METHYL ETHYL KETONE PEROXIDE
(MEK PEROXIDE)

Method no.:	77
Matrix:	Air
Target concentration:	1.5 mg/m^3
Procedure:	Air samples are collected by drawing known volumes of air through XAD-4 adsorbent tubes. The samples are desorbed with 2-propanol and analyzed by HPLC using postcolumn derivatization and an ultraviolet detector.
Recommended air volume and sampling rate:	15 L at 1.0 L/min
Reliable quantitation limit:	0.30 mg/m^3
Standard error of estimate at the target concentration: (Section 4.7)	7.41%
Special requirements:	Ship samples at reduced temperature. Store samples in a freezer upon receipt at the laboratory. Use clean silanized glassware for standard and sample preparations.
Status of method:	Evaluated method. This method has been subjected to the established evaluation procedures of the Organic Methods Evaluation Branch.

Date: September 1989 Chemist: Yihlin Chan

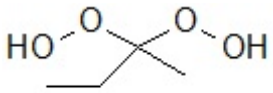
Organic Methods Evaluation Branch
OSHA Analytical Laboratory
Salt Lake City, Utah

1. General Discussion

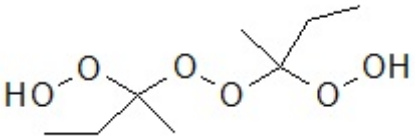
1.1 Background

1.1.1 History

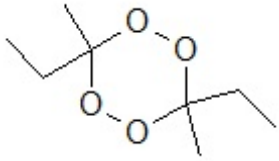
Airborne methyl ethyl ketone peroxide (MEK peroxide) was first determined by collecting in a midget impinger containing dimethyl phthalate (DMP). (Ref. 5.1) A portion of the solution was treated with diphenylcarbazide and the absorbance of the resulting color complex was measured at 565 nm. A bubbler containing an acid solution of titanium tetrachloride has also been used. (Ref. 5.2) NIOSH Methods P&CAM 331 and 3508 (Refs. 5.3 and 5.4) are based on the former procedure. However, these colorimetric methods are prone to interference and they do not differentiate the isomeric forms of MEK peroxide shown below.



monomer



dimer



cyclic dimer

A misconception of the true identity of MEK peroxide is prevalent in IH literature. For example, both ACGIH (Ref. 5.5) and NIOSH (Refs. 5.3 and 5.4) assign cyclic dimer as the structure for MEK peroxide when it has been shown conclusively (Refs. 5.6 and 5.7) that the main components of the commonly used industrial MEK peroxide are monomer and dimer and that the cyclic dimer is not present.

Preparing analytical standards of the two isomers was a major obstacle since MEK peroxide with known concentrations of monomer and dimer is not available commercially. In this evaluation, the preparation of monomer and dimer for analytical standards was accomplished by modifying a procedure reported in the literature (Ref. 5.8).

A two-column HPLC method, based on the reaction between hydroperoxide and triphenylphosphin (Ref. 5.9), has been developed (Ref. 5.10) to quantitate the MEK peroxide monomer and the dimer separately. But the method suffers from a long run time as it requires dual injections and a column wash. An HPLC method using electrochemlcal detection has been reported, (Refs. 5.11 and 5.12) but the dissolved oxygen in the sample interfered with detection of the dimer.

The analytical procedure of this method was adapted from the literature (Ref. 5.13). It is an HPLC/postcolumn derivatization method using a sodium iodide/acetic acid system where the MEK peroxide monomer and dimer can be analyzed within a 10-min run time. XAD-4 adsorbent was selected as the sampling medium because it has previously been found to be suitable for collecting airborne MEK peroxide (Ref. 5.10).

The ACGIH has set a TLV (ceiling) of 0.2 ppm (1.5 mg/m^3) for MEK peroxide. This value was selected for the target concentration. After most of the work in this evaluation had been done, OSHA published a new PEL (ceiling) of 0.7 ppm (5 mg/m^3). The sampler of this method easily permits the collection of MEK peroxide at the new PEL.

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

Following is a direct quote from Ref. 5.14.

> Given orally, by inhalation, or by intraperitoneal injection, methyl ethyl ketone peroxide causes hyperemia of the lungs with petechial or gross hemorrhage in mice and rats. Subacute exposures have been associated with mild liver damage in rats. In addition, this compound can be severely irritating to the eyes and skin. In rabbits, maximum nonirritating strengths were found to be 1.5 and 0.6% for the skin and eyes, respectively.

Mice given a total dose of (about) 7 mg methyl ethyl ketone peroxide developed malignant tumors, the first of which appeared after fifteen months. One subcutaneous sarcoma, three malignant lymphomas, and a pulmonary adenoma were noted in 34 of the 50 mice surviving exposure.

Chemical burns of the gastrointestinal tract, as well as residual scarring and stricture of the esophagus, were noted in an individual surviving ingestion of two ounces of a 60% methyl ethyl ketone peroxide solution.

1.1.3 Workplace exposure

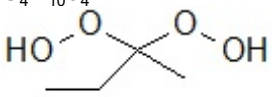
Methyl ethyl ketone peroxide is used widely in the polymer industry for curing unsaturated polyester resins. According to the NIOSH National Occupational Exposure Surveys of 1972 and 1982, workers in the following industries (with standard industrial code) are most likely to be exposed to MEK peroxide: boat building and repairing (SIC 3732), cut stone and stone products (SIC 3281), pressed and blown glass (SIC 3229), terrazzo, tile, marble, mosaic (SIC 1743), household furniture (SIC 2519), and transportation equipment and supply (SIC 5088).

