2-BUTANONE
(METHYL ETHYL KETONE)

Method no.:	16
Matrix:	Air
Target concentration:	200 ppm (590 mg/m^3) (OSHA PEL)
Procedure:	Collection on silica gel, desorption with DMSO, and analysis by gas chromatography with a flame ionization detector.
Recommended air volume and sampling rate:	3 L at 0.1 L/min
Detection limit of the overall procedure:	1.4 ppm (4.0 mg/m^3)
Reliable quantitation limit:	1.5 ppm (4.3 mg/m^3)
Standard error of estimate at the PEL: (Section 4.6.)	5.9%
Special requirements:	Samples are collected on 2 silica gel tubes in series. The second tube is used as a backup for the first tube.
Status of method:	Evaluated method. This method has been subjected to the established evaluation procedures of the Organic Methods Evaluation Branch.

Date: January 1980

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1. General Discussion

   1.1. Background

      1.1.1. History

         MEK (Methyl Ethyl Ketone) samples analyzed at the OSHA laboratory have normally been collected on activated charcoal and analyzed by gas chromatography after desorption with carbon disulfide as described in NIOSH Method S3 (Ref. 5.1.). It was found by a later study that MEK was not stable on coconut shell charcoal, especially when the vapor samples were collected at high humidity and also when the samples were stored at room temperature (Ref. 5.2.). Since the OSHA laboratory analyzes a large number of MEK samples (more than 4300 MEK samples were analyzed in fiscal year 1979) and a stability problem has been established for samples collected using the NIOSH method, it was necessary to find a more suitable method of collection.

         Several different solid adsorbents were tested for breakthrough. Among those tested that gave unsatisfactory breakthrough volumes were: Chromosorb 101, Chromosorb 102, Chromosorb 103, Chromosorb 104, Chromosorb 105, Chromosorb 106, Chromosorb 107, Chromosorb 108, XAD-2 resin, Alumina, Tenax, Porapak P, and Chromosorb 102 coated with 15% SP2401. These adsorbents exhibited a relatively low capacity under the following test conditions: MEK concentration - 1176 mg/m^3, relative humidity - 80%, sampling rate - 0.2 L/min, amount of solid adsorbent - the same volume as the front section of a 150-mg charcoal tube. This study does not rule out the possible use of these adsorbents, but collection tubes would have to be made larger to increase the capacity or sampling rates would have to be lowered so an integrated sample could be taken over a reasonable time. Since it is desirable to use a small sampling device and the sampling pumps presently used for field sampling have a minimum sampling rate of 0.05 L/min, these solid adsorbents were not acceptable.

         The only solid adsorbents found suitable for collection besides coconut shell charcoal were petroleum-base charcoal (SKC Lot 104) and silica gel. These two adsorbents were evaluated according to the evaluation scheme used by the Organic Methods Evaluation Branch. The analytical procedure was essentially NIOSH Method S3 for the Lot 104 charcoal samples and an adapted method (Ref. 5.3.) using DMSO as the desorption solvent for the silica gel samples.

         The silica gel collection is the recommended method of choice since samples are more stable if collected this way. Charcoal should not be used unless absolutely necessary. If charcoal is used, the samples must be refrigerated immediately after sampling and during shipment to the laboratory. Data for both procedures is included in this report. Data for the Lot 104 charcoal tube method is given in Section 4.8.

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

         MEK may be irritating to eyes, mucous membranes, and in high concentrations, narcotic. (Ref. 5.4.) MEK is similar to but more irritating than acetone. The vapor is irritating to mucous membranes and conjunctiva. No serious poisonings were reported in man except for dermatitis. (Ref. 5.5) Dermatitis can result if excessive repeated prolonged skin contact occurs. Minor skin contacts have been shown to cause no evidence of irritation. (Ref. 5.6.) MEK can be recognized at 25 ppm by its odor, which is similar to acetone but more irritating. The warning properties prevent inadvertent exposure to toxic levels. (Ref. 5.7.) The TLV was established at a level to prevent injurious effects and minimize complaints about odor and irritation. (Ref. 5.8.)

      1.1.3. Operations where exposure occurs

         MEK is mainly used as a solvent for formulations of nitrocellulose. (Ref. 5.9.) It is also used as a solvent in fabric coating, the manufacture of colorless synthetic resins, the manufacture of smokeless powder, the surface coating industry, the manufacture of artificial leather, the lacquer and varnish industry, pharmaceuticals and cosmetics, the manufacture of synthetic rubber, production of lubricating oils, vinyl coatings, adhesives, acrylic coatings, hardwood pulping, the manufacture of ink, and lube oil de-waxing by solvent extraction. (Ref. 5.10.)

1.1.4. Size of work population that are exposed

NIOSH estimates that over 3 million workers are potentially exposed to MEK in the United States. (Ref. 5.9.)

1.1.5. Physical Properties (Ref. 5.4. and 5.11.)

molecular weight:	72.10
boiling point:	79.6°C
color:	clear, colorless
vapor pressure:	90.7 mmHg at 25°C
flash point:	35°F
odor:	acetone-like
specific gravity:	0.805 (20/4°C)
lower explosive limit:	1.8% (by volume)
molecular formula:	$CH_3COC_2H_5$
synonyms:	2-butanone, methyl ethyl ketone, MEK, ethyl methyl ketone

1.2. Limit defining parameters

1.2.1. Detection limit of the analytical procedure

The detection limit of the analytical procedure is 12.1 ng per injection. The magnitude of the detection limit is due to an interference in DMSO. (Section 4.1.)

1.2.2. Detection limit of the overall procedure

The detection limit of the overall procedure is 13.0 µg per sample (1.5 ppm/4.3 mg/m³). This is the amount of MEK spiked on a silica gel tube which allows recovery of an amount of MEK equivalent to the detection limit of the analytical procedure. (Section 4.2.)

1.2.3. Reliable quantitation limit

The reliable quantitation limit is the same as the detection limit of the overall procedure since the recovery at this level is greater than 75% and the 95% confidence limit is within ±25%. (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 analyte. When the target concentration of an analyte is exceptionally higher than these limits, they may not be attainable at the routine operating parameters.

1.2.4. Sensitivity

The sensitivity of the analytical procedure over a concentration range representing 335 to 1342 mg/m³ based on the recommended air volume is 140,800 area units per mg MEK/mL DMSO. The sensitivity is determined by the slope of the calibration curve. (Section 4.4.) The sensitivity will vary somewhat with the particular instrument and operating parameters used in the analysis.

