# FINAL PERFORMANCE REPORT

## CDC/NIOSH

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# Development of an Exposure Matrix for Construction Painters Based on Specific Work Tasks

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## Significant Findings

Video exposure monitoring was effective in identifying specific activities that make the greatest contribution to overall volatile organic compound (VOC) exposure. The use of a portable photoionization detector (PID) with datalogger can be used to characterize VOCs arising from the application of complex mixtures of solvents. The spray application of lacquer is a task associated with the highest VOC exposure in construction painting. Characterization of both the aerosol and vapor phases of this exposure indicated that the contribution of the aerosol was not substantial. Construction painters in Colorado have intermittent but sometimes very high exposures to VOCs for which respiratory protection is required. Painters, in response to a self-administered questionnaire, reported a number of acute symptoms that were related to their exposure to VOCs.

## Usefulness of Findings

The findings demonstrate the prevalence of exposure to volatile organic compounds (VOCs) in the construction painting industry. Newly developed, portable photoionization detectors with dataloggers are very useful in assessing exposure in this group of workers. Since this method of exposure assessment is cost effective, if adopted for workers exposed to complex mixtures such as solvent based paints, it will lead to improved quantitative characterization of employee exposures.

Although the use of solvent based products in construction painting is on the decline the findings provide support for the hypothesis that painters have exposures that have an adverse impact on their health. Very high ceiling and peak levels were found during the spray application of solvent borne coatings. Painting contractors generally have poor respiratory protection programs and this puts employees at risk because of these very high but intermittent exposures. The results of this research can be used to support the development of educational programs in the area of respiratory protection.

Additional outreach related to the safety implications of applying lacquer in confined spaces or close to open flames such as furnaces, would help reduce injuries and fatalities in the painting industry.

## Abstract

Construction painters have not been well studied in terms of their exposures or the impact of work on their health. The reason so little work has focus on this group is that they are highly mobile, difficult to trace for follow-up, and perform tasks that do not fit the typical 8-hour time weighted average exposure scenario. Additionally, construction painters may be exposed to solvent based products that are present in both the vapor and liquid (mist) phases. The goal of this investigation was to utilize new techniques in exposure assessment to characterize exposures to volatile organic compounds during construction painting activities.

The research was divided into four projects each addressing separate aims. Project 1 was conducted to develop the video exposure monitoring technique and customize its application to construction painting tasks for which exposures to volatile organic compounds (VOCs) are very high. Project 2 tested the utility of using a newly developed portable photoionization detector (PID) with datalogger in assessing overall VOC exposures in construction painting. Project 3 was conducted to specifically address the issue of the contribution of aerosol in the overall VOC exposure of the construction painter during the application of lacquer. Project 4 developed and used the task-exposure matrix to assess the relationships between project, process, and task variables and VOC exposure. Additionally, symptom data which reflected acute health effects of exposures to organic solvents was collected and models were developed to determine if symptom scores were associated with VOC exposure.

Project 1 demonstrated that video exposure monitoring could be effectively used to determine which specific activities within a work task make the greatest contribution to

overall VOC exposure. The distribution of data obtained was nonnormal and a log transformation was required to stabilize the variance. Exposure indices were shown to be effective in determining which tasks should be controlled to reduce employees' exposure to VOC. A drawback of the system was the size and awkwardness of the equipment that must be worn by the worker.

The use of equipment for detailed video exposure monitoring was not well received by construction painters who volunteered for the study. Project 2 was undertaken to assess the utility of a much smaller PID and datalogger for collection of data that would be suitable for less rigorous video exposure analyses. Additionally, a goal of this project was to determine if data from a PID are reflective of overall VOC exposures. Side-by-side using a portable PID and sorbent tubes was conducted to compare time weighted average PID results with the more common integrated sampling method. A high degree of correlation between results obtained using the two methods was found.

Since the highest exposures were encountered during the spray application of solvent based lacquers, Project 3 was conducted to determine the most appropriate method of characterizing exposures for this task. Previous investigations have indicated that traditional methods of measuring exposure may lead to an underestimation because they fail to account for VOCs in the aerosol phase. Prototype vapor-aerosol samplers were obtained from SKC Inc. and samples were collected side-by side also using traditional charcoal tubes, prefiltered charcoal tubes, and passive vapor samplers (diffusional). No significant differences between VOC concentrations from charcoal tube and vapor-aerosol samplers was found. This finding was unexpected but may have occurred because the components of the sprayed material were extremely volatile resulting in only a small proportion of inhalation exposure due to the mist.

Data collected during 107 painting process involving 85 employees from 62 companies was analyzed as part of Project 4. The overall geometric mean VOC concentration was 54.8 ppm indicating that painters in the study were substantially exposed to organic

vapors. Although there has been a tremendous shift to water borne architectural coatings in commercial and residential construction, this study found that there are specific tasks in which exposures to VOCs may be extremely high. Solvent based coatings are used on metal and bare wood where finish and durability are required to exceed that achieved with water borne products. In residential construction, exposures to VOCs are most common during the application of stain and lacquer. In the commercial construction sector, solvent based products are uncommon in typical building construction (offices) with use limited to lacquering of doors and application of alkyd paint on metal door frames.

The use of solvents throughout the duration of the painting process was associated with very high exposures to VOCs (geometric mean, 96.6 ppm). Because of high exposures during the spray application of lacquers, samples obtained on painters in residential construction were higher than those obtained on workers on other projects. When the data were grouped by painting process or by specific work tasks, the differences in means were statistically significant. Application of lacquer and sander sealer were associated with very high exposures both in residential and commercial construction projects.

There was considerable variability in exposure data and very few independent variables were statistically significant predictors of an employees' VOC exposure. Similarly, symptom scores were, for the most part not associated with level of VOC exposure. Two exceptions were that the symptoms "been feeling run down" and "felt high or intoxicated at work" were significantly positively associated with exposure level. These symptom scores increased with increasing level of VOC exposure.

Overall, the investigation found that construction painters in Colorado have the potential for intermittent but very high exposures to VOCs. The use of a portable PID is extremely useful in assessing exposure to construction painters as it provides data which is highly correlated to that obtained from charcoal tube sampling. Additionally,

the PID with datalogger provides information on ceiling and short term exposures which are of concern from both a health and safety point of view. Most painters work for small contractors and these small businesses place little emphasis on health and safety and generally do not have respiratory protection programs. . It is recommended that additional information be provided to employees and small painting contractors regarding the hazards of using solvent based products.

# 1. Background

Construction painters are typically exposed to products which contain a variety of chemical constituents which cause a wide array of adverse health effects. Toxic components of coatings can gain entry into the body through inhalation, dermal absorption and ingestion; although the last route is of little occupational significance. The potential health effects range from acute neurological effects to an increased risk of developing cancer. Neurological effects have received the most attention from investigators while effects on other organ systems have largely been ignored. The organic solvents are a class of compounds in construction coverings which have been associated with occupational disease. Despite known adverse human health effects from solvent exposure, information pertaining to the characterization of occupational exposure is limited.

Exposure assessment has been one common methodological weakness in much of the research which has explored the relationship between health outcomes and solvent exposure. The work environment of the construction painter is highly variable, whereby workers may be exposed to a mixture of several solvents in a work day with potential for combined effects with other contaminants. The nature of the work environment prevents proper control of exposure; therefore, air concentrations of solvents may fluctuate highly during painting tasks. Exposure assessment becomes difficult when there are multiple compounds of concern, with widely varying concentration and near-infinite number of variables involved. Because of the complexity of the work environment, few researchers have performed personal breathing zone sampling of solvent mixtures during construction painting tasks.

When air sampling for organic solvents, the industrial hygienist has the option of using either a solid/liquid sorbent trapping technique or direct reading instrumentation. The sorbent tube technique followed by gas chromatographic analysis (GC) is most often used for ascertaining compound specific concentrations for integrated personal air

sampling. While this method may indicate a certain level of exposure, an evaluation of activities affecting exposure may be difficult.

By using direct reading instrumentation, important information can be obtained for assessing worker exposure. The direct reading instrument provides the advantage of supplying real time data which permits an immediate assessment of contaminant levels. The real time data can provide more detailed information regarding peak exposures, short-term exposures, and activities affecting exposure patterns. If work tasks are video recorded it is possible to link data obtained from a direct reading instrument to information on video tape to further characterize peak exposures and exposure patterns. This evaluation technique, termed video exposure monitoring (VEM), has been used effectively to identify procedures and tasks which make the greatest contribution to a workers overall exposure.

Considerable changes have occurred over the last decade in the paint and coating industry. In response to tightening environmental regulations regarding the volatile organic compound (VOC) component of coatings, the volatility and amount of organic solvents used in paints have declined. Surface coatings used in both residential and commercial construction have been the focus of industry efforts as waterborne substitutes have shown to perform as well as solvent-based products in most applications. Construction painters are known to have been at increased risk of solvent induced adverse health effects, yet little research has been conducted to determine if changes in coating chemistry have reduced this risk.

The overall goals of this investigation were to characterize exposures to VOCs in the construction painting industry in Colorado and determine if workers are at significant risk of adverse health effects as a result of such exposures. Additional goals were to identify specific work tasks in which VOC exposures were elevated in order to make recommendations for ways to reduce such exposures. As exposure assessment is especially complex due to the construction painter's unique work environment, the

presence of aerosol and vapor chemical contaminants, and the variety of chemical constituents of the coatings used, a considerable portion of the investigation focused on developing suitable sampling and analytical techniques. The resulting database of tasks and exposures, a specific goal of the investigation, thus incorporated data from multiple methods of exposure assessment.

## 2. Specific Aims

The overall purpose of the investigation is to develop a task-exposure matrix for exposures to volatile organic compounds (VOCs) for construction painters. The specific aims of the project include the following:

(a) to develop a method in which specific work tasks can be quantitatively and qualitatively evaluated
(b) to use video exposure monitoring (VEM) to identify peak exposures
(c) to assess the statistical relationships between dependent (time- weighted average exposures) and independent (e.g., task characteristics, work habits, environmental factors) variables
(d) to develop a matrix in which specific tasks are linked to exposure levels
(e) to develop a method of quantifying exposures that would be suitable for epidemiology studies
(f) to collaborate with investigators at NIOSH in the area of exposure assessment
(g) to incorporate the results of VEM in the training of construction painters

## 3. Methods

The work that was completed can be categorized into four projects. Project 1 was the development of the video exposure monitoring technique; Project 2 was the testing of portable PID instrumentation for evaluation of complex VOC exposures; Project 3 was the characterization of exposures during spray applications of coatings; and Project 4 was conducted to characterize exposures during specific work tasks, to describe the acute symptoms experience by painters, and to determine the overall prevalence of VOC use in construction painting. Methods for each of the projects are described separately although subject selection and recruitment of companies and subjects were common for projects 2 to 4 and are described below. Projects 1, 2, and 3 were conducted as part of Master's degree thesis requirements in the Department of Environmental Health.

Recruitment of subjects through contact with owner/managers of painting companies met with limited success. Of 220 introductory letters (see Appendix I) mailed out to companies, only 6 agreed to participate. Telephone follow-up also failed to increase the participation rate of companies. Presentation of the goals and objectives of the study at local Painting and Decorating Contractors of America (PDCA) meetings led to the successful recruitment of another 11 painting companies.

The work organization of construction painting in Colorado also had an impact on the recruitment of painting companies and individual subjects. The protocol called for first obtaining informed consent of the paining company (owner or manager) to approach their employees for possible participation. After permission of the painting company was received, the general contractor was contacted to obtain access to the work sites. Over 30% of general contracts refused to allow investigators on site, most often citing insurance or liability concerns. The majority of general contractors who allowed site sampling considered the investigator/research assistant as part of the painting crew.

In Colorado most painting companies employ less than 10 workers usually split into 1 to 3 crews. During the course of the investigation the Front Range was undergoing a residential construction boom, so many companies performed the majority of their work in the home building sector. Letters inviting participation of these small painting contractors were not successful in recruiting companies, and telephone calls to these companies did not improve participation rates. Most of these small employers were very busy and worked with one or two general contractors so were not interested in returning telephone calls or participating in the study. A slight modification of the protocol for recruiting companies was necessary and it was found that contact with company owners at the work sites was the only way to recruit these companies. If company owners agreed to participate, the general contractor was notified by telephone that investigators would be performing monitoring. Reluctance of general contractors to allow data collection was initially very prevalent. In response, the investigators asked, and were granted, permission to address members of the Home Builders Association regarding the importance of the study at various local meetings held along the Front Range. General contractors who were active participants in the HBA were more receptive to the data collection protocol after these presentations.

At the work site, eligible construction painters were verbally asked to participate in the study and given a consent form familiarizing them of the objectives, nature of their participation, freedom to decline to participate and to withdraw at any time, and the procedures taken to ensure confidentiality of information. After the consent form was signed the subject was be given a work task history questionnaire. Upon completion of the consent forms, the sampling equipment was set up as described in the methods for each project. In many cases the subjects were not able to complete the questionnaire on-site and were provided a postage-paid envelope so it could be completed at home and mailed in.

While sampling was being conducted the investigator or research assistant collected information on the work site and tasks using the forms reproduced in Appendix I. Consent forms are also reproducted in Appendix I. Video taping of work tasks was

performed only if approved by the general contractor, painting contractor, and subject. If the worker requested detailed information regarding his exposure, his address was obtained and summary information along with general material on the hazards of working with solvents was later mailed out. Summary data, using no names of the workers monitored, was forwarded to owner/managers if requested.

**Project 1: Development of the Video Exposure Monitoring Technique**

In residential construction painting it is commonly known that significant exposures to VOCs occur during the staining and lacquering of doors, trim and other wood products. The purpose of this project was, in a controlled environment, to develop a method incorporating video exposure monitoring to measure the total VOC concentrations in breathing zone air of workers as they performed the many tasks involved in applying a stain to wood. The location selected for this study was a kitchen cabinet manufacturer in Colorado. One of the conditions required for cooperation from the company was anonymity in name and location. This facility sprayed their wood pieces prior to assembly in a spray booth supplied with local exhaust ventilation. The majority of the objects to be sprayed were transported to the spray booth via an overhead track and pivoting arms which secured the wood pieces. A small percentage (about 15%) of the cabinetry were outsized pieces which had to be sprayed by hand on various tables that were wheeled into the booth. Other tasks included pausing between stain application, setting up the pieces on the conveyor line, wiping down the spray once it was applied, sanding, and reloading the stain cans with stain and solvent. All of the stain was sprayed by one coatings applicator technician over five runs of approximately thirty minutes in duration through the span of three days during the same week.

Wood Stain Spraying Methodology

The stain used was a carbon pigment carried in a toluene-xylene solvent. Its brand name is "Alderglow" and is known generically as a pigment stain. Manufactured by Guardsman Products, Inc., Alderglow is supplied as a concentrate which is thinned with xylene and toluene at the spraying station. The mixing ratio was 21 parts xylene to 17 parts toluene to 1 part Alderglow. A table of the chemicals used in the wood stain, along with their concentrations and their ACGIH Threshold Limit Values (ACGIH, 1994) are shown in Table 1. Although Alderglow is not typically used in construction painting, its components are similar to those found in lacquers and sealers which are also applied by spray.

Table 1. Chemical distribution and threshold limit values (TLV's) for Alderglow.

| Chemical | % By Weight | TLV | Units |
|---|---|---|---|
| Stoddard Solvent | 7 | 100 | ppm |
| n-Butyl Alcohol | 8 | 50 Ceiling SK | ppm |
| Isobutyl Alcohol | 1 | 50 | ppm |
| Butyl Acetate | 1 | 150 | ppm |
| Ethyl Benzene | 1 | 100 | ppm |
| Carbon Black Pigment | 2 | 3.5 | $mg/m^3$ |
| Toluene | 40 | 50 SK | ppm |
| Xylene | 40 | 100 | ppm |

The stain concentrate was mixed with the appropriate ratio of xylene and toluene in a five gallon stain pot that rested on the floor by the spray booth. One air line delivered thirty pounds per square inch (psi) to advance the stain to the spray nozzle. A second air line containing eight to ten psi atomized the spray at the nozzle head. This high

volume low pressure (HVLP) stain delivery was selected by the manufacturer to lower the solvent aerosol content in the worker's breathing zone and reduce stain waste.

