Method no.:	55
Matrix:	Air
Target concentration:	2 ppm (9.1 mg/m^3 for MCA, 10.2 mg/m^3 for ECA)
Procedure:	Samples are collected by drawing a known volume of air through phosphoric acid-treated XAD-7 sampling tubes. Following desorption with 2 mL of 0.2% (v/v) phosphoric acid in acetonitrile, the samples are analyzed by high pressure liquid chromatography (HPLC) with ultraviolet (UV) detection.
Recommended air volume and sampling rate:	12 L at 0.1 L/min
Reliable quantitation limit:	10 ppb (0.05 mg/m^3) for MCA 14 ppb (0.07 mg/m^3) for ECA
Standard error of estimate: (Figures 4.6.2 & 4.6.4)	6.5% for MCA 5.8% for ECA
Special requirements:	After sampling, the sampling tubes must be kept at reduced temperature. (Section 2.1.3)
Status of method:	Evaluated method. This method has been subjected to the established evaluation procedures of the Organic Methods Evaluation Branch.

Date: October 1985 Chemist: Kevin J. Cummins

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

1. General Discussion

1.1 Background

1.1.1 History

Methyl and ethyl 2-cyanoacrylate are two of the more common members of a family of alkyl 2-cyanoacrylates which are used industrially and domestically as adhesives (Ref. 5.1). Although OSHA has not established a PEL for either MCA or ECA, the American Conference of Governmental Industrial Hygienists (ACGIH) has adopted a 2 ppm TLV and a 4 ppm STEL for MCA. A target concentration of 2 ppm for both methyl and ethyl 2-cyanoacrylate has been selected for this evaluation.

The previous method for measuring occupational exposures in air to alkyl 2-cyanoacrylates uses a 0.1 N NaOH bubbler solution to trap the alkyl 2-cyanoacrylate vapors (Ref. 5.2). The samples are analyzed by either colorimetric or polarographic means for formaldehyde which is a decomposition product of the alkyl 2-cyanoacrylates formed in the bubbler (Refs. 5.2 and 5.3). This method is nonspecific for the alkyl 2-cyanoacrylates and inconvenient to use in field sampling.

The sampler evaluated in this method contains the porous polymer resin XAD-7 coated with phosphoric acid. Phosphoric acid is commonly used as an anionic inhibitor for stabilizing alkyl 2-cyanoacrylate monomers (Ref. 5.1) and is transparent at the UV detector wavelength used in the analysis. Other adsorbents, including charcoal, silica gel, XAD-2, XAD-4, and untreated XAD-7 were found to be unacceptable because of significant analyte loss due to decomposition. The formation of derivatives with aromatic or aliphatic amines also proved to be unsuccessful.

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

The alkyl 2-cyanoacrylates are primarily irritants. Sensory response to the cyanoacrylates is reported to occur at approximately 1 ppm, with nose and eye irritation reported to occur in the 3- to 5-ppm range (Ref. 5.4). No report of an acute cyanoacrylate exposure to humans was found in the literature. Based on animal toxicity data, it is presumed that methyl 2-cyanoacrylate is of low toxicity (Ref. 5.5). An LD_{50} of 180 mg/kg is reported for rats from a single oral dose of ethyl 2-cyanoacrylate and an LD_{50} of 220 mg/kg is reported for rabbits from a single subcutaneous injection (Ref. 5.6). No LD_{50} data were found in the literature for methyl 2-cyanoacrylate. Also no information was found to indicate that the alkyl 2-cyanoacrylates are considered to be very toxic to humans. Because of their highly reactive nature, skin and eye contact with alkyl 2-cyanoacrylates should be avoided.

1.1.3 Potential workplace exposure

The alkyl 2-cyanoacrylates are used as adhesives in a variety of different work settings. They are used to assemble trophies, golf clubs, tools, digital watches, optical lenses, electronic components, and in many other items. An estimate of world production in the 1970s for industrial, consumer, and medical use is less than 150,000 kg/year (Ref. 5.1). No estimate of the number of workers potentially exposed to the alkyl 2-cyanoacrylates was found in the literature.

1.1.4 Physical properties (Ref. 5.1 unless otherwise indicated.)

Methyl 2-cyanoacrylate

CAS no:	37-05-3
molecular weight:	111.11
boiling point:	48-49°C (2.5-2.7 mm Hg)
vapor pressure:	less than 2 mm Hg at 25°C
appearance:	clear, colorless liquid
odor:	acrid, ester-like*
specific gravity:	1.1044 at 20°C
solubility:	Reacts with water or protic solvents. Soluble in methylene chloride, acetonitrile, dimethylformamide, acetone, and toluene.*
synonyms:	2-cyanoacrylic acid, methyl ester; methylcyanoacrylate; methyl alphacyanoacrylate; mecrylate; 2-propenoic acid, 2-cyano-methyl ester; Permabond 910; Permabond 910FS.
molecular formula:	$CH_2CCNCO_2CH_3$

Ethyl 2-cyanoacrylate

CAS no.:	7085-85-0
molecular weight:	125.14
boiling point:	54-56°C (2.6-3.0 mm Hg)
vapor pressure:	less than 2 mm Hg at 25°C
appearance:	clear, colorless liquid
odor:	irritating, sweet, ester-like*
specific gravity:	1.0501 at 20°C
solubility:	same as methyl 2-cyanoacrylate*
synonyms:	ethyl alpha-cyanoacrylate; 2-propenoic acid, 2-cyano, ethyl ester; 2-cyano-acrylic acid, ethyl ester; N135; Permabond 101.
molecular formula:	$CH_2CCNCO_2CH_2CH_3$

* personal observation

1.2 Limit defining parameters (The analyte air concentrations listed throughout this method are based on a 12-L air sample and a solvent desorption volume of 2 mL for both MCA and ECA)

1.2.1 Detection limit of the analytical procedure

The detection limits of the analytical procedure for MCA and ECA are 5.6 and 8.7 ng per injection respectively. These are the amounts of analyte which will give a measurable response with the amounts of interferences present in a standard. (Section 4.1)

1.2.2 Detection limit of the overall procedure

The detection limits of the overall procedure for MCA and ECA are 0.56 and 0.87 µg respectively per sample [0.05 mg/m^3 (0.01 ppm) for MCA and 0.07 mg/m^3 (0.01 ppm) for ECA]. These are the amounts of analyte spiked on the sampling device which allow recovery approximately equivalent to the detection limit of the analytical procedure. (Section 4.2)

1.2.3 Reliable quantitation limit

The reliable quantitation limits for MCA and for ECA are 0.56 and 0.87 µg per sample respectively [0.05 mg/m^3 (0.01 ppm) for MCA and 0.07 mg/m^3 (0.01 ppm) for ECA]. These are the amounts of analyte 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 4.2)

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 sensitivities of the analytical procedures for MCA and for ECA over the concentration range representing 0.5 to 2 times the target concentration are 18490 area units per µg/mL for MCA and 11052 area units/µg/mL for ECA. Sensitivity is determined from the slope of the calibration curve. These values may vary with the particular instrument used in the analysis. (Section 4.4)

1.2.5 Recovery

The recoveries of MCA and of ECA from samples collected from separate test atmospheres of the two alkyl 2-cyanoacrylates remained above 90% for both MCA and ECA when the samples were stored at 5°C in a refrigerator. This is the percent recovery at the 17th storage day for both MCA and ECA which is determined from the linear least squares line of the refrigerated storage data for each analyte. The recovery of the analyte from the collection medium during storage must be 75% or greater. (Section 4.6)

1.2.6 Precision (analytical method only)

The pooled coefficients of variation obtained from replicate determinations of analytical standards at 0.5, 1, and 2 times the target concentration for MCA and for ECA are 0.008 and 0.020 respectively. (Section 4.3)

1.2.7 Precision (overall procedure)

The precision at the 95% confidence level for the 17-day refrigerated storage tests are ±12.7% for MCA and ±11.4% for ECA. This includes an additional ±5% for sampling error. The overall procedure must provide results that are ±25% or better at the 95% confidence level. (Section 4.6)

1.2.8 Reproducibility

Six samples spiked with a stock solution of MCA in 0.2% (v/v) H_3PO_4 in acetonitrile and a draft copy of the analytical procedure were given to a chemist unassociated with this evaluation. The samples were analyzed after 9 days of refrigerated storage and the average result was 88.5 % (SD=1.1%). For the evaluation of ECA, six samples collected from a test atmosphere of ECA and a draft copy of the analytical procedure were given to another chemist who was also unassociated with this evaluation. The samples were analyzed after 11 days of refrigerated storage and the average result was 90.1% (SD = 1.1%). (Section 4.7)

1.3 Advantages

1.3.1 The acid-treated sampling tube is convenient to use in the field.

1.3.2 The analytical procedure is sensitive, specific, and reliable.

1.4 Disadvantages

The samples must be kept refrigerated at all times prior to analysis.

