

ABSTRACT

Daniel G. Strait. The Evaluation of Various Control Methods for the Solvent 2-ethoxyethanol in the Production of Foam Pad Packaging. (Under The Advisement of Dr. Parker C. Reist).

Workers in a foam pad packaging area were exposed to vapors of 2-ethoxyethanol, above the TLV of 5.0 ppm. This study investigated the methods to reduce this exposure through administrative and engineering controls. Sampling was done using charcoal tube and passive dosimeters. Administrative controls reduced exposures typically by 70% or more. Some areas required local ventilation to maintain exposures less than 5.0 ppm. The methods used accomplished these goals without great cost or affecting the plant production.

key words:

2-ethoxyethanol
engineering control
administrative control
packaging

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I. INTRODUCTION

Exposures of working populations are altered by new process technologies at the workplace as well as by the information discovered by the scientific community that adds to or lessens the concern of the worker's environment on his health. The industrial hygienist must be responsive to the protection of the workforce in his charge. He must also offer solutions that are practical for the company whose processes are creating the exposure. These constraints may either be operational and/or financial. It is desirable that the solutions offered do not significantly alter the intended production or be so costly that they put a financial strain on the resources of the company.

The purpose of this study was to investigate various control practices in a foam pad production process. These controls were instituted to reduce employee exposure to the solvent 2-ethoxyethanol to a level of 5.0 ppm or less. After the application of these controls at selected production sites their effectiveness was evaluated by personal monitoring. These samples quantified the reductions so recommendations to the plant could be made.

The problem under study was an evaluation of exposures to workers contacting vapors of 2-ethoxyethanol. These exposures were identified primarily at sites where foam packing pads, used to package components of electronic

equipment, were produced, at the point of distribution of chemicals in the plant. The 2-ethoxyethanol was used to keep clean the nozzle of the spray gun from which the reactive foam producing chemicals were sprayed.

Inhalation of the 2-ethoxyethanol vapors by the workers in these foam-in-place (FIP) operations presented a potential health hazard. This study determined what levels of solvent concentrations were encountered at the different areas of foam pad production, compared these levels to currently accepted standards, and then evaluated any needs to reduce exposures through administrative or engineering controls. During the time of evaluation, it was announced that the 8-hour Time Weighted Average (TWA) of the Threshold Limit Value (TLV) for 2-ethoxyethanol as recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) was being reduced. This increased the concern to evaluate the existing exposures and provide practical solutions for the plant and its labor force.

The resulting initial samples indicated that there were consistent values at several FIP sites exceeding the proposed TLV concentration for 2-ethoxyethanol of 5.0 ppm. It was concluded that operating procedures should be changed and engineering controls added to reduce the exposures. Recommended alterations to working habits, and practices, and the introduction of additional engineering controls were made that reduced the exposures. The effect

of these changes were monitored by taking samples after the controls were instituted, ensuring that exposures to the solvent 2-ethoxyethanol had been reduced to safe levels.

II. THE HAZARDS AND CHARACTERISTICS OF 2-ETHOXYETHANOL

The Chemical and Physical Properties of 2-Ethoxyethanol

2-Ethoxyethanol is a colorless liquid at room temperature with a sweetish odor. Its chemical formula is $C_2H_5OCH_2CH_2OH$ and is known by other synonyms, which are Ethylene Glycol Monoethyl-Ether and Cellosolve. It has an OSHA permissible exposure limit of 200 parts per million (ppm) or 740 mg/m³. The action level is 100 ppm. The ACGIH had a recommended TLV of 50 ppm until the summer of 1982 when it published an intended change down to 5 ppm or 18.5 mg/m³ with a skin notation.

2-Ethoxyethanol has a molecular weight of 90.12, a boiling point of 135 C, specific gravity of 0.93 and, at normal conditions, a vapor pressure of 3.7 mmHg at 20 C. The solvent has a flashpoint of 49 C and an autoignition temperature of 235 C. It is incompatible contacting strong oxidizers and may result in an explosion. Fires involving this solvent may produce toxic gases and vapors, predominantly carbon monoxide.

2-Ethoxyethanol is easily soluble in water as well as organic solvents. It is widely used in industry for paints, resins, lacquers, dyes, soaps and cosmetics. NIOSH has estimated in a 1972-1974 survey that 360,000 workers were exposed to 2-ethoxyethanol on an occupational basis. Estimates are that in 1978 100,000 tons of this chemical

were produced in the United States.

Toxicology

2-Ethoxyethanol may enter an individual through ingestion, inhalation and absorption through the skin. Though there are no reports of events attributed to worker exposures in industrial settings, its hazard potential has long been recognized and studied. The recognized effects as noted in toxicological studies have been lung, liver and kidney damage, and eye and lung irritation. It has caused various effects on the blood characteristics in animals, including decreased levels of immature red blood cells. Animal tests have concluded that the solvent can be absorbed through the skin in lethal amounts. These toxic effects had resulted in the ACGIH establishing a TLV of 50 ppm or 185 mg/m³ and a STEL of 100 ppm, 370 mg/m³.

However, in the summer of 1982, the ACGIH listed a notification that they were intending to change the TLV of 2-ethoxyethanol to 5.0 ppm and 18.5 mg/m³. Two toxicologic studies were major contributors to this decision. One by Nagano et al. held that a significant increase in testicular atrophy and leukopenia were observed at dosages of 1000 and 2000 mg/Kg/day in mice on a 5 day/week for a 5-week basis. This was via ingestion, but pointed to increased effect on the blood system at lower concentrations and a previously unrecognized reproductive hazard. The other report by F. D. Andrews et al. revealed extreme embryomortality at concentrations of 617 and 767

ppm in rats and rabbits. While at concentrations of 160 and 202 ppm increased incidences of growth retardation, terata and again embryomortality. These concentrations were at or below the OSHA PEL, and were alarming to the TLV standards review board who reduced the TLV to a new level of 5.0 ppm.

When the notice of intended change was published in the annual booklet of TLVs, it was necessary to modify procedures and controls in the foaming areas to comply with the 5.0 ppm, 8-hour TWA. The normal action level policy for this plant was for an employee 8-hour time-weighted exposure to be one quarter of the TLV, unless this level was impracticable for production process. The corporation philosophy and policy was that the recommended TLV was to be the ceiling limit of any employee exposure. Any case of an excursion to the TLV from the normal action level had to be justified.

Therefore, the plant needed to establish the exposure levels of its affected employees, analyze these concentration levels, reduce these to levels below the TLV if needed, or reduce the exposures to the lowest practical level by additional control techniques. After the implementation of any controls, sampling measurements quantifying their effectiveness on reducing the exposures of 2-ethoxyethanol were made. Finally, recommendations were to be made so that use of the solvent in all foam pad production areas might be continued at the plant.

III. DESCRIPTION OF THE SOLVENT, INDUSTRY AND PROCESSES STUDIED

Solvent

2-Ethoxyethanol is utilized in the packaging production process to eliminate the clogging of spray injection guns which emit two chemicals, polyurethane resin and diphenylmethane diisocyanate, in two liquid streams. In a container or molded form, the chemicals react, expand, and become a solid compressible foam pad.

TABLE I
Characteristics of 2-Ethoxyethanol

Formula: C ₂ H ₅ OCH ₂ CHOH
Molecular weight: 90.12
Specific gravity: 0.93
Vapor pressure: 3.7 mmHg. (at 20°C)
Boiling point: 135°C
Flashpoint: 49°C
Autoignition: 235°C

Since small amounts of the chemicals can remain in the barrel of the spray nozzle after spraying, there is a need to keep a foam plug from developing. To eliminate this potential problem, the gun's barrel is submerged in a tray container of 2-ethoxyethanol. The solvent prevents the two foaming components from reacting and breaks down any foam as it forms in the gun's barrel.

When the barrel was plugged by foam, the operator used the 2-ethoxyethanol, along with brushes and scrappers, to remove the obstruction. This procedure required close

inspection by the worker who typically came within 18 inches of the solvent-wetted gun, brushes, and probes.

The close distance the worker assumed to the solvent tray where the gun was positioned between injections caused exposures during normal working procedures. Vapors were also generated due to excess solvent that dripped on the tabletop, floor, gloves, or protective clothing of the worker when removing or replacing the gun in the tray. All of these spills evaporated and added to the continual vaporization from the tray container itself. The amount of spilled solvent varied with each worker due to their personal techniques, but elimination of some exposure was impossible. Because of the volume of pads produced in the high volume area, the solvent at times pooled and collected on the tray table and evaporated over a much larger surface area. Solvent disposal and replacement between trays, safety cans, and solvent cabinets also resulted in worker exposure to 2-ethoxyethanol vapors. The transfer of the solvent into trays in unventilated areas and vapors noted upon opening the solvent cabinets resulted in additional contact to 2-ethoxyethanol vapors. This was experienced in all of the plant areas sampled.

General Descriptions of Plant Areas

The major products produced at the plant site were component and final assembly of high technology electronic data analysis and display equipment. Due to the fragile

nature of the products made, proper and secure packaging to prevent breakage of the products during transportation was required. Since shock and direct impact could destroy the units, foam packing that conformed to the shape of the specific product eliminated any shifting in the cardboard box container protecting the products during shipment. The foam pad arrangements were made in-house at operations referred to as foam-in-place (FIP) sites. Thirty-seven FIP lines were in production throughout the plant. These sites were usually located where final assembly took place prior shipped the product out of the plant. The sites varied in the volume of pads made, since the items they protected were be produced in small or large numbers.

The FIP sites were classified into two major categories based on the method of foam formation .These two methods were referred to as free foaming and molded foam areas.

The molded foam pads were made in production areas where large numbers of a single product type were prepared for shipment. Since the pads had identical configurations, the outside dimensions of a pad could be made rapidly in a molded foam form prior to the product arriving for packaging.