1.2.5. Desorption efficiency

The recovery of analyte from the collection medium must be 75% or greater. The average recovery over the range of 0.5 to 2 times the target concentration is 97.9%. (Section 4.5.)

1.2.6. Precision (analytical method only)

The pooled coefficient of variation obtained from replicate determinations of analytical standards at 0.5, 1 and 2 times the target concentration is 0.0061. (Section 4.4.)

1.2.7. Precision (overall procedure)

The overall procedure must provide results at the target concentration that are ±25% or better at the 95% confidence level. The precision at the 95% confidence level for the 15-day storage test is ±12.2%. (Section 4.6.) This includes an additional ±5% for sampling error.

1.3. Advantages

1.3.1. The sampling procedure is convenient.

1.3.2. The analytical procedure is sensitive and reproducible.

1.3.3. Reanalysis of samples is possible.

1.3.4. Samples are stable, even at room temperature.

1.3.5. It may be possible to determine other compounds simultaneously.

1.3.6. Interferences can be circumvented by proper selection of GC parameters.

1.3.7. The desorption solvent (DMSO) elutes later than most solvents normally analyzed for in industrial air.

1.4. Disadvantages

1.4.1. The amount of sample that can be taken is limited by the total milligrams the silica gel will adsorb before overloading.

1.4.2. The precision is limited by the reproducibility of the pressure drop across the tubes. The pumps are usually calibrated for one set of tubes only.

1.4.3. The desorption solvent (DMSO) elutes late, which increases the run time for analysis.

1.4.4. DMSO has trace contaminants that may be potential interferences under high sensitivity conditions. Under normal operating conditions, these contaminants pose no problem to analysis.

1.4.5. After repeated injections of DMSO, there is a build-up of residue formed in the collector of the detector.

2. Sampling Procedure

2.1. Apparatus

2.1.1. An approved and calibrated personal sampling pump whose flow can be determined within ±5% at the recommended flow.

2.1.2. Silica gel tubes: glass tube with both ends flame sealed, 70 mm × 6-mm i.d. containing 2 sections of 20/40 mesh silica gel separated by a 2-mm portion of urethane foam. The adsorbing section contains 150 mg of silica gel, the backup section 75 mg. A 3-mm portion of urethane foam is placed between the outlet end of the tube and the backup section. A plug of silane-treated glass wool is placed in front of the front section. The pressure drop across the tube must be less than one inch of mercury at a flow rate of 1 L/min. SKC No. 226-10 tubes or equivalent.

2.2. Reagents

None required

2.3. Sampling technique

2.3.1. Immediately before sampling, break open the ends of the silica gel tubes. All tubes must be from the same lot.

2.3.2. Connect two tubes in series to the sampling pump with flexible tubing. The short sections of the silica gel tubes should be positioned nearer the sampling pump. The tube closer to the pump is used as a backup. A minimum amount of tubing is used to connect the two sampling tubes together.

2.3.3. The tubes should be placed in a vertical position during sampling to minimize channeling.

Note: OSHA no longer uses or supports this method (December 2019).

2.3.4. Air being sampled should not pass through any hose or tubing before entering the silica gel tubes.

2.3.5. Seal the separate silica gel tubes with plastic caps immediately after sampling and wrap lengthwise with an official OSHA seal (Form 21).

2.3.6. With each batch of samples, submit at least one blank tube from the same lot used for samples. This tube should be subjected to exactly the same handling as the samples (break, seal, transport) except that no air is drawn through it.

2.3.7. Transport the samples (and corresponding paperwork) to the lab for analysis.

2.3.8. If bulk samples are submitted for analysis, they should be transported in glass containers with Teflon-lined caps. These samples must not be put in the same container used for the silica gel tubes.

2.4. Breakthrough

2.4.1. The average 5% breakthrough volume for a single silica gel tube containing both sections of adsorbent is 3.4 L. This value was obtained from three separate determinations by sampling a 1174 mg/m^3 test atmosphere (at 80% relative humidity) at 0.092 L/min. The amount of MEK in the breakthrough volume is 3.96 mg. (Section 4.7.)

2.4.2. The breakthrough volume is severely lowered by high relative humidity. With dry air (essentially 0% relative humidity) the breakthrough volume under the conditions described in 2.4.1. is increased to 20.3 L. Also, water will displace MEK as shown in Figure 4.7.

2.5. Desorption efficiency

2.5.1. The desorption efficiency, from liquid injections onto silica gel tubes, averaged 97.9% from 0.5 to 2 times the target concentration for a 3.0-L air sample. (Section 4.5.)

2.5.2. The desorption efficiency may vary from one laboratory to another and also from one lot of silica gel to another. Thus, it is necessary to determine the desorption efficiency for a particular lot of silica gel.

2.6. Recommended air volume and sampling rate

2.6.1. The recommended air volume is 3 L.

2.6.2. The recommended maximum sampling rate is 0.1 L/min.

2.7. Interferences

2.7.1. Besides water, it is unknown if any other compound would severely interfere with the collection of MEK on silica gel. In general, the presence of other compounds that have a higher affinity for silica gel than MEK does (i.e., higher polarity than MEK) would decrease the breakthrough volume for MEK.

2.7.2. Suspected interferences should be listed on the sample data sheets.

2.8. Safety precautions

2.8.1. Attach the sampling equipment on the employee so that it does not interfere with work performance.

2.8.2. Wear safety glasses when breaking the ends of the sampling tubes.

2.8.3. If possible, place the sampling tubes in a holder so the sharp end is not exposed while sampling.

3. Analytical procedure

3.1. Apparatus

3.1.1. A GC equipped with a flame ionization detector.

Note: OSHA no longer uses or supports this method (December 2019).

3.1.2. A GC column capable of separating MEK and an internal standard from any interferences and DMSO. The column used for validation studies was: 10-ft × 1/8-in. stainless steel, 20% SP2401, 0.1% CW1500 on 100/120 Supelcoport.

3.1.3. An electronic integrator or some other suitable method of measuring peak areas.

3.1.4. Two-milliliter vials with Teflon-lined caps.

3.1.5. Microliter syringes, 10-µL or other convenient sizes for preparing standards and 1-µL for sample injections.

3.1.6. Pipets for dispensing DMSO. A Glenco 1-mL dispenser is adequate and convenient.

3.1.7. Volumetric flasks, 5-mL and other convenient sizes for preparing standards.

3.2. Reagents

3.2.1. 2-Butanone (MEK), reagent grade.