Study Design

In this investigation, the first problem was assembling the direct reading instrumentation and datalogging equipment into a cohesive package that was usable by the worker. No off the shelf products existed commercially that took direct sample readings and stored them with the frequency and storage volume this study required. Considerable time and expense were invested in finding the appropriate photoionization detector, data logger, computer, and video camera. A HNU (HNU Systems, Inc.) PID was selected because of its linear response and reliability. Continuous one second sampling was required from the HNU PID to have enough data to have statistical power to detect significant differences in mean concentrations of the tasks sampled. To store over 1,800 continuous one second sample values each run, a Rustrak Ranger II$^{TM}$ data logger was selected to store the information.

The PID and data logger had to be attached firmly to a backpack that the worker would wear during his job activity. A short length of Teflon tubing was used to draw the sample from the worker's breathing zone to the PID. Several worker trials were required to design the proper placement of the sampling equipment to ensure a safe and comfortable unit for the employee to wear. A concern was the weight of the apparatus and the worker fatigue this weight would cause. At a total of twelve pounds, the sampling unit was limited to thirty minutes of use before worker fatigue could be expected. On the lapel adjacent to the tube collecting the PID sample, sorbent tube samples were also collected. The results would be compared to the results obtained from the HNU PID.

The data logger was programmed to store the voltage from the PID at one second intervals. Approximately thirty minutes of this continuous data was stored for each sampling run. After each run, the data was downloaded to a portable computer (PC) in

ASCII file format. Each file was formatted into a computer spreadsheet. During sampling the worker was video taped performing his job of spraying cabinetry with wood stain. The time on the data logger and camera were synchronized to the nearest second prior to video taping.

Tasks were coded using the numbers 1-7 to identify work activities that were expected to have distinct exposures as compared to other tasks. The coding was implemented by analyzing the video tape and assigning a task code for each second of work in the run. The task code was inserted as a separate data column in the exposure data spreadsheet.

All data were combined into one data file with six columns of information: hours, minutes, seconds, exposure concentration in ppm, task number, and run identification number. An important assumption in standard regression is the independence of variables. However, real-time exposures obtained using direct reading instruments do not provide results that are independent of each other[1] (Heitbrink et al., 1993). This lack of independence is due to the delay in response to changes in concentration due to mixing and detector response. In this investigation, residuals from the multiple regression analyses were be evaluated to determine if autocorrelation was present. If autocorrelation was present, the data would be systematically censored to include samples taken once every three seconds. The censored data would also be checked for autocorrelation.

A six second time lag was measured for the PID to register a full VOC concentration. This time lag was measured by timing the introduction of a standard calibration gas of known concentration and noting the time required for the instrument to reach with 5 % of the known concentration. Then the gas was withdrawn and the time was measured for the instrument to drop to zero concentration. Knowing the six second time lag of the HNU PID for full response, the first six seconds of a run's exposure samples were

[1] If readings are taken every second or less, generally the previous reading has an effect on the next. As an example, if the true concentration of a contaminant dropped very quickly to near zero the reading taken just after the true concentration dropped would be influenced by the previous reading of a high concentration.

discarded and the entire exposure data column was shifted upward six rows. This exposure data manipulation allowed the exposure at the worker's breathing zone to match the real time on the video tape.

Analytical Methods

The PID manufacturer claimed a linear response in the range of concentrations expected to be encountered in this study. As a check of the HNU's linearity of response to volatile organic compounds, the PID's total response in parts per million to six known concentrations of isobutylene gas were plotted. The procedure was executed with a Standard Technology Standard Gas Divider™ that split 204 ppm isobutylene gas into one-sixth increments. The accuracy of the divider was +/- 2 percent. Figure 1 shows the response curve for isobutylene standard gas using the HNU PID.

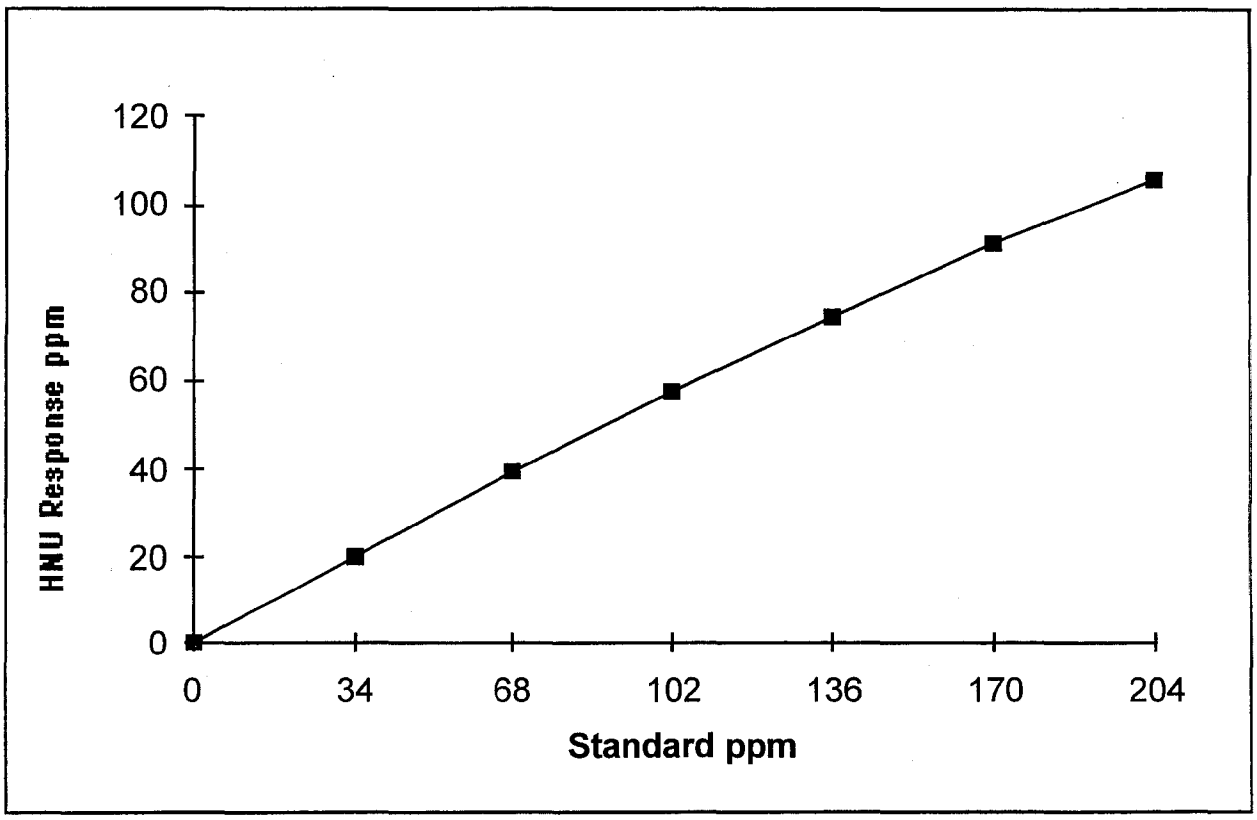



Figure 1. Response curve of the HNU DL 101$^{TM}$ to known concentrations of isobutylene in air.

Isobutylene at 100 ppm in air was used to field calibrate the HNU PID. This instrument was spanned to 56 ppm in reference to benzene as per the manufacturer's instructions. Field calibration of the instrument was conducted immediately before and after each sampling run.

Gilian® 5 Personal Air Samplers with SKC® Sorbent Sample Adjustable Low-Flow Tube Holders were used to collect charcoal tube samples simultaneously at varying flow rates ranging from 10 ml/min-100 ml/min. SKC® Lot 120 charcoal tubes which contained a 100 mg front and a 50 mg back were used to collect integrated air samples. To initiate sampling, the sealed ends of the charcoal tube were broken and the tube was placed in the sample holder connected to the inlet of the pump. After the completion of

the work task, the charcoal tube was removed from the sample holder and both ends capped with plastic caps. During the sampling procedure, one charcoal tube was opened at the sampling site and the ends capped. No air was drawn through this tube which served as a field blank and was submitted with other samples for analysis. The samples and blanks were labeled and stored refrigerated until analyzed. The sample label consisted of a date, worker identification, task number and manifold flow rate. The air pumps were pre- and post-calibrated the day of sampling using the Gilibrator® Primary Flow Calibrator. To determine volume of air sampled for concentration calculations, the average flow rate between the pre- and post-calibration values was employed in the calculation. For work tasks with multiple charcoal tube samples collected at different flow rates, the sample with the lowest percent difference between pre- and post-calibration flow rates was submitted for analysis. Samples were sent to an AIHA accredited laboratory (Industrial Hygiene Technologies Inc.) for gas chromatographic analysis.

Task Analysis Methods

Task analysis was initiated by video taping the entire job activity or "run" at the same time that direct-readings samples were being taken. Each task was assigned a number code. Most sample runs entailed the execution of four to five tasks and many tasks such as conveyor spraying were repeated many times during a sampling run. The video tape of each sample run was analyzed and coded according to the task being performed. A printout of the real time in minutes and seconds was filled in with the appropriate task code for each second of the video Next, the ASCII file containing the sampling information was converted to an EXCEL™ spreadsheet and the task codes were entered next to the real time of the sample.

Coding of the tasks was an integral part of the study. Once the task was defined, care was taken to follow the task code specifications when assigning a numeric task code to each second of the video taped job activity. A description of the tasks were as follows.

Task 1 Table Spraying. This task involved spraying parts on a flat or inclined table that was within the spray booth. The task was defined to start when the operator squeezed the spray gun trigger and stopped when he released the trigger.

Task 2 Pausing Between Spraying. This task represented the removal of the sprayed item from the spray table and the set up of the next object onto the table. The task was defined to start when the operator released the spray trigger and stopped when the trigger was squeezed or another task initiated.

Task 3 Wipe Down. This task involved taking a rag and wiping the excess stain spray from the wood object. The task started when the operator touched the rag and ended when he laid the rag down to start another task.

Task 4 Conveyor Spraying. This task consisted of spraying wood objects suspended from an overhead track that moved horizontally through the spray booth at approximately two feet per second. This spraying activity was differentiated from table spraying because the two tasks were thought to have different VOC exposures related to their respective tasks.

Task 5 Sanding . This task entailed leaving the spray booth area and walking 20 to 50 fifty feet to a drying tunnel. At this station the worker would manually sand the wood finish. The stain was not sanded, but the lacquer finish applied over the stain by another worker was the object of the sanding activity. Sanding began when the worker left the spray booth and ended when the worker stopped sanding his last wood piece. Traveling from piece to piece was considered part of the sanding task.

Task 6 Handling Spray Solvent. This task included the retrieval of toluene and xylene from the bulk storage room and the filling of the spray can at the spray station. This code was also applied when the operator would change spray stains or otherwise handle open containers of spray solvent.

Task 7 Other. This miscellaneous category covered tasks not included in the above mentioned categories. This category was meant to include only low exposure tasks such as hanging wood objects on the conveyor hooks and running errands away from the spray station. This code was enacted when the worker left the spray station and did not perform any of the other tasks.

Statistical Methods

Several terms need to be defined to aid in the discussion of the statistical analyses conducted. A run consisted of all the continuous samples taken during a thirty minute session. A run would contain the performance of several different tasks and the same task often occurred several times. Five distinct runs were sampled with the same five to seven tasks being repeated within each run. Task concentration was the measured VOC level in parts per million for all airborne organic chemicals detected by the HNU PID. An occurrence was the emergence of a distinct task event from beginning to completion of the task. Each occurrence was preceded and followed by a different task. The same task, such as table spraying, might occur a few or many times during a run.

The nested analysis of variance (ANOVA) procedure was performed to compare the means of VOC sample readings between separate sampling runs, among distinct tasks in the same run, within a given task in the same run, and within separate occurrences of the same task within the same run. It is hypothesized that video exposure monitoring would be effective in detecting differences in VOC exposures between tasks. If the $p$ values for the explained components in the model were less than 0.05, the sampling procedure would yield statistically significant differences in the sample means measured. Another hypothesis tested for was a difference in the VOC concentration levels for runs. In other words how much did the data differ between runs for a given task. If evidence was found to support this hypothesis, then it would be concluded there was a difference in the exposures measured among runs.

Logarithmic transformations were required prior to data analysis to stabalize the variance and satisfy the assumption of a normal distribution. The dependent variable was log concentration. Separate ANOVAs were performed for each task among runs, for each task within a run, and for each occurrence of a task within a given run. Statistical significance was defined as those effects having a probability level of 0.05 or less. Each statistical analysis was performed using SAS's General Linear Models (GLM) procedure (SAS Institute Inc., 1993) provided by the Statistics Department at Colorado State University.

## Project 2: Field Evaluation of a Portable PID for Assessing Exposure to Solvent Mixtures

The primary purpose of this project was to evaluate the response of a portable PID for assessing exposure to solvent mixtures during construction painting tasks. The time-weighted average (TWA) total solvent concentration of the personal breathing zone charcoal tube samples analyzed by gas chromatography-flame ionization detection (GC-FID) were compared to the PID TWA solvent concentration for identical work tasks. A secondary objective was to perform a detailed exposure assessment to determine the time-weighted average (TWA), 15-minute short-term exposure limit (STEL), and ceiling concentrations of solvent mixtures during seven different construction painting tasks utilizing a portable PID and charcoal tubes analyzed by a GC-FID. This study was conducted under true field conditions which were not affected by the presence of the investigators; therefore, the study design was observational. Some experimental work was conducted in research laboratories at Colorado State University (CSU) to obtain data on response factors and charcoal desorption efficiencies.

Any painter working at a job site in Colorado was eligible for inclusion in the study. All work sites were located in the State of Colorado with most in the vicinity of Fort Collins. Due to difficulty in obtaining volunteers, any painter using solvent-based

products willing to participate was included in the study. All participants were contacted either by telephone or in-person to volunteer. Once at the work site, eligible painters were given a consent form familiarizing them of the objectives, nature of their participation, freedom to decline to participate and to withdraw at any time, and the procedures taken to ensure confidentiality of information. The air sampling was completed over the course of 26 different sampling days in a period of 13 months.

Overview

Exposure to volatile organic solvents were monitored utilizing two sampling methods simultaneously; thereby, obtaining a set of side-by-side samples for each work task. The first method used a portable PID (MiniRAE Professional PID®) coupled to an extended data logger (DataRAE Datalogger) to continuously monitor levels of total ionizable hydrocarbons (TIHs) in the breathing zone of the worker during the various job tasks. The PID responded to all compounds with an ionization potential (IP) less than 10.6 electron volts (eV), the energy of the ultraviolet (UV) lamp in the detector of the instrument. The energy of the PID UV lamp was capable of ionizing all solvents listed on the Material Safety Data Sheets (MSDSs) of the construction coverings, except methanol and methylene chloride.

The second method collected personal breathing zone samples on standard charcoal tubes which were analyzed by a laboratory GC-FID. The charcoal tubes were used in series with a portable, battery operated pump to collect solvent vapors from the air. The charcoal tube samples were collected in the breathing zone of the worker adjacent to the sampling inlet of the PID (side-by-side) for the duration of a work task. The charcoal tube sampling results were utilized as the "gold standard" or "actual air concentration" for determining TWA concentrations of the major solvents of interest during the work task. In some instances, charcoal tube samples were collected without the corresponding PID data. The analytical results from the charcoal tube samples without PID data were used in the descriptive statistics for the seven work tasks listed below; however, the data were not used in the comparison analyses.

Characterization of Work Tasks and Environmental Conditions

This study was conducted at several different job locations including apartments, houses, schools, health clubs and public buildings. Although the nature of the work environment changed, there were seven broad categories of construction painting tasks which were monitored: 1) spraying lacquer or lacquer sealer (LQ), 2) painting pool with epoxy-based paint (PlPT), 3) spraying solvent-based paint (SpPT), 4) applying stain (ST), 5) brush/roller solvent-based paint (BPT), 6) street painting (StPT), and 7) cleaning tasks (Cl).