2. Sampling Procedure

2.1 Apparatus

2.1.1 A constant flow personal sampling pump is used which can be calibrated to within ±5% of the recommended 0.1 L/min flow rate while the sampling tube is in line.

2.1.2 Sampling tubes containing H_3PO_4-treated XAD-7 adsorbent which are made at the laboratory were used in this study. (See Section 4.9. for the method of preparation of adsorbent and sampling tubes).

2.1.3 An ice chest or Styrofoam cooler packed with ice is used for maintaining samples at reduced temperature following the completion of sampling. Dry ice is necessary for shipment of the samples to the laboratory. However, caution should be exercised in using dry ice in an enclosed space such as an automobile in order to avoid possible suffocation.

2.2 Reagents

None required

2.3 Technique

2.3.1 Properly label the sampling tube before sampling.

2.3.2 Attach the sampling tube to the pump using a section of flexible tubing such that the large, front section of the sample tube is exposed directly to the atmosphere. Do not place any tubing ahead of the sampling tube. The sampling tube should be attached vertically in the worker's breathing zone in such a manner that it does not impede work performance.

2.3.3 After sampling for the appropriate time, remove the sampling tube from the pump and then cap the tube. Wrap the tube end to end with an official OSHA seal (Form 21). Samples should be kept at reduced temperature immediately following sampling. This can be easily accomplished at the sampling site by using an inexpensive Styrofoam cooler packed with ice to store the samples.

2.3.4 Include at least one blank for each sampling set. The blank should be handled in the same manner as the samples with the exception that air is not drawn through it.

2.3.5 List any potential interferences on the sample data sheet.

2.3.6 Samples must be shipped on dry ice. A Styrofoam cooler well-packed with dry ice and tightly sealed is a convenient means of shipping the samples. The sealed cooler should be packed inside a cardboard box and cushioned with packing material prior to shipment.

2.4 Breakthrough

Breakthrough studies for MCA and for ECA were performed in separate experiments using the vapor generation system described in Section 4.5. The breakthrough air volume for MCA was determined by sampling at 0.10 L/min, a 12.5 mg/m^3 (2.75 ppm) atmosphere of MCA (40% R.H. and ambient temperature) with the front section of a sampling tube. A second sampling tube containing acid-treated XAD-7 was placed behind the front sampling section and it was periodically changed and analyzed to detect breakthrough from the front sampling section. The 5% breakthrough volume for MCA is approximately 30 L at this concentration. This is the volume of air sampled that results in a concentration of MCA downstream from the front section of the sampling device which is 5% of the upstream concentration (Figure 2.4.1).

The breakthrough air volume for ECA was determined by sampling at 0.19 L/min, a 13.1 mg/m^3 (2.6 ppm) atmosphere of ECA (40% R.H. and ambient temperature) in the same manner as MCA. The 5% breakthrough volume for ECA is approximately 79 L at this concentration. A higher sampling

rate was used to determine breakthrough for ECA because of the much higher capacity of the sampling tube for ECA (Figure 2.4.2).

2.5 Desorption efficiency

The desorption efficiencies of MCA and of ECA were determined in separate experiments by spiking sampling tubes with an amount of alkyl 2-cyanoacrylate in 0.2% (v/v) H_3PO_4 in acetonitrile equivalent to 0.5, 1, and 2 times the target concentration for the recommended air volume. The average percent recoveries of MCA and of ECA obtained upon analysis of spiked samples tubes were 94.4 and 97.7% respectively (Section 4.8).

2.6 Recommended air volume and sampling rate

The recommended air volume is 12 L for both MCA and ECA. The recommended sampling rate for both analytes is 0.1 L/min. The sensitivity of the method will permit a sampling period as short as 15 min for both MCA and ECA at the recommended sampling rate of 0.1 L/min.

2.7 Interferences

Any substance collected with MCA or ECA that is capable of reacting with it is a potential interference. Basic compounds, alcohols, and free radical initiators are all capable of reacting with the alkyl 2-cyanoacrylates.

2.8 Safety precautions

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 that apply to the work area being sampled.

2.8.3 Caution should be exercised in using dry ice to avoid possible suffocation from CO_2 vapors. Dry ice containers should not be transported in the passenger section of an automobile, or other confined areas.

3. Analytical Procedure

3.1 Apparatus

3.1.1 A liquid chromatograph equipped with a variable wavelength UV detector and a reverse phase C_{18} column is needed for the analysis. A Model M-6000A (Waters Associates, Milford, MA) pump equipped with a Waters Model 710 WISP autosampler and a Spectroflow 773 UV detector (Kratos Anal. Instruments, Ramsey, NJ) was used along with an IBM C_{18} (25 cm × 4.6 mm) stainless steel column in this analysis.

3.1.2 An electronic integrator or other suitable means of measuring detector response is needed. The Hewlett-Packard 3357 data system was used in this evaluation.

3.1.3 Small sample vials fitted with septa were used in this analysis. Four-milliliter, screw-cap vials (WISP-type vials) obtained from Sun Brokers Inc. (Wilmington, NC) were used for this purpose.

3.1.4 An inexpensive Styrofoam cooler was used to maintain an ice bath around the analytical column.

3.2 Reagents

3.2.1 Commercial alkyl 2-cyanoacrylates (95%+ purity) containing ppm levels of a proprietary inhibitor were furnished courtesy of Bob Blomquist of Permabond International (Englewood, NJ) and used for analytical standards for both MCA and ECA.

For the MCA evaluation, Permabond 910 FS adhesive was used as received for an analytical standard of methyl 2-cyanoacrylate. Permabond 910 adhesive was used in the permeation oven to generate a test atmosphere of MCA since it appeared to be more stable than the Permabond 910 FS at elevated temperatures.

For the ECA evaluation, Permabond 101 was used as received for an analytical standard of ethyl 2-cyanoacrylate. Ethyl 2-cyanoacrylate adhesive, lot no. T006, (Three Bond of America, Inc., Torrance, CA) was used as the source of ethyl 2-cyanoacrylate in the permeation oven since this study was begun before the Permabond standards were obtained.

3.2.2 Acetonitrile (Burdick and Jackson, Muskegon, MI).

3.2.3 Phosphoric acid, reagent grade.

3.2.4 HPLC quality water. Water obtained from a Milli-Q reagent grade water system (Millipore, Inc., Bedford, MA) was used in this evaluation.

3.2.5 Ice for use in maintaining the column ice bath.

3.3 Standard preparation

A stock solution of the alkyl 2-cyanoacrylate is prepared by accurately weighing approximately 0.2 g of the standard into a 10-mL volumetric flask and diluting to volume with 0.2% (v/v) H_3PO_4 in acetonitrile. A 1 to 25 dilution of this stock solution is then prepared from which a series of dilutions is made to give working standards in the 15 to 120 µg/mL range. All dilutions are prepared in the 0.2% (v/v) H_3PO_4 in acetonitrile desorbing solution. For the analysis, 2 mL of each working standard are placed in individual autosampler vials over approximately 80 mg of the sampling adsorbent (approximate mass of front section of sampling tube). The sampling adsorbent is placed in the standard vials solely for the purpose of obtaining consistent peak integration as discussed in Section 4.10 and may not be necessary if the analysis is performed at 0°C using the ice bath. The vials are then capped, shaken vigorously for several seconds and analyzed along with samples as described in Section 3.5.

3.4 Sample preparation

The front adsorbent section including the front glass wool plug, and the back adsorbent section including the remaining two glass wool plugs are each placed in separate vials and 2 mL of the desorbing solution are added to each vial. The vials are then capped, shaken vigorously for several seconds and analyzed as described in Section 3.5.

3.5 Analysis

3.5.1 HPLC chromatographic conditions (For a discussion of these analytical conditions see Section 4.10)

column:	IBM, C_{18} (25 cm × 4.6 mm), stainless steel maintained at 0°C with an ice bath.
mobile phase:	44/56/0.2 (v/v/v) acetonitrile/water/phosphoric acid
flow rate:	1 mL/min
UV detector wavelength:	220 nm
injection volume:	20 µL
retention time:	6.1 min for MCA; 8.0 min for ECA

3.5.2 Chromatograms of standards of MCA and ECA in the presence and absence of acid-treated XAD-7 are shown in Figures 3.5.1 and 3.5.2. Both of these chromatograms were obtained by analysis at 0°C.