3.2.2. Dimethyl sulfoxide (DMSO), chromatographic grade.

3.2.3. A reagent grade internal standard, such as ethyl benzene.

3.2.4. Desorbing reagent, 1 µL internal standard/mL DMSO.

3.2.5. Helium, hydrogen, and air, purified GC grade.

3.3. Sample preparation

3.3.1. The combined contents (front and back section) of each sample tube are transferred to a 2-mL vial.

3.3.2. Each sample is desorbed with 1.0 mL of desorbing reagent.

3.3.3. The vials are sealed immediately and the samples are desorbed for 30 min with occasional shaking.

3.4. Standard preparation

3.4.1. Standards are prepared by diluting pure MEK with the desorbing reagent.

3.4.2. One microliter of MEK per milliliter of desorbing reagent is equivalent to 91.0 ppm for a 3-L air sample desorbed with 1 mL of desorbing reagent. This amount is uncorrected for desorption efficiency. The corrected amount is 92.95 (91.00/0.979).

3.5. Analysis

3.5.1. GC conditions

zone temperatures (°C)		flow rates (mL/min)	
column:	140	nitrogen:	25
injector:	200	hydrogen:	22
detector:	300	air:	240

injection size:	1 µL
elution time:	1.3 min
chromatogram:	Figure 3.5.1.

3.5.2. Peak areas are measured by an integrator or other suitable means.

3.5.3. An internal standard procedure is used. The integrator is calibrated to report results in ppm for a 3-L air sample after correction for desorption efficiency.

Note: OSHA no longer uses or supports this method (December 2019).

3.6. Interferences

3.6.1. Any compound having the same general retention time of MEK or the internal standard used is an interference. Possible interferences are listed on the sample data sheets. GC parameters should be chosen so these interferences will pose no problems.

3.6.2. GC parameters may be changed to circumvent any other interferences.

3.6.3. There are usually trace contaminants in DMSO. At normal operating parameters, they are insignificant.

3.6.4. Retention time data on a single column is not considered proof of chemical identity. Samples over the PEL should be confirmed by GC/MS or other suitable means.

3.7. Calculations

Since the integrator is programmed to report results in ppm for a 3-L air sample (corrected for desorption efficiency), the following calculation is used to correct results to the actual air volume sampled:

$$\text{ppm MEK} = \frac{(\text{ppm on report})(3)}{(\text{liters of air sampled})}$$

3.8. Safety precautions

3.8.1. All work done with the solvents (preparation of standards, desorption of samples, etc.) should be done in a hood.

3.8.2. Avoid skin contact with any of the solvents.

3.8.3. Wear safety glasses at all times.

4. Backup Data

4.1. Detection limit data

The detection limit was determined by injecting 1 µL of a 12.1 µg/mL standard of MEK in DMSO. The detection limit of the analytical procedure is taken to be 12.1 ng per injection. This is equivalent to 1.4 ppm (4.0 mg/m^3) for the recommended air volume. Chromatograms for this determination are shown in Figure 4.1.

4.2. Detection limit of the overall procedure

The detection limit of the overall procedure was determined from the following desorption data. These data are presented graphically in Figures 4.2.1. and 4.2.2.

Table 4.2.
Desorption Data Used to Determine the
Detection Limit of the Overall Procedure

µg/sample	3528	1764	882	402.5	201.3	12.1
µg recovered	3474.7	1734.4	854.0	385.2	186.8	11.59
	3471.2	1738.2	848.3	389.6	192.0	11.14
	3509.2	1717.3	832.9	390.4	193.7	10.68
	3495.2	1738.2	854.0			
	3475.1	1730.1	854.1			
		1731.7	858.2			

4.3. Reliable quantitation limit

The reliable quantitation limit is the same as the detection limit of the overall procedure. The data of Table 4.3. show that the requirements of at least 75% recovery and a precision (1.96 SD) ±25% or better are met.

Table 4.3.
Recovery and Precision for
the Reliable Quantitation Limit

µg/sample	13	
% recovered	95.8	$\overline{X}$ = 92.1
	88.3	SD = 3.8
	92.1	1.96(SD) = 7.4

4.4. Sensitivity and precision data (analytical method only)

The following data, which were obtained from the repeated analysis of three analytical standards representing 0.5, 1, and 2 times the target concentration, was used to determine the calibration curve and precision of the analytical method. The calibration curve is shown in Figure 4.4.

Table 4.4.
Sensitivity and Precision

x target conc.	0.5x	1x	2x
mg/mL	1.006	2.012	4.025
area counts	146007	287364	565884
	144168	286358	565567
	142940	285360	566004
	144050	283879	564308
	143825	282414	563603
	144138	281906	567043
$\overline{X}$	144188	284547	565401
SD	1002.0	2183.9	1244.8
CV	0.00695	0.00768	0.00220

$\overline{CV}$ = 0.0061

4.5. Desorption efficiency

The desorption efficiency was determined by spiking MEK onto silica gel tubes and desorbing with DMSO. Recoveries were done at 0.5, 1, and 2 times the target concentration for the recommended air volume.

Note: OSHA no longer uses or supports this method (December 2019).

Table 4.5.
Desorption Efficiency

x target conc.	0.5x	1x	2x
desorption	96.8	98.3	98.5
efficiency,	96.2	98.5	98.5
%	96.4	97.4	98.4
	96.8	98.5	99.5
	96.8	98.0	99.1
	97.3	98.2	98.5
$\bar{X}$	96.7	98.2	98.8

$\bar{\bar{X}} = 97.9$

4.6. Storage data

Thirty-six samples were collected from a test atmosphere containing 531 mg/m^3 MEK at 80% relative humidity, 21°C and 644 mm Hg. All samples were taken for 30 min and 0.1 L/min. Six samples were analyzed immediately and the remaining thirty were divided into two equal groups. One group was stored at reduced temperature (-5°C) and the other at ambient temperature (23°C). These stored samples were analyzed over a period of 15 days. The results are shown in Table 4.6. and in Figures 4.6.1. through 4.6.3.

Table 4.6.
Storage Tests

storage time (days)	% recovery (refrigerated)			(ambient)		
0	94.3	97.6	95.0	94.3	97.6	95.0
0	93.6	95.9	99.3	93.6	95.9	99.3
3	99.0	99.9	96.2	98.5	95.4	97.5
6	105.5	97.3	101.2	101.1	107.7	97.9
9	99.9	98.5	98.4	99.0	96.0	99.1
12	98.0	97.3	96.8	97.8	96.5	96.9
15	99.2	96.9	98.5	99.8	95.5	96.0

4.7. Sampler capacity

Breakthrough studies were done at 1174 mg/m^3 MEK at 80% relative humidity and 22°C. Both sections of silica gel were left in the tube. The flow rate was 0.092 L/min. A typical breakthrough curve is shown in Figure 4.7.