The free foaming type of packaging was specific or customized to a single product type when it arrived to be packed for shipment. Work was virtually continuous during the day at some molded foam sites, whereas fewer pads were made in the free foam areas, as required by the variable production rates.

The High Volume production area, in this study, was at a mezzanine level 18 feet above the main plant floor. The area was 180 feet by 25 feet and had a 12-foot overhead. There were four pairs of pad production sites, with a container retaining the 2-ethoxyethanol solvent at each location (see Figure 1). The container, which was 4 inches by 6- inches by 3-1/4 inches, was fixed to a tabletop located between the two ventilating hoods. The table had a one-half inch lip along its upper ledge and was accessible to the worker in an approximate 270° arc about its base. The table was 24 inches high, was 36 inches deep, and 25 inches across.

Behind each mold there was a slot hood for local ventilation of heat, water vapor, and gases produced from the reacting liquid chemicals that produced the foam material. These hoods captured vapors, but were not designed to remove the vapors emitted at the solvent container (see Figure 2). Any ventilation of the solvent vapors was accomplished originally only by room ventilation, which consisted of the normal air supplied throughout the plant plus an additional HVAC vent directed down toward the floor behind the work area, at a distance of five feet. This ventilation was not intended to transport the solvent vapors away from the workers, but rather to cool the work area (the foaming areas in general were 5-10° F warmer than the normal plant environment).

A higher relative humidity also was present in this

department. These conditions resulted from the chemical reaction producing the pad material, limited air movement, and the elevated location. The air circulation in the high volume area was restricted by walls and partitions. All four sides were partially obstructed compared to the other production areas which were free from obstructions. A few of the partitions extended from the floor to ceiling. These obstructions reduced air changes, stagnated vapors, and elevated ambient temperatures and humidity.

The two Lower Volume areas of pad production were on the ground floor of the plant and located in two separate buildings. The ceiling height of each building was 25 feet and both areas were effectively free of walls or obstructions that might constrain the dilution of the solvent vapors emitted in the work area. One of the Low Volume areas used molds, but a much smaller number of products passed through it during a work day. Approximately 140 units in the High Volume area were produced each day compared to 30 to 40 in this Low Volume area. The other Lower Volume area was a free foaming area and did not use molds because of the variety of products to be packaged. The free foaming production sites were also ventilated by a slotted hood intended only to remove vapors resulting from the reaction of the foaming chemicals. The only ventilation for the vapors of 2-ethoxyethanol was the general room ventilation of the plant floor.

The fourth pad production area studied, an Automated production area, was similar with respect to the general

area characteristics. The ceiling was 25 feet in height and free of walls and obstructions. The unique design of this production area, which limited the amount of solvent, will be discussed in a later section.

TABLE II
Characteristics of the plant Areas Studied

<u>Location</u>	<u>Production Process</u>	<u>Ventilation</u>
High Volume Area	Molded foam pads	restricted, general plant
Low Volume Area I	Molded foam pads	open, general plant
Low Volume Area II	Free foaming pads	open, general plant
Automated System	Molded foam pads	open, general plant
Chemical Repackaging	Solvent Transfer	high volume room exchange

The chemical repackaging area was an isolated room where chemicals used in the plant were subdivided into safety cans from 55 gallon drums and retained used chemicals for future disposal. The room was approximately 120 by 30 feet with a 25 foot ceiling. Due to the chemical storage, the room was vented with rapid air exchanges. Local ventilation was not available during the emptying or filling of the safety can containing the 2-ethoxyethanol for distribution to the locations of use in the plant.

The automated pad production area was a conveyor configuration of molds, periodically passing under jets that injected the chemicals that generated the foam. The jets were mechanically moved between their injection and standby position, in a horizontal tray containing the 2-ethoxyethanol. Above this tray and the molds was an open-face canopy hood located to remove vapors generated by both foam formation and the solvent held to soak the jets. The workers spent time in this area at a distance which was beyond potential exposure to the solvent vapors. At times cleaning a jet or replacing the solvent was necessary. Similar procedures were employed as described previously at other locations. These actions did expose the worker to 2-ethoxyethanol vapors.

The chemical repackaging area created exposures when 2-ethoxyethanol was pumped into 5 or 10-gallon safety cans for future use in the plant or when used solvent was discharged into waste barrels for temporary storage. Exposures took place in the exchange of pumps from one barrel to another or in holding a pump nozzle into a safety can mouth.

Local ventilation was not used, but there was a rapid air exchange in the room. The exposures to workers in this area were short-term exposures, usually 15-30 minutes per day.

Time and motion studies were subjectively determined by observation at all the production areas. These studies

were supplemented with information provided by the workers and management personnel at these lines. The studies were designed to identify any abnormal contact, estimate its frequency, and acquire samples to measure the exposures throughout the plant. Since one of the goals was to measure 8-hour TWA for workers, special work routines were included during sampling, such as exposures from gun cleaning and solvent pouring. These observations and the time and motion studies estimated the actual work time spent in potential contact with the solvent.

Six and one-half hours (390 minutes) was judged to be representative of the time workers were exposed to 2-ethoxyethanol during a normal eight hour work shift. This accounted for time spent at lunch, shift breaks and time spent in preparing for the next workday and housekeeping at the end of the day.

Methods of Control Prior to the Study

When this study began, various control procedures were in place to reduce exposures to employees and to limit safety hazards to the physical plant facility. Based upon previous routine samples taken in the past ten years, the controls in place to limit the worker exposures to 2-ethoxyethanol appeared adequate. These controls on the foaming locations are also summarized in Table III.

TABLE III

Existing Production Sites and Their Original Controls

<u>Locations</u>	<u>Controls</u>
High Volume	Protective clothing Slotted side-hood at production site
Low Volume (molded pads)	Ventilated solvent cabinets Worker education Protective gloves
Low Volume (free foaming)	Safety cans Positioning solvent tray/table away from worker's normal location HVAC vented from behind the worker

2-Ethoxyethanol was stored and transported throughout the plant in safe restrictive containers (safety cans). These were effective in the elimination of vapors from the solvent containers that may adversely effect human health and potentially result in property damage through fire or explosion. The 55-gallon drums held in the chemical distribution area and the 5-and 10-gallon safety cans isolated the solvent in safe and protected quantities. Solvent cabinets were used to store the safety cans at work line locations, safety cans were stored inside the cabinets. Most of the solvent cabinets in the plant were ventilated to prevent inhalation of vapors that might accumulate by workers when the cabinet doors were opened. Safety cans were used to contain both fresh and used solvent at all the foaming sites.

The solvent was contained at the production areas (not the automated area) in small containers placed on a rimmed tabletop. Most drips and splashes of the solvent were

confined to the tabletop. The pooling of the solvent produced additional vapors generated by the continual evaporation of solvent from the solvent tray and tabletop.

Worker education by the Industrial Hygiene Department was conducted for employees prior to working in the foam packaging areas in the plant. During these sessions, workers were instructed on the various hazards that could be encountered during normal operational procedures. Guidelines expected to be carried out in handling, proper care and use of the 2-ethoxyethanol solvent, and recognized dangers were announced. Workers were warned of skin contact, its flammability and any unnecessary inhalation of solvent vapors.

The workers were provided with personal protective clothing to eliminate skin contact of 2-ethoxyethanol. Foaming spray gun operators were required to wear goggles, a half-length smock, and gloves. The smocks were made of Dupont Tyvek, and gloves were made of Neoprene. These materials give excellent protection against skin contact and subsequent absorption through the skin. The substances of the smock and gloves gave the longest breakthrough protection available. Each work area required new smocks and gloves to be exchanged twice a day.

As previously mentioned, the ventilation at all manually operated foaming sites was initially limited to general room ventilation and additional local cooling vented into the immediate area for temperature comfort. This ventilation was not designed to limit the potential

exposure of the workers to the 2-ethoxyethanol vapors. The only local ventilation available was the slot hoods at each site designed to remove the vapor produced in the foam pad-generating process. The range of capture of these hoods could not remove any vapors produced at the solvent containers. This was shown by smoke tube testing of the area and hoods.

IV. SAMPLING

Procedure

In this investigation, 2-ethoxyethanol was sampled using the NIOSH approved and recommended method, S-361. This method was selected because the measurements were to be used as a basis for deciding potential courses controlling the solvent if exposure levels were excessive and to document that the exposures were within OSHA and company guidelines. The method is easily performed to give sensitive and reliable results to the concentrations encountered in workplaces, and it is suitable to measure the exposure of employees within the breathing zone. Samples were also obtained on a comparison basis by using passive dosimeters. The dosimeters were sampled within the breathing zone of the exposed employee. They served to verify the values of the charcoal samples and to provide an actual test of the dosimeters' accuracy for future sampling when routine monitoring of work sites was required.

Method S-361 is valid within a range of 340-1460 mg/m³ (91-396 ppm). This range was not expected to be approached during sampling (in fact, the highest single sample analyzed was 61 ppm). The effective lower limit was established by the chemical analysis, a gas chromatographic procedure, and reportable down to a concentration of 0.1 ppm. Validation for the method was done at temperatures of

23 to 23.5^o C and atmospheric pressures of 757.1 to 770.3 mmHg using a six liter sample volume. The actual samples were taken at a temperature range of 21.1 to 26.7^o C and an atmospheric pressure range of between 745 to 765 mmHg. The actual sample volumes ranged from 2.45 to 6.05 liters. These variations about those of the tested NIOSH validation are not significant in altering the validity of the samples in this study.

Using Method S-361, a known volume of air is drawn through an activated charcoal tube by means of a sampling pump, absorbing the 2-ethoxyethanol vapors upon the charcoal. The charcoal is then removed from the tube, placed in a vial, and the solvent is desorbed into solution for injection and analysis by gas chromatography. The response of the gas chromatograph to each sample is compared to a calibration of standards and the amount of 2-ethoxyethanol collected in the samples is reported by weight (mg). This value is then used to quantify the concentration of the sample period in parts per million (ppm).