3.6 Interferences

No interferences to the analytical method were observed during this evaluation. Nevertheless, any substance that has a similar retention time as either MCA or ECA under the existing analytical conditions is a potential interference. It may be necessary to modify the analytical conditions in order to circumvent an interference.

3.7 Calculations

3.7.1 A calibration curve is prepared by plotting µg/mL of the alkyl 2-cyanoacrylate per sample versus area response. A parabolic least squares fit is used to determine the amount of MCA or ECA present in the samples.

3.7.2 To determine results in mass per unit volume use the following formula. No desorption efficiency correction is applied to these results if the standards are prepared in the presence of the acid-treated adsorbent:

$$mg/m^3 = \frac{(\text{total µg/mL cyanoacrylate}) \times (2\ mL)}{(\text{liters of air sampled}) \times (DE)}$$

where: total µg/mL cyanoacrylate = the sum of the amounts found in the front and back sections.
D.E. = desorption efficiency

3.7.3 To express the results in ppm (760 mm and 25°C) use the following formula:

$$ppm = \frac{(\text{total µg/mL cyanoacrylate}) \times (2\ mL) \times (24.46)}{(\text{liters of air sampled}) \times (DE) \times (MW)}$$

where: 24.46 = the molar volume of an ideal gas at 760 mm Hg and 25°C.
MW = molecular weight (MCA = 111.04, ECA = 125.14)

3.8 Safety precautions

3.8.1 Wear safety glasses in the laboratory at all times.

3.8.2 Avoid skin contact with all solvents and reagents.

3.8.3 Minimize exposure to all reagents and solvents by performing all sample and standard preparations in a well-ventilated hood.

4. Backup Data

4.1 Detection limit of the analytical procedure

The detection limits of the analytical procedure for MCA and for ECA respectively are 5.6 and 8.7 ng per injection. These are based on a 20-µL injection of a 0.28 ng/µL MCA standard and on a 20-µL injection of a 0.43 ng/µL ECA standard. These are the amounts of analyte which will give a measurable response with the amounts of interferences present in a standard. Chromatograms of both MCA and of ECA at the detection limit are shown in Figures 4.1.1 and 4.1.2 respectively. MCA is retained longer than ECA as can be seen upon comparison of Figures 4.1.1 and 4.1.2 because the MCA analysis was performed at reduced temperature while the ECA analysis was performed at ambient temperature. Under identical analytical conditions MCA will elute before ECA (Figures 3.5.1 and 3.5.2).

4.2 Detection limit of overall procedure and reliable quantitation limit

The reliable quantitation limits and the detection limits of the overall procedure for this method are 0.56 µg per sample (0.05 mg/m^3 or 10 ppb based on a 12-L air sample) for MCA, and 0.87 µg per sample (0.07 mg/m^3 or 14 ppb based on a 12-L air sample) for ECA. The reliable quantitation limits were determined by spiking six front sections of acid-treated adsorbent contained in autosampler vials with a standard of the cyanoacrylate. The samples were allowed to sit for approximately 30 min, and then desorbed and analyzed. For the MCA determination, each adsorbent section was spiked with 10 µL of a 56.14 µg/mL MCA standard (0.56 µg). For ECA, each adsorbent section was spiked with 4.2 µL of a 208 µg/mL ECA standard (0.87 µg).

Table 4.2
Data for Reliable Quantitation Limits

MCA		ECA	
% recovery	statistics	% recovery	statistics
102		95.2	
105	$\overline{X}$=105	101	$\overline{X}$=96.1
107	SD=2.9	95.5	SD=2.9
110	1.96SD=5.7	97.1	1.96SD=5.7
103		92.1	
105		96.0	

4.3 Precision of the analytical method

The pooled coefficients of variation for MCA and for ECA over a range of 0.5 to 2 times the target concentration are 0.0073 and 0.020 respectively. These values were determined from six injections each 33 of three working standards which correspond to 56.14, 112.3, and 224.5 µg of MCA per sample, and 63.26, 126.5, and 253.0 µg ECA per sample.

Table 4.3.1
Precision of the Analytical Method for MCA

× target concn	0.5×	1×	2×
µg/sample	56.14	112.3	224.5
area counts	543834	1060630	2103890
	536156	1059220	2108980
	530234	1054600	2102670
	531995	1053600	2092790
	528030	1053710	2073110
	532342	1053330	2069360
$\bar{X}$	533765	1055848	2091800
SD	5614	3217	16813
CV	0.011	0.0030	0.008
$\overline{CV}$	0.0080		

Table 4.3.2
Precision of the Analytical Method for ECA

× target concn	0.5×	1×	2×
µg/sample	63.26	126.5	253
area counts	352080	677938	1417140
	357494	673315	1337510
	347056	698116	1423280
	344913	677321	1435380
	350780	687284	1404810
	354606	670451	1352690
$\bar{X}$	351155	680738	1395135
SD	4666	10250	40279
CV	0.013	0.015	0.029
$\overline{CV}$	0.020		

4.4 Sensitivity

The slope of the calibration curve over the range of 0.5 to 2.0 times the target concentration for the analytes represents the sensitivity for the method. The sensitivities for MCA and for ECA are 18490 and 11052 area units per µg/mL respectively. The difference in sensitivity observed between MCA and ECA is due to the enhanced response obtained upon analysis of MCA at 0°C versus the ambient temperature analysis of ECA (Figures 4.4.1 and 4.4.2).

4.5 Generation and determination of test atmosphere concentrations

Test atmospheres for both MCA and ECA were generated using the laboratory vapor generation system and a Metronics 450 Dynacalibrator permeation device. Four small glass diffusion bulbs (12- to 15-mm diameter) which had a 2 cm long glass neck attached and a 5.5-mm i.d. opening were used to contain the alkyl 2-cyanoacrylate in the permeation device. The permeation oven was maintained at 40°C for the MCA study and at 50°C for the ECA study. Compressed air that had first passed through silica gel, molecular sieve, and finally charcoal was used as the carrier and the dilution gas in the permeation oven. For humidity studies the dilution air was passed through a bubbler that was maintained at constant temperature in a water bath before being mixed with the dry air containing the alkyl 2-cyanoacrylate. The diluted air from the permeation device containing the alkyl 2-cyanoacrylate then passed into a glass sampling manifold which permitted up to six samples to be collected at once. Calibrated rotameters on the permeation device were used to vary the amount of dilution air and thus vary the final test concentration. The total gas flow rate through the permeation oven was determined with a calibrated dry test meter. Critical flow orifices attached to a vacuum pump were used to sample the test atmosphere from the gas sampling manifold.

Although the rate of mass loss of alkyl 2-cyanoacrylate, as determined by the weight loss of the diffusion tubes with time, was reasonably constant within a day after the preparation of the test atmosphere, measurements of the concentration of the atmosphere with the recommended acid-treated XAD-7 sampling tube resulted in recoveries which were approximately 70% of the total

expected mass. Since there was visual evidence of polymerization occurring in the diffusion tubes during the evaluation, it is believed that the gravimetric results reflected a mass loss which was not exclusively alkyl 2-cyanoacrylate. The loss of volatile reaction products from the diffusion tubes, such as formaldehyde, water, and alkyl cyanoacetates, which can be produced from the polymerization and decomposition of alkyl 2-cyanoacrylates, could account for the low recovery of alkyl 2-cyanoacrylate. Consequently, the gravimetric method could not be used to determine the concentration of the test atmospheres.

A Hewlett-Packard Model 5730A gas chromatograph equipped with a nitrogen-phosphorus detector and an automated gas sampling valve was used to independently determine the concentration of the alkyl 2-cyanoacrylate test atmosphere. A 10-ft stainless steel column packed with 20% SP-2401/0.1% Carbowax 1500 on 100/120 mesh Supelcoport maintained at 155°C was used to chromatograph both MCA and ECA. Standards for the GC were prepared by spiking Teflon gas bags filled with clean, dry air with a freshly-prepared, concentrated stock solution of the alkyl 2-cyanoacrylate in methylene chloride. These gas bags were attached to the gas sampling valve with Teflon tubing and a vacuum was used to draw the sample into the sampling valve. Teflon tubing attached directly to the gas sampling manifold was also used to draw air from the test atmosphere into the gas sampling valve. Air samples of the test atmosphere were taken with the acid-treated XAD-7 sampling tubes in conjunction with the GC sampling and the results compared in Table 4.5.1. As observed, both the sample tube and the GC give comparable measures of the concentration of the test atmospheres for both MCA and ECA. Although the GC results may potentially be subject to error due to decomposition of the standards in the gas bags and to other undetermined error sources, the good correlation obtained with the sampling tube method is supportive evidence that the sampling tube method is an accurate means of measuring alkyl 2-cyanoacrylate air concentrations.