Note: OSHA no longer uses or supports this method (December 2019).

Table 4.7.
Breakthrough Data

	min for 5% breakthrough	liters of air sampled	mg of MEK collected
	38.5	3.54	4.16
	37.0	3.40	4.00
	34.5	3.17	3.73
$\bar{X}$	36.7	3.37	3.96

An additional sample was tested for breakthrough under the above conditions except dry air was used. The breakthrough volume was increased to 20.3 L or 23.8 mg of MEK.

4.8.   Collection of MEK on lot 104 (petroleum-base) charcoal

The collection of MEK on Lot 104 charcoal was also evaluated. The procedure is the same as the silica gel method except the collection volume is increased to 5 L, only one tube is used for collection, and carbon disulfide is used as the desorption solvent.

4.8.1.   Detection limit (analytical procedure only)

The detection limit of the analytical procedure is 0.32 ng per injection. (Figure 4.8.1.)

4.8.2.   Sensitivity and precision data (analytical procedure only)

The following data, which were obtained from the repeated analysis of three analytical standards representing 322 to 1610 mg/m^3 (for a 5-L air sample), was used to determine the calibration curve and precision of the analytical method. The sensitivity of the analytical procedure over the range studied is 173,000 area units per mg MEK/mL CS$_2$. The sensitivity is the slope of the calibration curve which is shown in Figure 4.8.2.

Table 4.8.2.
Sensitivity and Precision

mg/mL	1.61	3.22	8.05
	281844	556085	1365890
	228542	568482	1388810
	281451	557165	1400030
	280060	567225	1395220
	282081	570739	1372920
	280368	563104	1386640
$\bar{X}$	281391	563800	1384920
SD	982.6	6096.4	13104.5
CV	0.00349	0.0108	0.00946

$\overline{CV} = 0.0085$

Note: OSHA no longer uses or supports this method (December 2019).

4.8.3. Desorption efficiency

The desorption efficiencies were determined by injecting MEK onto the front sections of charcoal tubes at concentrations equivalent to 0.5, 1, and 2 times the target concentration for the recommended air volume of 5 L.

Table 4.8.3.
Desorption Efficiency

x target conc.	0.5x	1x	2x
desorption	93.0	95.8	95.0
efficiency,	93.3	96.5	95.6
%	92.9	95.3	95.9
	92.6	95.5	95.3
	93.0	95.5	95.6
	93.4	95.3	94.6
$\overline{X}$	93.0	95.6	95.3

$\overline{\overline{X}} = 94.6$

4.8.4. Storage data

Thirty-six samples were collected from a test atmosphere containing 588 mg/m^3 of MEK at 80% relative humidity and ambient temperature. The samples were taken for 50 min at 0.1 L/min. Six samples were analyzed immediately and the remainder divided into two equal groups. One group was stored at reduced temperature and the other at ambient temperature. The stored samples were analyzed over a period of 16 days. The results are given below and shown graphically in Figures 4.8.4.1. through 4.8.4.3. The recovery falls below 75% recovery at 4.3 days if the samples are refrigerated immediately and 2.0 days if the samples remain at room temperature.

Table 4.8.4.
Storage Tests

storage time (days)	% recovery (refrigerated)			(ambient)		
0	85.3	84.4	84.5	85.3	84.4	84.5
0	84.8	85.9	86.4	84.8	85.9	86.4
3	75.4	77.3	77.5	68.2	68.6	66.7
6	71.4	70.6	71.7	60.7	60.8	59.2
10	68.6	68.8	68.2	54.6	56.6	54.9
12	68.5	67.2	66.9	53.6	53.9	54.4
16	66.5	66.4	66.8	50.6	51.9	52.4

Note: OSHA no longer uses or supports this method (December 2019).

4.8.5. Sampler capacity

A breakthrough study was done on the front section of Lot 104 charcoal. The MEK vapor concentration was 1176 mg/m^3 at 80% relative humidity and 20°C. The sampling rate was 0.10 L/min. A breakthrough curve under these conditions is shown in Figure 4.8.5.

Table 4.8.5.
Breakthrough Data

	min for 5% breakthrough	liters of air sampled	mg of MEK collected
	56.5	6.65	6.64
	60.2	6.02	7.08
	56.8	5.68	6.68
$\bar{x}$	57.8	5.78	6.80
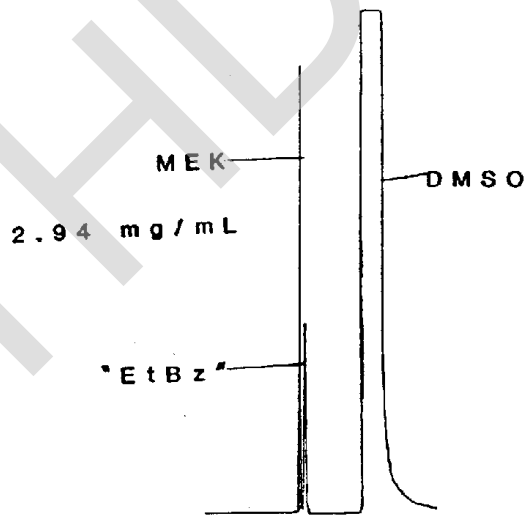
Figure 3.5.1.   Chromatogram of an MEK standard.

Note: OSHA no longer uses or supports this method (December 2019).

Blank (DMSO)

Interference

MEK

12.1 ug/mL
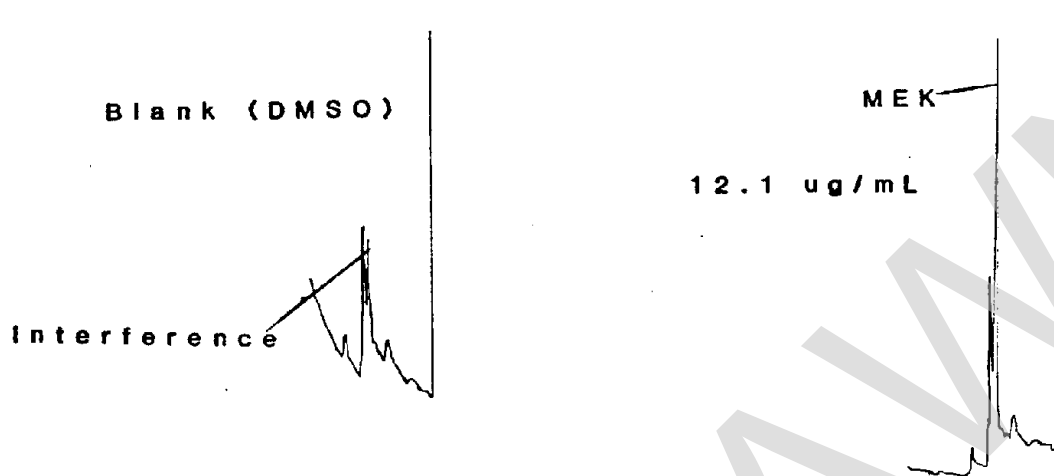
Figure 4.1.Chromatograms for the detection limit.