Although several different coating products were used during the course of this investigation, there were 19 different organic solvents which were most commonly listed on the MSDSs of the coatings. Therefore, the GC-FID analyses were limited to these 19 solvents: (1) acetone, (2) n-butyl acetate, (3) ethyl alcohol, (4) ethyl benzene, (5) n-heptane, (6) isobutyl acetate, (7) methyl alcohol, (8) methyl amyl ketone (MAK or 2-heptanone), (9) methyl ethyl ketone (MEK), (10) methyl isobutyl ketone (MIBK or 4-methyl-1-pentanone), (11) isobutyl alcohol, (12) isopropyl alcohol, (13) toluene, (14) xylenes, (15) mineral spirits*, (16) petroleum distillates*, (17) V.M.&P naphtha*, (18) 2-butoxyethanol, and (19) propyl acetate. Any remaining unidentified peaks were summed and reported as (20) n-hexane equivalents.

The compounds identified above with a * presented analytical difficulties due to their complexity, variability, and lack of published PID correction factors. A list of the 19 chemicals along with their corresponding density, molecular weight, ACGIH Threshold Limit Values (TLVs), PID response factor and desorption efficiency are presented in Table 2. PID response factors were provided by manufacturer or were developed in the laboratory by the investigator. Desorption efficiencies were estimated for all chemicals which were detected during the course of the research. Due to the similar retention

time of MAK with xylenes, MAK was reported as xylenes; therefore, no desorption efficiency was developed for MAK.

Table 2. Important parameters of the 19 solvents analyzed by gas chromatography

| ID# | Chemical | Density | VP | MW | TLV (ppm) | PID RF | DE(%) |
|---|---|---|---|---|---|---|---|
| 1 | acetone | 0.79 | 180 | 58.1 | 750 | 1.1 | 95.4 |
| 2 | n-butyl acetate | 0.88 | 10 | 116.2 | 150(200)* | 2.6 | 84 |
| 3 | ethanol | 0.79 | 12 | 46.1 | 1000 | 12 | 58.4 |
| 4 | ethyl benzene | 0.87 | 7 | 106.2 | 100 | 0.52 | 77.9 |
| 5 | n-heptane | 0.68 | 40 | 100.2 | 400(500) | 2.6 | 90.6 |
| 6 | isobutyl acetate | 0.87 | 13 | 116.2 | 150 | 5.2 L | 79.3 |
| 7 | methanol | 0.79 | 96 | 32.1 | 200(250) | N/A | - |
| 8 | MAK | 0.81 | 3 | 114.2 | 50 | - | - |
| 9 | MEK | 0.81 | 78 | 72.1 | 200(300) | 0.86 | 78.8 |
| 10 | MIBK | 0.8 | 16 | 100.16 | 50 | 1.2 | 78.6 |
| 11 | isobutyl alcohol | 0.8 | 9 | 74.1 | 50 | 9.3 L | 49.3 |
| 12 | I.P.A | 0.79 | 33 | 60.1 | 400(500) | 6 | 61.2 |
| 13 | toluene | 0.87 | 21 | 92.1 | 50 S | 0.5 | 58.4 |
| 14 | xylene | 0.86 | 9 | 106.2 | 100(150) | 0.5 | 77.4 |
| 15 | mineral spirits | 0.78 | - | 140 | 100 | 0.82 L | 52.7 |
| 16 | petrol. distillates | 0.74 | - | 97 | 100 | 1.4 L | 81.2 |
| 17 | V.M.&P. naphtha | 0.74 | - | 87-114 | 300 | - | - |
| 18 | 2-butoxyethanol | 0.90 | 0.8 | 118.2 | 25 | 4.4 L | 53.2 |
| 19 | propyl acetate | 084 | 25 | 102.2 | 200 | 3.5 | 91.0 |

* listed in the ACGIH TLV Notice of Intended Changes (for 1995-1996).

( ) indicates a TLV for a STEL

S chemical with an ACGIH skin designation.

L indicates a response factor estimated from lab data; other response factors were supplied by manufacturer.

Source of density, vapor pressure, molecular weight and TLV data (NIOSH, 1994).

In addition to the exposure data, other information pertaining to the task and work environment was collected. Temperature and relative humidity were recorded several times during the course of a work task and averaged to obtain a single value for each set of samples. Data was gathered on other important parameters such as the coating constituents, method of application, and equipment used for the various tasks.

PID Procedures

The MiniRAE™ Professional PID with DataRAE extended data logger were secured to a waist belt and worn by painters for the duration of a work task. The PID used a three foot length of Tygon/Teflon-lined tubing to collect air from the breathing zone of the painter and deliver to the UV lamp of the instrument. A water trap was inserted at the sampling inlet at the end of tubing to prevent damage to the instrument. The air sampling pump of the PID operated at a flow rate of approximately 220 ml/min. The PID provided an instantaneous reading every one second in isobutylene equivalent part per million (ppm) of TIHs.

The PID was pre-calibrated utilizing a "zero gas" and a span gas, of 101 ppm isobutylene, following the operation manual instructions for the bag technique (RAE Systems Inc., 1993). The instrument was allowed to operate for at least 5 minutes prior to calibration. The "zeroing" of the instrument was performed by placing an activated charcoal filter at the end of the sampling inlet. The calibrant gas was provided by Scott Specialty Gases® in compressed gas cylinders of 101 ppm isobutylene in balance air containing 20.5% oxygen and 79.5% nitrogen. The isobutylene gas cylinder was attached to a 1-L Tedlar® bag with a small piece of Tygon tubing. After purging the Tedlar® bag, the regulator on the gas cylinder was turned on and connected to the Tedlar® bag. Once the bag was 3/4 filled, the PID sampling inlet was attached to the bag for calibration while the gas cylinder was left on.

For solvents without manufacturer supplied response factors, laboratory derived response factors were developed by the investigator. By using a static calibration technique, standards of known concentration were prepared in triplicate by introducing a known volume of the solvent into a known volume of air (Supelco, Inc., 1977). The standards were prepared in 40-L Tedlar® bags using a Hamilton® microliter syringe to inject the solvent into the bag. The PID was attached to the three standards and the readings were recorded. The response factor was derived from the average of the three trials by dividing the concentration of the standard by the PID readings.

Sampling data from the PID was stored in a portable extended data logger, the DataRAE®, to facilitate later analysis. The DataRAE® was capable of storing up to 16,000 data points in the memory. Due to data logging memory restrictions, the PID was programmed to provide an average isobutylene equivalent ppm concentration of TIHs over a three second sampling interval (the average of three, one second readings). The data logger was enabled from the beginning to the end of each work task. The data was downloaded to a PC and saved in PRORAE-80® and EXCEL® software programs. The time-weighted average (TWA), short-term exposure limit (STEL) and ceiling concentrations were obtained from the EXCEL® software by graphically reviewing the data. The PID TWA isobutylene equivalent ppm was obtained by averaging all three-second average readings obtained during a job task. The STEL value was the highest 15-minute exposure period for each work task. The ceiling value was the highest single three second average reading for each task.

Analytical Procedures

The GC-FID analytical results of the charcoal tube samples were utilized for evaluating the ability of the portable PID to assess exposure to solvent mixtures. The charcoal tube samples were collected in the breathing zone of the painter adjacent to the PID inlet for the various work tasks. The TWA concentrations obtained from the GC-FID analyses were employed as the "gold standard" or “actual air concentrations” for assessing worker exposure to solvent mixtures. Gilian® 5 Personal Air Samplers with

SKC® Sorbent Sample Adjustable Low-Flow Tube Holders along with SKC® Lot 120 charcoal tubes (100mg/50 mg) were used to collect two or three charcoal tube samples simultaneously. The charcoal tube sampling methods used were identical to those described in Project 1.

Gas Chromatography Analysis

The charcoal tube samples were analyzed in the Department of Environmental Health's Analytical Toxicology Laboratory at Colorado State University. The laboratory technician developed a 30-minute assay to scan for the 19 solvents of interest which utilized a single column, a temperature ramp and a flame ionization detector (FID). Unfortunately, the assay was unable to provide reasonable separation between o-xylene and MAK due to their similar retention times. Therefore, the solvent scan was limited to the identification of 18 different solvents since any MAK was reported as xylenes.

To prepare the sample for analysis, the charcoal was desorbed in 1 ml carbon disulfide for 20 minutes using a SKC® developing vibrator and 1.8 ml glass septum vial. The front and back sections of the charcoal tubes were analyzed separately to detect "breakthrough" of contaminants from the front to back section. After the 20-minute desorption period, the sample was analyzed for the 18 solvents using a Hewlett Packard® 5890 gas chromatograph equipped with a flame ionization detector (GC-FID). The GC was equipped with a 25-meter Rustek® MTX-502.2 capillary column using helium as a carrier gas which was operated at a flow rate of 9.5 ml/min. The detector temperature was 250 °C and the injector temperature was 225 °C. Five microliter injections of the samples and standards were introduced into the GC-FID using the "solvent flush" technique (Supelco, Inc., 1977).

The instrument was calibrated using prepared volumetric standard solutions of the solvents in carbon disulfide of six different concentrations. Solvent standards were obtained from Chem Service Inc.® and were reported to have a 99.9% purity. A six-point calibration curve was obtained by injecting 5 microliter of each standard and

plotting concentration versus area response. Solvent peaks were compared to the calibration curves to determine the concentration of each solvent in the sample. All unidentified peaks were summed and compared to a n-hexane calibration curve. An internal standard of 2-pentanone was incorporated into the method to eliminate operator variability in the volume of sample injected.

The desorption efficiency of carbon disulfide for charcoal was tested for all solvents found in samples by injecting a known amount of each solvent onto the charcoal (RAE Systems Inc., 1993). Unused charcoal tubes were taken and the 100 mg front section were removed and placed in a septum sealed vial. Three different volumes of each solvent were injected onto the 100 mg of charcoal by piercing the septum cap with a microliter syringe. The sealed vials were allowed to stand for 24 hours to assure complete absorption of the solvent on the charcoal. The three treated charcoal samples and a blank were desorbed and analyzed in the same manner as the sampling tubes described previously. Standards were prepared by injecting the same volume of solvent into 1.0 ml of carbon disulfide as used in the sample vials. The desorption efficiencies (DE) were determined by:

$$DE = \frac{\text{mass of charcoal sample}}{\text{mass of standard}}$$

Several procedures were implemented to assure the quality of the GC results including interlaboratory checks, field blanks, and laboratory spikes. Interlaboratory checks performed by Industrial Hygiene Technologies Inc. were conducted on two sets of samples which were collected during the spray application of lacquer. Field blanks were collected daily and analyzed with every set of samples. Any mass detected on the field blank was subtracted from all samples from that day of sampling. Laboratory spikes were performed on a weekly basis by the laboratory technician as part of the quality assurance procedures.

Data Analysis

In order to save the PID data, the extended data logger was downloaded with the PRORAE® software after each sampling day. The PID data from the PRORAE® software was transferred to the spreadsheet program, Microsoft Excel®. With Microsoft Excel®, the three-second average ppm concentrations were graphed and averaged to provide a time-weighted average (TWA), short-term exposure limit (STEL), and a ceiling concentration in isobutylene equivalent ppm for each job task. The PID TWA isobutylene equivalent ppm (PID ppm) was used to express total solvent exposure and was used in comparison to the GC-FID total solvent exposure.

For charcoal tube samples the laboratory reported the mass (mg) of each solvent for the front and back sections of each tube. The GC samples were reported in micrograms (mg) of contaminant which were divided by the desorption efficiency (DE) for that solvent to provide the actual mass of solvent. The final air concentrations were calculated by dividing the mass of solvent by the volume of air sampled and converting to the site concentration in part per million (ppm). The equations for the above calculations are listed below:

$$\text{actual mg of contaminant} = \frac{\text{reported mg of contaminant}}{\text{DE}}$$

$$\frac{\text{mg of contaminant}}{V_s} = \text{mg/m}^3 \text{ of contaminant}$$

$$\text{ppm}_{(\text{site})} = \frac{\text{mg/m}^3 (V_{ms})}{\text{MW}}$$

where:

mg = micrograms of contaminant

| | | |
|---|---|---|
| $V_s$ | = | volume of air sampled in cubic meters |
| $mg/m^3$ | = | concentration of air contaminant |
| $V_{ms}$ | = | molar volume of air @ 640 mm Hg & 25 °C |
| MW | = | molecular weight of contaminant |
| $ppm_{(site)}$ | = | concentration of contaminant at work site |

For each charcoal tube sample, the TWA concentration of all solvents detected were summed to provided a measure of total solvent exposure. For total solvent exposure from GC-FID method, the concentration of chemicals not detected by the PID (methanol) were not included in the measure.

In addition to the total solvent exposure comparison, the TWA solvent concentrations from the GC-FID and the PID method were incorporated into the ACGIH mixture calculation for comparison to TLV-TWA which assumes additive effects (ACGIH, 1995):

$$\text{The TLV of mixture} = \frac{C_1}{T_1} + \frac{C_2}{T_2} + \frac{C_3}{T_3} + .... = 1$$

where:

$C_1$ = concentration of solvent

$T_1$ = TLV-TWA of that solvent

If the sum of all solvent ratios exceed unity then the worker is determined to have exceeded the TLV-TWA for that particular mixture. Since the GC-FID analyses provided data for almost all solvent components of the mixture, the above equation was utilized for comparison to a TLV.

However, since the concentrations of each component are unknown for the PID data, a TLV-TWA for the mixture was calculated from the percent composition data of the

MSDSs. When the source of contaminant is a mixture and the atmospheric composition is assumed to be similar to that of the original material, a TLV for the mixture can be calculated if the percent composition of the liquid material is known (ACGIH, 1995).

$$\text{TLV of mixture} = \frac{1}{\frac{f_a}{TLV_a} + \frac{f_b}{TLV_c} + \frac{f_c}{TLV_c} + \ldots \frac{f_n}{TLV_n}}.$$

where:

$f_a$ = % composition of constituent a by weight

$TLV_a$ = TLV of constituent a in $mg/m^3$

The composition data used to develop the TLV for the each mixture was obtained by reviewing the MSDSs of the products used and calculating a percent composition for each solvent listed. The PID TWA total solvent exposure was divided by the calculated TLV of the mixture to provide a measure which is based on unity, thus directly comparable to the GC-FID TLV mixture calculation.

Statistical Analysis

The statistical analysis was performed on all data to explore the relationship between the PID response and the GC analytical results for the side-by-side sample sets. The comparison of PID response and the GC analytical results were investigated by using linear regression analysis with Minitab Inc.® Statistical Software Package. Because the variation about the regression line was expected to be lognormal, the data were log transformed prior to performing the regression analyses. Three separate linear regressions were performed to evaluate the ability of the PID for assessing exposure to painting solvent mixtures using the PID results as the dependent variable and the GC-FID analytical results as the independent variable.

The first regression was between the log PID total solvent exposure and the log GC-FID total solvent exposure. By exploring the statistical relationship between the PID results and the GC-FID results, the amount of variability in the PID results explained by the GC-FID results was determined. In order to justify the use of linear regression, several important statistical assumptions were tested. The assumption of normality, linearity and homoscedicity were evaluated in all final models. Due to the known effects of humidity on the PID response, relative humidity (%RH) was tested for significance in the model. The second regression analysis was performed between the PID TLV mixture calculation and the GC-FID TLV mixture calculation. Since both results were calculated on unity being the basis for exceeding the TLV, the results were directly comparable. Lastly, a regression was conducted between the log PID isobutylene equivalent ppm and the log response factor predicted PID isobutylene equivalent ppm. This analysis attempted to evaluate the effectiveness of response factors when assessing exposure to paint solvent mixtures.

**Project 3: Comparison of Sampling Methods for Evaluating VOC Exposures During the Spray Application of Lacquer**

The primary objective for this project was to examine the capabilities of charcoal sorbent tubes, passive samplers, prefiltered charcoal tubes and vapor/aerosol samplers to accurately and precisely determine volatile organic compound (VOC) exposures for specific work tasks in construction painting. The time-weighted average (TWA) concentrations of organic solvents obtained from different samplers were compared to each other.

This study was conducted at several construction sites where painters were spraying lacquers and sanding sealers. All sampling was conducted under true field conditions which were not affected by the presence of the investigators. Work sites were located in Fort Collins, Colorado. Information pertaining to the task and work environment

was collected, including material safety data sheets (MSDS), spray pressure, tip size, spray gun, surface type, room size and sampler location. Air temperature, relative humidity and air velocity were also recorded during the course of a work task for each set of samples (See Appendix II).