Midget fritted-glass bubblers containing 0.2% (v/v) H_3PO_4 in acetonitrile were also used to sample both the MCA and ECA test atmospheres alongside the recommended sampling tube. The results are presented in Table 4.5.2. The good correlation obtained in this study is further evidence that the recommended sampling tube is a reliable means of measuring exposures. Although this bubbler method has not been previously evaluated, it was observed that both MCA and ECA standards are very stable in the acidified acetonitrile solution. No loss of alkyl 2-cyanoacrylate is expected to occur in the bubbler solution when sampling a humid atmosphere since no loss in recovery was observed for bubbler solutions which were prespiked with MCA and then used to sample the test atmosphere. Although this sampling method appears to be an effective means of monitoring alkyl 2-cyanoacrylates in air, it was not evaluated for OSHA use because of the inconvenience of using bubblers in the field.

Table 4.5.1
Determination of Test Atmosphere Concentration
(Comparison of acid-treated sampling tube with GC results)

compound	average mg/m^3		ST/GC
	sampling tube (ST)	GC	
MCA	10.61 ± 0.33 (5)[1]	9.43 ± 0.071 (2)	1.13
MCA	10.68 ± 0.02 (2)	10.02 ± .045 (2)	1.07
ECA	11.00 ± 0.12 (5)	11.25 ± 0.44 (3)	0.98

[1]number of determinations in parenthesis

Table 4.5.2
Determination of Test Atmosphere Concentration
(Comparison of acid-treated sampling tube with bubbler)

compound	average mg/m^3 ± SD[1]		ST/bubbler
	sampling tube (ST)	bubbler	
MCA	11.27 ± 0.12	12.07 ± 0.12	0.93
MCA	13.24 ± 0.27	14.28 ± 0.11	0.93
ECA	11.10 ± 0.22	11.87 ± 0.43	0.94

[1]average for three samples

4.6 Storage

Storage of MCA and of ECA samples was performed at both ambient and refrigerated temperatures. For MCA storage the samples were prepared by sampling at 0.20 L/min a test atmosphere at 40% R.H. and ambient temperature for 60 min. The concentration of this test atmosphere was determined to be 9.9 mg/m^3 based on the analysis of six samples collected during the generation of the storage samples. (The GC method was not used to determine the concentration of the test atmosphere for the storage results because it was not developed until after the storage data had been collected. Nevertheless the good correlation obtained with the GC method and the sample tube method under sampling conditions which were similar to the conditions used in this storage study supports the validity of using the test method to determine the test atmosphere concentration.) This sample load is approximately equivalent to a 2-h exposure at the 2-ppm target concentration for a 0.10 L/min sampling rate. A total of 36 samples were generated for the MCA evaluation in one day from the vapor generation system. Six of these samples were selected at random and analyzed the same day to determine the test atmosphere concentration as indicated above. The remaining 30 samples were randomly split into two groups of 15 samples each for storage either at ambient temperature in the dark or at reduced temperature in a refrigerator. Three samples from each group were selected at random and analyzed at 3- to 4-day intervals over the next 17 days. The percent recoveries for each sample are listed in Table 4.6.1 and are shown graphically in Figures 4.6.1 and 4.6.2.

Storage samples for ECA were prepared in a manner similar to MCA. In this case, however, the samples were collected on two different days. On the first day, 24 samples were collected by sampling a test atmosphere of ECA at 40% R.H. and ambient temperature at a 0.2 L/min for 2 h. Six of these samples were selected at random and analyzed on the same day. Based on the analysis of these samples the concentration of this test atmosphere was determined to be 4.3 mg/m^3. Of the remaining eighteen samples, nine samples were stored in a refrigerator, and nine were stored at ambient temperature for later analysis. Three days later another 24 samples were collected under the same test atmosphere conditions. Six of these samples were selected at random and analyzed on this same day to obtain the zero-storage day results. In addition, three samples each from ambient and refrigerated storage were analyzed on this same day to obtain the 3-day storage results. The remaining 12 samples were split into two equal-sized groups and stored with the other storage samples. The stored samples were analyzed at 7-day intervals over the next two weeks in two groups of 12 by selecting 3 ambient and 3 refrigerated samples for analysis from both storage groups. The percent recovery is reported for each sample in Table 4.6.2. The results are presented graphically in Figures 4.6.3 and 4.6.4.

Storage samples were also collected from a test atmosphere of ECA at low relative humidity (<5% R.H.) and ambient temperature that was determined to be 5.3 mg/m^3 based on sample tube analysis. This study was done in the same manner as the high humidity ECA storage study except that the dry dilution air was not passed through the water bubbler before sampling an atmosphere of ECA. The results of this storage study are presented in Table 4.6.3 and in Figures 4.6.5 and 4.6.6. No low humidity studies of MCA were undertaken in this study because of time and instrumentation constraints at the laboratory, although it is not anticipated that low humidity would adversely affect recoveries for MCA.

It is apparent that serious losses in recovery are observed upon storage of MCA samples at ambient temperature. Losses in recovery of MCA at reduced temperature are much less severe. Storage losses for ECA are also less at reduced temperature than at ambient, but the loss in recovery at ambient temperature is not as great as for MCA. There is no apparent difference in storage results for ECA samples generated from either low or high humidity. No low humidity storage data were collected for MCA in this study. Because of the instability of the alkyl 2-cyanoacrylates at ambient temperature it is necessary that the samples be kept refrigerated at all times.

Table 4.6.1
Storage Test for MCA

time (days)	% recovery (ambient)			% recovery (refrigerated)		
0	96.7	93.4	99.8	96.7	93.4	99.8
0	103	102	105	103	102	105
3	78.1	71.8	86.8	96.4	90.7	95.7
5	69.2	68.2	78.7	91.4	88.9	87.0
7	67.5	69.4	70.4	90.9	87.7	91.1
10	70.4	62.8	71.8	85.6	94.3	95.3
14	61.8	64.6	56.9	91.8	94.3	92.6
17	63.6	52.2	3.8	93.8	83.8	87.2

Table 4.6.2
Storage Test for ECA

time (days)	% recovery (ambient)			% recovery (refrigerated)		
0	102	101	97.1	102	101	97.1
0	95.2	102	102	95.2	102	102
3	95.8	93.5	92.6	92.1	93.5	91.6
7	88.7	88.5	89.9	92.3	93.3	95.7
10	88.6	83.3	85.8	92.8	94.2	92.8
14	88.0	84.9	86.6	87.5	87.3	91.6
17	83.8	84.4	87.5	94.7	90.7	86.8

Table 4.6.3
Storage Tests for ECA, Low Humidity Sampling

time (days)	% recovery (ambient)			% recovery (refrigerated)		
0	101	106	97.8	101	106	97.8
0	102	96.8	96.8	102	96.8	96.8
3	92.4	88.0	88.9	94.6	93.0	94.3
7	92.8	94.3	93.0	97.0	100	99.0
10	88.7	86.9	87.8	92.6	92.2	92.4
14	92.8	92.6	91.3	94.7	98.5	99.4
17	84.3	88.0	90.6	91.3	93.3	91.3

4.7 Reproducibility

Six sample tubes were each spiked with 5.8 µL of a 23.4 mg/mL stock standard of MCA (117 µg) and then capped and stored in a refrigerator until analysis. The samples, after being stored for 9 days, were analyzed by a chemist unassociated with this method.

Six samples were collected from a test atmosphere of ECA and then capped and stored in a refrigerator until analysis. These samples, after being stored for 11 days, were also analyzed by a chemist unassociated with this method.

Table 4.7
Reproducibility for MCA and ECA

MCA		ECA	
% recovery	statistics	% recovery	statistics

90.1		90.1	
87.9		89.9	
88.6	$\overline{X}$ = 88.5	88.2	$\overline{X}$ = 90.1
87.1	SD = 1.1	91.0	SD = 1.1
89.4		90.0	
87.9		91.3	

4.8 Desorption efficiency

The percent recovery of MCA and of ECA spiked onto 80-mg portions of the acid treated XAD-7 resin was determined at levels corresponding to 0.5, 1, and 2 times the target concentration by spiking the front section of the sampling tubes contained in autosampler vials with a stock standard of the alkyl 2-cyanoacrylate in 0.2% (v/v) H_3PO_4 in acetonitrile. A total of 18 samples for each cyanoacrylate was prepared by spiking six front sections of the sampling tube with either 5.0, 10 or 20 µL of 11.7 mg/mL MCA or of 10.77 mg/mL ECA. The samples were allowed to sit for 1 h before being desorbed and analyzed. The average percent recovery over the 0.5 to 2 times target concentration for MCA and for ECA was 94.4 and 97.0% respectively.