MEK on Silica Gel

(Data from section 4-2
expanded x 10)

ug of MEK Recovered

If the detection limit is 12.1 ug for
the analytical procedure, then the
detection limit of the overall procedure
i= 13.0 ug.

ug of MEK Spiked on Tube
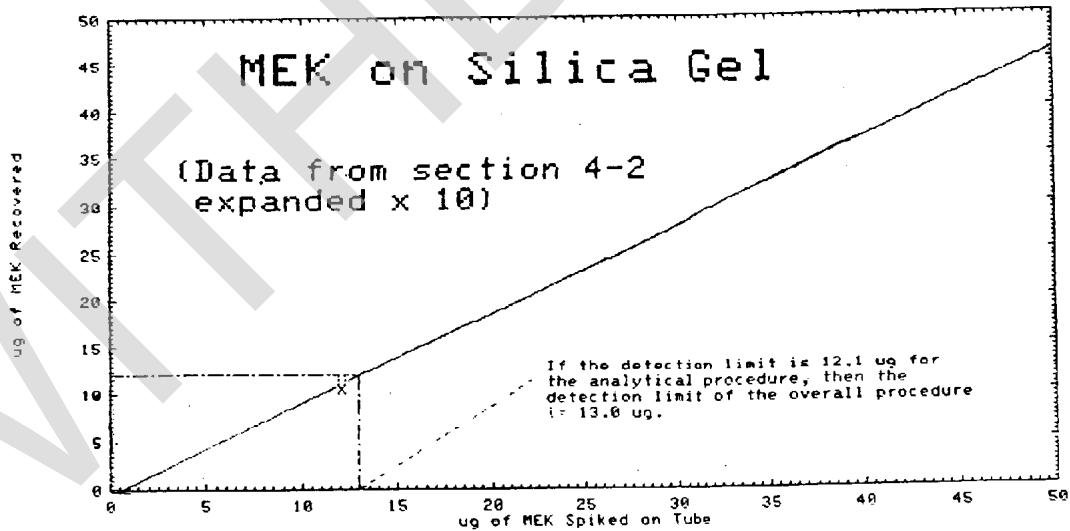
Figure 4.2.1.   Detection limit of the overall procedure.

Note: OSHA no longer uses or supports this method (December 2019).
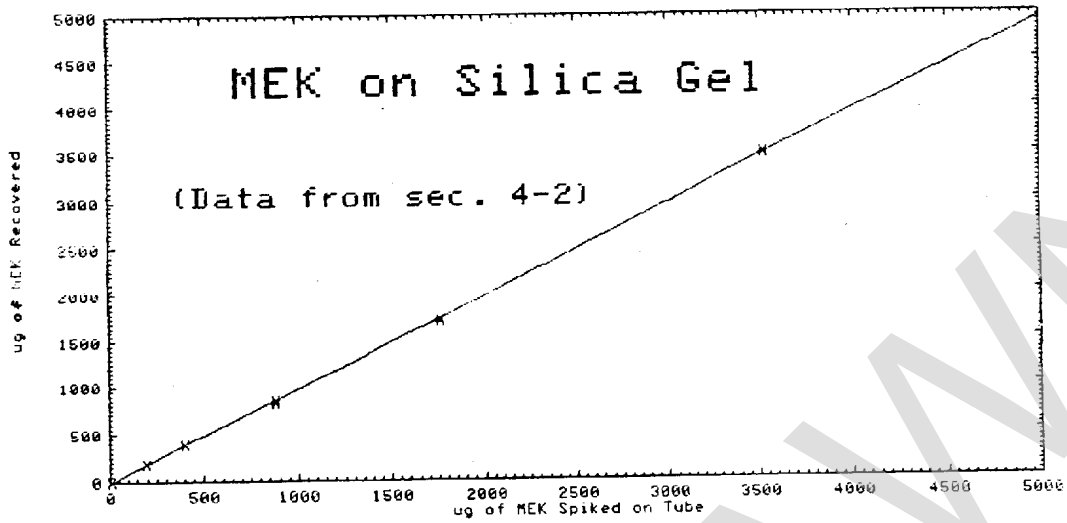
Figure 4.2.2.   Detection limit of the overall procedure.
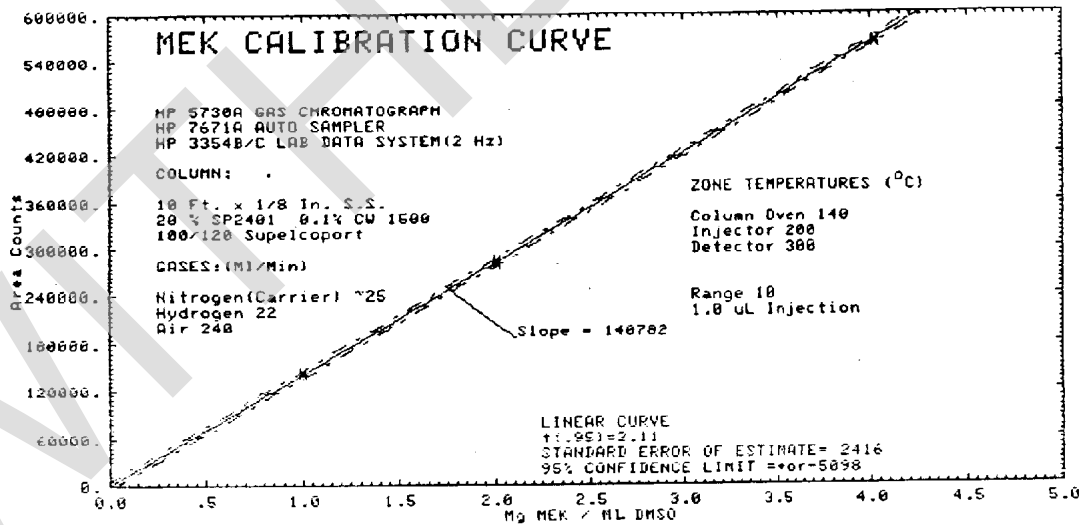
Figure 4.4.   Calibration curve.