1.1.4 Physical properties and other descriptive information (Ref. 5.15 unless noted otherwise)

Commercial mixture

chemical name:	methyl ethyl ketone peroxide
CAS no.:	1338-23-4
synonyms:	2-butanone peroxide; MEK peroxide; methyl ethyl ketone hydroperoxide; NCI-C55447
trade names:	Butanox 1PT; Butanox M 50; Butanox M 105; Cadox; Chaloxyd MEKP-HA 1; Chaloxyd MEKP-LA I; Esperfoam FR; FR 222; Hi-Point 90; Hi-Point PD-I; Kayamek A; Kayamek M; Ketonox; Lucidol Delta X; Lupersol Delta X 9; Lupersol DNF; Lupersol DSW; MEK Peroxide; Mekpo; Mepox; Permek G; Permek N; Quickset Extra; Quickset Super; RCRA Waste Number U16O; Sprayset MEKP; Thermacure; Trigonox M 50
description:	a colorless to pale yellow liquid
solubility:	soluble in water

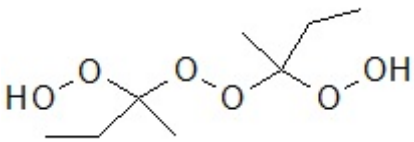
MEK peroxide monomer

chemical name:	(1-methylpropylidene)bishydroperoxide
CAS no.:	2625-67-4
synonyms:	2,2-dihydroperoxybutane; MEK peroxide monomer
molecular weight:	122.12
molecular formula:	$C_4H_{10}0_4$
structural formula:	

monomer

appearance:	colorless liquid
solubility:	miscible with water, alcohols, ether (personal observation)
derivative:	bis-p-nitrobenzoate: mp 107.5-l09°C (personal observation)

MEK peroxide dimer

chemical name:	[dioxybis(1-methylpropylidene)]bishydroperoxide
CAS no.:	126-76-1
synonyms:	2,2'-dihydroperoxy-2,2'-dibutyl peroxide; MEK peroxide dimer
molecular weight:	210.23
molecular formula:	$C_8H_{18}0_6$
structural formula:	

dimer

description:	may exist in two stereo isomeric forms: dl and meso
melting points:	one isomer: 43-49°C; the other isomer: liquid at room temperature (mp not determined) (personal observation)
solubility:	soluble in hexane, isooctane, methyl t-butyl ether; slightly soluble in water (personal observation)
derivatives:	bis-p-nitrobenzoate of one isomer: mp 192-218°C; bis-p-nitrobenzoate of the other isomer: sublimes at around 120°C (personal observation)

In this method, MEK peroxide from K&K was used in preparing validation samples. The composition was 26.0% monomer and 20.7% dimer. Unless specifically stated, the analyte amounts throughout this method are the sum of the monomer and the dimer. The analyte air concentrations are based on the recommended sampling and analytical parameters.

1.2 Limit defining parameters

1.2.1 Detection limit of the analytical procedure

The detection limit of the analytical procedure is 31 ng per injection. This is the amount of analytes which gave MEK peroxide monomer and dimer peaks with heights about 5 times the baseline noise. (Section 4.1)

1.2.2 Detection limit of the overall procedure

The detection limit of the overall procedure is 4.51 µg per sample (0.30 mg/m^3). This is the amount of analyte spiked on the sampling device which allows recovery of an amount equivalent to the detection limit of the analytical procedure. (Section 4.2)

1.2.3 Reliable quantitation limit

The reliable quantitation limit is 4.51 µg per sample (0.30 mg/m^3). This is the smallest amount of MEK peroxide spiked on the sampling device which can be quantitated within the requirements of a recovery of at least 75% and a precision (±1.96 SD) of ±25% or better. (Section 4.3)

The reliable quantitation limit and detection limits reported in the method are based upon optimization of the instrument for the smallest possible amount of the analyte. When the target concentration of the analyte is exceptionally higher than these limits, they may not be attainable at the routine operating parameters.

1.2.4 Instrument response to the analyte

The instrument response over the concentration range of 0.5 to 2 times the target concentration is linear with a slope of 120700 area counts per µg/mL for MEK peroxide dimer and 113200 area counts per µg/mL for MEK peroxide monomer. (Section 4.4)

1.2.5 Recovery

The recovery of MEK peroxide from samples used in a 16-day storage test remained above 92.2% when the samples were stored in a freezer. (Section 4.5) The recovery of an analyte from the collection medium during storage must be 75% or greater.

1.2.6 Precision (analytical procedure only)

The pooled coefficient of variation obtained from replicate injections of analytical standards at 0.5, 1 and 2 times the target concentration is 0.027 for MEK peroxide dimer and 0.035 for MEK peroxide monomer. (Section 4.6)

1.2.7 Precision (overall procedure)

The precision at the 95% confidence level for the refrigerated 16-day storage test is ±14.5%. (Section 4.7) This includes an additional ±5% for sampling error. The overall

procedure must provide results at the target concentration that are ±25% or better at the 95% confidence level.

1.2.8 Reproducibility

A draft copy of this procedure and six samples spiked with MEK peroxide were given to a chemist unassociated with this evaluation. The samples were analyzed after 7 days of storage at about -25°C. No individual sample result deviated from its theoretical value by more than the precision reported in Section 1.2.7. (Section 4.8)

1.3 Advantages

1.3.1 This sampling and analytical method provides a simple and convenient means of monitoring occupational exposure to MEK peroxide.

1.3.2 Individual isomers of MEK peroxide can be determined.

1.4 Disadvantage

Samples must be stored in a freezer until analysis.