All sampling done for this study was accomplished by using personal sampling at the breathing zone of the employee. Area sampling was not representative of actual exposures encountered by employees in their normal work practices and handling of 2-ethoxyethanol. The previous description of the time and motion studies of the employees involved in these operations indicated a great variance in time spent at sites where the solvent was present. Also,

the employees were exposed to varying amounts of the solvent vapors because of their individual work practices. Due to this non-uniform characteristic of the solvent exposure, area samples were not taken. Personal samples, however, were used to monitor the extent of employee exposures on a real-time basis. This sample type was used to account for the variable volume of foam pads made at different production lines and the time spent at the solvent containers where vapors were emitted. Personal samples also addressed individual work practices with the solvent such as pouring, gun cleaning, or spillage in the removal and replacement of the gun from the solvent container. This monitoring best evaluated any modifications to either work practices or new controls that may reduce the levels of exposure. Since one of the points of concern was whether the revalued 8-hour TLV could be met, the personal monitoring scheme documented specific exposures to a worker (or group of workers) and measured the effect of controls introduced for later comparison.

The personal sampling pump was hung on the employee's belt with the sampling line run over the back and shoulder. The charcoal tube was contained in a protective holder and clipped to the employee's smock collar. Any duplicate charcoal tube samples or passive dosimeters used were attached in a similar manner to the opposite smock collar. The charcoal tubes were protected by plastic holders

to allow the atmosphere to be drawn into the charcoal tube. These tubes were hung in a vertical position to prevent a channeling of the exposure atmosphere. Passive dosimeters were hung so the exposed open face was unobstructed. Immediately before beginning the sampling, the glass ends of the charcoal tubes to be used were broken off and the protective facing over the passive dosimeter was removed.

During each sampling day, a blank charcoal tube was opened and capped, as was a passive dosimeter blank. These blanks accompanied the actual samples to which they corresponded to offset any background response detected that would be added in error to a reported exposure value taken during a particular day. These blanks were immediately capped and received no exposure to the 2-ethoxyethanol.

The charcoal tubes were attached to the sampling lines, and the pump's analog counter number was recorded, as was the sample start time. The pumps were turned on and the sampling was observed. At the conclusion of sampling, the counter number and finish time were noted, the pump was turned off, and the samples were sealed with plastic end caps. The passive dosimeters were handled in a similar manner and matched with individual charcoal tube samples. Initial and final sample times were recorded. The passive dosimeters were then capped with a manufacturer-supplied cap immediately after the end of the sampling. At the end of the day, all samples were taken to a small laboratory freezer and stored until analysis was arranged.

The samples were never stored for more than one week and typically for only two or three days.

During sampling, temperature and psychometric readings were made to note temperature and relative humidity. These levels never exceeded 80 F or 65%, respectively. Each sample was given an individual sample number to denote the sequence in which it was taken, a date, and an operational area. The specific foaming areas within an operation were recorded by the exhaust hood number at the site. Each employee used in sampling was noted by a specific individual number so time-weighted averages could be calculated.

Observations of the samples were made so the occurrence of any abnormalities affecting the employee's exposure would be known. These observations allowed notation of the work practices occurring during the sampling and, thus, indentified samples taken during high exposure practices, such as solvent pours, gun cleanings, and spills. When control procedures were begun, notes were also taken on whether the proceedures were followed and their effectiveness evaluated.

Equipment and Its Use

The equipment used in the sampling procedures for 2-ethoxyethanol conformed to the requirements of Method S-361. The use of passive dosimeters followed the recommended guidelines supplied by the manufacturer, the 3-M Company.

Two Sipeen SP-15 model personal sampling pumps were

used in this study. The performance characteristics of the two pumps did not substantially differ. The pumps had internal piston stroke counters and were flow compensating. They were powered by internal rechargeable batteries and had an operational lifetime longer than the uses of this study. The nominal calibration flowrate of 0.050 liters/minute was well within their intended flow range of 0.005 to 0.3 liters/minute.

The SKC charcoal tubes were approximately 6 cm long and had a 4-mm inner diameter. They had a 100-mg front section of charcoal separated by a small portion of urethane foam from a rear section of charcoal containing 50 mg. The ends of each tube were plugged with glass wool. The charcoal was 20/40 mesh activated coconut charcoal. Three different lots of tubes were used for these samples, but the tubes from different lots were never mixed.

A Bendix battery powered psychrometer was used to determine the relative humidity at the sample sites. It was also used to record the ambient temperature at the sites by reading the dry bulb thermometer.

Passive dosimeters were 3-M 3500 Organic Vapor Monitors. Their effective sampling rate determined for 2-ethoxyethanol of 0.032 liters/minute, established by 3-M.

Prior to and immediately after each day of sampling, the pumps used were calibrated to document their flow rates and evaluate their performance. The flow rate for each sample was an average of the two calibration flows. Calibrations were used with a charcoal tube in line,

acquired from the same lot used during the sample taken that day. The pressure drop across the tube was measured with a water manometer. These values varied between 0.3 and 0.55 inches of water at a flow rate of 0.05 liters/minute. An NBS traceable 50 cc bubble flowmeter was used to measure the volume a bubble traversed, timed by a Chronus stopwatch accurate to one-hundredth of a second. Three timings of a 500-cc volume were taken at each calibration and averaged. This time was divided into the volume measured to obtain the flow rate. The temperature was recorded during calibrations, but volumes were not corrected to a standard for temperature and pressure since the corrections proved insignificant.

During each of the three timings, the initial and final pump strokes, as indicated by the pump's internal counter, were recorded. When the number of strokes counted was referenced to the time measured, a back-up calibration in strokes per minute was established in the event that a pump temporarily stopped and had to be restarted. All the conditions observed and the values taken during calibration were recorded in a notebook permanently kept for the plant.

Several methods of quality control were used in the calibration and sampling processes. Multiple timings of each calibration and calibrations prior to and after each day's sampling ensured that pump flowrate values were accurate and that the flows were constant during the

sampling periods. Flows varied by plus or minus five percent, but this variation did not invalidate any of the samples taken. On the one occasion when a pump stopped during sampling, the pump's internal counter was used to calculate the volume of the sample taken. Since the pump immediately restarted when it was turned on and the recalibrated flow rate approximated the previous rate, the sample was considered accurate and valid, and it was analyzed using the volume calculated by the strokes counted.

As previously discribed a blank charcoal tube and passive dosimeter were included with each day's samples. These blanks were not identified to the laboratory prior to analysis, to verify that only actual samples showed significant concentrations of 2-ethoxyethanol. All blanks were reported at undetectable values.

The observation of the samples taken, established another form of quality control. Abnormal exposures of the samples were noticed and evaluated. The investigator observed the sampling process greater than 95% of the sampling time during this study. Employee cooperation was high and although several accidents invalidated samples the investigator firmly believes that during the unobserved periods, the employees did nothing to jeopardize the samples.

The use of the 3-M 3500 organic vapor passive dosimeter was originally begun as a quality control check. It was hoped that the concentration reported by the

dosimeter would closely reflect those taken by the charcoal tubes. Two side-by-side charcoal samples were also made to verify the accuracy of the entire sampling procedure through the final laboratory analysis.

Sample Analysis

Two different outside laboratories analyzed the charcoal tube samples and passive dosimeters. Both labs were AIHA approved and the analyses followed requirements set forth in Method S-361. Hager Laboratories of Denver, Colorado, analyzed the first four samples taken. The Research Triangle Institute (RTI), Research Triangle Park, North Carolina analyzed the remaining fifty-seven samples. This change in laboratories was primarily made because of the close proximity of RTI to the plant, which made it possible to hand carry samples to the lab, leaving them in a frozen state from the storage at the plant to storage at the laboratory. Sample integrity was thus maintained to a greater extent.

Method S-361 requires analysis of the charcoal tube samples by gas chromatography, with a flame ionization detector. Gas chromatography is used to physically separate a sample into its chemical components by passing an injected aliquot through a column. The column individualizes the components on the basis of their retention time as they move through the column. After passing through the column the components are burned in a hydrogen flame, ionizing each component. These ions are

then collected on an electrode. The response is measured on a recorder that integrates the peak (resulting from the response) area. Comparing that area to the areas of standards to ascertain the amount of the component in the aliquot. The procedure is described in detail in NIOSH Method S-361.

The gas chromatograph used to analyze the samples at RTI was Hewlett-Packard HP-5880A Level-Four gas chromatograph, with auto-sampler and internal calibration capabilities programmable to report values of the analyses. The 20-foot column was 1/8-inch stainless steel packed with 10% FFAP stationary phase on 100/120 mesh Supelcoport. The desorbing reagent was 5% methanol in methylene chloride. Actual desorbing coefficients were determined for each day's samples and analyzed with respect to that day's charcoal tube samples. The stated manufacturer's desorbing coefficient by 3-M Company was used when analyzing the passive dosimeter values.

The investigator reported to the laboratory other vapors in the atmosphere when the samples were captured. Vapors included freon, M.D.I., and dimethyl ethanol amine. These might show as potential interferences to the analysis. Approximate atmospheric pressure, temperature, and humidity were recorded for the lab's information. Any abnormalities affecting the samples were reported. The analysis of charcoal tube samples was made for both front and rear sections of charcoal separately to determine if

there had been any breakthrough in the front section and if saturation of the sample had occurred.

The laboratory at RTI calibrated the gas chromatograph prior to each batch of samples analyzed. The calibration was accomplished by injections of three known standards ranging from 5 to 25 ppm. The internal calibrator extrapolated the calibration curve above and below these levels for any samples analyzed at those levels. Fresh standards were prepared at the time of each batch analyzed. Standards were injected at the end of analysis to ensure that the gas chromatograph remained constant in its reported values of the amount of 2-ethoxyethanol detected; therefore, all samples run between this and the original calibration were accurate measures of the sample injected into the gas chromatograph.