Note: OSHA no longer uses or supports this method (December 2019).
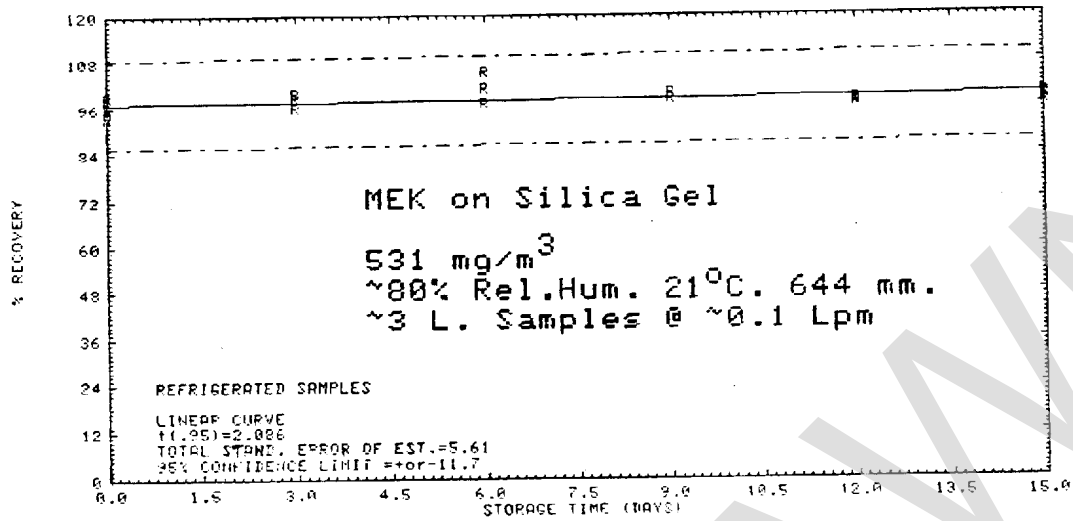
Figure 4.6.1.   Refrigerated storage.
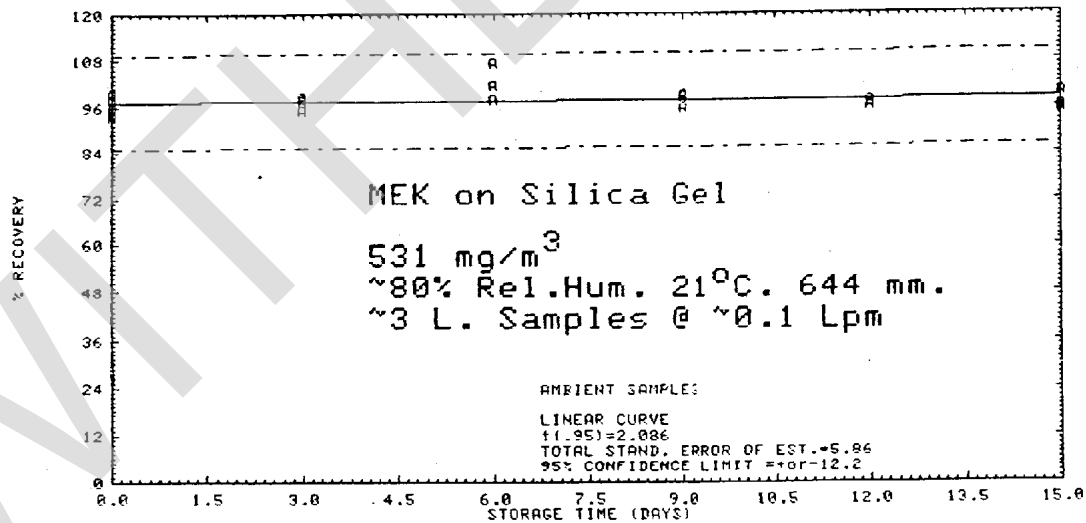
Figure 4.6.2.   Ambient storage.

