. These samples were stored overnight at ambient temperature and then desorbed and analyzed. The average desorption efficiency over the working range of 0.5 to 2 times the target concentration is 100.8%.

Table 4.10.4.3.1
Desorption Efficiency of Isoflurane from Anasorb 747 at Low TC

× target concn	0.05×	0.1×	0.2×	0.5×	1.0×	2.0×
(µg/sample)	4.50	9.00	18.0	45.0	90.0	180.0
DE (%)	97.1	100.0	98.1	103.2	99.3	99.4
	92.3	99.6	102.2	97.6	99.9	102.8
	96.4	100.2	101.1	99.4	99.2	100.8
	97.8	100.0	102.5	98.5	101.5	101.7
	99.4	100.0	101.0	104.0	102.9	100.8
	97.9	100.1	101.4	103.8	97.5	101.5
$\bar{X}$	96.8	100.0	101.1	101.1	100.1	101.2

The stability of desorbed samples was investigated by reanalyzing the target concentration samples 22.5 h after initial analysis. After the original analysis was performed, three vials

were recapped with new septa while the remaining three retained their punctured septa. The samples vials were stored in the refrigerated sampling tray for the GC injector. The samples were reanalyzed with fresh standards. The average percent change was −1.3% for samples that were resealed with new septa, and −4.4% for those that retained their punctured septa.

Table 4.10.4.3.2
Stability of Desorbed Samples for Isoflurane from Anasorb 747

punctured septa replaced			punctured septa retained		
initial DE (%)	DE after one day (%)	difference	initial DE (%)	DE after one day (%)	difference
99.3	97.4	−1.9	101.5	96.8	−4.7
99.9	97.0	−2.9	102.9	95.0	−7.9
99.2	100.2	+1.0	97.5	96.8	−0.7
	(averages)			(averages)	
99.5	98.2	−1.3	100.6	96.2	−4.4

4.11 Qualitative analysis

The anesthetic gases can be easily separated and identified by GC/MS. Mass spectra for enflurane, halothane and isoflurane, which were separated using conditions similar to the information given in Section 3.5, were obtained from a Perkin-Elmer Ion Trap Detector interfaced to a Hewlett-Packard Series II GC.

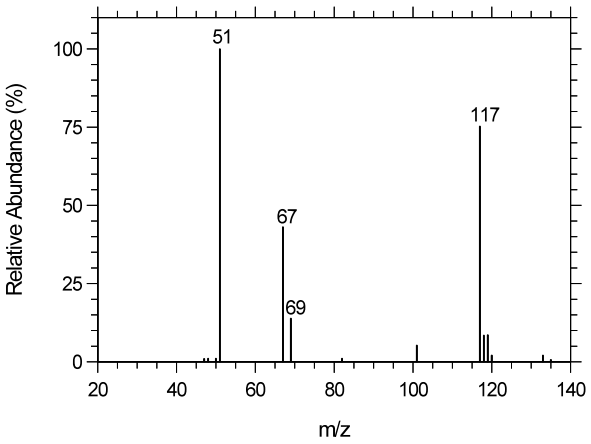


Figure 4.11.1. Mass spectrum of enflurane.

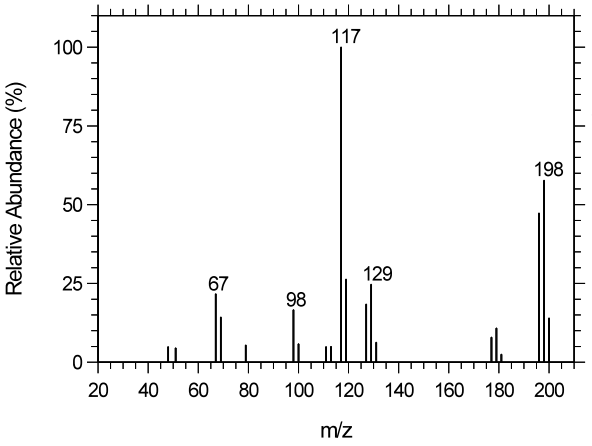


Figure 4.11.2. Mass spectrum of halothane.

4.12 Nitrous oxide interference

A test was developed to study the ability of nitrous oxide to interfere with the collection of anesthetic gases on the recommended sampling tubes. A 100-L gas-sampling bag was filled with dry air and 1.50 mL of water was added to raise the humidity to 80% at 22°C. Halothane was selected as a typical anesthetic gas and 20 µL (37.4 mg) was added to the bag. Nitrous oxide (430.5 mg) was also added. This produced an atmosphere containing 46.4 ppm of halothane and 2390 ppm of nitrous oxide. A second bag was prepared to duplicate the first one except no nitrous oxide was added. Air samples were drawn at 0.05 L/min for 4 h from both bags using Anasorb CMS and Anasorb 747. No halothane was detected on any of the back-up sections. The results show that nitrous oxide does not substantially interfere with the collection of halothane from an atmosphere containing both gases.

Table 4.12
Parts-per-million recovered from Gas-Sampling Bags

Anasorb	halothane	halothane with nitrous oxide
CMS	44.9	40.3
747	45.6	45.7

5. References

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5.8 Material Safety Data Sheet: 2-Bromo-2-chloro-1,1,1-trifluoroethane, Aldrich Chemical Co., Milwaukee, WI, May 1992.

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