Sampling Devices

There were four types of sampling devices used in this study: charcoal sorbent tubes, passive samplers, prefiltered charcoal tubes and vapor/aerosol samplers.

The charcoal tube sampling method involved a sorbent tube connected to a calibrated personal sampling pump to measure workers' exposure to airborne organic vapors and the procedures followed those described in Project 1. The charcoal sorbent tubes used were small tubes (SKC 226-01 Lot 2000, 6 mm o.d. x 70 mm, coconut charcoal sorbent, 20/40 mesh, 100/50 mg).

A passive diffusion-type organic vapor sampler was a lightweight badge that relied on natural wind currents rather than pumps to move contaminated air to the collection surface. Airborne chemicals passed through a barrier and then they were collected on a charcoal adsorbent. The passive sampler used in this study was obtained from SKC Inc. (SKC 575-001, charcoal sorbent, 350 mg).

A prefiltered charcoal tube is recommended in an environment where vapors and aerosols are both present. The IOM sampler (SKC 225-70) incorporating a reusable filter cassette, a 25 mm filter (SKC 225-702 AE glass fiber) and a sampling head collects inhalable dust as recommended by the American Conference of Governmental Industrial Hygienists. When connected to a charcoal sorbent tube (SKC 226-16, 10 mm o.d. x 110 mm, coconut charcoal sorbent, 800/200 mg), the charcoal sorbent tube would capture not only vapor but also vaporized droplets.

A vapor/aerosol sampler also obtained from SKC Inc. consisted of a sample flow inlet nozzle (1.0 mm), an anisokinetic tube, a 25 mm glass filter (SKC 225-702 AE), and two charcoal sorbent tubes (SKC 226-16, 10 mm o.d. x 110 mm, coconut charcoal sorbent, 800/200 mg). The flow inlet nozzle was aligned at the centerline of the anisokinetic tube and at the center of the filter disc. The vapor in the air was divided into two dichotomous flow portions which were collected by two on-line charcoal sorbent tubes. The tube behind the filter served as a filter backup to collect the vapor portion that evaporated from the aerosol collected on the filter during the sampling process.

Exposure Monitoring

A typical test stand sampling array consisted of the following four types of samplers placed side by side:

1) A charcoal sorbent tube (CT);
2) A passive sampler (PS);
3) A prefiltered charcoal tube (FC); and
4) A vapor/aerosol sampler (VA)

The first two sampler types were expected to measure only vapor exposures, while the third and fourth samplers captured both droplets and vapors. The sequence of these four samplers was assigned randomly for each trial. No personal sampling was conducted in this experiment because too many pumps were needed for the four sampling methods. The test stand consisting of four sampling devices was carried to follow the painters determining airborne concentrations within six feet of the workers breathing zone

The charcoal sorbent tubes were operated at a flow of 0.2 L/min. The sampling rates for the passive vapor samplers were taken directly from the manufactures' instructions, 0.0145 L/min for toluene and 0.0125 for m-xylene for example. The prefiltered charcoal tubes were operated at flows of 2.0 L/min. The vapor/aerosol samplers were

operated at a flow of 1.0 L/min for each outlet to two on-line charcoal tubes. The air sampling pumps (SKC Airchek$^{TM}$50 224-51 or Airchek 224-43XR) were connected to each sampler by Tygon tubing. All flows were checked with a direct-reading bubble meter (Gilian Gilibrator) before and after each sampling.

Sampling time for each trial varied from 5 to 20 minutes due to different room sizes. At the end of the sampling time, the filters for the IOM samplers and the vapor/aerosol samplers were removed from the cassettes and placed in vials immediately. The charcoal tubes for different samplers and badges were removed and capped or sealed immediately to avoid any further contamination. All vials, tubes and badges were placed in a cooler in the field to prevent further evaporation of volatile compounds. At the laboratory the samples were kept in a refrigerator (2°C) until gas chromatography analysis. The glass fiber filters were analyzed within two days of sampling and the remaining samples (sorbent tubes and passive samplers) were analyzed within two weeks.

Sample Preparation

Samples were desorbed with $CS_2$ and analyzed by gas chromatography according to a method similar to the NIOSH analytical methods for organic solvents in air. Some variations were necessary to accommodate the complex mixtures of solvents found. Approximately 150 charcoal tubes, 30 passive samplers and 28 filter samples were analyzed in the study, including approximately 36 charcoal tube and 12 passive sampler spiked samples.

For charcoal tubes, the front and back sorbent sections were placed in separate vials and the glass wool and foam plugs were discarded. Volumes of 1.0 mL and 3.0 mL of $CS_2$ were added to the vials for small and jumbo tubes, respectively. Then Teflon lined caps were attached to each vial immediately. The vials were placed on a developing vibrator (SKC 226D-03) to stand 30 minutes with occasional agitation.

Sample preparation for passive samplers was performed according to SKC's instructions. The samplers were desorbed by addition of 2.0 mL $CS_2$ (added slowly) and shaked on a sorbent extractor shaker (SKC 226D-03-1) for 1 hour. The filters placed into vials in the field were desorbed by adding 3.0 mL of $CS_2$ and shaked on a developing vibrator (SKC 226D-03) for 30 minutes. Then five microliter samples were withdrawn from each vial and analyzed by gas chromatography.

Gas Chromatography (GC) Analysis

The analysis of volatile organic compounds were performed on a Hewlett-Packard Model 5890 gas chromatography (GC) equipped with a 30m x 0.53 mm i.d. x 3 microns MXT-502.2 (Restek Corporation, Bellefonte, PA) megabore column, and a flame ionization detector (FID). The operating conditions were as follows: detector temperature 250°C; injector temperature 225°C; oven temperature 40°C for 6 min, increased at 5°C $min^{-1}$ to 140°C and held for 2 min; carrier gas: helium at 10.0 ml/min. The gas flow for the detector: Air 610 mL/min; Hydrogen 50 mL/min. The output signal of the GC was connected to an integrator (Hewlett-Packard Chemstaton 3365 ) and operated in the peak area mode.

Two mixture organic solvent standards were prepared on the basis of a better separation in the GC. Mixture I standard consisted of: methanol, isopropyl alcohol, methyl ethyl ketone, n-heptane, toluene, n-butyl acetate, m-, p-, and o- xylene, and 2-butoxyethanol. Mixture II standard consisted of ethanol, acetone, isobutyl alcohol, benzene, methyl isobutyl ketone, isobutyl acetate, ethyl benzene, 2-heptanone, and 2-butoxyethyl acetate. The standard curves were established for these nineteen compounds by using the same operating conditions on the GC as were used for the unknown samples. Two six-point calibration curves were generated for each solvent using concentration ranges of approximately 0-100 μg and 10-2004 μg of solvent per mL of $CS_2$. Correlation coefficients ($r^2$) were close to 1.000 for each calibration curve. Appendix II, Table 1 lists the concentration ranges and correlation coefficients ($r^2$) for each calibration curve.

The mass of a volatile organic solvent desorbed from the sampling media was calculated by inserting the peak area into the regression equation generated from the calibration curve for the particular solvent, and then multiplying by the amount of desorbing solvent used.

Desorption efficiency (DE)

Desorption efficiency (also known as analytical recovery) was determined for the nineteen organic compounds by injecting a known quantity of the mixture standard onto charcoal sorbent. It was determined separately for small charcoal tubes, jumbo charcoal tubes and passive samplers at three levels of loading in duplicate.

Two techniques for spiking known quantities of mixture standards on charcoal tubes were used to determine desorption efficiencies: 1) direct spiking of a known standard solution of analyte in $CS_2$ onto the front section of a charcoal tube; 2) transferring the front section of a charcoal tube (100 mg charcoal) into a vial with Teflon lined cap followed by spiking of a known standard solution into the vials. The back sorbent sections were removed and discarded. The sealed tubes and vials were placed in a refrigerator (2°C) to stand overnight to assure complete absorption of the solvent on the charcoal.

Desorption efficiencies for passive samplers (SKC 575-001, charcoal sorbent, 350 mg) were determined by spiking a known amount of standard solution analyte in $CS_2$ directly into passive samplers. The O-rings were sealed all around the samplers before injection and the plugs were tightly pressed in place after injection. The samplers were placed in a refrigerator (2°C) to stand overnight.

The treated tubes and vials were desorbed and analyzed in the same manner as the sampling tubes described previously. Standards were prepared by injecting the same volume of solvent into 1.0 mL of $CS_2$ as used in the sample vials. The desorption efficiencies (DE) were determined by:

$$DE\ (\%) = \frac{\text{mass of sample}}{\text{mass of standard}} x\ 100$$

Data Analysis

The TWA concentrations obtained from the four types of samplers were analyzed with analysis of variance (ANOVA) using SAS statistical software (SAS Institute, Cary, N.C.). Since the ANOVA could not specify which means differed, Duncan's Multiple Range Test was conducted to identify means that were significantly different (SAS Institute Inc., 1988). The TWA concentrations for the four types of sampling devices were calculated as follows.

(a) Charcoal tube: after determining the mass of a VOC found in the sample front and back sorbent sections, the mass of each solvent was divided by the desorption efficiency for that solvent to provide the actual mass of solvent. The final air concentrations were calculated by dividing the mass of solvent by the volume of air sampled. The equation for the above calculations were listed below:

$$C_{ct} = \frac{(W_f + W_b) - (B_f + B_b)}{DE \times V} \qquad \text{eq. 1}$$

where:

$C_{CT}$ (mg/m$^3$) = concentration of a VOC for a charcoal tube

$W_f$ (mg) = mass found in front sorbent section of sample

$W_b$ (mg) = mass found in back sorbent section of sample

$B_f$ (mg) = mass found in front sorbent section of blank

$B_b$ (mg) = mass found in back sorbent section of blank

DE (%) = desorption efficiency

V (m$^3$) = volume of air sampled

(b) Passive sampler: after determining the mass of a VOC found in the sample, the mass of each solvent was divided by the desorption efficiency for that solvent to provide the actual mass of solvent. Air concentration of each analyte was calculated using equation 2:

$$C_{ps} = \frac{W_p - B_p}{DE \times V} \qquad \text{eq. 2}$$

where:

$C_{PS}$ ($mg/m^3$) = concentration of a VOC for a passive sampler

$W_P$ (mg) = mass found in the passive sampler

$B_P$ (mg) = mass found in the blank passive sampler

DE (%) = desorption efficiency

V ($m^3$) = volume of air sampled

Sampling rates were taken directly from manufacture's instruction.

(c) Prefiltered charcoal tube: after determining the mass of a VOC retained on filter, the air concentration of analyte was calculated using equation 3:

$$C_F = \frac{W_{filter} - B_{filter}}{V} \qquad \text{eq. 3}$$

where:

$C_F$ ($mg/m^3$) = concentration of a VOC for a filter

$W_{filter}$ (mg) = mass found in the sample filter

$W_{filter}$ (mg) = mass found in the blank filter

V ($m^3$) = volume of air sampled

Air concentration of a VOC for the charcoal tube behind the filter was calculated using equation 1. Then these two concentrations were added together to be the TWA concentration of VOCs for prefiltered charcoal tube.

(d) Vapor/aerosol sampler: the air concentrations of a VOC in the particulate phase and in the gas phase were determined based on measured values of the masses collected on the filter and two charcoal sorbent tubes, and the sample inlet flowrate and two dichotomous flowrates as:

$$C_v = \frac{M_{fct}}{Q_v \times t}$$

$$M_p = C_p \times (Q_0 \times t) = (M_f + M_{bet}) - [\frac{Q_p}{Q_v}] \times M_{fet}$$

$$C_p = \frac{M_p}{Q_0 \times t}$$

$$Q_0 = Q_p + Q_v$$

where:

$C_v$ (mg/m$^3$) = the air concentrations of a VOC in the vapor phase

$C_p$ (mg/m$^3$) = the air concentrations of a VOC in the particulate phase

$M_f$ (mg) = the mass of a VOC collected on the filter

$M_{fct}$ (mg) = the mass of a VOC collected in the front charcoal tube

$M_{bct}$ (mg) = the mass of a VOC collected in the back charcoal tube

$M_p$ (mg) = the mass of a VOC in the particulate phase

$Q_0$ (m$^3$/min) = the sample inlet flowrate

$Q_v$ (m$^3$/min) = the dichotomous flowrate for the front charcoal tube

$Q_p$ (m$^3$/min) = the dichotomous flowrate for the back charcoal tube

t (min) = sampling time

Then the concentrations of a VOC in the particulate phase and in the gas phase were added together to calculate the TWA concentrations of VOCs for the vapor/aerosol sampler.

In addition to the solvent exposure comparison for each sampling device, the TWA solvent concentration from the charcoal tube method was incorporated into the ACGIH

mixture calculation for comparison to TLV-TWA which assumes additive effects (ACGIH, 1994):

$$\text{The TLV of mixture} = \frac{C_1}{T_1} + \frac{C_2}{T_2} + \frac{C_3}{T_3} + \ldots\ldots = 1$$

where:

C1 = the observed VOC concentration

T1 = the corresponding threshold limit (TLV-TWA)

If the sum of all solvent ratios exceeded unity then the worker was determined to have exceeded the TLV-TWA for that particular mixture.

**Project 4: Task Exposure Matrix and Summary of Questionnaire Data**

The primary object of this project was to develop a method in which the specific work tasks in construction painting can be quantitatively evaluated in order to improve the overall assessment of exposure. Exposure profiles based on specific tasks were determined and stored in a database for later retrieval and development of overall exposure estimates. Data were obtained as part of Projects 2 and 3 and other data used in the analysis were collected soley as part of this project.

Exposure data, obtained using PID, charcoal tubes and GC analysis, or passive dosimeters and GC analysis, were entered into one data file and field information that characterized the task and work environment was entered in another. Additionally, data from completed questionnaires were entered in another file. These files were linked by subject number and were merged in to build the task exposure matrix.

Video recordings made at the jobsites were reviewed to conduct activity analyses. Each job task consists of a series of distinct elements, and these elements were identified and assigned unique codes. For example, to apply lacquer by spray to wood trim in

residential construction, a number of tasks must be performed such as assembling equipment, ensuring the surface is prepared, preparing the equipment for application, applying the coating, and equipment cleanup. Each task is made up of a series of elements which were the focus of the activity analysis.

Detailed task analyses using video recordings and PID data were very time consuming and a decision was made to perform such work on a small number of construction painting processes. Additionally, the use of VEM was limited because very few painters volunteered to wear the required equipment (see Project 1). Application of lacquer and sander sealer to wood, application of stain to wood, and application of solvent based paint to metal doors and door trim were selected for detailed VEM analyses, as they are common tasks performed by construction painters and there is the potential for significant VOC exposure. Data obtained through this video exposure monitoring was entered into the databases described above.

Although the focus of this investigation was to improve the evaluation of exposure in construction painting, a short questionnaire was developed to assess the prevalence of symptoms related to the acute effects of exposure to solvents. This short questionnaire required about 15 minutes to complete and was given to workers at the work site. Self reported symptoms such as dizziness, fatigue, poor coordination, trouble concentrating, trouble remembering, feeling "high", feeling tense, nausea, and headache were scored on a Likert-type four point scale (not at all, a little, sometimes, often). These symptoms are most reflective of the acute effects of organic vapor exposure, and although their determination in no way provides an in-depth assessment of neurobehavioral effects, they may provide an indication of effect.

The questionnaire also contained a number of items regarding work tasks performed over the past year as well as items on the use of protective equipment. A number of items were identical to those used by Fidler et al. (1987a; 1987b) to estimate past exposures to VOCs in construction painters. One important use of the questionnaire

data on painting tasks was to estimate the overall prevalence of possible exposures to VOCs in the construction painting population.

Statistical Analysis

The first stage in the data analysis was to plot exposures of individual construction painters as a function of job tasks and time. Some examples of these plots are contained in the Appendix III. Descriptive statistics were conducted to provide measures of central tendency and variation of exposure results based on specific work tasks. Analysis of variance was conducted to assess the relationship of task performed and TWA, STEL, and ceiling exposure concentrations (values in ppm). STEL and ceiling values were obtained from PID data, while the TWA data may have been obtained from either PID or GC data. If both GC data and PID data were available for a task the GC data (total VOC in ppm units) was used in the statistical analyses. Multiple linear regression was used to develop models in which characteristics of the task and environment were used as predictors of the exposure levels.