2. Sampling Procedure

2.1 Apparatus

2.1.1 A personal sampling pump that can be calibrated to within ±5% of the recommended flow rate with the sampling device in line.

2.1.2 Glass sampling tubes each packed with an 80-mg front section and a 40-mg back section of XAD-4 adsorbent. XAD-4 sampling tubes from SKC, Inc. (catalog no. 226-30-11-04, Lot 146) were used in this evaluation.

2.2 Reagents

No sampling reagents are required.

2.3 Sampling technique

2.3.1 Break open both ends of the sampling tube so that the holes are at least one-half the inside diameter of the tube. Attach the tube to the sampling pump with a piece of flexible tubing such that the front section is exposed directly to the atmosphere. Attach the sampler vertically in the worker's breathing zone.

2.3.2 After sampling, seal the tube with plastic end caps. Wrap the tube lengthwise with an official OSHA seal (Form 21).

2.3.3 Submit at least one blank with each set of samples. Handle the blank the same as the other samples except draw no air through it.

2.3.4 List any potential interferences on the sample data sheet.

2.4 Sampler capacity

The sampler can be used to collect MEK peroxide at 10 times the target concentration for at least 8 times the recommended sampling time without breakthrough. (Section 4.9)

2.5 Desorption efficiency and stability of desorbed samples

2.5.1 The average desorption efficiency for MEK peroxide from 80 mg of XAD-4 over the range of 0.5 to 2 times the target concentration was 99.4%. (Section 4.10)

2.5.2 Desorbed samples remain stable for at least 24 h when stored at room temperature.

2.6 Recommended air volume and sampling rate

2.6.1 The recommended air volume is 15 L.

2.6.2 The recommended air sampling rate is 1 L/min.

2.7 Interferences (sampling)

MEK peroxide is very labile. Heat, acids, bases, or trace amounts of metal ions will cause decomposition.

2.8 Safety precautions (sampling)

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

2.8.2 Follow all safety practices applicable to the work area being sampled.

3. Analytical Procedure

3.1 Apparatus

3.1.1 An HPLC equipped with a UV detector. A Waters HPLC system consisting of a 60OE pump, a 900 photodiode array detector, and a 712 WISP autosampler was used in this evaluation. For the alternate analytical conditions, a BAS 200 HPLC equipped with electrochemical detector was used.

3.1.2 An HPLC column capable of separating MEK peroxide monomer and dimer from potential interferences. A 25-cm × 6-mm Bakerbond cyanopropyl column was used in this evaluation. A 25-cm × 6-mm Supelco LC18DB column was used in the alternate analytical conditions.

3.1.3 A postcolumn derivatization system. Two Waters 6000 pumps, pulse dampeners (part nos. 98060 and 25561), ninhydrin reaction coil and temperature controller were used in this study. A schematic of the HPLC/postcolumn system is illustrated in Figure 3.1.3.

3.1.4 An electronic integrator or other suitable means of measuring detector response. A Hewlett-Packard 3357 laboratory data system was used in this evaluation.

3.1.5 Four-milliliter vials with polytetrafluoroethylene (PTFE)- lined caps. New unsilinized vials were used in this evaluation. If old vials are to be used, they must be silanized.

3.1.6 Volumetric flasks and pipets, silanized. Sylon CT from Supelco was used in silanizing the glassware. The directions supplied with the reagent were followed.

3.2 Reagents

3.2.1 MEK peroxide solution in DMP. Methyl ethyl ketone peroxide, 60% in DMP, from K & K Laboratories was used in this evaluation.

3.2.2 2-Propanol (IPA) and isooctane, HPLC grade. 2-Propanol, Optima, and isooctane, Optima, both from Fisher Scientific Co., were used in this evaluation.

3.2.3 10% Acetic acid solution: Dilute 100 mL of glacial acetic acid to 1 L with 2-propanol.

3.2.4 Sodium iodide solution: Dissolve 1 g of sodium iodide in 1 L of 2-propanol.

3.3 Standard preparation

3.3.1 Determine the concentration of the dimer and monomer in the DMP solution by using the pure dimer and monomer synthesized in Section 4.12. Although MEK peroxide/DMP solutions are quite stable when stored in a refrigerator, determine the dimer and monomer concentrations once every 6 months.

3.3.2 Prepare stock standards by weighing 3 drops of MEK peroxide/DMP solution in 10-mL volumetric flasks and diluting to volume with 2-propanol. Prepare fresh stock standards daily.

3.3.3 Prepare analytical standards by further diluting stock standards with 2-propanol.

3.3.4 Prepare a sufficient number of standards to generate calibration curves. Analytical standard concentrations must bracket sample concentrations.

3.4 Sample preparation

3.4.1 Transfer the front section of XAD-4 to a 4-mL glass vial. Place the back section in a separate 4-mL vial. Discard the glass wool and foam plugs.

3.4.2 Add 2.0 mL of 2-propanol to each vial.

3.4.3 Seal the vials with PTFE-lined caps and shake them on a mechanical shaker for 1 h.

3.5 Analysis

3.5.1 Analytical conditions

column:	Bakerbond cyanopropyl, 25 cm × 6 mm
mobile phase:	95:5 (v/v) isoctane/2-propanol
flow rate:	1.0 mL/min
postcolumn derivatization:	10% acetic acid in 2-propanol at 0.5 mL/min; 1 g/L sodium iodide in 2-propanol at 0.5 mL/min; the reaction coil was heated to 65°C.
injection volume:	15 µL
detector:	292 nm or 360 nm
chromatogram:	Figure 4.11.1

3.5.2 Alternate analytical conditions

column:	Supelco LC18DB, 25 cm × 6 mm
mobile phase:	45:55 (v/v) methanol/0.1 M lithium perchlorate
flow rate:	1.0 mL/min
injection volume:	15 µL
electrochemical detector:	Aµ/Hg electrode at -550 mV relative to the reference electrode
chromatogram:	Figure 4.11.2
note:	The two isomers of the dimer are separated under these conditions.