Typically, the analyses done at the RTI laboratory were made within three days after receiving the samples from the investigator. As previously mentioned, samples were kept cold during storage at the plant, hand transported to the laboratory (less than ten minutes in travel), and re-stored in a freezer until analysis was to be performed. This should have heightened the accuracy by eliminating the hazards of long distance transportation.

V. CONTROL STRATEGIES

As the result of the analysis of the initial samples during the study, the plant sought new methods to reduce the exposure levels below that of the new TLV (5.0 ppm). This was attempted from two basic control strategies, administrative procedures and engineering devices.

A third method was under investigation during this sampling study, substitution of an alternative solvent for 2-ethoxyethanol. This method was to be evaluated on the basis of the substitute's effectiveness in the production process (that is, did it keep the spray gun free of obstructions) and any health and safety effects unique to the solvent to be substituted.

The management of the plant desired to continue to use the solvent 2-ethoxyethanol because of its history of good performance in the production area. It was expected that maintaining the exposures with the TLV reduced to 5.0 ppm would be difficult, requiring greater care, although it could be accomplished with perhaps less effort and expense than switching to an alternative substance. Therefore, it was necessary to devise various methods and combinations of further controls that would effectively reduce the exposures below the 5 ppm TWA and do so without significantly disrupting the production of foam pads or

without entailing great expense.

Administrative controls were immediately tried to reduce exposures. First, a review of the hazards to which the workers were exposed to daily by this solvent was conducted to spur careful work practices by the employees. It was emphasized to the workers and management that care in the handling of the solvent and use of any personal or engineered protection would be necessary in all future operations in these areas. The managers of these production areas were made aware of the revised controls, because production managers are the first line of responsibility to enforce the health and safety procedures required in the plant's structure of responsibilities.

Another administrative control was a change in the procedure for pouring solvent to or from the container and a change in the procedure for cleaning the foaming gun if it became clogged. Prior to this study, there were no recommended locations for these tasks, subsequently, locations were identified where local ventilation hoods might remove the extra vapors inhaled by the worker in these types of operations. The top of the foam molds with their slot hoods were the first areas denoted. When the solvent tables were vented, this area was prescribed.

Four measures were introduced to the High Volume production area to reduce the exposures by engineered controls. An automated foam pad machine was evaluated from a health exposure prospective. The solvent cabinets used to store 2-ethoxyethanol were actively vented. The solvent

tray tabletops were drained so the solvent could not collect. The tray tabletops were ventilated with a slotted vent to remove vapors generated from the solvent container or tabletop.

For production purposes, the plant, was considering the use of an automated foam pad producing machine. With the new concerns of solvent exposures in the manual production process, the measured exposures to personnel operating the automated system might increase the attractiveness of this type of system. A limitation with the automated system was that it was practical only for high volume areas where the pads could be molded, and it was not applicable to the free foaming production areas. Therefore, if the production of pads was successful from a production and investment standpoint, the automated system could relieve a significant portion of exposures if the measured solvent exposures at this prototype were satisfactory too.

Solvent cabinets in the High Volume area were actively vented to pull any vapors of the solvent that might accumulate and be inhalable when a worker opened the doors of the cabinet. This action resulted in a noticeable absence of the 2-ethoxyethanol odor that had previously been detected by workers. This action eliminated only two or three very short duration exposures to the workers, and it had the added value of reducing the potential for fire hazards.

A slot hood ventilating the tray tabletop and solvent container was built at one production site in the High Volume area and used experimentally to attempt to quantify the levels of reductions that might be observed using this method. The High Volume area was picked because, if its relatively higher exposure levels could be reduced, the Low Volume areas would measure exposure values that were at least as low as those in the high volume areas.

The slot hood was 14 inches in length, with a 1.5 inch slot pulling 1800 feet per minute. Additional side panels were placed down the sides of the tray tabletop to constrict the flow and capture the vapors more efficiently. This slot hood was tested with smoke tubes to evaluate its capture of vapors. It proved to be adequate in ventilation of the entire table and container arrangement.

The rims around the tray tabletops caused the solvent to pool because of drips and spills that occurred. These were drained with a half-inch hole approximately six inches from the end of the longest length of the tabletop. The top was also slanted to force the free-flowing solvent to the drainhole. A flexible line connected this drain hole to a safety can containing the waste solvent and eliminated any further vaporization in the working area, as well as safety or fire hazards.

Each control method was expected to result in some measurable reduction of exposure. Through a progression of installation, measurement and combination, a complete evaluation of control options was made.

VI. SAMPLING RESULTS

Sample measurements were taken in the High Volume Area, the two Low Volume Areas, and the chemical storage area, establishing the levels of exposures to the workforce prior to the implementation of any controls to reduce vapors and contact of the workers to the 2-ethoxyethanol. Each area was sampled to the extent representing the normal employee exposure for the areas. Measurements were then made in specific working sites where controls had been implemented singularly or in combination to measure reductions in exposures (if any occurred).

The Chemical Repackaging area was sampled on August 23, using a single charcoal tube. This was a sixteen minute sample taken during the entire time that the employee was exposed to the 2-ethoxyethanol solvent.

The employee moved the pump from one 55-gallon drum to another and filled six safety cans with the 2-ethoxyethanol. This procedure was very representative of normal employee duties in this area. The sample concentration was 0.67 ppm. This area was judged an area of short-term exposure. The standard STEL values permit a maximum concentration of 10.0 ppm. The level was less than 10% the STEL and, therefore, no further sampling was done, surmising that the exposures in this area were well below the STEL under any normal circumstances.

On May 27, the molded form Low Volume production area was sampled using charcoal tubes. Two samples were acquired sampling one employee's exposure to the solvent. The samples did not include either solvent pouring or gun cleaning operations. The total sampling time was 179 minutes, representing one-half of an employee workday. The two samples were analyzed to have concentrations of 4.8 ppm and 7.1 ppm, respectively. The 8-hour TWA for this employee was 4.8 ppm.

Sampling was conducted at the other Low Volume area in the plant on August 2, 3, and 4. This was a free foaming site in of the plant's production area. Samples were acquired using one employee and a full eight hour sample was measured. Both charcoal tubes and a passive dosimeter were used. Results are shown in Table IV.

TABLE IV

Low Volume Free Foaming Area - Prior To Controls

<u>Date</u>	<u>Sample type</u>	<u>Time (min)</u>	<u>Concentration (ppm)</u>	<u>Observations</u>
8/2	Charcoal	97	2.7	pour
8/2	Charcoal	85	2.1	pour
8/2	Dosimeter*	181	3	pour
8/3	Charcoal	121	2.4	pour & cleaned
8/3	Dosimeter*	122	4	pour & cleaned
8/4	Dosimeter	113	4	normal operation

* Denotes passive dosimeter samples taken as duplicates

The dosimeter sample of August 4 was used in developing the employee 8-hour TWA because two charcoal tube samples taken that day were broken. Since the passive dosimeter samples of August 2 and 3 were reflective of their corresponding charcoal tube samples, the dosimeter sample taken on August 4 was used in estimating the TWA exposure of the worker in this area. His TWA was a concentration of 2.5 ppm.

Samples taken in the High Volume area were obtained from May 29 to June 18. Sampling was done with five different employees in this molded foam area. These sampling results are given in Table V. Note that duplicate passive dosimeter results pairing with the corresponding

charcoal tube sample.

TABLE V
High Volume Molded Foam Area -Prior to Controls

<u>Date</u>	<u>Sample type</u>	<u>Time (min)</u>	<u>Concentration (ppm)</u>	<u>Observation</u>
5/29	Charcoal	69	60.3	
5/29	Charcoal	93	61.0	
6/1	Charcoal	73	14.0	
6/1	Charcoal	58	35.0	
6/15	Charcoal	86	37.0	pour
6/15	Dosimeter	85	49.0	pour
6/15	Charcoal	81	34.0	pour
6/15	Dosimeter	83	21.0	pour
6/16	Charcoal	120	27.0	
6/16	Dosimeter	115	11.0	
6/16	Charcoal	119	13.0	
6/16	Dosimeter	125	22.0	
6/17	Charcoal	62	43.0	gun
6/17	Dosimeter	62	19.0	cleaned
6/17	Charcoal	49	35.0	gun
6/17	Dosimeter	49	32.0	cleaned
6/18	Charcoal	94	32.0	gun
6/18	Dosimeter	94	24.0	cleaned
6/18	Charcoal	90	12.0	gun
6/18	Dosimeter	90	7.7	cleaned

The results of the uncontrolled exposures in the High Volume area indicated two points. First, there were high exposures, regularly in excess of the 5 ppm TLV. Second, when employees either poured solvent (fresh or waste) or

cleaned the foaming guns, they experienced significantly higher exposures than during periods when only foam was shot and cast into the molded forms. The concentrations to which workers were exposed to were variable, from 12.0 to 61.0 ppm for the charcoal tube samples. These were all well above the 5.0 ppm level. Yet, both Low Volume areas were very near this TLV level. The only reasonable differences found were that the workers in the High Volume area spent more time in close proximity to the solvent container and that this working area in general was more, confined with restricted air movement. 8-hour TWAs for the High Volume areas were 31.0 ppm, 20.2 ppm, and 23.2 ppm.

The results in the High Volume area prompted the need to find solutions to reduce work exposures to 2-ethoxyethanol. It was thought that, if solutions could be found to reduce the exposures in the High Volume area, then similar steps taken at the low volume areas would result in lower exposures as well. This would produce a margin of safety at all foam work places.

Samples were taken on one employee maintaining the prototype automated foaming machine process. The results are shown in Table VI. Note that the samples are listed in pairs, showing duplication measurements.