# 4. Results and Discussion

## Project 1. Development of the Video Exposure Monitoring Technique

This study was designed and executed in order to test the hypothesis that implementation of the video exposure monitoring method would yield data that statistically defined the volatile organic compound exposure of tasks within a wood staining job run. In other words, did the exposure data of one task differ significantly from the data of the other tasks that made up the job activity. Another hypothesis to be tested was that exposures from the same task compared among runs would differ significantly ($p < 0.05$). If this hypothesis were true, then factors among runs were causing the difference and attempts to explain the error in the exposure model would be made using video analysis of the job activity.

Just as important as the testable hypotheses of this study was the investigation of the field implications and "user friendliness" of video exposure monitoring to study coating trade workplace exposures. The literature has shown very little use of this technique in studying the chemical inhalation exposure of coating application trades. What are the measurable parameters of the tasks that make up staining wood in the study's chosen workplace? How can these parameters explain the measured exposure for risk assessment purposes? Can VEM be used to give more timely exposure information to management and the worker than traditional interval sampling?

Data Distribution

Five sampling runs were conducted over three days in the spray room of the manufacturing site. A total of 8,592 direct-reading VOC datapoints were obtained using the HNU PID. Because of autocorrelation among the data, only every third concentration reading was included in the data for statistical analysis. Thus 2,864 samples were included in the data analysis. Seven tasks comprised the job of spraying wood stain on cabinet pieces. The distribution of the number of samples taken for tasks and runs respectively is included in Tables 3 and 4. The arithmetic mean VOC concentration was 26.5 parts per million and the geometric mean concentration was 1.237 ppm for all samples. Table 5 contains a summary of the analysis of variance results.

Comparison of Task Concentration

Seven tasks were regularly included in a wood stain spraying job activity. Detailed descriptions of each task were described in the Methods section (Task analysis methods). The code numbers assigned to each activity were as follows:

| **Task** | **Description** |
|---|---|
| 1 | Table Spraying |
| 2 | Pause between Spraying |
| 3 | Wipe-down |
| 4 | Conveyor Spraying |
| 5 | Sanding |
| 6 | Handling Solvent |
| 7 | Other |

The data in Table 3 represents the log of the mean adjusted VOC concentration for the tasks for all runs combined. The concentration difference between each task was shown to be highly significant ($p < 0.0001$) by the nested ANOVA. For clarity of comparison, Figure 2 shows a chart of the mean adjusted log concentrations[2] for the sampled tasks.

[2] Mean adjusted log concentration is calculated by least square means analysis on SAS.

Table 3. Task mean adjusted log concentration and standard errors for all runs.

| TASK | N | MEAN LCONC ppm | SE of LCONC |
|---|---|---|---|
| Table Spraying | 327 | 1.30 | 0.06 |
| Pausing Between Spraying | 475 | 1.13 | 0.05 |
| Wiping Down | 92 | 1.57 | 0.11 |
| Conveyor Spraying | 518 | 1.40 | 0.05 |
| Sanding | 204 | 1.14 | 0.08 |
| Handling Solvent | 169 | 1.65 | 0.08 |
| Other | 1079 | 1.12 | 0.03 |

N= number of samples
MEAN LCONC = Mean log concentration determined by Least Square Means analysis
SE= Standard error

The solvent handling and wipe down tasks showed the highest mean adjusted log VOC concentrations at 1.65 and 1.57 parts per million respectively. The solvent handling task was performed in only two runs for relatively short periods of time. Solvent exposure in the bulk storage area was the highest recorded for any distinct area (up to 450 ppm for 10-15 seconds). The wipe down task involved the worker leaning over to hand wipe the sprayed pieces and therefore the higher exposure was anticipated.

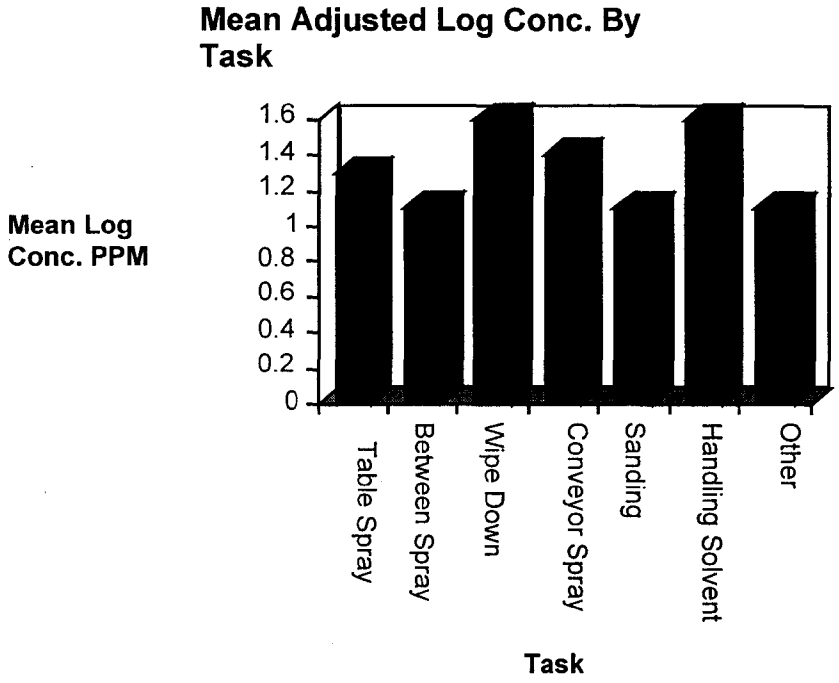



Figure 2. Mean adjusted log conc (ppm) of each task (all runs combined).

Conveyor spraying showed a higher log concentration (1.40) than table spraying (1.30). This finding was surprising, since table spraying involved the worker occasionally leaning over the sprayed objects and breathing air which should have had higher VOC concentrations. However, the exposure level for conveyor spraying was influenced markedly by the spraying of large surface area cabinet panels (See Table 4, task number 4). When the panels were turned for spraying, a significant amount of solvent-laden air was directed toward the worker's breathing zone. The two runs that did not contain these large panels had exposure levels for the conveyor spraying task that were two to three times lower. This is an example of variation that was not explained in the model and is, therefore, a source of error that will be discussed in greater detail later in this chapter.

The lowest exposure tasks were task 2, pausing between spraying (1.13 ppm), task 5, sanding (1.14 ppm), and task 7, the "other" (1.12 ppm) category which contained a lot of set up activity. The pause between spraying task concentration was low because the spray booth ventilation was drawing the solvent vapor away from the worker's breathing zone. Sanding and "other" were theorized to be low exposure tasks because they did not have spraying activity closely associated in time with the performance of these duties. See Table 4 for task mean concentrations for each run.

Table 4 Task means for each run. All concentration data in parts per million.

Task 1 Table Spraying

| RUN | N | MEAN CONC ppm | SD CONC | MEAN LCONC ppm | SD LCONC |
|---|---|---|---|---|---|
| 10103 | 38 | 14.2 | 3.1 | 1.17 | 0.08 |
| 10118 | 136 | 29.7 | 20.6 | 1.38 | 0.32 |
| 101310 | 283 | 28.7 | 26 | 1.36 | 0.29 |
| 101312 | 530 | 14.2 | 14.2 | 1.09 | 0.26 |

Task 2 Pausing Between Spraying

| RUN | N | MEAN CONC ppm | SD CONC | MEAN LCONC ppm | SD LCONC |
|---|---|---|---|---|---|
| 10103 | 75 | 15.2 | 5.3 | 1.19 | 0.12 |
| 10116 | 62 | 30.0 | 19.5 | 1.41 | 0.25 |
| 10118 | 142 | 12.7 | 8.8 | 1.04 | 0.31 |
| 101310 | 367 | 15.5 | 11.1 | 1.15 | 0.23 |
| 101312 | 773 | 9.6 | 6.7 | 0.95 | 0.24 |

Task 3 Wipe Down

| RUN | N | MEAN CONC ppm | SD CONC | MEAN LCONC ppm | SD LCONC |
|---|---|---|---|---|---|
| 10103 | 253 | 56.4 | 50.7 | 1.58 | 0.41 |
| 101312 | 25 | 26.6 | 28.6 | 1.28 | 0.37 |

Table 4 (continued)

Task 4 Conveyor Spraying

| RUN | N | MEAN CONC ppm | SD CONC | MEAN LCONC ppm | SD LCONC |
|---|---|---|---|---|---|
| 10116 | 302 | 63.2 | 40.4 | 1.71 | 0.29 |
| 10118 | 907 | 45.0 | 26.4 | 1.6 | 0.22 |
| 101310 | 338 | 21.1 | 13.8 | 1.24 | 0.32 |

Task 5 Sanding

| RUN | N | MEAN CONC ppm | SD CONC | MEAN LCONC ppm | SD LCONC |
|---|---|---|---|---|---|
| 10103 | 27 | 9.3 | 6.5 | 0.93 | 0.27 |
| 10116 | 216 | 20.1 | 6.2 | 1.31 | 0.13 |
| 10118 | 360 | 23.2 | 10.1 | 1.34 | 0.2 |
| 101312 | 9 | 9.1 | 4.7 | 0.96 | 0.2 |

Task 6 Solvent Handling

| RUN | N | MEAN CONC ppm | SD CONC | MEAN LCONC ppm | SD LCONC |
|---|---|---|---|---|---|
| 10103 | 270 | 26.5 | 30 | 1.27 | 0.37 |
| 10116 | 235 | 184.3 | 136.1 | 2.08 | 0.49 |

Task 7 Other

| RUN | N | MEAN CONC ppm | SD CONC | MEAN LCONC ppm | SD LCONC |
|---|---|---|---|---|---|
| 10103 | 1059 | 9.6 | 8.2 | 0.95 | 0.24 |
| 10116 | 532 | 20.1 | 11.2 | 1.24 | 0.29 |
| 10118 | 286 | 21.7 | 17.1 | 1.26 | 0.28 |
| 101310 | 803 | 18.1 | 21.6 | 1.16 | 0.29 |
| 101312 | 554 | 9.6 | 5.8 | 0.95 | 0.27 |

Table 4 (continued)

N= number of samples
MEAN CONC= mean VOC concentration in parts per million
SD= standard deviation
MEAN LCONC= mean log of the VOC concentration in parts per million

Analysis of Variance Results

The mean of the log concentration of each task was compared to the other tasks using nested analysis of variance modeling to test the hypothesis that significant differences existed between the task concentrations. The sources of variation were differences among runs, among tasks, among occurrences of a task within the same run, and among samples within the same occurrence (known as error or residual variation). Results in Table 5 show that significant differences ($p < 0.05$) occurred between all tasks ($p = 0.0048$) but not all runs ($p = 0.0562$). The $R^2$ value which represents the variation explained by the model was 0.65.

Table 5. Analysis of variance of log conc in ppm

| Source | DF | SUMSQ | MSQ | F Value | P Value |
|---|---|---|---|---|---|
| Task | 6 | 38.30 | 6.38 | 5.31 | 0.0048 |
| Run | 4 | 14.36 | 3.59 | 2.99 | 0.0562 |
| Run*Task | 14 | 16.82 | 1.20 | 21.71 | 0.0001 |
| Occ Run*Task | 196 | 71.98 | 0.37 | 6.64 | 0.0001 |
| Error | 2643 | 146.28 | 0.05 | | |
| Total | 2863 | 423.27 | | | |

DF= Degrees of Freedom SUMSQ=Sum of squares MSQ=Mean square

Comparison of Runs

The mean log concentration of each run was tabulated and compared by least square means ANOVA and shown to have significant differences between the distribution about their mean log concentration (F value = 21.71). Table 6 lists the mean adjusted log of the VOC concentration and standard error for each run. Figure 3 shows the adjusted log means of each run.

Run number 2 had the highest log VOC exposure, 1.56 ppm, because of the performance of the solvent handling task for the longest period of time. Run number 2 also had a large amount of door spraying that directed spray vapor toward the sprayer when he turned the doors to spray the other side. Run number 3 also had a high log concentration level, 1.49 ppm. This was due primarily to the long duration of table spraying and conveyor spraying tasks and a high percentage of large surface area pieces stained.

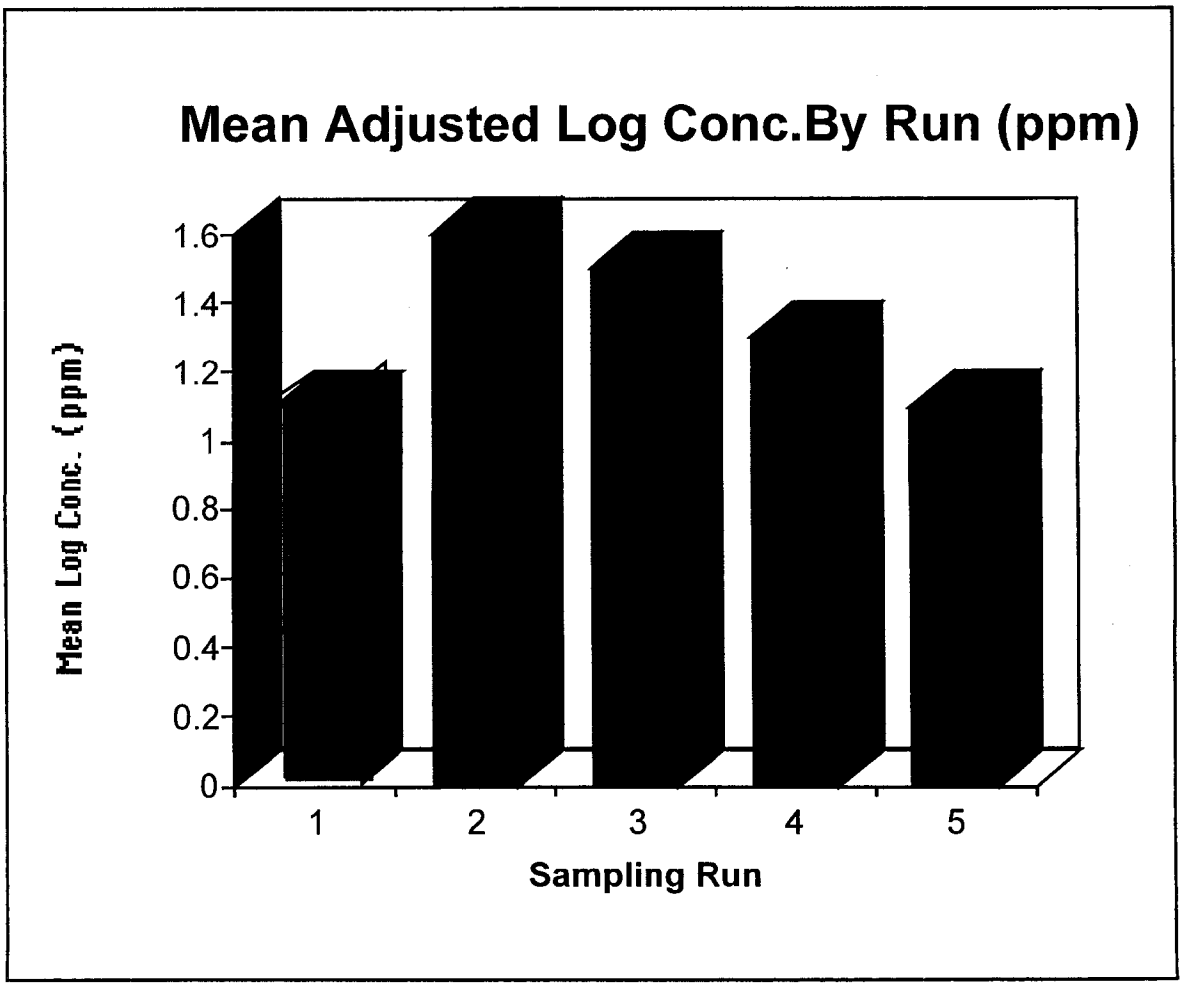
The low exposure runs, numbers one and five, had a low amount of spraying activity and large durations of low exposure tasks such as sanding and the "other" category which involved placing pieces on the conveyor hangers to be sprayed. These tasks were done far from spraying activity and had low exposure levels.