3.5.3 Measure detector response using a suitable method such as electronic integration.

3.5.4 Prepare a calibration curve using several standards over a range of concentrations. Bracket the samples with analytical standards.

3.6 Interferences (analytical)

3.6.1 Any compound having a similar retention time as MEK peroxide monomer or dimer and capable of liberating iodine from the sodium iodide/acetic acid mixture is a potential interference. Generally, chromatographic conditions can be altered to separate an interference.

3.6.2 Hydrogen peroxide and dimethyl phthalate are not interferences.

3.6.3 A useful means of confirming the MEK peroxide is by electrochemical detector using reverse phase column (Section 3.5.2). A GC/MS procedure would not be viable because MEK peroxide is thermally labile.

3.7 Calculations

3.7.1 Prepare separate calibration curves for MEK peroxide monomer and dimer by plotting detector responses versus the analytical standard concentrations. Determine the best-fit lines.

3.7.2 Determine the concentrations of a sample, in micrograms of MEK peroxide monomer or dimer per milliliter, by comparing its detector responses to the calibration curves.

3.7.3 Perform blank corrections for each section.

3.7.4 The air concentration of MEK peroxide can be obtained by using the following equations:

$$mg/m^3 = \frac{(A + B)(C)}{DE}$$

where A = g/mL of MEK peroxide dimer
B = µg/mL of MEK peroxide monomer
C = desorption volume (2 mL)
D = liters of air sampled
E = desorption efficiency, 0.994

Values in ppm are not calculated because they are dependent on the dimer/monomer ratio.

3.8 Safety precautions (analytical)

3.8.1 Avoid skin contact and inhalation of all chemicals.

3.8.2 Restrict the use of all chemicals to a fume hood.

3.8.3 Wear safety glasses in all laboratory areas.

4. Backup Data

4.1 Detection limit of the analytical procedure

The detection limit of the analytical procedure is 31 ng per injection. It is based on a 15µpL injection of a 2.07 µg/mL standard (consisting of 0.92 µg/mL of MEK peroxide dimer and 1.15 µg/mL of MEK peroxide monomer.) This amount produced MEK peroxide monomer and dimer peaks whose heights were about 5 times the height of the baseline noise. A chromatogram of the detection limit of the analytical procedure is shown in Figure 4.1.

4.2 Detection limit of the overall procedure

The detection limit of the overall procedure is 4.51 µg per sample (0.30 mg/m^3). Six vials containing 80 mg of XAD-4 were each liquid spiked with 4.51 µg of MEK peroxide. The samples were desorbed 24 h later with 2 mL of 2-propanol.

Table 4.2
Detection Limit of the Overall Procedure

sample number	theoretical amount (µg)	amount recovered (µg)
1	4.51	3.85
2	4.51	4.35
3	4.51	4.28
4	4.51	3.83
5	4.51	4.05
6	4.51	3.84

4.3 Reliable quantitation limit

The reliable quantitation limit is also 4.51 µg per sample (0.30 mg/m^3). This was derived from the samples and data of Table 4.2. Because the recovery of MEK peroxide from the spiked samples was greater than 75% and the precision (1.96 SD) was less than ±25%, the detection limit of the overall procedure and reliable quantitation limit are the same.

Table 4.3
Reliable Quantitation Limit
(Based on samples and data of Table 4.2)

% recovered	statistics
85.4	
96.5	$\bar{X}$ = 89.4%
94.9	SD = 5.21%
84.9	Precision = (1.96)(±5.21%)
89.8	= ±10.2%
85.1	

4.4 Instrument response to MEK peroxide

The instrument response to MEK peroxide over the range of 0.5 to 2 times the target concentration is linear with a slope of 120700 area counts per µg/mL for the dimer and 113213 area counts per µg/mL for the monomer. The responses to MEK peroxide were determined by multiple injections of standards. The data in Tables 4.4.1 and 4.4.2 are presented graphically in Figures 4.4.1 and 4.4.2.

Table 4.4.1
Instrument Response to MEK Peroxide Dimer

× target concn	0.5×	1×	2×
µg/mL	2.30	4.60	9.19
area	264032	539484	1106430
counts	283125	559323	1114170
	268162	544467	1107150
	288679	568779	1105220
	265246	566636	1091830
	263122	563841	1106160
$\bar{X}$	272061	557088	1105160

Table 4.4.2
Instrument Response to MEK Peroxide Monomer

× target concn	0.5×	1×	2×
µg/mL	2.89	5.77	11.54
area	292902	593403	1293120
counts	295536	654713	1247620
	295780	606887	1295690
	311831	638146	1268240
	321387	649278	1281930
	291448	653518	1304220
$\bar{X}$	301481	632658	1281803

4.5 Storage data

Thirty-six samples were generated by liquid-spiking 22.62 µg of MEK peroxide onto XAD-4 adsorbent tubes. Humid air (80% relative humidity at 24°C) was pulled through the tubes for 15 min at 1 L/min. Six tubes were analyzed the same day. Fifteen tubes were stored in a freezer (-25°C) and the other fifteen were stored in the dark at ambient temperature (about 22°C). Every few days over a 15-day period, three samples were selected from each of the two sets and analyzed. Another set of storage samples were prepared and analyzed over a 16-day period. The combined results are listed Table 4.5. There was no significant loss of MEK peroxide in the refrigerated samples, but those stored at ambient temperature suffered a significant loss. The storage data are also presented graphically in Figures 4.5.1 and 4.5.2.