Table 4.8
Desorption Efficiencies for MCA and ECA

× target conc. µg/sample	MCA			ECA		
	0.5× 58.5	1× 117	2× 234	0.5× 53.9	1× 107.7	2× 215.3
desorption efficiency, %	91.6	90.8	94.5	96.1	98.1	96.0
	97.8	94.1	92.7	95.5	97.2	97.5
	94.6	93.3	94.2	95.4	98.1	98.9
	93.3	96.8	94.9	95.7	98.2	98.0
	96.0	94.1	94.1	94.6	97.6	97.9
	94.0	98.7	98.7	95.0	97.7	97.9
$\overline{X}$	94.6	94.6	93.9	95.4	97.8	97.7
mean $\overline{X}$		94.4			97.0	

4.9 Preparation of acid-treated XAD-7 sampling tubes

Approximately 100 g of Amberlite XAD-7 20-60 mesh, a porous polyacrylate adsorbent manufactured by Rohm and Haas and obtained from Aldrich Chemical, Milwaukee, WI (lot # 3311PJ) was washed with numerous volumes of deionized water in an Erlenmeyer flask until all suspended particles were removed. The adsorbent was then rinsed with several volumes of HPLC grade methanol (total volume 300-400 mL) and then with several volumes of HPLC grade acetonitrile (total volume approximately 300-400 mL) and the excess solvent removed by vacuum filtration. The adsorbent was treated with phosphoric acid by adding a solution of 14 mL of reagent grade phosphoric acid and approximately 200 mL of acetonitrile to a 500-mL round bottom flask containing the adsorbent. After allowing to stand for a few minutes, the mixture was dried on a rotary evaporator using a hot water bath and vacuum. This acid-treated XAD-7 resin, with the odor of acetonitrile still present, was then stored in a tightly-sealed brown bottle for use in packing sample tubes. No difference in recovery was observed with different lots of the acid-treated resin even though drying times varied.

The sampling tubes consist of 6-mm o.d. × 4-mm i.d. × 45-mm glass tubes packed with two sections of the phosphoric acid-treated XAD-7 resin. These sample tubes are made from used, clean, SKC Inc. charcoal sampling tubes from which one end of the tube is removed. The open end is fire polished prior to packing. Small silanized glass wool plugs are used at both ends of the tube and in the middle to contain and separate the two sections. The front and back sections of the tube contain approximately 80 and 40 mg of the adsorbent respectively. The sample tubes are sealed with 7/32 plastic caps which are supplied with the charcoal sampling tubes obtained from SKC Inc.

4.10. Discussion of analytical conditions

Although the cyanoacrylates react rapidly in water, a standard reverse phase HPLC technique employing a C_{18} analytical column and an aqueous phosphoric acid/acetonitrile mobile phase was successfully used to analyze for both methyl and ethyl 2-cyanoacrylate. The alkyl 2-cyanoacrylates are relatively sensitive to UV detection at 220 nm because of conjugation of the double bond with the carbonyl group. Although the phosphoric acid present in the mobile phase apparently inhibits the on-column decomposition of the cyanoacrylates, some decomposition does occur at room temperature. This decomposition is evident by the rise in the baseline which precedes the analyte peak.

The purpose for adding adsorbent to the standards prior to analysis is to obtain consistent integration of samples and standards. These inconsistencies arise because the data system is unable to reliably reset a proper baseline for integration due to the rise in the baseline preceding the standard peak. No integration problems were observed for the samples because a peak from the adsorbent which eluted before the analyte peak eliminated this baseline reset problem. If the analysis is performed at 0°C as described for the MCA analysis below, the baseline rise due to on-column decomposition is virtually eliminated. Under these conditions addition of adsorbent to the standard vials is unnecessary.

Fluctuations in room temperature during the analysis of MCA produced poor reproducibility due to the variation in the on-column decomposition of the cyanoacrylate. Initially this problem was solved by using a column temperature heater to maintain a constant temperature slightly above ambient conditions. Analytical conditions were later optimized by placing the analytical column in an ice bath. Although retention times were increased significantly at these reduced temperatures, decomposition was minimized, reproducibility was improved, and sensitivity was enhanced. Analysis of ECA is also best performed under these conditions. One to two trays of ice from a commercial style refrigerator/freezer were adequate to maintain a constant reduced temperature for approximately 8 to 10 h under these conditions.

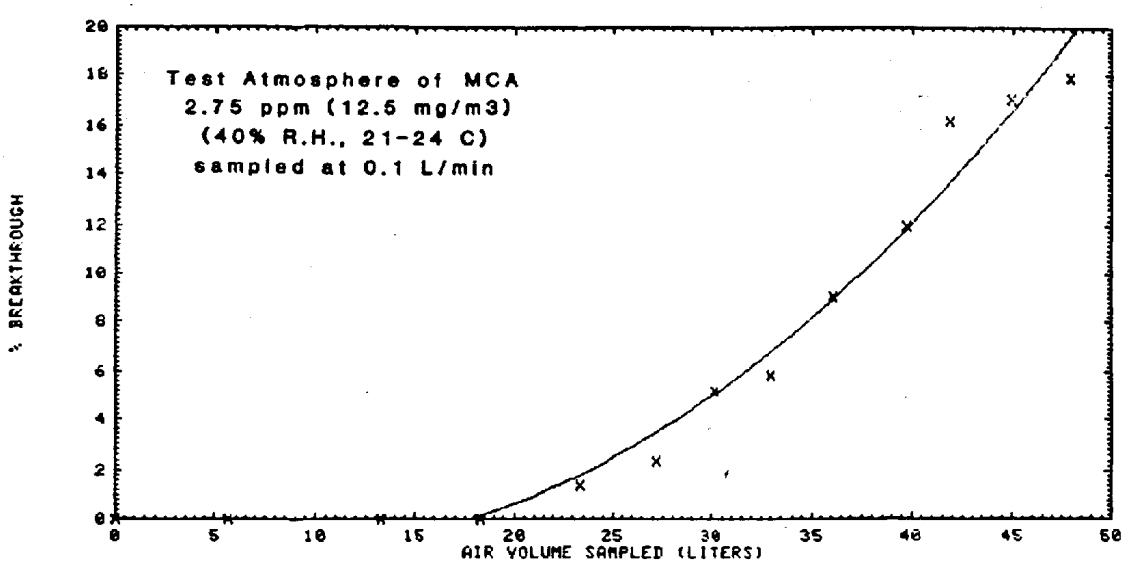

Figure 2.4.1. Breakthrough study for MCA.

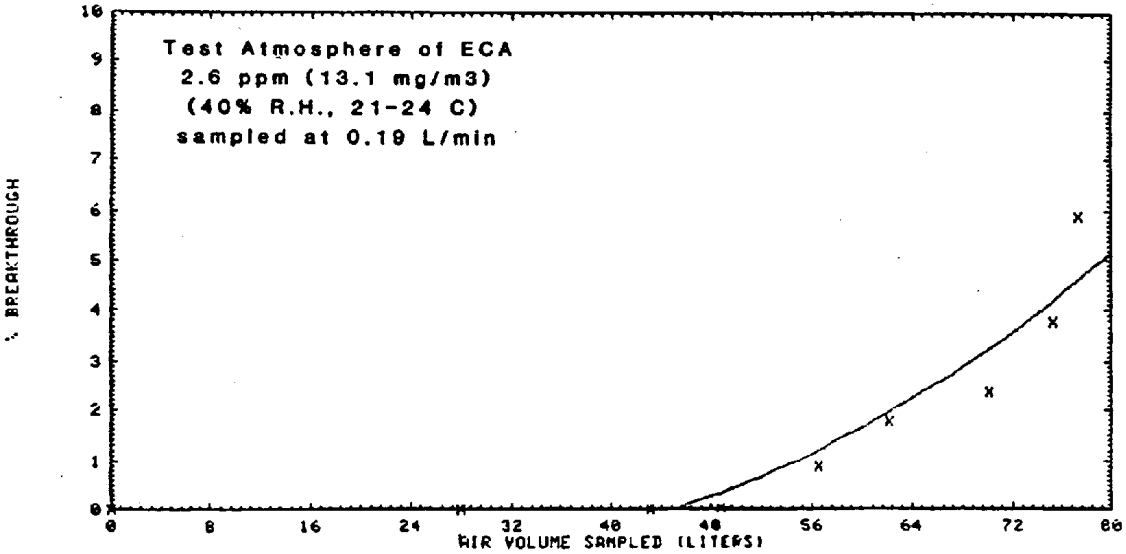

Figure 2.4.2. Breakthrough study for ECA.