As expected, no run was identical in the combination or duration of tasks performed. Variations in the size and configuration of the pieces sprayed also were present among runs. There was also worker variation in behavior to the degree the spray table was placed within the spray booth prior to spraying. The more completely the table was within the booth the lower the average worker exposure measured. All of these factors contributed to the variation of VOC exposure among runs.

Table 6. Mean adjusted log concentration and standard error for all runs.

| Run | N | LCONC ppm | SE |
|---|---|---|---|
| #1 10103 | 490 | 1.13 | 0.05 |
| #2 10116 | 450 | 1.56 | 0.05 |
| #3 10118 | 611 | 1.49 | 0.04 |
| #4 101310 | 682 | 1.33 | 0.04 |
| #5 101312 | 631 | 1.15 | 0.04 |

LCONC= log concentration determined by least square means.




Run 1= 10103 Run 2= 10116 Run 3= 10118 Run 4= 101310 Run 5= 101312.

Figure 3. Mean adjusted log conc. (ppm) of each sampling run.

ANOVA Component Analysis

The principal components of variation explained in the exposure model were:

Variation among runs - Var (RUN);
Variation of tasks within a run - Var (RUN*TASK);
Variation of occurrences of the same task within a run - Var(OCC(RUN));
Sample variation within a task - Var(Error).

The results of the variance of components analysis are listed in Table 7. This data shows some variation among the runs and occurrences within a run for the same task. The components explained by the model, VAR(RUN), VAR(RUN*TASK), and VAR(OCC(RUN), have small LCONC variance and therefore are good indicators of factors which explain exposure variance. The variance of the error component (Var(Error) suggests that other factors could be singled out to reduce the amount of unexplained error.

Table 7. ANOVA component analysis of log concentration data.

| Variance Component | Estimated LCONC (ppm) |
|---|---|
| Var(RUN) | 0.0206 |
| Var(RUN*TASK) | 0.0030 |
| Var(OCC(RUN)) | 0.0267 |
| Var(Error) | 0.0642 |

Many sources of error were possible in this project. The use of direct reading instrumentation to determine VOC concentrations could have introduced error. However, the calibration curve, based on known concentrations of isobutylene in air, showed the response of the instrument was linear for the VOC concentrations encountered in this study. It is possible that the PID response time varied over the

duration of the study which would cause some degree of exposure misclassification (i.e., linking task to exposure level). This error was reduced by ensuring that both the instrument flowrate and measured response time remained constant.

The video recording of the job tasks in this study offer the opportunity to go back and look at sources of error in the spraying process. A component of the spraying process not controlled for was the size or configuration of the object to be sprayed. Task number 4f, the conveyor spraying activity, illustrated a good example of how the surface area and configuration of the object to be sprayed appeared to influence the VOC exposure to the worker. To help illustrate the point, the concentration of the sample will be substituted for the log concentration.

For run 2, a large percentage of the objects sprayed were solid, flat cabinet panels measuring two feet by three feet. The turning of these panels to spray the other side created a burst of exposure as the solvent vapor evaporating from the sprayed panel was directed toward the breathing zone of the worker. The average VOC concentration for the conveyor spraying task of this run was 63 ppm. Evidence of the variation this spraying procedure would introduce is contained in the 40 ppm standard deviation this task produced. Run 4 on the other hand, contained a majority of table top frames that were not solid and contained much less surface area. When these objects were turned, very little solvent vapor was directed toward the worker. The average VOC level of run 4 was 21 ppm and the standard deviation was 14 ppm. This example was one of many which illustrated that size and configuration of the object to be sprayed had influence on the VOC exposure measured.

Another source of unexplained error for this investigation was generalization of task. For instance, task number 6 involved the handling of solvent chemicals. There were two activities that involved handling solvent, each with their own magnitude of exposure. The first activity required that the worker go to the solvent storage room and transfer toluene from a drum to the one gallon spray can. The VOC exposure of this sub-task was the highest concentration recorded from the entire sampling project (250-

450 ppm). The second duty involved mixing the solvent into different stain compositions. VOC levels ranged from 30-150 ppm for this procedure. Run 2 task 6, which had a mean of 184 ppm contained only the solvent-transferring activity for task 6. This activity had a very high standard deviation of 136 ppm. Run 1 task 6 involved only the stain-mixing activity. Run 1 task 6 showed a mean of only 26 ppm and a standard deviation of 30 ppm. Although both activities were classified as handling solvent, they clearly had different error variations among their respective samples. The high standard deviations appear to emanate from the time delay of the solvent vapor reaching the worker's breathing zone. There is a concentration gradient that is encountered as the vapor reaches full concentration in the breathing zone and is repeated in reverse as the worker leaves the area.

Another source of unexplained error was variation in the performance of certain sub-tasks within the task by the worker. For example, table spraying involved placing a table within the spray booth. Variation occurred in the degree which the table stuck out of the booth when the spraying started. The main factors affecting where the table was located in the booth were size of the wood pieces to be sprayed and the worker's attitude. It was observed that the worker's attitude could be influenced by his work load. If the operator had pressure to work quickly, the spray table often was not placed completely in the spray booth. When the table was not completely in the booth when spraying occurred, the exposure measured was higher. The variation with which a worker follows safe work practices will introduce error into the sampling results.

Comparison of charcoal-collected and direct-reading samples

Three runs had continuous charcoal-collected air sampling conducted simultaneously with the direct-reading samples. The concentrations of the individual chemicals detected for charcoal-collected samples were used to estimate the exposure levels for individual chemicals for the HNU DL 101. Tables 8 and 9 lists the results of both sampling methodologies for toluene and xylene.

Table 8. Comparison of the estimated toluene concentration from the HNU DL 101 and the charcoal-collected toluene concentration.

| Run | HNU Conc ppm | Lab Conc ppm | Toluene Lab Conc ppm | Estimated HNU Toluene Conc* ppm | Percent Difference |
|---|---|---|---|---|---|
| 10116 | 57.6 | 25.8 | 11 | 23.9 | +117.0 |
| 101310 | 23.9 | 35.2 | 14.7 | 10.0 | -32.0 |
| 101312 | 11.3 | 16.8 | 9.3 | 6.3 | -32.8 |

*Toluene sensitivity for 10.2 eV lamp is 100%

Table 9. Comparison of the estimated xylene concentration from the HNU DL 101 and the charcoal-collected xylene concentration.

| Run | HNU Conc ppm | Lab Conc ppm | Xylene Lab Conc ppm | Estimated HNU Xylene Conc* ppm | Percent Difference |
|---|---|---|---|---|---|
| 10116 | 57.6 | 25.8 | 12.4 | 24.5 | +97.6 |
| 101310 | 23.9 | 35.2 | 12.7 | 8.6 | -32.3 |
| 101312 | 11.3 | 16.8 | 6.5 | 4.4 | -32.8 |

* Xylene sensitivity for 10.2 eV lamp is 113%.

Run 10116 showed a higher total VOC for the direct reading instrument (57.6 ppm) than for the charcoal sample (25.8 ppm). This discrepancy could be explained by the aberration of the researcher wearing the sampling unit during a portion of the solvent handling task. In addition, a complete lab analysis was not performed on run 10116 due to cost considerations. The lab concentration would have been closer to the HNU

concentration had the lab analysis analyzed all chemicals present. For run 10116 the worker wore the air sampling pump but declined to wear the HNU sampling unit because of close quarters in the solvent storage room. Personal differences in how the sampling tube was worn between worker and researcher could well have caused the disparity of concentrations between the HNU instrument and the integrated charcoal tube sample.

Runs 101310 and 101312 showed a 32.0 and 32.8 percent discrepancy between direct reading instrumentation and charcoal-collected samples with the lab toluene concentrations being the higher levels. The xylene levels were similar to the toluene percentage differences. These measured solvent exposure levels closely relate to the percent by weight solvent ratios used to dilute the stain concentrates. For all the runs measured by laboratory gas chromatographic methods, toluene and xylene made up approximately 80 percent of the total VOC exposure level. The direct reading samples were estimated to contain toluene and xylene at roughly the same levels.

None of the individual volatile chemicals detected by laboratory analysis showed levels approaching their OSHA Permissible Exposure Limit (PEL). Toluene averaged 11.7 ppm while its PEL is 50 ppm. Xylene averaged 10.5 ppm with a (PEL) of 100 ppm. Other VOC components had lower proportions to their PELS.

The mean concentration for all direct-reading VOC samples measured by the HNU PID was 26.5 ppm. Two major engineering controls are responsible for the lower than expected solvent exposure levels in the spraying room of this manufacturing site. The first control was an effective spray booth exhaust ventilation system. The average face velocity measured at the worker-booth interface was 95 feet per minute. Smoke direction tests showed good air flow from the worker's breathing zone into the spray booth exhaust hood and away from the work area. The second engineering control responsible for low VOC exposures was the employment of high-volume/ low pressure (HVLP) spray gun technology. This spray application technique requires less solvent

for application and less solvent aerosol and vapor directed into the breathing zone of spraying personnel.

Since the goal of industrial hygiene is to reduce hazardous chemical exposure whenever practical even if regulatory exposure limits are not exceeded, certain job tasks could be altered to lower worker VOC exposure. The solvent storage room showed the highest VOC (255 ppm) exposure of any area in the study. At the time of the investigation, the worker had to physically enter the room to retrieve solvent for his spray operation. Exposure rose quickly once the worker dipped the solvent into his open bucket. The exposure continued as the operator returned to his work station with the bucket of solvent. Running a pressurized overhead solvent supply line to the work station fifty feet away would be expensive. A less expensive solution is running a hose from the sealed solvent drum through the wall of the storage room to a collection sink that would hold the spray can to be filled. Solvent which was spilled would be caught in a liquid trap in the sink. An alternative method would be to augment the inadequate exhaust ventilation currently supplied in the storage room. This last method of solvent vapor control also seems to be more expensive than necessary. Although the solvent transfer to the spray can is done less than once a day, the workers dread the task and regard it as a chore. Removing the need to enter the solvent storage room would limit solvent exposure and improve worker morale.

A second high exposure activity involves the table spraying task. Large, flat cabinet panels are sprayed on flat tables within the spray booth. When the worker leans into the spray booth to reach the farthest part of the panel, he/she must lean closer to the recently sprayed surface of the panel. The closer the operator is to the sprayed work the higher the exposure. VOC levels would shoot up as high as 220 ppm when the worker had to lean into the booth to spray. The solution is to spray the panels on an adjustable slanted table that eliminates the worker's need to lean into the work to complete the task. A few very large pieces may need to be sprayed on a flat table, but the majority of the cabinet panels can be sprayed efficiently on the slanted tables. A

quick video exposure monitoring experiment of spraying on a slanted table at the spray work station showed an eighteen percent reduction in the VOC level.

A final work activity that showed high exposure levels was the spraying of large wood doors on the conveyor line. This activity consistently exhibited an exposure of 60 to 80 ppm. The problem lies in the large surface area of the object and the need the to turn the piece around to spray the other side. When the piece is turned, the solvent vapor from the sprayed side is propelled toward the worker. Unlike the table spraying task, no engineering control is feasible without a very expensive re-tooling of the spray booth. The majority of the objects sprayed on the conveyor line have small surface areas and cause small exposures. For this reason, the use of half-mask air purifying respirators are recommended when spraying large flat wood panels on the conveyor line. This a recommendation only, since time weighted averages for this task are below regulatory levels.

Video Exposure Monitoring Field Parameters

A goal of this study was to investigate worker exposure to volatile organic compounds during the performance of seven work tasks involved with spraying wood stain. The previous section had dealt with the validity of the video exposure assessment procedure. In a typical exposure assessment consultation scenario, there may only be time for one exposure sampling run. With that situation in mind, the VOC exposure results for a given run will be discussed in terms of identifying tasks within a larger job activity which are candidates for additional exposure control measures.

The exposure assessment field parameters to be discussed relate the tasks measured to each other in three main categories. The categories are relative VOC concentration, cumulative VOC exposure, and total time distribution. The manner in which a defined task relates to these three categories determines the calculation of an exposure index for each task. The exposure index ranks the various tasks in their exposure risk to the

worker. The industrial hygienist can use this index to recommend which tasks, if any, should have additional control measures instituted to lower worker exposure.

The run selected for assessment is run number 4 (101310) and involved five tasks. The tasks performed were table spraying, pausing between spraying, wipe down, conveyor spraying, and other. The "other" task category included low exposure tasks such as setting up the wood pieces on the spray hooks prior to spraying and running errands to other areas of the plant. Two tasks, sanding and handling solvent were not conducted during this sample run. The samples were measured from the direct-reading HNU DL 101 photoionization detector. The exposure levels are for total volatile organic compounds in parts per million.

Relative concentration is the concentration of each task relative to the task with the highest exposure concentration. For instance, if the wipe down task has the highest average concentration of all tasks measured, that task's concentration is assigned as the denominator in determining the relative percentage concentration of the remaining tasks. The formula is as follows:

$$\text{Rel. Conc. } \% = \frac{\text{Ave. Conc. Of Task}}{\text{Ave. Conc. Of Highest Conc. Task}} \times 100$$

The relative VOC concentrations for the tasks performed in run 101310 are compared in Figure 4. Note that relative concentration does not consider the total time distribution of the task, only its concentration.

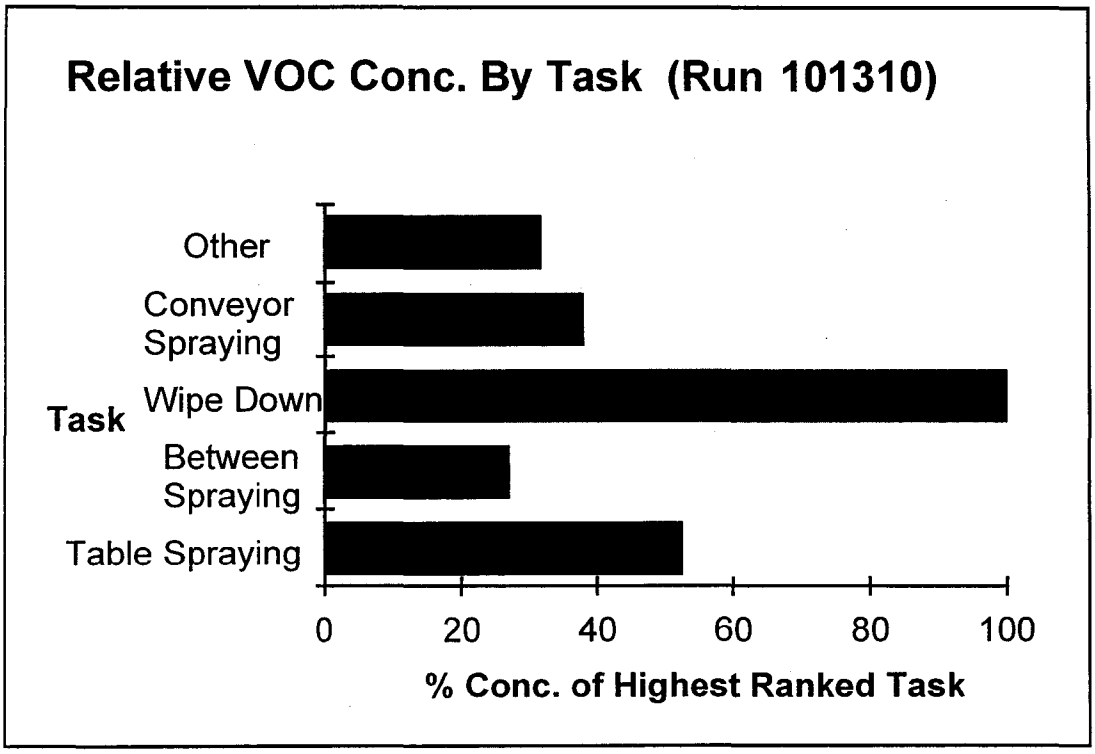



Figure 4. Relative concentration of VOC by task for Run 101310.