Table 4.5
Storage Test

storage time (days)	% recovery (ambient)			% recovery (refrigerated)		
0	95.7	89.8	93.8	95.7	89.8	93.8
	90.1	72.4	81.9	90.1	72.4	81.9
	95.4	96.4	100.4	95.4	96.4	100.4
	98.1	95.4	95.1	98.1	95.4	95.1
3	77.7	84.2	78.2	92.8	93.8	95.0
6	68.0	12.6*	72.6	95.7	91.6	80.3
7	64.2	78.3	59.0	93.1	93.8	97.4
9	57.3	55.9	59.5	96.9	96.2	94.3
10	65.3	66.9	57.8	102.3	98.0	97.8
11	96.5	72.2	52.0	94.7	97.4	97.7
15	44.7	70.4	62.1	93.4	90.7	98.3
16	45.6	51.9	51.7	95.0	95.8	95.6

* outlier, excluded

4.6 Precision (analytical method only)

The precision of the analytical procedure is 0.027 for MEK peroxide dimer and 0.035 for MEK peroxide monomer. The precision of the analytical procedure is defined as the pooled coefficient of variation determined from replicate injections of MEK peroxide standards at 0.5, 1 and 2 times the target concentration.

Table 4.6.1
Precision of the Analytical Method
for MEK Peroxide Dimer
(Based on the Data of Table 4.4.1)

× target concn µg/mL	0.5× 2.30	1× 4.60	2× 9.19
SD[1]	10996	12228	7286
CV	0.0404	0.0219	0.0066
$\overline{CV}$	0.0268		

[1]standard deviation is in area counts

Table 4.6.2
Precision of the Analytical Method
for MEK Peroxide Monomer
(Based on the Data of Table 4.4.2)

× target conc µg/mL	0.5× 2.89	1× 5.77	2× 11.54
SD[1]	12210	26203	20861
CV	0.0405	0.0414	0.0163
$\overline{CV}$	0.0347		

[1]standard deviation is in area counts

4.7 Precision (overall procedure)

The precision of the overall procedure is determined from the storage data. The determination of the standard error of estimate (SEE) 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 is similar to the standard deviation except it is a measure of dispersion of data about a regression line instead of about a mean. It is determined with the following equation:

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

where

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

An additional ±5% for pump error is added to the SEE by the addition of variances. The precision at the 95% confidence level is obtained by multiplying the SEE (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 Figure 4.5.1. The data for Figure 4.5.1 was used to determine the SEE of ±7.41% for MEK peroxide.

4.8 Reproducibility data

Six samples, liquid spiked with MEK peroxide, were given to a chemist unassociated with this study. The samples were analyzed after being stored for 7 days at about -25 °C. No sample result had a percent deviation greater than the precision of the overall procedure, which was ±14.5%.

Table 4.8
Reproducibility Data

µg spiked	µg recovered	% recovered	% deviation
31.44	28.58	90.0	-10.0
31.44	27.87	88.6	-11.4
26.20	23.66	90.3	-9.7
26.20	24.11	92.0	-8.0
20.96	18.51	88.3	-11.7
20.96	19.74	94.2	-5.7

4.9 Sampler capacity

Aerosol generation was found to be unsuitable for preparing a standard atmosphere of MEK peroxide because it drastically changes the latter's composition. The sampler capacity was tested by the following method.

A plug of glass wool was placed upstream of an XAD-4 tube. The back section of the tube was removed. Another XAD-4 tube was placed downstream. Humid air (80% RH at 22 °C) was pulled through the train at 1 L/min. At 15-min intervals, 229 µg of MEK peroxide was spiked onto the glass wool and the downstream XAD-4 tube was replaced with a new one. This

Table 4.9
Breakthrough Data
at 10× Target Concentration

air volume (L)	breakthrough (%)
15	0.00
30	0.00
45	0.00
60	0.00
75	0.00
90	0.02
105	0.02
120	0.06

simulates an atmosphere of 15.3 mg/m^3 MEK peroxide which is about 10 times the target concentration. The test was conducted for a total of 120 min, 8 times the recommended sampling time. At the end of the test, all 8 downstream tubes as well as the front tube were analyzed. Essentially all of the MEK peroxide was collected on the front tube. The sampler capacity is at least 8 times the recommended sampling volume at 10 times the target concentration.

4.10 Desorption efficiency and stability of desorbed samples

4.10.1 Desorption efficiency

The desorption efficiency (DE) of MEK peroxide was determined by liquid-spiking 80-mg portions of XAD-4 with MEK peroxide at 0.5, 1 and 2 times the target concentration. These samples were stored in a refrigerator overnight and then desorbed and analyzed. The average desorption efficiency over the studied range was 99.4%.

Table 4.10.1
Desorption Efficiency of MEK Peroxide

× target concn µg/sample	0.5× 10.86	1× 21.72	2× 43.43
DE, %	98.3	98.8	98.6
	100.9	100.2	99.7
	96.5	99.6	99.9
	96.8	98.0	101.5
	97.5	98.2	101.5
	97.9	102.3	102.9
$\bar{X}$	98.0	99.5	100.7

4.10.2 Stability of desorbed samples

The stability of desorbed samples was investigated by reanalyzing the 1 times the target concentration desorption samples about 24 h after the original analysis. The samples had been recapped and stored at room temperature.