Note: OSHA no longer uses or supports this method (December 2019).
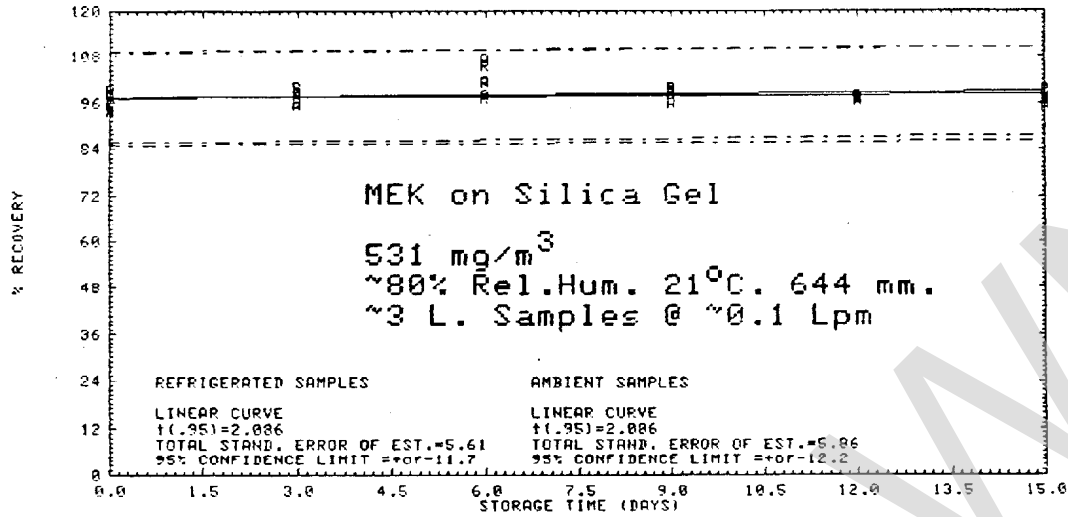
Figure 4.6.3.   Refrigerated versus ambient storage.
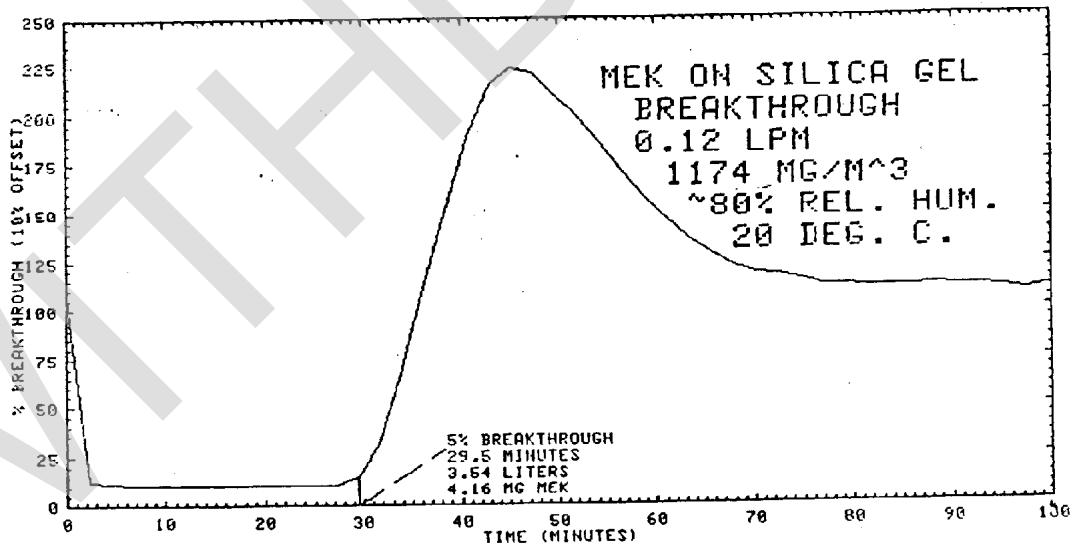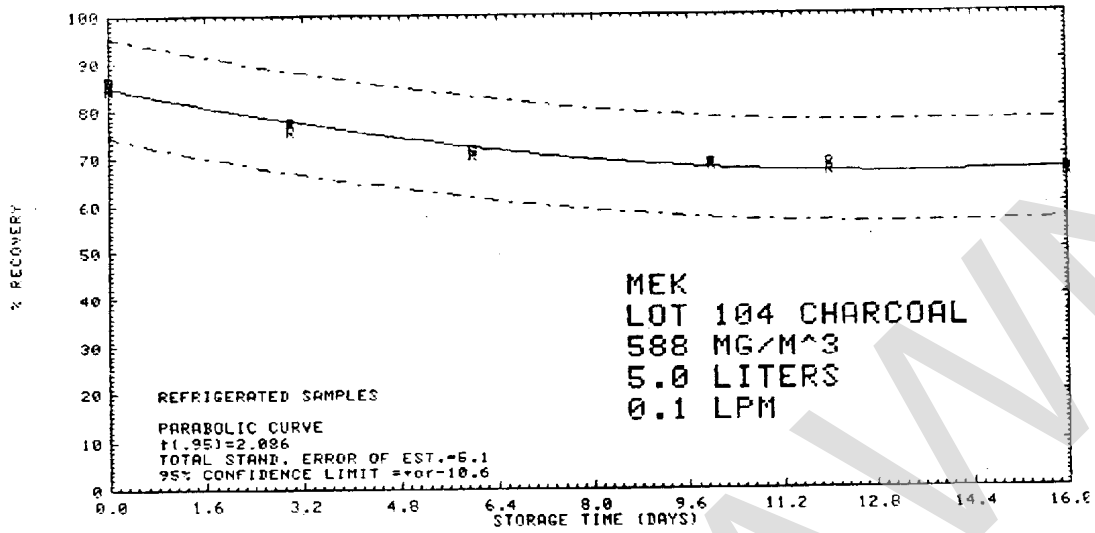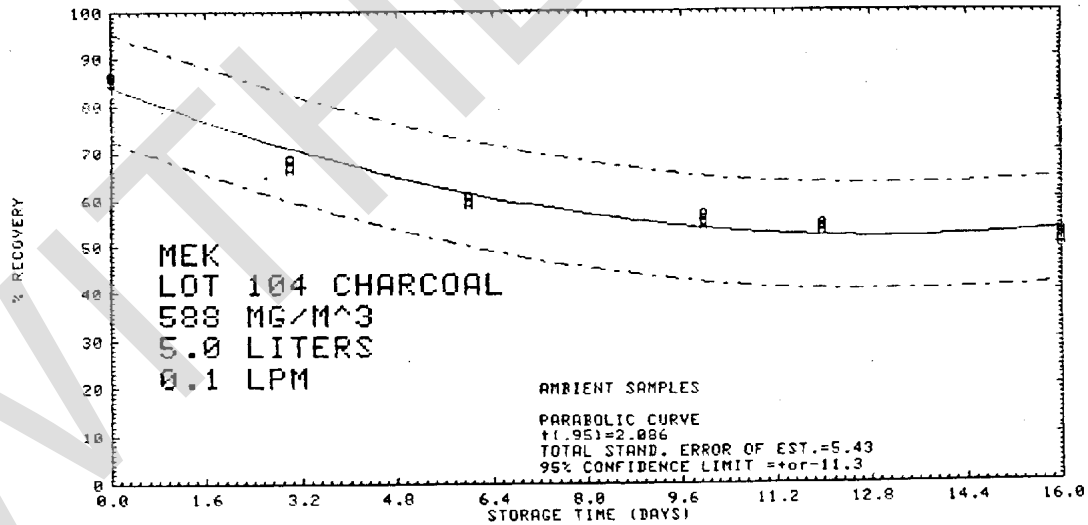

Figure 4.7.   Breakthrough curve.