Time distribution of a task is the total time given performing a task during one run. Time distribution can be divided by the total time of the job activity to give the percentage time consumed by each task. The time distribution of each task is illustrated in Figure 5. The formula for time distribution is given as follows:

$$\text{Percentage of Task Duration} = \frac{\text{Cumulative Time of Task}}{\text{Total Time of Job Activity}} \times 100$$

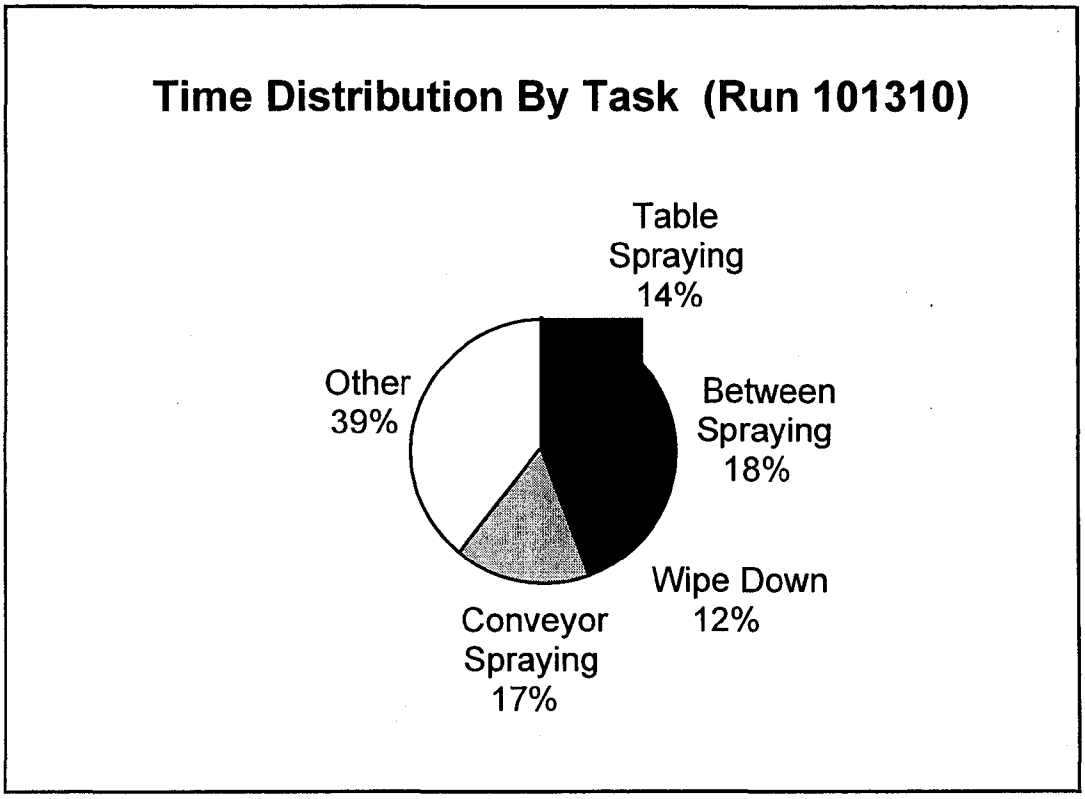



Figure 5. Distribution of time by task for Run 101310.

Cumulative exposure of a task is the product of the task average concentration and the total time distribution of that task. Cumulative exposure represents the total exposure for that task during the job activity. Cumulative exposure must be evaluated with attention paid to the duration of the task. If a task has a high cumulative exposure but constitutes a large percentage of the total job activity then its average concentration might be below levels that should be controlled by new engineering controls. Figure 6 shows the task percent cumulative exposures for run 101310. Percent cumulative exposure is calculated as follows:

Percent cumulative exposure = Average Concentration Of Task X Task Duration divided by the Total Cumulative Exposure of the entire run.

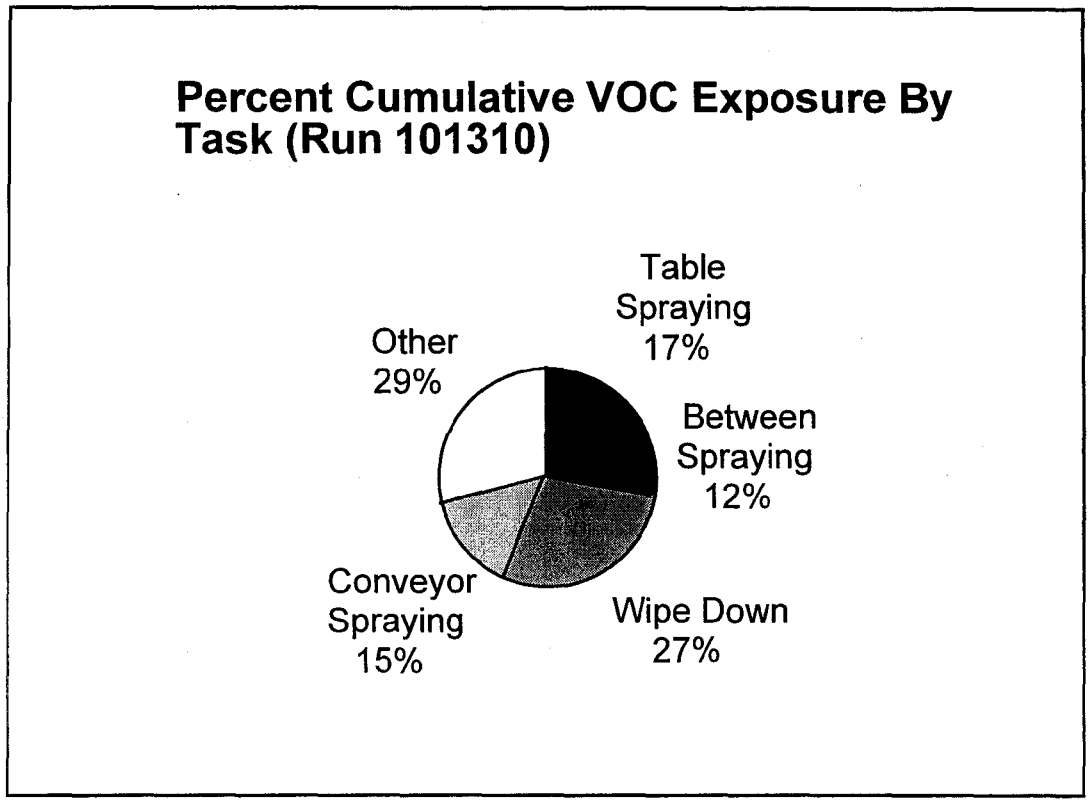



Figure 6. Percent cumulative VOC exposure by task for Run 101310.

Exposure Index is cumulative exposure percentage divided by the total time percentage of the task. Exposure Index is a unit free number that can be used along with the duration of task to determine if the task needs to be controlled. Figure 7 compares the exposure indexes for run 101310. Exposure index of a task is determined as follows:

$$\text{Exposure Index} = \frac{\%\ \text{of Cumulative Exposure}}{\%\ \text{of Total Time of Job Activity}}$$

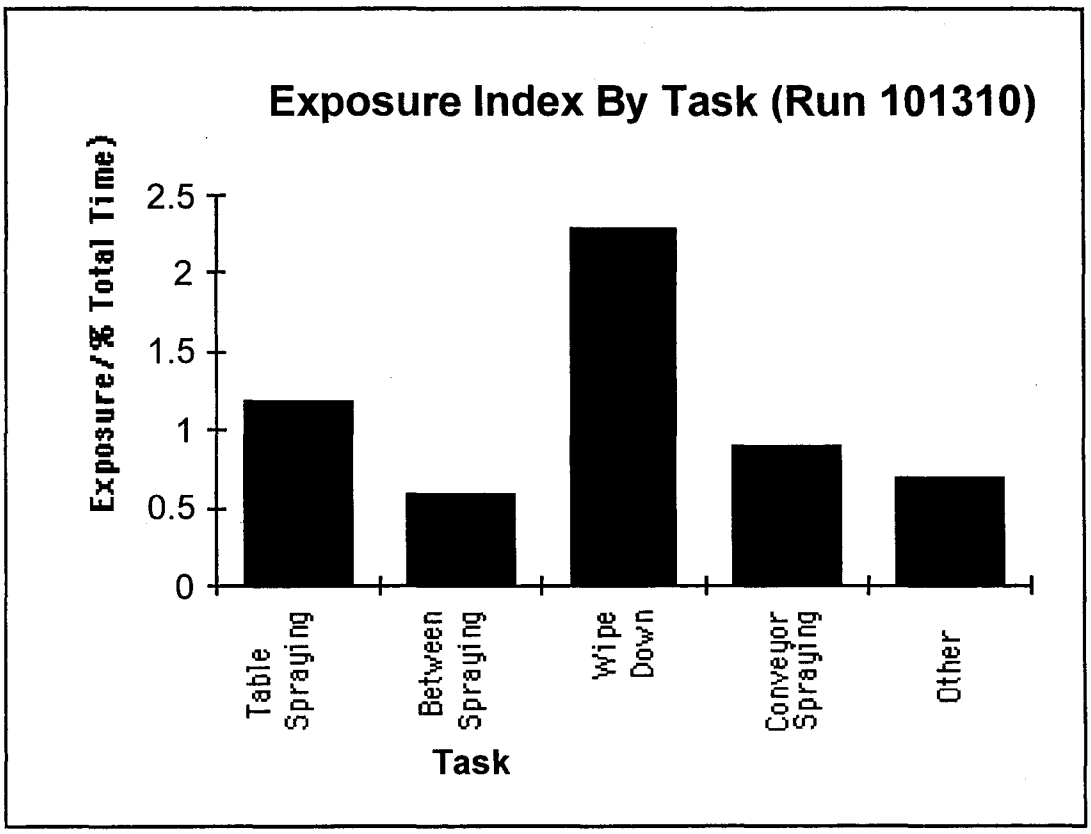



Figure 7. Exposure index of each task for Run 101310.

These four parameters; relative concentration, task duration, cumulative exposure, and exposure index allow the researcher to evaluate whether a task's exposure should be lowered. In this run, the wipe down task had the highest relative concentration. Although wiping down the wood stained parts took the least time to perform of all the tasks (12%), the cumulative exposure of this task still accounted for 27% of the exposure in this job activity. The exposure index of the wipe down task (2.3) was much higher than the next most exposed activity, table spraying (1.2).

When the video record of that run was examined, the wipe down task was often executed by the operator leaning down over the work to wipe the wood by hand with a rag. This work behavior brought the worker much closer to the evaporating surface of the stained product. The exposure to VOCs was quite high whenever the worker leaned over to wipe the stained wood down. The exhaust ventilation was reasoned to actually bring the contaminated air into the breathing zone of the worker. Two

engineering controls should inexpensively solve the problem. A slanted table should be used to decrease the leaning the worker must do to reach his work. Also a tool should be used to wipe down the wood. A long-handled sponge could be employed to wipe down the wood, which would increase the distance from the work surface to the worker's breathing zone. Both of these simple engineering controls should lower the exposure index of the wipe down task. Future video exposure monitoring can be used to test the efficacy of the proposed control measures before they become company safety policy. Table 10 shows the field parameters and exposure indices for each of the five sampling runs.

Table 10. Video exposure monitoring field parameters by individual run.

RUN 1

ST10103

| Task | Ave. Conc. ppm | Relative Conc. % | Total Time % | Cumulative Exposure % | Exposure Index |
|---|---|---|---|---|---|
| 1 | 14.3 | 53 | 2.4 | 2.7 | 1.1 |
| 2 | 15.4 | 57 | 5.3 | 6.2 | 1.2 |
| 5 | 8.8 | 32 | 1.8 | 1.3 | 0.7 |
| 6 | 27.2 | 100 | 18.4 | 38.1 | 2.1 |
| 7 | 9.4 | 35 | 72.1 | 51.7 | 0.7 |
| | | | | | |

Table 10. (continued)

RUN 2

ST10116

| Task | Ave. Conc. ppm | Relative Conc. % | Total Time % | Cumulative Exposure % | Exposure Index % |
|---|---|---|---|---|---|
| 2 | 28.6 | 16 | 4.7 | 2.3 | 0.5 |
| 4 | 60.4 | 34 | 22.4 | 23.5 | 1.1 |
| 5 | 20.1 | 11 | 16 | 5.7 | 0.4 |
| 6 | 180.5 | 100 | 17.6 | 54.9 | 3.1 |
| 7 | 20 | 11 | 39.3 | 13.6 | 0.3 |

RUN 3

ST10118

| Task | Ave. Conc. ppm | Relative Conc. % | Total Time % | Cumulative Exposure % | Exposure Index |
|---|---|---|---|---|---|
| 1 | 31.1 | 70.9 | 7.4 | 6.6 | 0.9 |
| 2 | 12.8 | 29.2 | 3.6 | 3.1 | 0.9 |
| 4 | 43.8 | 100 | 52.1 | 66.2 | 1.3 |
| 5 | 22.9 | 52.1 | 20.5 | 13.6 | 0.7 |
| 7 | 22 | 50.2 | 16.4 | 10.5 | 0.6 |

Table 10. (continued)

RUN 4

ST101310

| Task | Ave. Conc. | Relative Conc. | Total Time | Cumulative Exposure | Exposure Index |
|---|---|---|---|---|---|
| | ppm | % | % | % | |
| | | | | | |
| 1 | 29 | 52.5 | 13.8 | 16.7 | 1.2 |
| 2 | 15.1 | 27.3 | 18.2 | 11.5 | 0.6 |
| 3 | 55.2 | 100 | 12.3 | 28.3 | 2.3 |
| 4 | 21 | 38 | 16.6 | 14.5 | 0.9 |
| 7 | 17.7 | 32.1 | 39.1 | 29 | 0.7 |

RUN 5

ST 101312

| Task | Ave. Conc. ppm | Relative Conc. % | Total Time % | Cumulative Exposure % | Exposure Index |
|---|---|---|---|---|---|
| | | | | | |
| 1 | 14.8 | 51.7 | 28.2 | 36.9 | 1.3 |
| 2 | 9.5 | 33.4 | 40.5 | 34.2 | 0.8 |
| 3 | 28.6 | 100 | 1.3 | 3.2 | 2.5 |
| 5 | 9.7 | 33.7 | 0.5 | 0.4 | 0.8 |
| 7 | 9.7 | 33.9 | 29.5 | 25.3 | 0.9 |

Video Overlay of Exposure Data

A video overlay procedure developed by Dr. Michael Gressel from NIOSH allows the exposure concentration of a chemical or physical hazard to be displayed on the video tape of the job activity. The exposure level for each second is supplied by the data on a spreadsheet. The NIOSH software program VEM BARS™ generates a bar graph of the exposure concentration which changes each second according to the sampled levels. This exposure bar graph is then overlaid onto the video tape of the sampled job activity such as spray painting. The real time of the sample data must match the real time on the video tape (adjusted for the time lag of the sampling event) for a true representation of task and its associated exposure level.

This overlay procedure creates a powerful diagnostic tool that allows the industrial hygienist to identify sources of exposure. The source may be within a task, such as work behavior by the operator which is causing a high exposure. The source may be between tasks where the engineering controls for a certain task are inadequate. By synchronizing the real time exposure with the real time video record (adjusted for lag time of the instrument) of the job activity the occupational health professional conducting the monitoring can often spot the problem the same day of the monitoring.

Video exposure overlays can be used to pin point key exposure concepts for a client. When the company president or owner can see the exposure peak as the result of a certain task or work procedure it should be easier for that individual to commit resources to the successful resolution of the health hazard.

Many times, high exposures are experienced by the worker because he/she fails to follow established safe work policies instituted by the employer. Sometimes the worker is unaware of the breach of policy, other times the policy is ignored because the association of the work behavior and the risk is not linked in the mind of the employee. The overlaid exposure video of their own work activities can be an effective training tool that enables the employee to identify action with exposure. Once the exposure is

visualized the next step to understanding health risk should be made easier. Further research is needed to determine if video exposure overlays are effective in modifying unsafe work behaviors.

Evaluation of the Sampling Instrumentation

The sampling unit consisted of a direct reading photoionization detector and a large data logger strapped to an external frame backpack. The weight of the complete sampling unit was twelve pounds, which is too much for many workers to wear for extended periods of time. The worker in this study was young and strong but even he was ready to take off the back pack at the end of the run. The back pack had an overhead stabilizer bar that was removed before sampling began to reduce the chance of the worker snagging the sampling unit on his surroundings. Working in the drying tunnel with its overhead hooks presented a safe operating problem for the worker. The researcher had to watch out for potential snags when work was performed in the drying tunnel.