Table 4.10.2
Stability of Desorbed Samples

original results (%)	reanalyzed result (%)	reanalyzed relative to original (%)
97.7	101.3	103.7
98.8	98.0	99.2
98.8	96.9	98.1
98.8	103.1	104.4
99.6	102.5	102.9
98.8	100.5	101.7

They were reanalyzed with fresh standards. The average of the reanalyzed samples relative to the average of the original analysis was 101.7%.

4. 11 Chromatograms

A chromatogram at the detection limit of the analytical procedure is shown in Figure 4.1 and a chromatogram at the target concentration is shown in Figure 4.11.1. A chromatogram at target concentration under the alternate analytical conditions is shown in Figure 4.11.2.

4.12 Standardization of MEK peroxide solution

4.12.1 Apparatus

Round-bottomed flask
Rotary evaporator
Separatory funnel
Vacuum oven
Sintered-glass filtering funnel

4.12.2 Reagents

Hydrogen peroxide, 30% aqueous solution
Methyl ethyl ketone
Sulfuric acid
Methyl t-butyl ether
Ammonium sulfate
Magnesium sulfate, anhydrous
0.01 N Sodium thiosulfate
Potassium dichromate, primary standard
Hexane
Liquid nitrogen

4.12.3 Synthesis of MEK peroxide monomer

Place methyl ethyl ketone (3.6 g, 0.05 mole) and 30% hydrogen peroxide (11.3 g, 0.1 mole) in a 20-mL scintillation vial. Cap the vial and shake to mix well. Let stand at room temperature overnight. Heat the vial in a 40°C water bath for 1 h. Dilute the mixture in 500 mL of methyl t-butyl ether and wash twice with a saturated aqueous solution of ammonium sulfate and twice with water. Dry over anhydrous magnesium sulfate and filter. Evaporate the filtrate under vacuum. The yield of the residue is approximately 2 g. Add approximately an equal volume of dimethyl phthalate to the residue and store in a freezer. Determine the monomer concentration by iodometric titration.

4.12.4 Synthesis of MEK peroxide dimer

Assemble a 500-mL round-bottom flask equipped with a stirring bar and a thermometer in an ice bath. Place methyl ethyl ketone (14.4 g, 0.2 mole) and 30% hydrogen peroxide (22.67 g, 0.2 mole) in the flask. Add sulfuric acid (0.49 g, 0.005 mole) slowly with stirring so that the temperature does not rise above 15^0C. Continue stirring at room temperature overnight. Take up the mixture in 500 mL of hexane and wash twice with saturated aqueous solution of ammonium sulfate and three times with 300 mL of water. Dry over anhydrous magnesium sulfate and filter. Chill the filtrate in an 2-propanol/liquid nitrogen bath. Collect the precipitated white crystals. Recrystallize from hexane, mp 43-49°C. The yield is approximately 5 g. Determine the dimer purity by iodometric titration. It should be near 100%. Store in a freezer.

4.12.5 Iodometric titration of MEK peroxides (Ref. 5.16)

Standardize the 0.01 N sodium thiosulfate solution with a potassium dichromate primary standard. Prepare stock solutions of monomer and dimer in 2-propanol. The concentration should be approximately 5 mg/mL. Place 20 mL of 2-propanol, 2 mL of glacial acetic acid, and 0.5 g of potassium iodide in a 500-mL Erlenmeyer flask. Add 1.0 mL of the MEK peroxide stock solution. Allow the flask to stand in the dark for 15 min. Add 10 mL of water and titrate the solution with 0.01 N sodium thiosulfate solution. Perform blank corrections. Calculate the purity of the monomer and dimer as follows.

$$\text{purity (\%)} = \frac{NV(EW)}{CD} \times 100$$

where N = normality of thiosulfate
V = volume (mL) of thiosulfate solution
EW = equivalent weight, 35.04 for dimer, 30.53 for monomer
C = concentration (mg/mL) of the dimer or monomer stock solution
D = volume (mL) of the stock solution

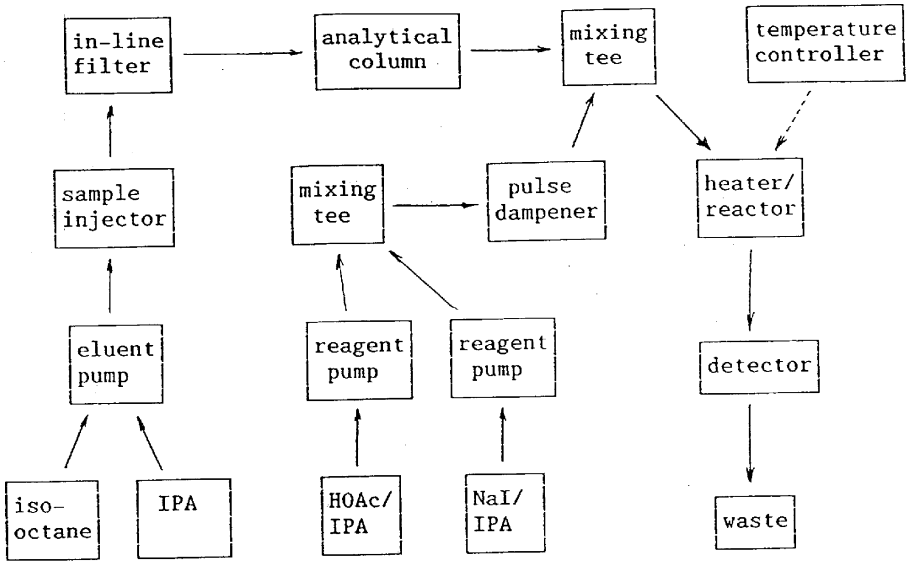


Figure 3.1.3. Schematic of an HPLC postcolumn system.