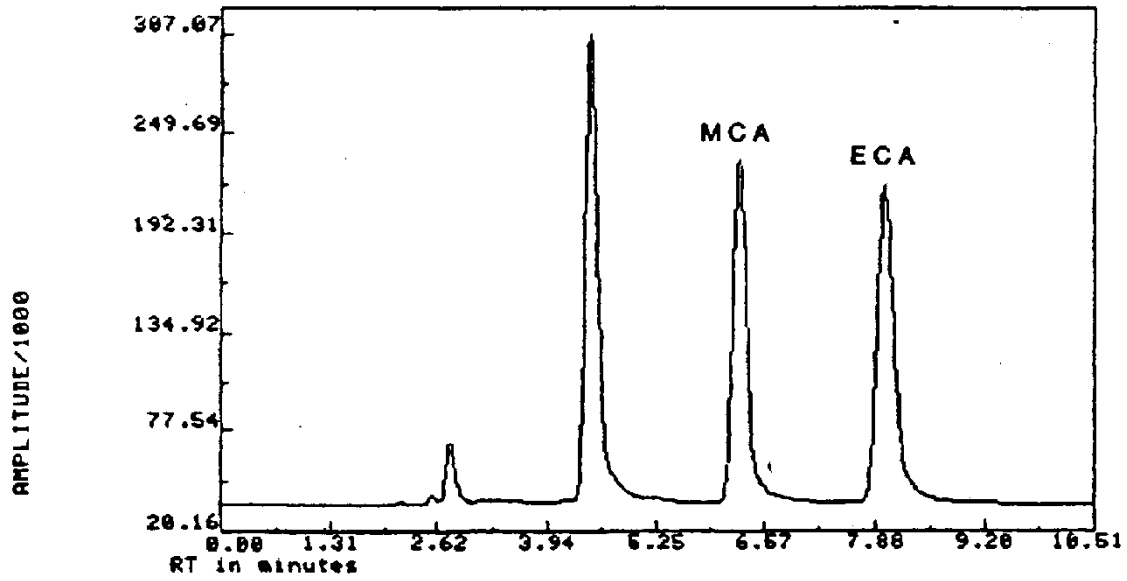

Figure 3.5.1. Analytical standard of MCA and ECA in presence of acid-treated XAD-7.

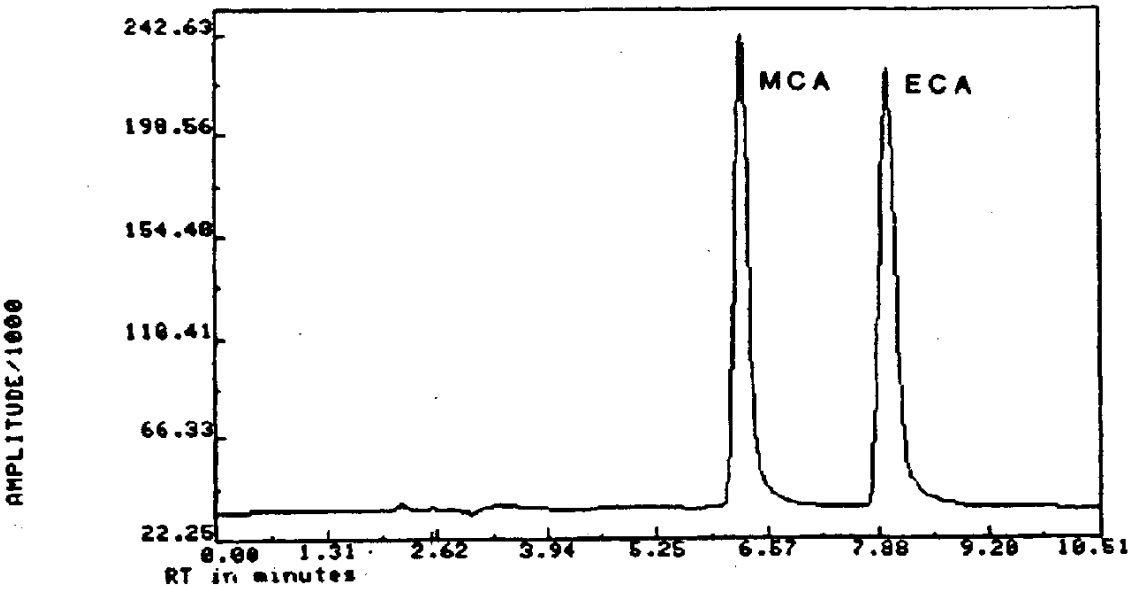

Figure 3.5.2. Analytical standard of MCA and ECA.

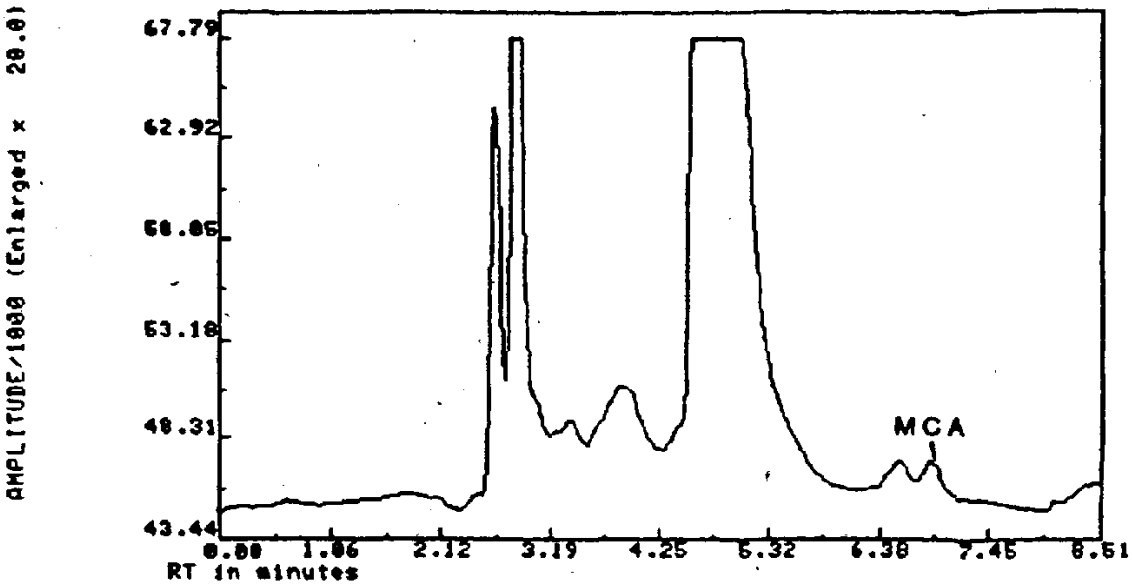

Figure 4.1.1. Detection limit for MCA (8.7 ng/injection, analysis at 0°C).

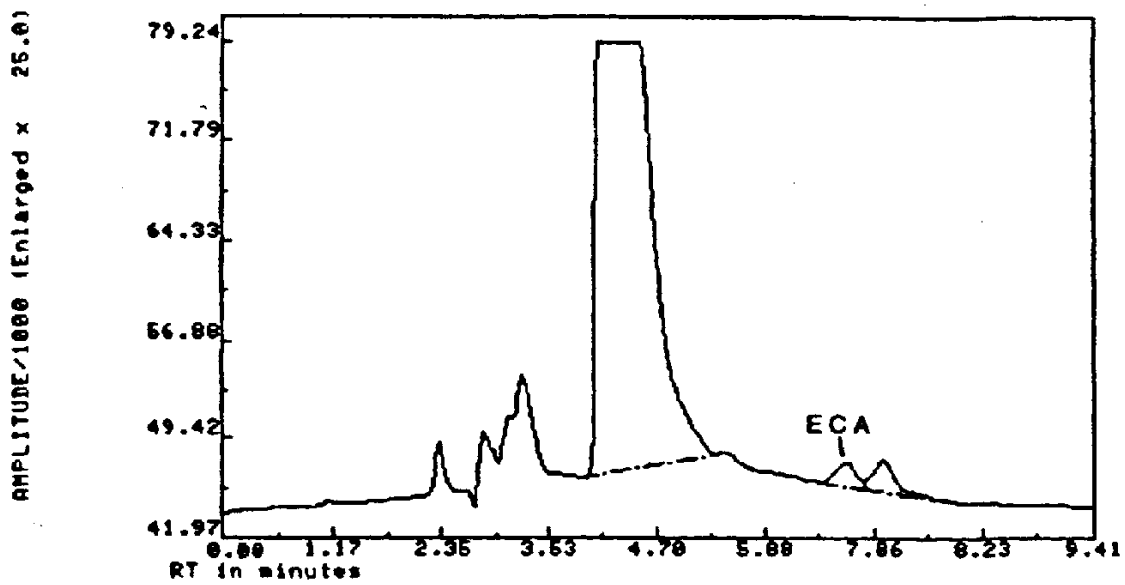

Figure 4.1.2. Detection limit for ECA (5.6 ng/injection, analysis at ambient temperature).