TABLE VI

Automated Foam Production Area

<u>Date</u>	<u>Sample type</u>	<u>Time (min)</u>	<u>Concentration (ppm)</u>	<u>Observation</u>
7/28	Charcoal	72	ND*	
7/28	Dosimeter	83	ND*	
7/29	Charcoal	115	1.1	gun cleaned
7/29	Dosimeter	114	2.6	gun cleaned
7/29	Charcoal	74	ND*	
7/29	Dosimeter	74	ND*	

* Not detectable, < 0.1 ppm

The TWA for an 8-hour exposure to this worker was 0.3 ppm. Again, it was apparent that exposures intensified during close manual contact with the solvent (gun cleaning). The low concentrations measured in the Automated area are shown using both sampling techniques. It is worth repeating that this automated system was a prototype and that the plant was determining whether the quality of the pads it produced or its costs involved were justifiable.

Sampling with administrative controls only were conducted in the High Volume area to determine their effectiveness. Samples shown in the following table were made with only administrative controls.

TABLE VII

High Volume Area - with Administrative Controls

<u>Date</u>	<u>Sample type</u>	<u>Time (min)</u>	<u>Concentration (ppm)</u>	<u>Observations</u>
9/15	Charcoal	108	9.5	pour & clean
10/11	Charcoal	106	6.4	gun cleaned
10/13	Charcoal	83	1.7	
10/13	Charcoal	105	4.1	

These controls were: (1) reemphasizing to the workers the importance of care in their work practices and (2) conducting solvent pours or gun cleaning only in front of ventilation. This was done at one fixed foaming site with one employee participating in the measurements.

The TWA for the worker was 5.6 ppm. In general, the results shown here, illustrate the large reduction made over the previous, uncontrolled conditions in the High Volume area, even with only the application of administrative controls. The samples again showed the direct relationship between higher exposures obtained when the foam gun was cleaned or when solvent in the tray container was exchanged.

Measured results using the drained tabletop in conjunction with administrative controls were inconclusive due to the lack of consistent tabletop drainage.

TABLE VIII

High Volume Area - with Administrative Controls
and a Drained Table Top

<u>Date</u>	<u>Sample type</u>	<u>Time (min)</u>	<u>Concentration (ppm)</u>	<u>Observations</u>
10/25	Charcoal	117	14.6	pour
11/1	Charcoal	90	3.6	
11/3	Charcoal	78	16.0	spill

Because of a drain blockage, the first and third samples were taken during a period when a small spill of 2-ethoxyethanol occurred, showing unrepresentative high values. The second sample is believed to be valid, but there are not enough data to evaluate this control independently.

The next set of samples were collected after the initiation of administrative controls and after a slot vent was placed at the edge of the solvent table to reduce worker exposure. Duplicate samples were arranged in pairs, as shown in Table IX.

TABLE IX
High Volume Area
with Administrative and Ventilation Controls

<u>Date</u>	<u>Sample type</u>	<u>Time (min)</u>	<u>Concentration (ppm)</u>	<u>Observations</u>
8/19	charcoal	95	0.8	gun cleaned
8/19	dosimeter	95	1.1	gun cleaned
8/19	charcoal	105	0.8	pour & clean
8/19	dosimeter	105	1.5	pour & clean
8/20	charcoal	82	1.2	gun cleaned
8/20	dosimeter	82	2.3	gun cleaned
8/20	charcoal	93	1.9	gun cleaned
8/20	dosimeter	93	12.9	gun cleaned
9/8	charcoal	77	1.8	gun cleaned
9/8	charcoal	77	1.1	gun cleaned
9/17	charcoal	58	1.4	
9/17	charcoal	58	1.1	
9/20	charcoal	81	2.0	gun cleaned

Samples were taken on three workers. TWA exposure concentrations for 8-hours were 0.7 ppm, 1.1 ppm, and 1.4 ppm, respectively, for these employees. The September 8 and 17 duplicate charcoal tube samples were very similar in values. Differences in concentration values, other than experimental errors that are inherent, may be accounted for by the position of the tube on opposite collars of the employee's smock or by the fact that right-left hand dominance may result in vapors from drippings or spills on one side of the worker.

The last group of samples in the High Volume area were taken using all three methods of control: administrative controls, draining of the solvent, table, and ventilation of the tabletop as well as found in Table X.

TABLE X

High Volume Area - with All Controls

<u>Date</u>	<u>Sample type</u>	<u>Time (min)</u>	<u>Concentration (ppm)</u>	<u>Observations</u>
10/11	charcoal	110	0.9	
10/13	charcoal	67	0.7	
10/13	charcoal	97	ND*	gun cleaned
10/13	charcoal	58	0.9	

* Not detectable < 0.1 (ppm)

One employee was sampled during these measurements. No duplicate samples were taken. The TWA exposure concentrations for 8-hours was 0.5 ppm under these conditions. The samples taken represented the lowest values sampled, with the exception of the automated system. They were consistent in their measured concentrations and controlled exposures when the foam gun was also cleaned.

Comparison of charcoal tube samples with the dosimeter sample results indicated two trends. The dosimeter measured slightly higher concentrations when the exposures were in the range of 0 to 10 ppm. Higher exposures resulted in a reversal of this relationship, with the dosimeters usually reporting lower values than the charcoal tube samples. This

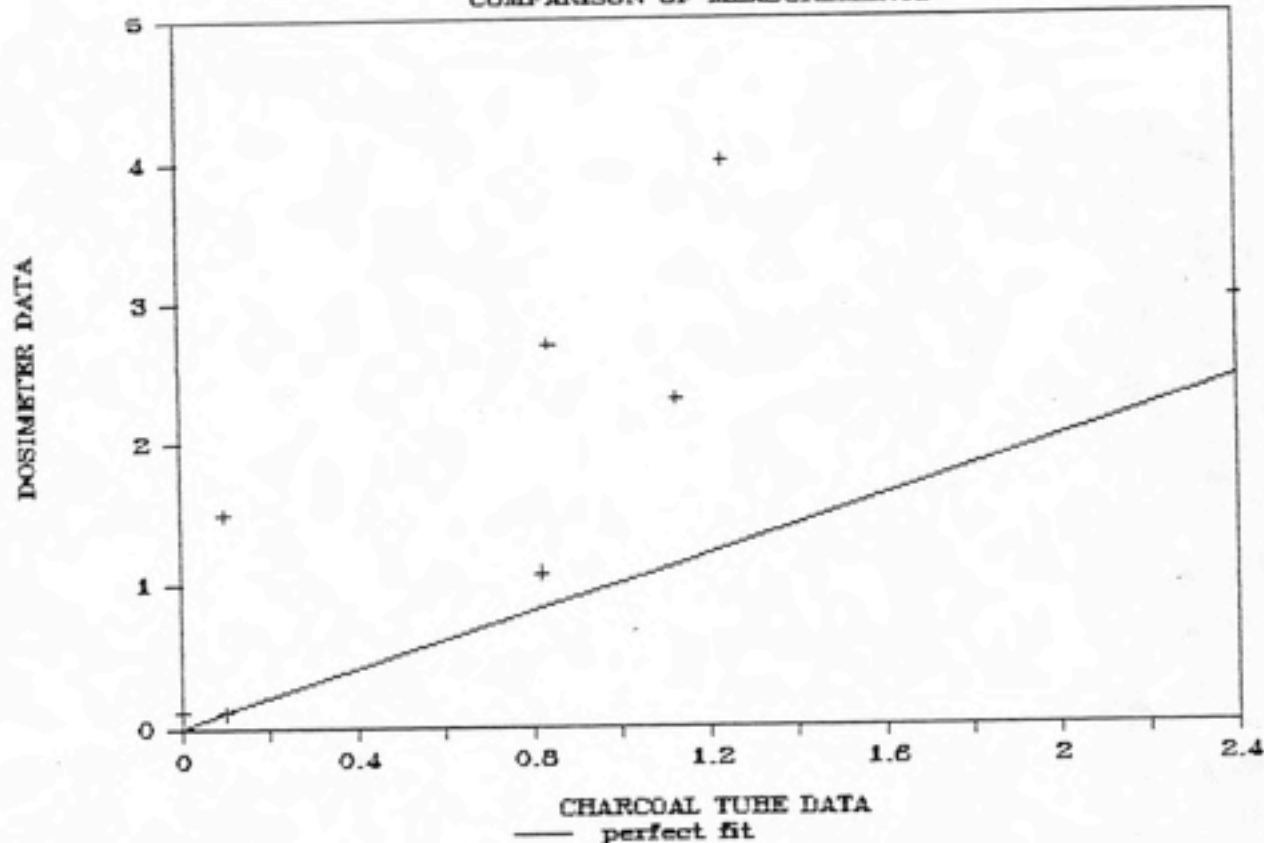
is illustrated in Graphs One and Two. The differences between the sample measurements were not significant until the concentration was over 10 ppm, when the lower dosimeter values were too large to be acceptable. Graphs Three and Four illustrate this point.

Variation of results was expected to some extent because the samples were taken from opposite sides of the workers' shirt collars. Since the solvent tray and table were positioned predominantly to the workers' right or left, this may account for some of the differences noted. Several investigators of passive dosimeter performance have noted, that in areas of high humidity, a decrease as much as 10% occurs. Temperatures in the range of 5-35 degrees celsius do not seem to present more than a 5% positive error and temperature was not a factor in this study. Air velocity, also appears to have no significant effect on the dosimeters' performance. Field testing by Langhorst noted that charcoal tube samples were 7% higher in reported values versus passive dosimeters. All of these conditions do not account for the large error noted in the concentrations above 10 ppm, however, these contribute to differences reported in this study.