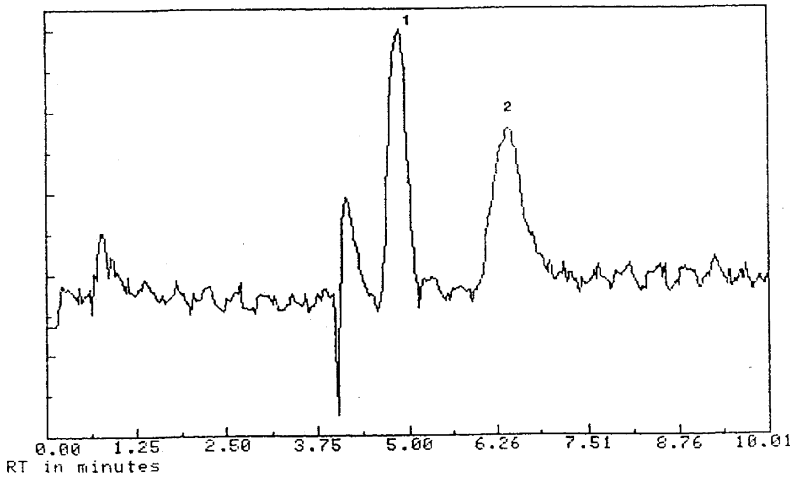


Figure 4.1. Detection limit of the analytical procedure. 1 = MEK peroxide dimer, 2 = MEK peroxide monomer.

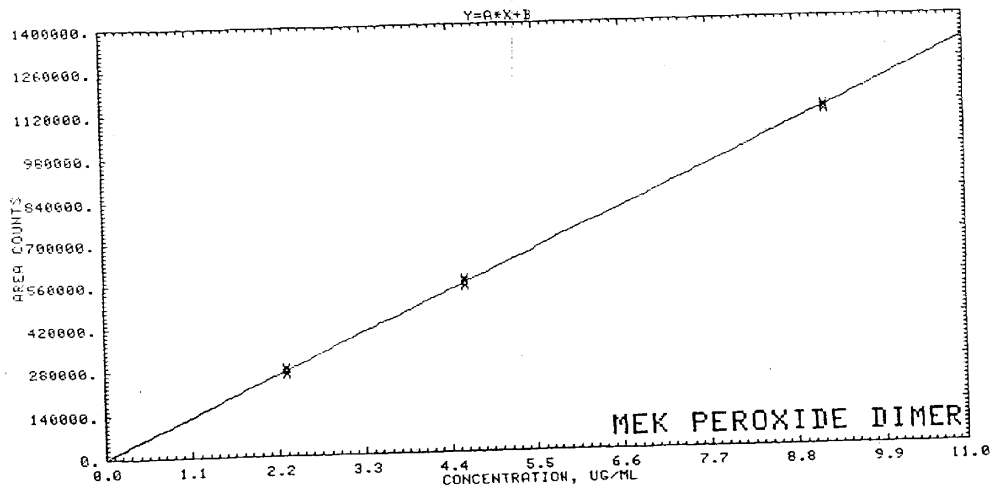


Figure 4.4.1. Calibration curve for MEK peroxide dimer.

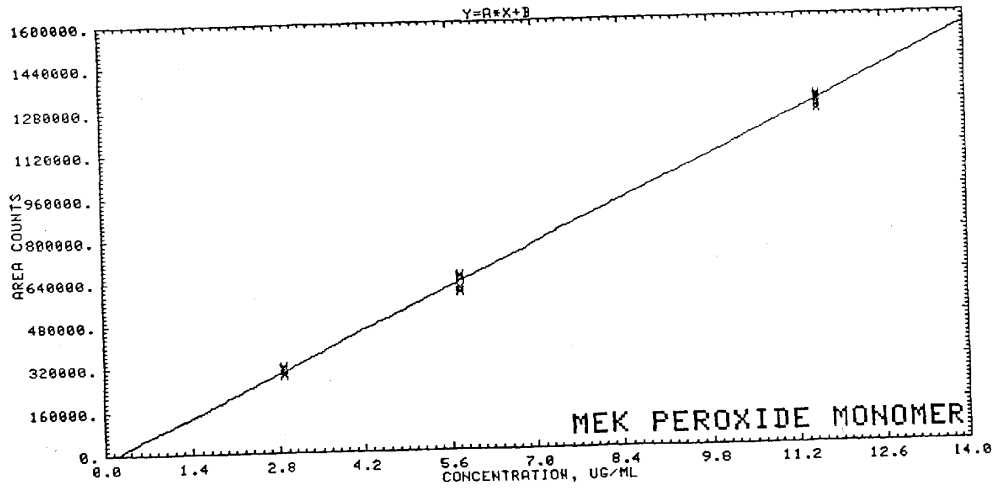


Figure 4.4.2. Calibration curve for MEK peroxide monomer.