Note: OSHA no longer uses or supports this method (December 2019).
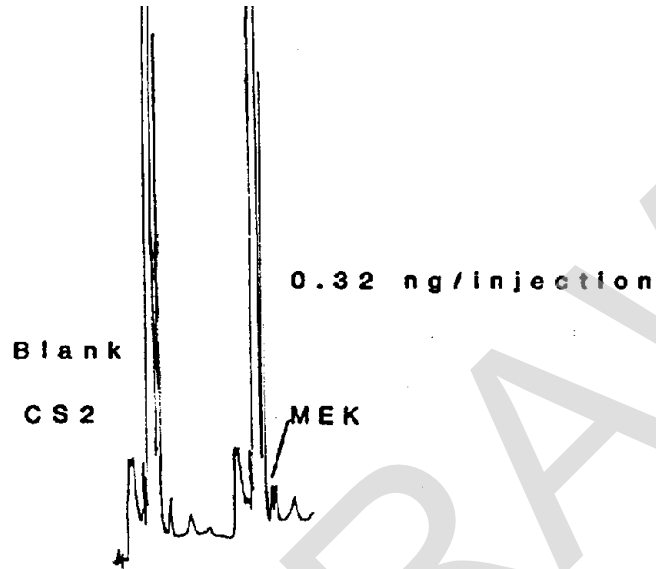
Figure 4.8.1.   Chromatograms for the detection limit.
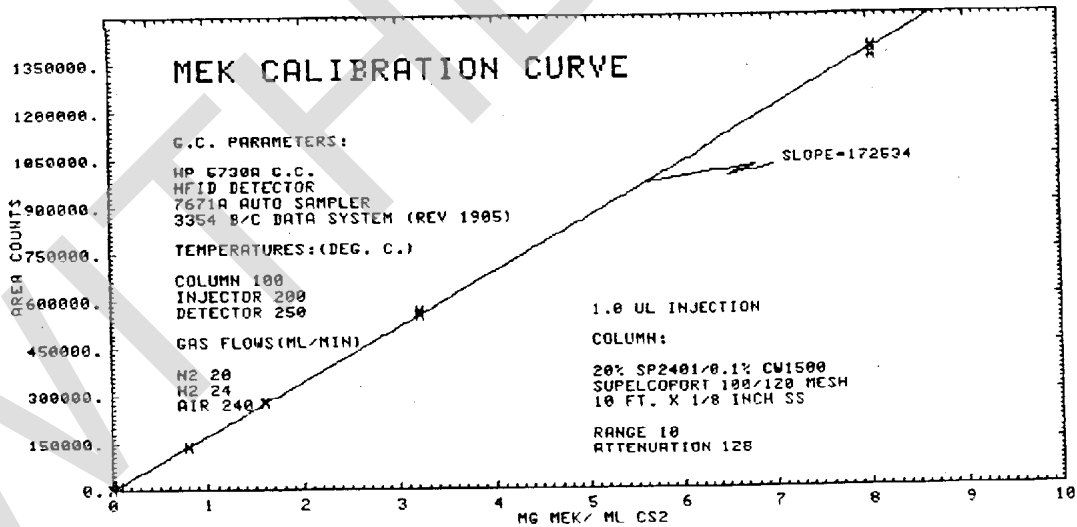
Figure 4.8.2.   Calibration curve.

Note: OSHA no longer uses or supports this method (December 2019).

Figure 4.8.4.1.   Refrigerated storage.

Figure 4.8.4.2.   Ambient storage.

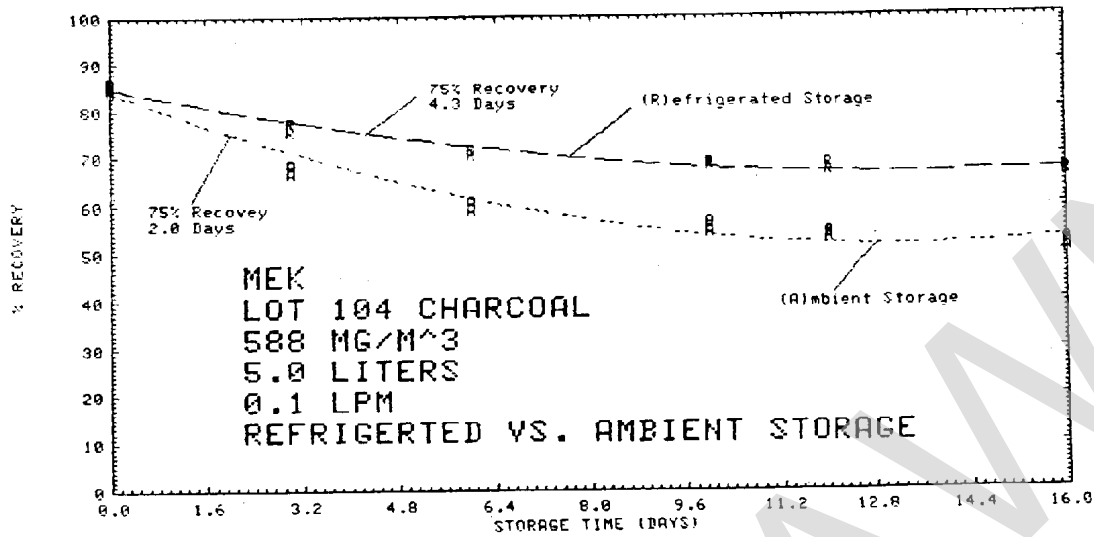Note: OSHA no longer uses or supports this method (December 2019).

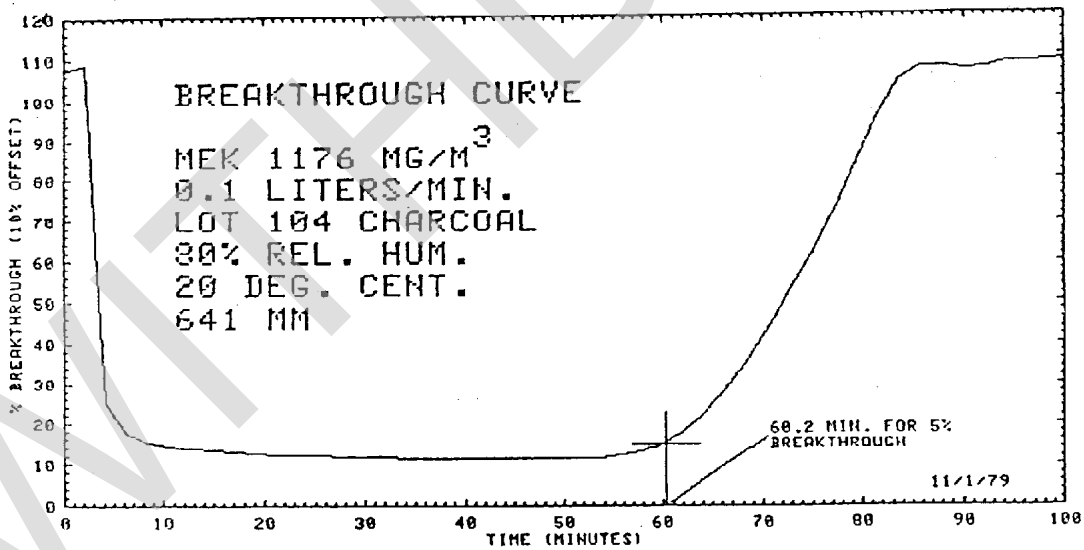Figure 4.8.4.3.   Refrigerated versus ambient storage.

Figure 4.8.5.   Breakthrough curve.

Note: OSHA no longer uses or supports this method (December 2019).

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