The trend of higher reported values by dosimetry, at exposures below 10 ppm, support the experiences of others' field testing the badges. Dosimeters generally lose sensitivity at low concentrations for short sampling durations. Because of this tendency the dosimeters should

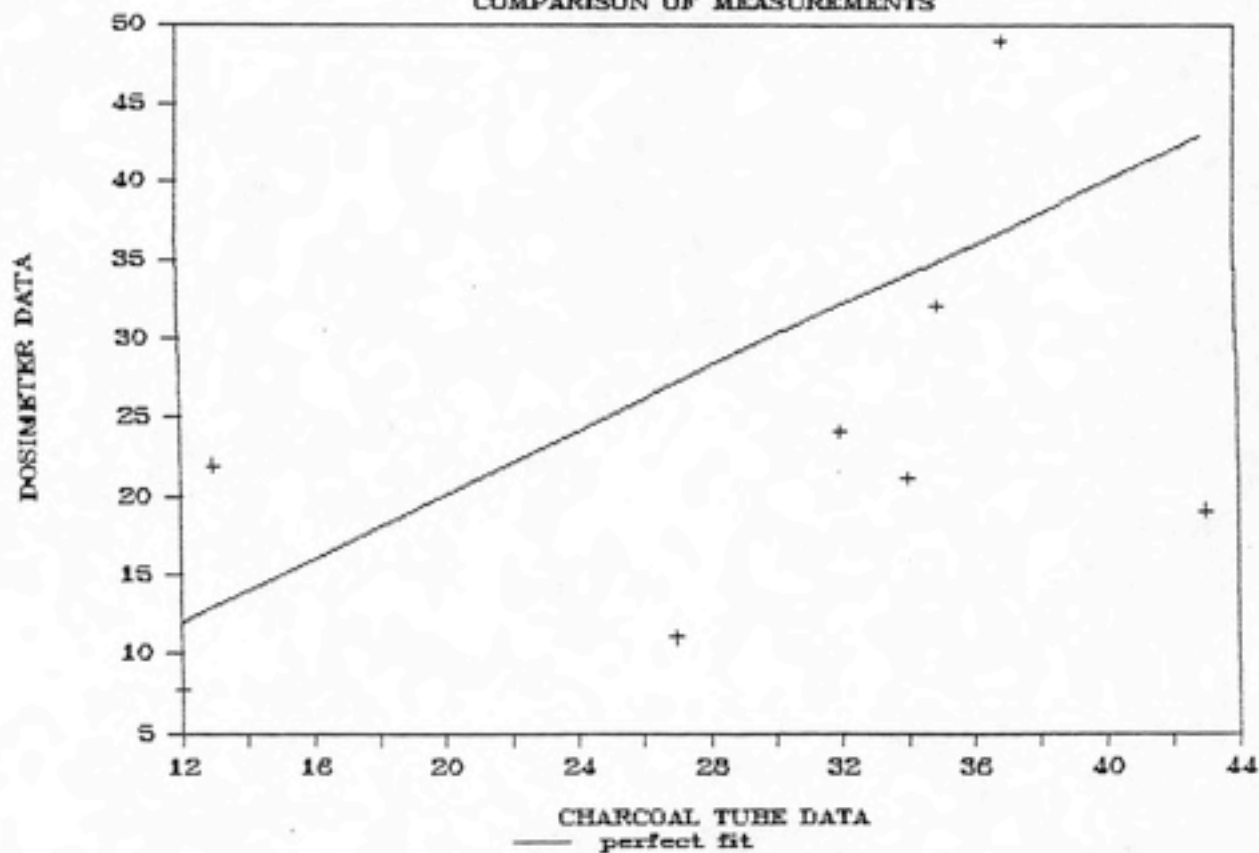
Graph 1: Lower Range

COMPARISON OF MEASUREMENTS



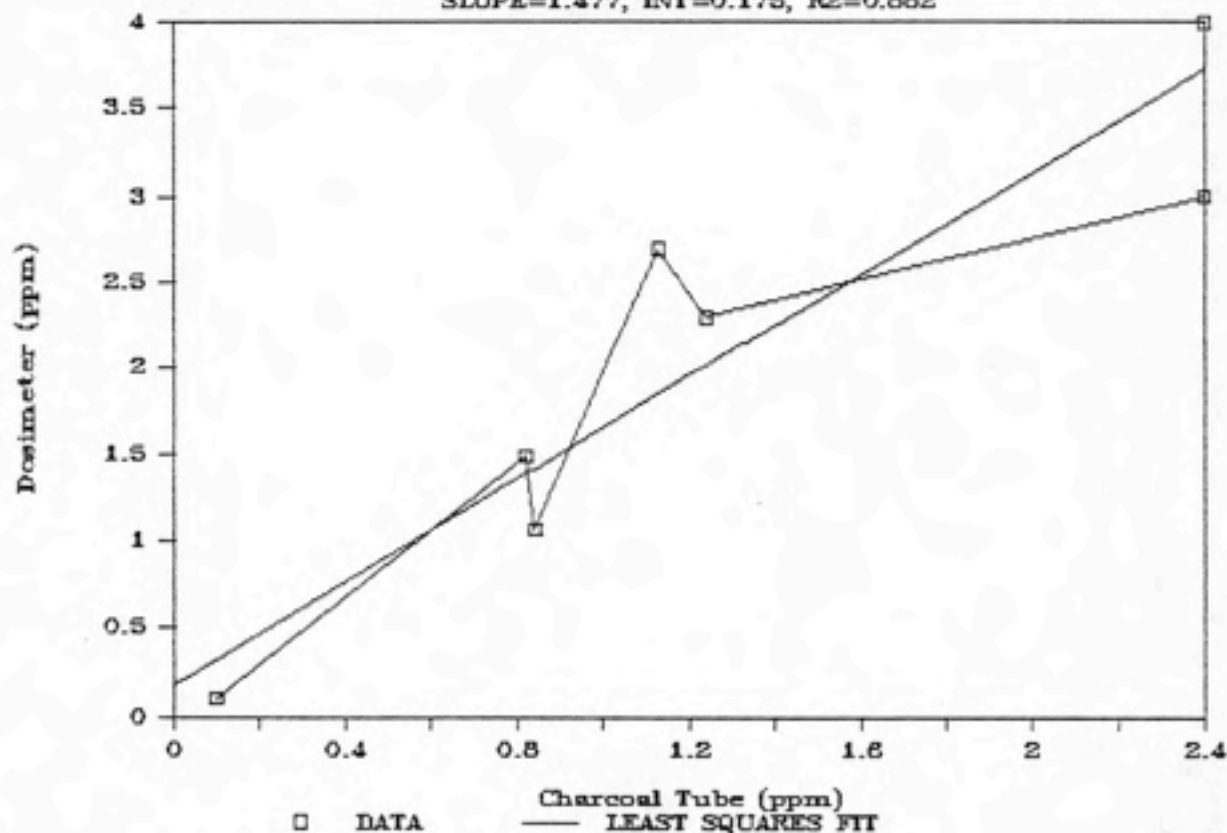
Graph 2: Upper Range

COMPARISON OF MEASUREMENTS



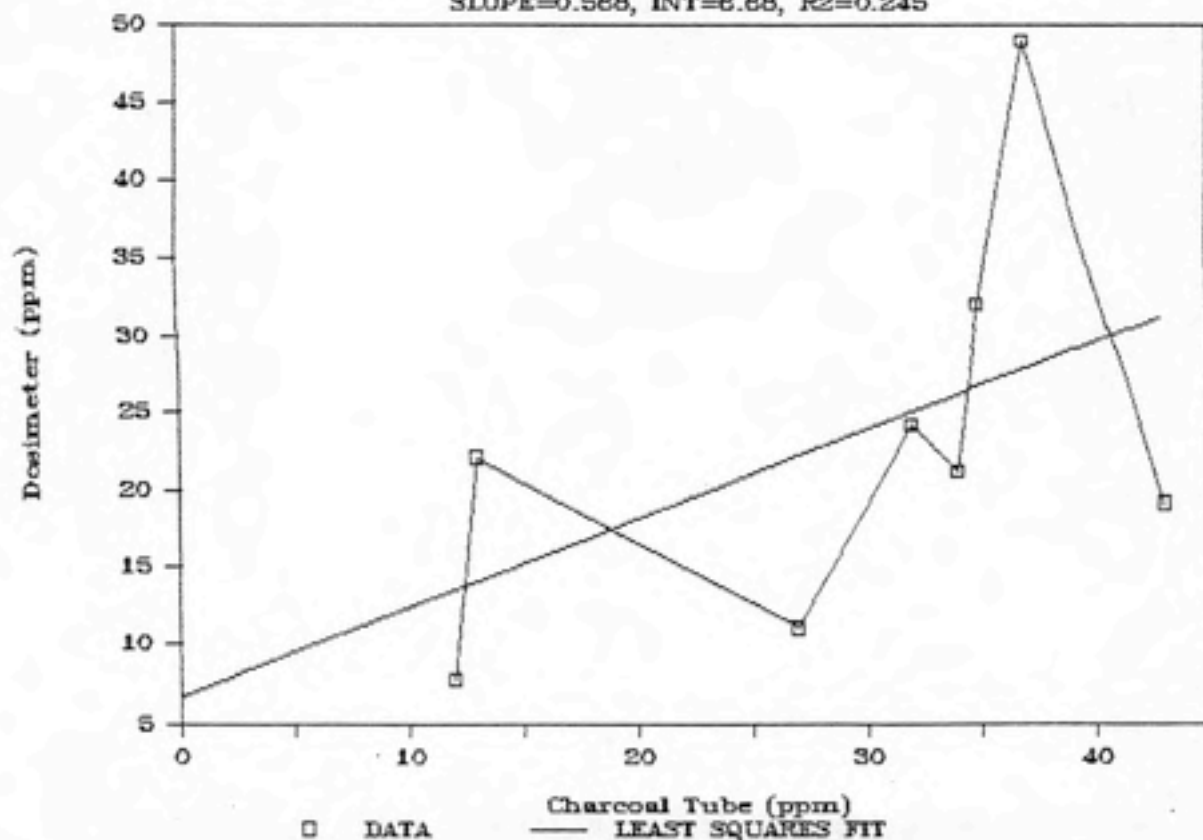
Graph 3: Low Concentration

SLOPE=1.477, INT=0.175, R2=0.882



Graph 4: High Concentration

SLOPE=0.568, INT=6.68, R2=0.245



have better performance if sampling times are lengthened. It should be noted that a 25% error between the two types of sampling would not be unusual.