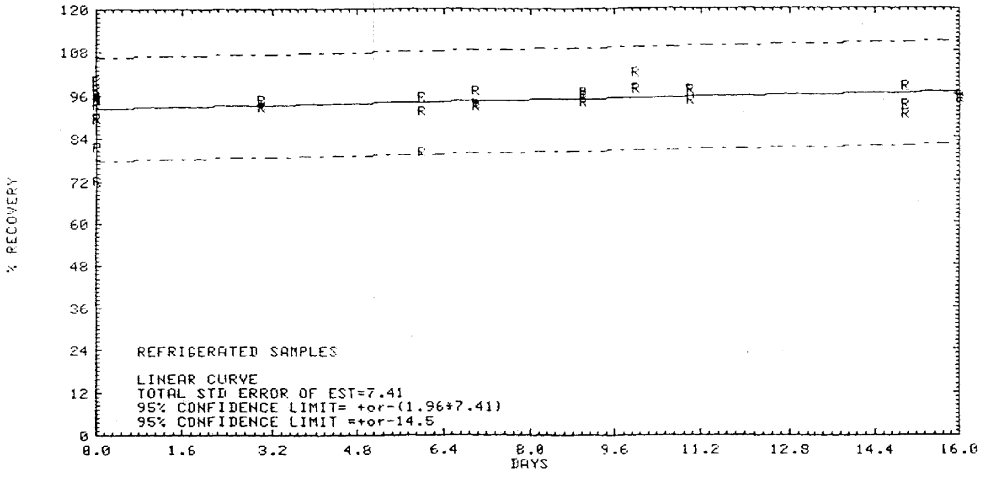


Figure 4.5.1. Storage test at reduced temperature.

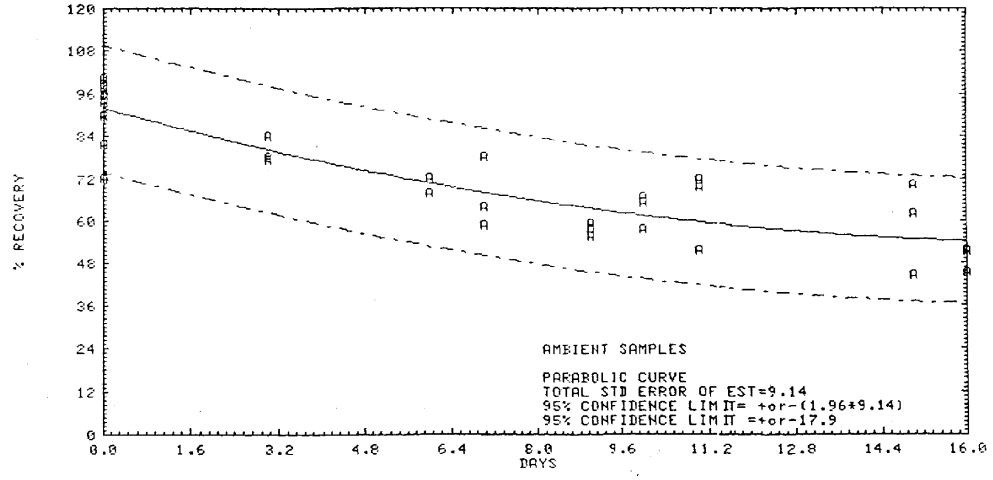


Figure 4.5.2. Storage test at ambient temperature.

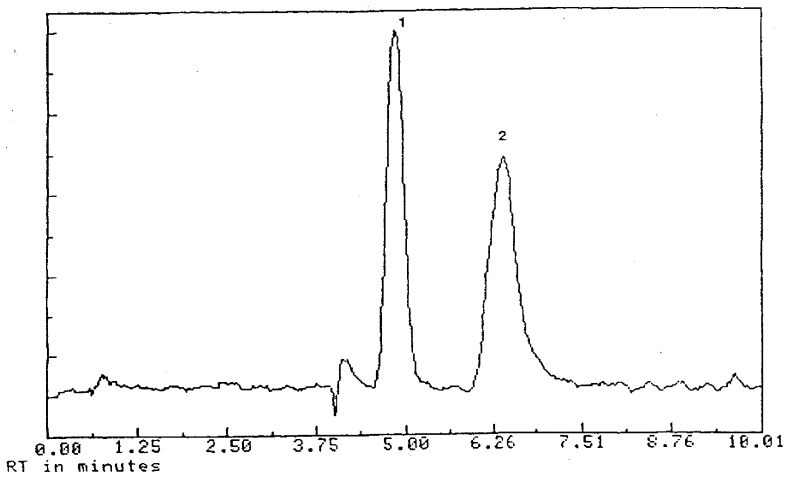


Figure 4.11.1. Chromatogram at target concentration. 1 = MEK peroxide dimer, 2 = MEK peroxide monomer.

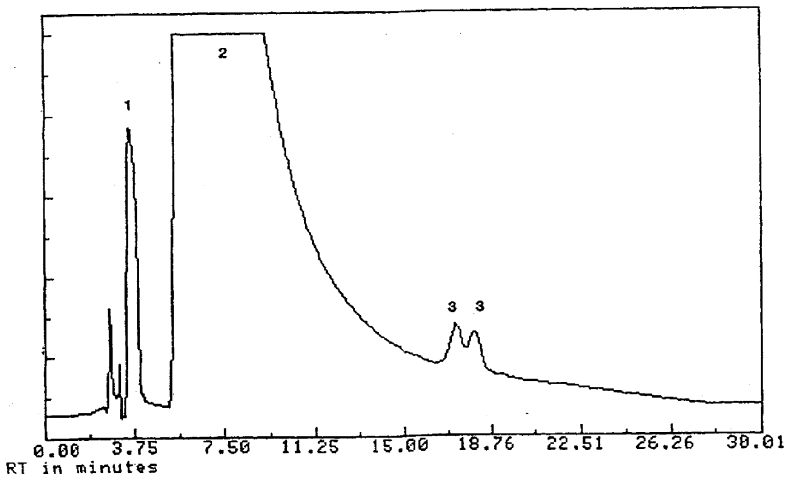


Figure 4.11.2. Chromatogram at target concentration under alternate analytical conditions. 1 = MEK peroxide monomer, 2 = oxygen, 3 = MEK peroxide dimer.

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