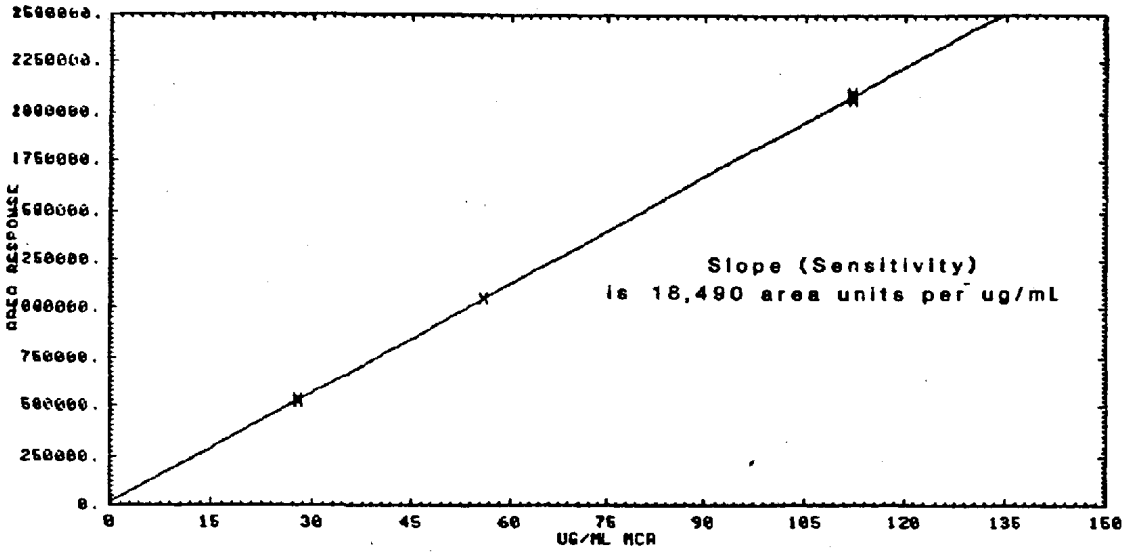

Figure 4.4.1. Calibration curve for MCA (analysis at 0°C).

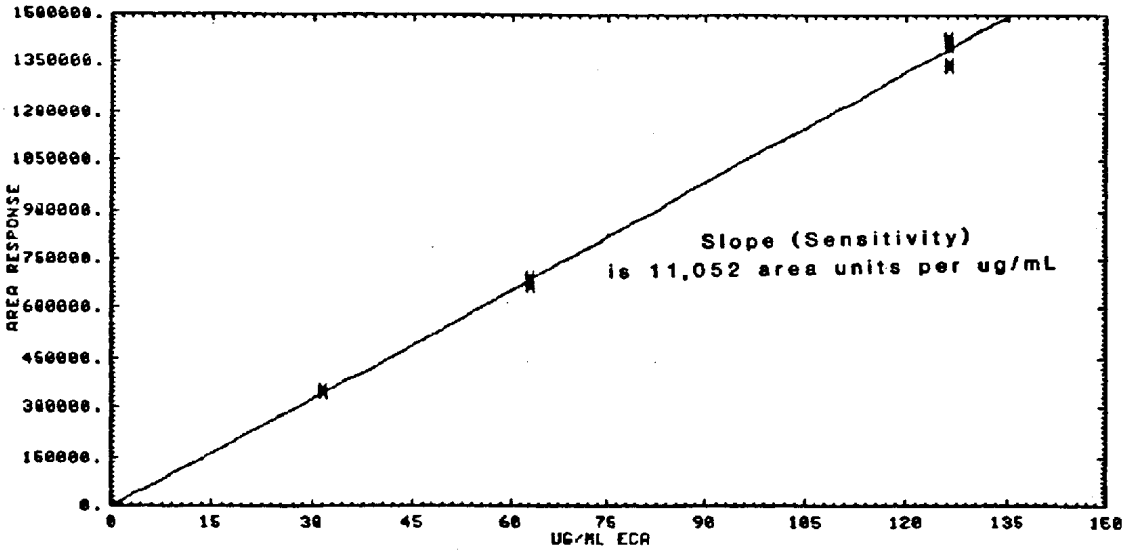

Figure 4.4.2. Calibration curve for ECA (analysis at ambient temperature).

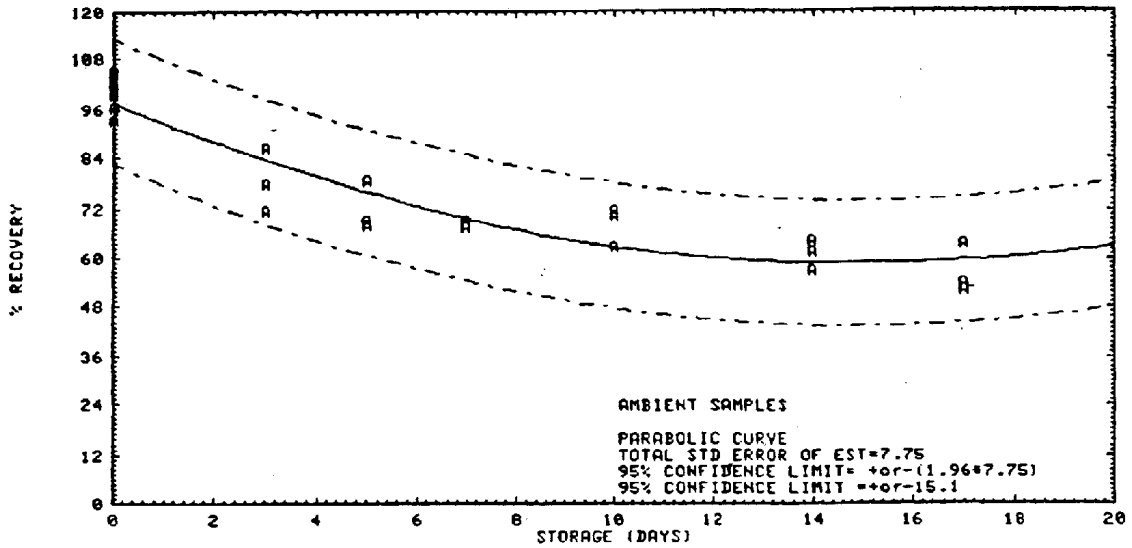

Figure 4.6.1. Ambient storage for MCA.

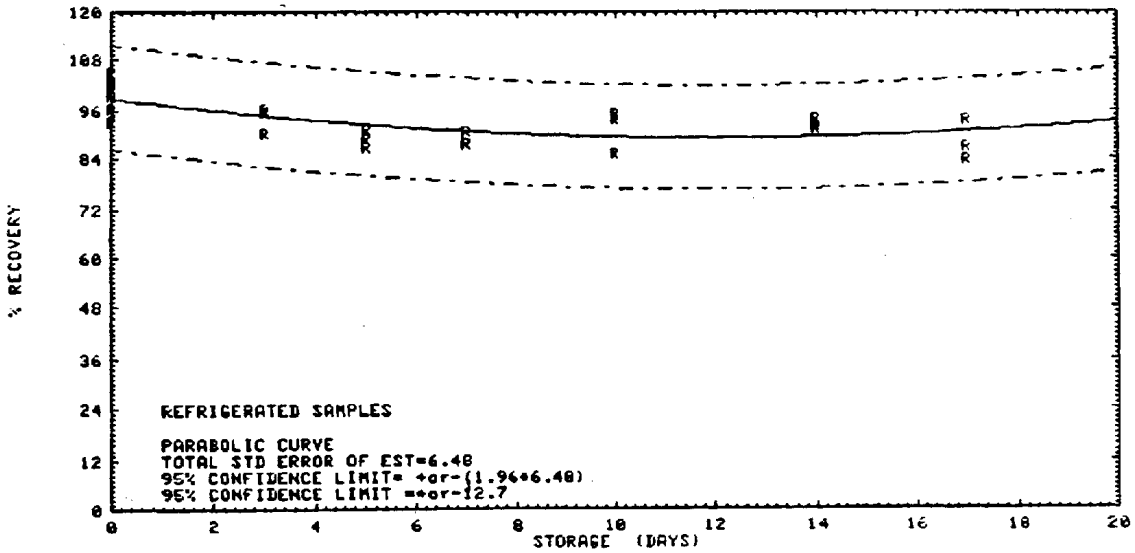

Figure 4.6.2. Refrigerated storage for MCA.