It is curious that the results show a shift in the error trends of the dosimeter versus charcoal tube sampling, but the magnitude of the error does not defeat the extent of the dosimeter results. The dosimeter should be used as a first cut in sampling and the charcoal tube sampling taken to determine exposures for regulatory documentation. Continued sampling and comparisons of the two methods may provide enough data to fix the limitations, if any, of the dosimeter sampling for 2-ethoxyethanol.

VII. CONCLUSIONS AND RECOMMENDATIONS OF THIS STUDY

The results of the uncontrolled samples in the Low Volume areas, prior to any controls, were below the TLV of 5.0 ppm. However, they could become higher if practices in the work area or the volume of foam pads produced increased. This would result in more contact with the 2-ethoxyethanol. Levels measured in the High Volume area were well above the 5 ppm TLV and some means to reduce the employees' exposures had to be developed if the use of 2-Ethoxyethanol was to continue.

The samples taken in the High Volume area after administrative controls were instituted produced a marked reduction in the 8-hour TWAs. These results showed a reduced exposure of 75-80% of their previous values. Despite this significant reduction, exposures were still higher than the 5.0 ppm TLV. Two of the samples fell below the TLV, but two others were over 5.0 ppm. Engineering controls, at this point, were added to further reduce the exposures. Since the Lower Volume areas had measured concentrations just below the TLV of 5.0 ppm, the introduction of the administrative procedures used in the High Volume area are expected reduce the exposures in the Low Volume areas with a margin of safety.

The measurement results of the samples taken with the drained tabletop were inconclusive. The table's drain was

easily plugged within 15-30 minutes and pooling of the solvent resulted in measured exposures that increased significantly over previous values. The drain opening in the tabletop needed to be increased to a diameter of about three-quarters of an inch to allow the splashed solvent and small particles of foam to freely flush into the drain and down into the safety can collecting the waste solvent. Because of this complication, sampled values taken with both the drained tabletop and administrative controls were suspected as invalid.

The results on the use of administrative controls coupled with the local ventilation attached to the solvent tabletop markedly reduced the TWAs encountered by the workers in the High Volume area. If these controls were used in the Low Volume areas, it would be expected that exposure levels would be at or below the highest values measured in the High Volume area. The TWA was cut to approximately 1.0 ppm, a level that would provide the margin of safety the plant sought for its employees.

A large reduction in the concentrations measured resulted from using all three controls: (1) the change of work procedures, (2) venting of the tabletop, and (3) adequate draining of the tabletop. When all three procedures were used, the TWA was reduced to 0.5 ppm (from 1.0 ppm), indicated that, when the drain of the tabletop was kept free and clear, a further reduction in 2-ethoxyethanol concentrations might be expected. These

results certainly furthered the opinion that 2-ethoxyethanol exposures in the High Volume area could be reduced well below the 5.0 ppm level and that its production use could be continued.

The Automated area sampling measurements showed that, if the automated foam pad production machine that the plant was testing could be successful from a production viewpoint, its related employee exposures would be minimal and well below the 5.0 ppm TLV. It should be emphasized that the automated machine would be practical in areas only of high volume foam production, leaving many low volume sites through the plant in the need of control by other means.

Based upon this study, the investigator cites several recommendations to the plant with respect to employee exposures to 2-ethoxyethanol.

- The results of the samples taken in an uncontrolled condition, whether high or low volume areas, require some additional controls to ensure that the 8-hour TWAs do not exceed 5.0 ppm.
- The exposures in the Chemical Repacking area were found to be sufficiently low, so that further control is not necessary. Periodical monitoring on a semi-annual basis would be prudent to ensure that exposures continue to remain at this low concentration.
- Should the automated pad machine pass quality standards set by manufacturing and production management, the machine could replace high volume

molded foam pad areas in the plant. This would eliminate the vast majority of exposures that are exceeding the 5.0 ppm TLV level, although it could not substitute for the low volume sites or sites where free foaming occurs. The automated system may not be practical for all high volume areas of production either.

- The first corrective control that should be instituted is administrative controls at all in-house foaming sites. The results of the study clearly show marked reductions are gained when more care in work practices are taken. The cleaning of foaming guns and the charging and discharging of solvent containers, where ventilation exists to carry vapors away from the workers, requires no capital expense and little additional time lost by either workers or supervisory personnel. This action alone could reduce the TWA concentrations in the Low Volume areas below the TLV with a significant margin of safety, and reductions in the high production areas by potentially 70% or more have been documented.
- The use of drainage tables should be studied further. If the drain hole is sufficiently large so that blockages are infrequent, less vaporized material will evolve. Since 2-ethoxyethanol is water soluble, the use of a squirt bottle to rinse the tabletop of

splashed and dripped solvent might increase the effectiveness of this control. Changing the tabletop would require little cost to implement, would reduce some housekeeping, and improve safety conditions, preventing solvent spills. The true values of this control is admittedly still somewhat unknown and measurements of its effectiveness following implementation should be made.

- The use of the slot vent at the solvent tray as an engineering control initially should only occur in the High Volume production areas. If the previously suggested controls do not significantly reduce the measured exposures in the low volume areas, then ventilation of the tabletops in these areas is also recommended. The use of local ventilation will reduce the TWA exposures in the High Volume areas well below the 5.0 ppm level. This control plus administrative controls are the minimum approach needed to reduce exposures to an acceptable level in these areas. Certainly the use of drained tabletops would be helpful.

The use of 2-ethoxyethanol in the foam pad production areas of the plant may be continued under safe exposure conditions with the implementation of recommended controls. Continued periodic measurements should be made to ensure and document the exposure levels encountered in these areas of the plant. Since the passive dosimeter results

reflected charcoal tube sample results at low concentrations (presumably levels that will be measured after controls are instituted throughout the plant), they might be used to make first-cut assessments of employee 8-hour TWAs with the controls in place. This could reduce the time and costs of sampling or, combined with charcoal tube sampling, thoroughly establish plant conditions. Charcoal tube samples should be taken in areas where exposures are critical or where accidental contact with the solvent might occur, invalidating the dosimeter measurements. Passive dosimeters may be used to sample the general work area or of worker transient through a foam site location. To heighten their sensitivity, sampling should occur for periods of time in excess of 4 hours unless saturation is anticipated.

Although the plant can continue to use 2-ethoxyethanol at production sites with confidence, a better and ultimate solution might be to investigate alternative solvents for the process. The substitution of another solvent that can give the necessary production results with a lower health risk (via toxicology, vapor pressure, concentrations, etc.) might eliminate the need to proceed with or continue these recommended controls.

The continued use of 2-ethoxyethanol in this production process will require both administrative and engineering controls. All areas should require the workers to carry out the administrative controls used in this

study. This will reduce exposures in the low volume areas below the 5.0 ppm TWA. However, in order to maintain the TWA in the High Volume area, a slot hood at each tray table should be constructed and in conjunction with the administrative controls. This engineering control could be accomplished for less than \$5,000. Both of these methods can be undertaken without alterations to the production process and with a minimum loss of worker productivity.

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Appendix A

2-Ethoxyethanol

Analyte: 2-Ethoxyethanol Method No. S361

Matrix: Air Range: 340-1460 mg/cu m

OSHA Standard: 200 ppm (740 mg/cu m)

Precision (CV): 0.059

Procedure: ^T Adsorption on charcoal, desorption with
methonal/methylene chloride GC-FID

Validation Date: 3/17/78

1. Principle of the Method

1.1 A known volume of air is drawn through a charcoal tube to trap the organic vapors present. The sampling tube consists of a front adsorbing section and a backup section.

1.2 The charcoal in each tube is transferred to a vial and the 2-ethoxyethanol is desorbed with a solution of 5% methanol in methylene chloride and analyzed by gas chromatography.

1.3 The area of the resulting peak is determined and compared with areas obtained from the injection of standards.

2. Range and Sensitivity

2.1 This method was validated over the range of 337-1459 mg/cu m at atmospheric temperatures of 23.5 and 23.0 °C, and atmospheric pressures of 757.1 and 770.3 mm Hg using a 6-liter sample volume. This sample volume is less

than two-thirds of the 5% breakthrough capacity determined at 90% relative humidity when sampling a test atmosphere at 2 times the OSHA standard. This method is capable of measuring much smaller amounts if the desorption efficiency is adequate. Desorption efficiency must be determined over the range used.

2.2 The upper limit of the range of the method is dependent on the adsorptive capacity of the charcoal tube. This capacity varies with the concentrations of 2-ethoxyethanol and other substances in the air (see Section 5.2).

3. Interferences

3.1 When two or more compounds are known or suspected to be present in the air, such information, including their suspected identities, should be transmitted with the sample.

3.2 It must be emphasized that any compound which has the same retention time as the analyte at the operating conditions described in this method is an interference. Retention time data on a single column cannot be considered as proof of chemical identity.

3.3 If the possibility of interference exists, separation conditions (column packing, solvent composition, etc.) must be changed to circumvent the problem.

4. Advantages and Disadvantages

4.1 The Coefficient of Variation (CV) for the total analytical and sampling method in the range of 337-1459 mg/cu m was 0.0593. This value corresponds to a 43.9 mg/cu m standard deviation at the OSHA standard level. Statistical information and details of the validation and experimental test procedures can be found in References 11.1 and 11.2.

4.2 On the average, the concentrations "found" at the OSHA standard level using the overall sampling and analytical method were 7.1% higher than the "true" concentrations for a limited number of laboratory experiments. Any difference between the two concentrations does not represent a bias in the sampling and analytical method, but rather a random variation from the experimentally determined "true" concentration.

5. Advantages and Disadvantages

5.1 The sampling device is small, portable, and involves no liquids. Interferences are minimal, and most of those which do occur can be eliminated by altering chromatographic conditions. The tubes are analyzed by means of a quick, instrumental method.

5.2 One disadvantage of the method is that the amount of sample which can be taken is limited by the number of milligrams that the tube will hold before overloading. The sample capacity of the charcoal tube is dependent on humidity. When an atmosphere at 90% relative humidity containing 1484 mg/cu m of 2-ethoxyethanol was sampled at

0.0425 liter per minute, no breakthrough was observed after 240 minutes, at which time this test was concluded. The capacity of the charcoal tube is at least 10.20 liters or 15.14 mg under the conditions of this breakthrough experiment.

5.3 When the sample value obtained for the backup section of the sorbent tube exceeds 25% of that found on the front section, the possibility of sample loss exists.

5.4 The precision of the method is affected by the reproducibility of the pressure drop across the tubes. This drop will affect the flow rate and cause the volume to be imprecise, because the pump is usually calibrated for one tube only.

6. Apparatus

6.1 Sampling Equipment

6.1.1 Sampling Pump. A calibrated personal sampling pump whose flow can be determined within $\pm 5\%$ at the recommended flow rate (Reference 11.3).

6.1.2 Sampling Tubes. The sampling tube consists of a glass tube, flame-sealed at both ends, 7-cm long with a 6-mm O.D. and a 4-mm I.D., packed with two sections of 20/40 mesh activated coconut charcoal. The two sections include a front adsorbing section containing 100 mg of charcoal and a backup section containing 50 mg. The two sections are separated by a 2-mm portion of urethane foam. A 3-mm portion of urethane foam is placed between the outlet end of the tube and the backup

section. A plug of silylated glass wool is placed in front of the adsorbing section. The pressure drop across the tube must be less than one inch of mercury at a flow rate of 1 liter per minute.

6.1.3 Barometer.

6.1.4 Thermometer.

6.1.5 Stopwatch.

6.2 Gas chromatograph equipped with a flame ionization detector.

6.3 Column, 20-ft x 1/8-in stainless steel packed with 10% FFAP stationary phase on 100/120 mesh Supelcoport.

6.4 An electronic integrator or some other suitable method for measuring peak areas.

6.5 Sample vials, 2-ml with Teflon-lined caps.

6.6 Microliter syringes, 10- and 500-microliter and other convenient sizes for preparing standards.

6.7 Pipettes, 1- and 5-ml, both delivery type.

7. Reagents

All reagents must be ACS reagent grade or better.

7.1 Methanol.

7.2 Methylene chloride.

7.3 2-Ethoxyethanol, purified.

7.4 Five percent methanol in methylene chloride. Prepare by diluting 5 ml of methanol to 100 ml with methylene chloride. This solvent is used for making standard solutions and as a desorption solvent.

7.5 1-Heptanol, 99% grade, or other suitable internal standard. The appropriate solution of the internal

standard is prepared in 5% methanol in methylene chloride.

7.6 Nitrogen, purified.

7.7 Hydrogen, prepurified.

7.8 Air, filtered, compressed.

8. Procedure

8.1 Cleaning of Equipment. All glassware used for the laboratory analysis should be detergent-washed and thoroughly rinsed with tap water and distilled water.

8.2 Calibration of Personal Sampling Pumps. Each personal sampling pump must be calibrated with a representative sampling tube in the line; the tube is described in Section 6.1.2. This will minimize the errors associated with uncertainties in the sample volume collected.

8.3 Collection and Shipping of Samples

8.3.1 Immediately before sampling, break the two ends of the charcoal tube to provide an opening at least one-half the internal diameter of the tube (2-mm).

8.3.2 The section containing 50 mg of charcoal is used as a backup and should be positioned nearest the sampling pump.

8.3.3 The charcoal tube should be placed in a vertical direction during sampling to minimize channeling through the charcoal.

8.3.4 Air being sampled should not be passed through any hose or tubing before entering the charcoal tube.

8.3.5 A sample size of 6 liters is recommended.

Sample at a flow rate between 0.05 and 0.01 liter per minute. The flow rate should be known with an accuracy of at least $\pm 5\%$.

8.3.6 Record the ambient temperature and pressure. If pressure reading is not available, record the elevation.

8.3.7 The charcoal tube should be labeled appropriately and capped with the supplied plastic caps. Under no circumstances should rubber caps be used.

8.3.8 With each batch of 10 samples, submit one charcoal tube which has been handled in the same manner as the sample tubes (break, seal and transport), except that no air is sampled through this tube. This tube should be labeled as a blank.

8.3.9 Unused, capped charcoal tubes should accompany the samples. These tubes are used in desorption efficiency studies in conjunction with these samples because desorption efficiency may vary from one batch of charcoal to another. Record the batch number of the charcoal used.

8.3.10 Capped charcoal tubes should be packed tightly and padded before they are shipped to minimize tube breakage during shipping.

8.4 Analysis of Samples

8.4.1 Preparation of Samples. In preparation for analysis, each charcoal tube is scored with a file in front of the first section of charcoal and broken open. The glass wool is removed and discarded. The charcoal in the front 100-mg section is transferred to another vial. These two sections are analyzed separately.

8.4.2 Desorption of Sample. Prior to analysis, 1.0 ml of 5% methanol in methylene chloride is pipetted into each 2-ml vial. The vial is capped immediately after solvent addition and then agitated. Desorption should be done for 30 minutes. Tests indicate that this is adequate if the sample is agitated occasionally during this period.

8.4.3 GC Conditions. The typical operating conditions for the gas chromatograph are:

1. 30 ml/min (60 psig) nitrogen carrier gas flow
2. 30 ml/min (25 psig) hydrogen gas flow to detector
3. 300 ml/min (60 psig) air flow to detector
4. 200 °C injector temperature
5. 225 °C manifold temperature (detector)
6. 140 °C column temperature

The solvent front appears after approximately 2.5 minutes. A retention time of approximately 6 minutes is to be expected for the analyte using these conditions and the column recommended in Section 6.3. The retention time for the internal standard, 1-heptanol, is approximately 14 minutes.

8.4.4 Injection of Sample. A 5-microliter aliquot of the sample solution is injected into the gas chromatograph. The solvent flush method or other suitable alternative such as an automatic sample injector can be used provided that duplicate injections of a solution agree well. No more than a 3% difference in area is to be expected.

8.4.5 Measurement of Area. The area of the sample

peak is measured by an electronic integrator or some other suitable form of area measurement, and preliminary results are read from a standard curve prepared as discussed in Section 9.

8.5 Determination of Desorption Efficiency

8.5.1 Importance of Determination. The desorption efficiency of a particular compound can vary from one laboratory to another and also from one batch of charcoal to another. Thus, it is necessary to determine the percentage of the specific compound that is removed in the desorption process for the particular batch of charcoal used for sample collection and over the concentration range of interest. The desorption efficiency must be at least 75% at a sample loading equivalent to a 6-liter collection at the OSHA standard level.

8.5.2 Preparation of Analytical Samples for Desorption Efficiency Determination. The desorption efficiency must be determined over the sample concentration range of interest. In order to determine the sample concentration range which should be tested, the samples are analyzed first and then the analytical samples are prepared based on the relative amount of 2-ethoxyethanol found in the samples. The desorption efficiency must be determined for each concentration level of 2-ethoxyethanol found in the samples analyzed.

The analytical samples are prepared as follows: Activated charcoal (100 mg) is measured into a 2-mL vial. This charcoal must be from the same batch as that used in

obtaining the samples. A known amount of 2-ethoxyethanol is injected directly into the charcoal by means of a microliter syringe. Adjust the concentration of the spiking solution such that no more than a 10 microliter aliquot is used to prepare the analytical samples.

For the validation studies conducted to determine the precision and accuracy of this method, six analytical samples at each of the three concentration levels (0.5, 1 and 2X the OSHA standard) were prepared by adding an amount of 2-ethoxyethanol equivalent to that present in a 6-liter sample at the selected level. This required the addition of 2, 4, and 8 microliter of 2-ethoxyethanol to the charcoal for 0.5, 1, and 2 of OSHA standard level. The analytical samples were allowed to stand at least overnight to assure complete adsorption of the analyte onto the charcoal. A parallel blank tube was treated in the same manner except that no sample was added to it.

The procedure described can be used to prepare the analytical samples which are analyzed to determine desorption efficiency over the concentration range of interest.

8.5.3 Desorption and Analysis. Desorption and analysis experiments are done on the analytical samples as described in Section 8.4. Calibration standards are prepared by adding the appropriate volume of spiking solution to 1.0 mL of 5% methanol in methylene chloride. Standards should be prepared and analyzed at the same time

the sample analysis is done.

The desorption efficiency (D.E.) equals the weight in mg recovered from the charcoal divided by the weight in mg added to

the charcoal or:

$$D.E. = \frac{\text{Weight (mg) recovered} - \text{Blank (mg)}}{\text{Weight (mg) added}}$$

The desorption efficiency may be dependent on the amount of 2-ethoxyethanol collected on the charcoal. Plot the desorption efficiency versus weight of 2-ethoxyethanol found. This curve is used in Section 10.4 to correct for adsorption losses. If the desorption efficiency is greater than 95%, no correction should be applied.

9. Calibration and Standards

9.1 Add 1.0 mL of 5% methanol in methylene chloride to a 2-mL vial. Add aliquots of 2-ethoxyethanol as described in Section 8.5.2 to prepare calibration standards. The concentration of standards can be expressed in terms of mg of 2-ethoxyethanol per mL of 5% methanol in methylene chloride.

9.2 A series of standards, varying in concentration over the range of interest, is prepared as described above and analyzed under the same GC conditions and during the same time period as the unknown samples. Curves are established by plotting concentration in mg/mL versus peak

area.

For the internal standard method, use 5% methanol in methylene chloride containing a predetermined amount of internal standard. The internal standard concentration used was approximately 75% of the concentration at the OSHA standard. The analyte concentration in mg per mL is plotted versus the area ratio of the analyte to that of the internal standard.