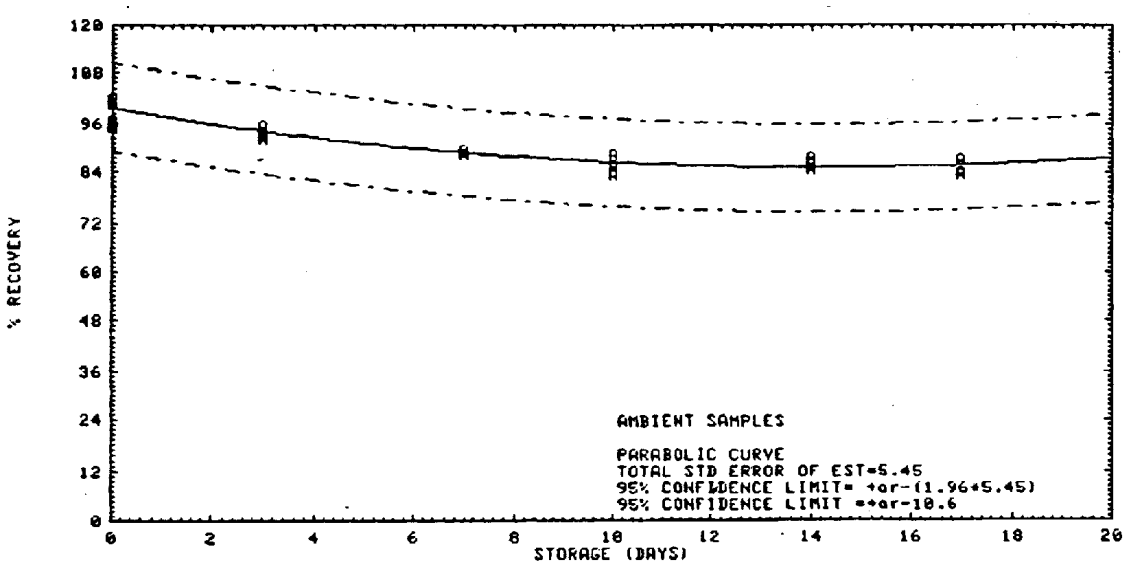

Figure 4.6.3. Ambient storage for ECA.

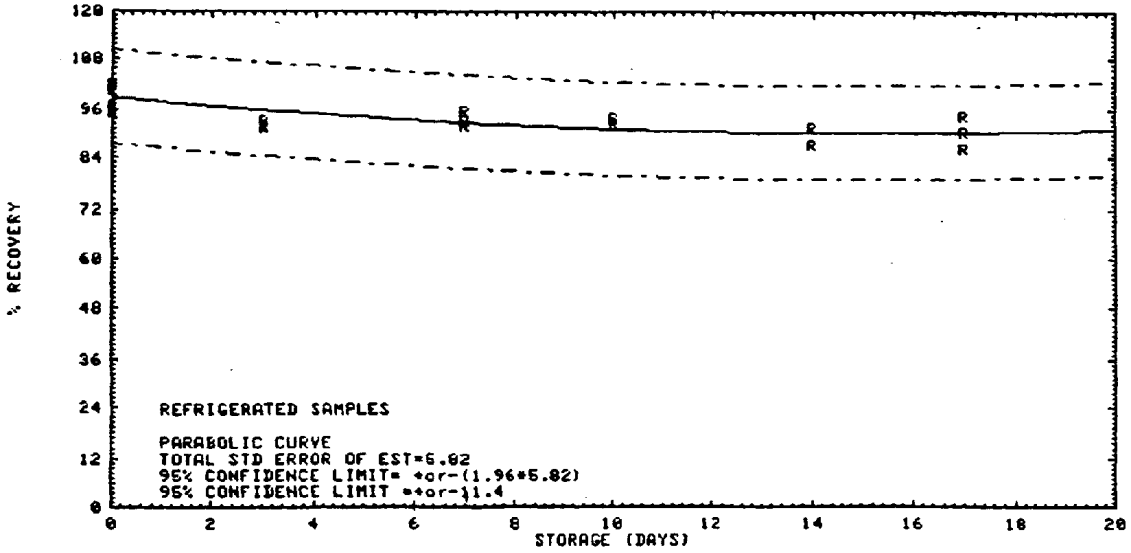

Figure 4.6.4. Refrigerated storage for ECA.

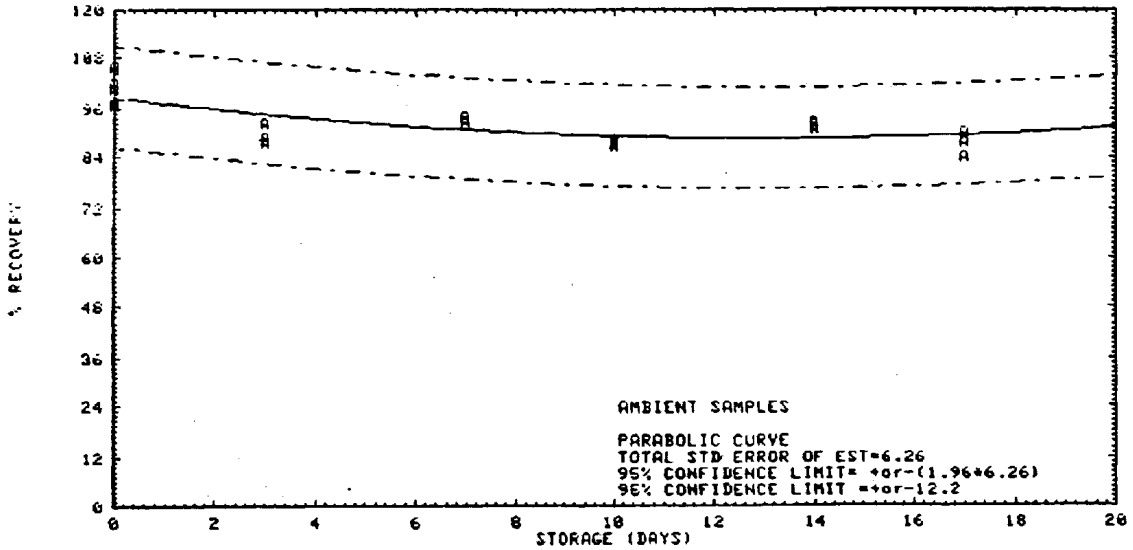

Figure 4.6.5. Ambient storage for ECA (low humidity).

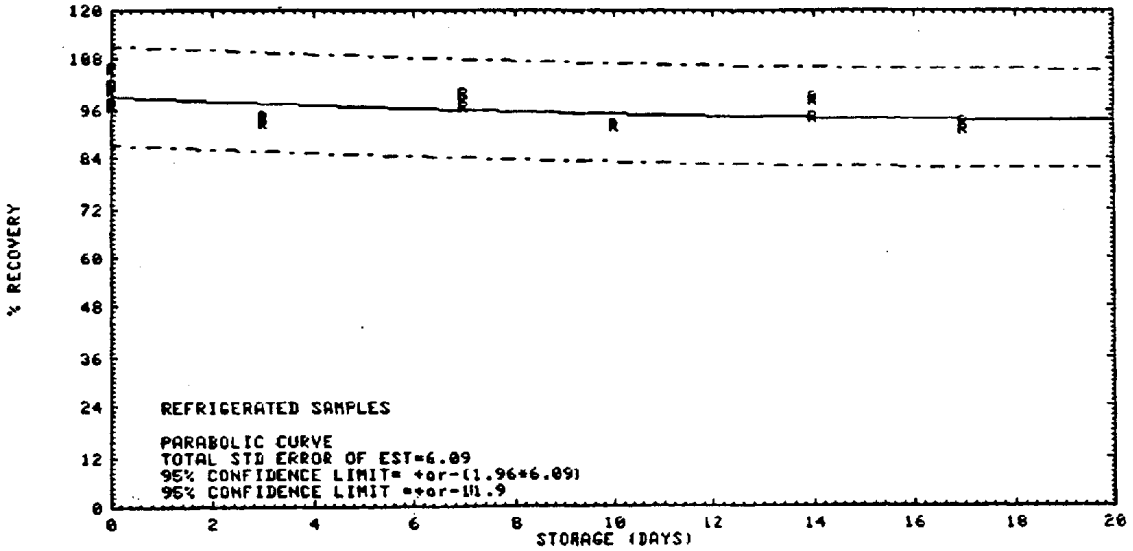

Figure 4.6.6. Refrigerated storage for ECA (low humidity).

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