For a VEM sampling unit to be worn a longer period of time, the weight of the unit should not exceed five pounds. Ideally, the sampling and data logging functions would be combined into one compact housing that could be worn on a worker's belt. Another desirable feature is the ability of the device to take and store short duration samples. The rule of thumb is the shorter the duration of task you are measuring, the shorter the sample interval should be. Our sampling unit took one second samples which gave us highly significant results. As of this date no instrument with all of these design specifications is on the market currently, so the researcher must assemble the sampling unit from modular off-the-shelf components. A commercial demand is anticipated for a light, compact, high resolution sampling unit.

The most time consuming procedure of the investigation was the coding of a task number to each one second concentration reading. The manipulation of data spreadsheet files took a lot of time also. One of the technical skills learned was to be

able to transfer data efficiently between various software programs. Reductions in the time required to code tasks is needed to make VEM a widely used exposure assessment tool.

Other investigators have used appropriate direct reading instrumentation to measure the exposure of dust aerosols or noise exposure. In fact, any chemical or physical modality which can be measured with a voltage output and which has a sampling capability shorter than the task to be examined can be assessed using the video exposure monitoring method. Median nerve velocity in ergonomics and radiation exposure are exposure modalities that could be candidates for VEM in the future.

Summary of Conclusions

By using direct reading concentration data and video task analysis, the researcher can develop an exposure index which will identify high exposure tasks within a larger job activity.

The engineering controls recommended for the wood stain spraying activity studied are:

- Eliminate entry into the Bulk Storage Room for the solvent handling task.
- Wear respirator when spraying large surface area objects.
- Use a slanted spray table for the table spraying task.
- Use a long-handled tool when wiping down excess spray on piece work.

The most important potential sources of error in this VEM spray coating study include coding misclassification and the size and configuration of the objects to be sprayed. Once high exposure tasks have been identified by VEM, appropriate control measures can be implemented.

Video exposure monitoring can yield valuable information on the sources of exposure in a complex work activity such as spray coating applications. However, variation will be present in exposure values measured at a given work site due to the conditions present at the time of analysis. Differences in the time distribution of various tasks as well as differences in employee safe work practices can effect the measured exposure levels. To insure that representative exposure is measured, the industrial hygienist should consult with management and the workers involved to create as realistic a work scenario to be sampled as possible. The engineering control conclusions drawn from a one time video exposure monitoring session can have long term implications in cost and time to management and health effects for the employee. A follow up VEM assessment is recommended to assess the effectiveness of new engineering controls proposed to reduce high worker exposures. The testing of exposures which would be the result of proposed engineering controls and new safe work policy is a very valid use of this new assessment technique.

Although this research was performed for a relatively fixed station work environment that had repeatable work tasks, VEM could also be valuable in assessing exposure to the construction painter. This person is highly mobile and exposed to an ever changing array of chemicals in a construction painting environment. VEM research is needed to characterize the more complex chemical exposures experienced by the construction painter.

Real time computer generated overlays of the exposure sample reading can be affixed to the video taped job activity to assist in exposure evaluation and worker training. Additional study is needed to determine the effectiveness of video exposure overlays to educate management and process workers to the sources of health hazards.

## Project 2. Field Evaluation of a Portable PID for Assessing Exposure to Solvent Mixtures

Due to the lack of specificity and portability, the PID has not been widely used for exposure monitoring of solvent mixtures. The investigation was designed and implemented in order to test the hypothesis that under identical field sampling conditions a portable PID TWA air concentration (in isobutylene equivalent ppm) would be highly related to GC-FID TWA air concentration of solvents. By testing this hypothesis, the researcher was attempting to evaluate the ability of a portable PID for assessing worker exposure to solvent mixtures during construction painting tasks. Linear regression analyses were conducted between the two sampling method results for measures of total solvent exposure and the TLV mixture calculation. Although single component, chemical specific PID correction factors are published by manufacturers, their application in mixtures has not been well studied. A third linear regression analysis was conducted on a predicated measure of total exposure for the PID method using the GC-FID results adjusted by correction factors. In addition to evaluating the response of the PID, characterization of solvent vapor exposure was obtained for various construction painting tasks.

### Gas Chromatography Results

The GC-FID laboratory results for the 48 charcoal tube samples are presented in Appendix III. The sampling results are sorted according to the seven broad work tasks: spraying lacquer (LQ), spraying paint (SpPT), pool painting (PlPT), staining (ST), cleaning (Cl), brush/roller paint (BPT), and street painting (StPT). The time-weighted average (TWA) air concentration in parts per million (ppm) are presented in Table 1 in Appendix III for each of the 18 solvents. The subsequent table (Table 2) provides the summary measures of the TWA total solvent ppm and TLV mixture calculation for each of the 48 charcoal tube samples. A summary of the GC air sampling results sorted by task is presented on the next page in Table 11.

Table 11: Geometric mean and standard deviation of GC TWA total solvent exposure in ppm for painting tasks

| Task | n | GM of Total PPM (Range) | G.S.D |
|---|---|---|---|
| Street Painting (StPT) | 8 | 6.9 ( 4.5 - 23.7) | 6.5 |
| Brush/Roller Paint (BPT) | 5 | 12.9 ( 1.8 - 44.0) | 19.2 |
| Cleaning (Cl) | 2 | 40.5 ( 21.4 - 76.8) | 39.2 |
| Staining (ST) | 11 | 49.2 ( 6.3 - 146.4) | 45.1 |
| Pool Painting (PlPT) | 3 | 236.5 ( 129.1 - 338.3) | 111.9 |
| Spraying Paint (SpPT) | 5 | 240.0 (37.5 -11674.5) | 718.7 |
| Spraying Lacquer (LQ) | 14 | 355.0 (55.3 - 1396.0) | 450.7 |

The data in Table 11 were arranged from the work task with the lowest exposure to the work task with the highest exposure, as expressed by the geometric mean (GM) of the TWA total solvent concentration in ppm. Therefore, street painting had the lowest mean exposure and spraying lacquer had the highest mean exposure.

The highest mean exposure task, that of spraying lacquer resulted in a mean total solvent concentration of 355 ppm. The GC analyses of the 14 lacquer samples (LQ), showed that all (100%) contained isopropyl alcohol, 93% contained toluene, xylenes, isobutyl acetate, and ethyl benzene, and 64% contained isobutyl alcohol and MEK. Several other solvents were detected in lacquer samples including, by order of prevalence: acetone, ethanol, heptane, methanol, MIBK and 2-butoxyethanol. Computation of the ACGIH mixture calculation revealed that 93 % (13/14) of the lacquering samples exceeded the TLV based on the additive effect of the solvents. For the task of lacquering, the exposure appeared to be characterized by a complex mixture of numerous solvents with varying concentrations.

For spraying paint, the next highest exposure task, the most common solvent was mineral spirits (80 %), also referred to as stoddard solvent. One paint spraying sample contained a mix of numerous solvents including methanol, acetone, toluene, petroleum

distillates, xylene and ethyl benzene. The majority of the paint spraying tasks were accomplished with alkyd products containing mineral spirits and/or petroleum distillates. The mean TWA total solvent concentration was 240 ppm for the work task of spraying paint. The ACGIH mixture calculation revealed that 60 % (3/5) of the paint spraying tasks exceeded the TLV-TWA.

Another task which resulted in significant solvent exposure was the task of pool painting with a mean TWA total solvent concentration of 236 ppm. Unlike many of the other work tasks, the solvent composition of the epoxy covering was not a complex mixture. The only two compounds contributing to the solvent exposure were xylenes and ethyl benzene with xylenes being the large majority. The mixture calculation determined that 100 % (3/3) of the samples exceeded the TLV. While the task was performed with rollers and brushes, it was not included in the brush/roller category because of the large surface area and volume of paint applied.

The task of staining was difficult to characterize the chemical constituents because lacquering often occurred concurrently. When samples in which only staining was taking place (n=6), the results indicate that exposure was primary to mineral spirits and toluene. When lacquering was performed, the painter was exposed to a complex mixture of solvents as described above. The mean TWA total solvent concentration was 49 ppm for the work task of applying stain which reflected contribution from concurrent lacquering tasks. The mixture calculation determined that 27 % of the staining samples exceeded the TLV.

The two cleaning tasks produced TWA total solvent concentrations of 77 ppm and 27 ppm. These samples contained a complex mixture of solvents including toluene, xylenes, ethyl benzene, MIBK, acetone and several other solvents. The lowest exposure work tasks were street painting and brush/rolling paint which resulted in mean TWA total solvent concentrations of 7 ppm and 13 ppm, respectively. For the tasks of brush/rolling paint and street painting, all of the samples were below the TLV mixture

calculation. Due to their low overall TWA exposure, these tasks were not characterized by chemical components.

As seen in the summary table there was wide variability in the geometric mean as shown by the high standard deviations among the different tasks. However, this is to be expected in a field trial with a small sample size and very broad categories of work tasks. For the same category of work task, samples varied by chemical constituents of materials, type of work environment, volume of material, length of sampling and ventilation effectiveness.

In conclusion, the GC results indicated that the tasks of spraying lacquer, spraying paint and pool painting resulted in the highest mean TWA total solvent concentrations. While it is difficult to find exposure data regarding painting tasks, a Finnish study of solvent exposure in painting tasks found the following TWA mean solvent naphtha exposures: 300 ppm for painting large surfaces in small poorly ventilated rooms; 210 ppm when walls or ceilings were painted; 35 ppm when doors and window-frames were painted; 67 ppm when doors were treated with wood preservative; and 115 ppm when spraying alkyd paint (Riala, et al. 1984) . Since the task classification was different in the two studies, direct comparisons were not possible, but overall the range of concentrations were similar.

Photoionization Detector Results

The portable PID was programmed to provide a three second average of the instantaneous ppm readings. The three second average isobutylene equivalent ppm readings were plotted for 24 of the 26 PID samples and are presented in Appendix III: (Figure 1 to Figure 26). The graphs are arranged in chronological order from the third sampling day to the last sampling day. The graphs list the TWA, STEL and ceiling concentrations in isobutylene equivalent ppm obtained from the PID for each of the samples. In addition, the graphs contain a text box with the chemical constituents identified from the GC analysis of the adjacent charcoal tube sample. Also presented in

Appendix III is a summary table (Table 3) of the 26 PID sample results including a TWA, STEL and ceiling concentration in isobutylene equivalent ppm sorted according to work task. The ACGIH TLV mixture calculation for each of the PID samples is also presented in Appendix III, Table 3. Table 12 below summarizes the PID sampling data for the 26 personal breathing zone samples sorted by task.

Table 12: Geometric mean and standard deviation of PID TWA isobutylene equivalent ppm exposure for painting tasks.

| Task | n | GM in PPM (Range) | S.D |
|---|---|---|---|
| Street Painting (StPT) | 4 | 5.8 ( 3 -14) | 4.9 |
| Brush/Roller Paint (BPT) | 2 | 6.9 ( 3 - 18) | 10.5 |
| Cleaning (Cl) | 1 | 85 | |
| Staining (ST) | 5 | 65.0 (35 - 245) | 88.7 |
| Pool Painting (PlPT) | 2 | 259.1 ( 184 - 366) | 128.5 |
| Spraying Paint (SpPT) | 5 | 157.9 (56 - 686) | 226.7 |
| Spraying Lacquer (LQ) | 7 | 196.8 (46 - 585) | 167.1 |

The three highest exposure tasks identified by the PID were pool painting (259 ppm), spraying lacquer (197 ppm) and spraying paint (158 ppm). These are the three highest exposure tasks identified by the GC-FID results; however, the ranking is different. The PID mean exposure for the pool painting task would be reduced by half if the PID correction factor for xylene of 0.5 was applied resulting in a mean exposure of 130 ppm. With this correction, both GC and PID identify the same three high exposure tasks in the same rank based on the geometric means. The TLV mixture calculation of the PID data revealed that 100 % of the pool painting samples, 86 % of the lacquering samples, and 60 % paint spraying samples, exceeded the TLV. Although the PID appears to underestimate the total solvent exposure of the highest exposure tasks, overall the sampling results compare favorably with the GC results (see Table 11).

From the graphs of the PID real time data, exposure to solvents during construction painting tasks was characterized by highly fluctuating concentrations. Integrated air sampling may not be the best method for evaluating exposure to highly fluctuating concentrations because of lack of information regarding exposure patterns. A direct reading instrument could improve the evaluation of STEL and ceiling exposures.

Unfortunately, the MiniRAE® Professional PID had a major deficiency. The data retrieved from the PRORAE® software provided a maximum value of 1009.9 ppm even though the range of the PID was reported to be 0- 2,000 ppm. Most high exposure tasks lost maximum exposure values; therefore, the TWA, STEL, and ceilings were probably underestimated for those tasks which reported 1009.9 ppm as a ceiling value (See Appendix III).

Data Distribution

The statistical analysis performed between the PID ppm data and the GC ppm data indicated that both data sets were lognormally distributed. In order to stabilize the variance within this analysis, the logarithm ($Base_{10}$) of each PID TWA isobutylene equivalent ppm and GG-FID TWA total solvent ppm value was calculated. Geometric means and geometric standard deviations were then used to describe the data and reflect the lognormal distribution for each data set. The descriptive statistics of total solvent exposure for the dependent variable, PID results, and the independent variable, GC-FID results, are listed in the Table 13 below.

Table 13: Descriptive statistics of x and y variables

| Variable | N | Mean | Median | TrMean | StDev | SEMean |
|---|---|---|---|---|---|---|
| GC ppm | 26 | 206.8 | 73.5 | 166.2 | 316.2 | 62.0 |
| PID ppm | 26 | 157.4 | 77.1 | 141.8 | 177.5 | 34.8 |
| log GC ppm | 26 | 1.889 | 1.866 | 1.904 | 0.712 | 0.140 |
| log PID ppm | 26 | 1.831 | 1.885 | 1.848 | 0.693 | 0.136 |

Comparison of air sampling results from GC-FID and PID methods

The first regression was conducted between the log PID TWA isobutylene equivalent ppm (log PID ppm) and the log GC-FID TWA total solvent ppm (log GC ppm) to evaluate the amount of variability in the response of the PID which was explained by the GC-FID analysis. This analysis evaluated the response of the PID against the "gold standard" of the charcoal tube samples analyzed by GC-FID. The regression analysis of the log PID ppm (y) with log GC ppm (x) from Minitab provided a final model of:

log PID ppm = 0.0408 + 0.948 log GC total ppm

The Coefficient of Determination ($R^2$) was 94.8% and the log GC total ppm was found to be statistically significant ($p < 0.001$) in the final model. This analysis revealed that 94.8% of the variability in the response of the PID was explained by the analytical results from the duplicate charcoal tube sample. Relative humidity and temperature were tested in the model; however, were not found to be significant. The assumptions of normality, linearity and homoscedicity were tested and accepted (See Appendix III (statistical analyses)).

Based on this regression it was determined that the variability of the PID response to solvent mixtures was largely explained (94.8 %) by the GC-FID air sampling results. While the PID data underestimated exposures, the correlation to the gold standard indicated that the PID response was representative of total solvent exposure. By using the regression equation, the percent of underestimation by the PID was determined to be 23 % for a 1000 ppm, 14 % for a 100 ppm and 3 % for a 10 ppm, solvent mixture. Therefore, the percent of underestimation increases as the air concentration of solvents increases partly due to the range limitation of the PID being a maximum response of 1009.9 ppm.

The other regression analysis which provided support for the effectiveness of the PID for assessing personal exposure was the comparison of the log PID mixture calculation

and the log GC mixture calculation. The PID mixture equation was derived from developing a TLV for the mixture based on percent composition data from the MSDS. The PID isobutylene equivalent ppm reading was divided by the calculated TLV of the mixture to evaluate exposure on the basis of unity. The final regression model was:

log PID Mixture Equation=0.0746 + 1.02 log GC Mixture Equation

The $R^2$ was 94.2 % which showed that 94 % of the variability in the PID mixture equation was explained by the GC mixture equation. Due to the complexity of the mixture or high levels of non-ionizable compounds, two samples were excluded from this analysis.

Despite the small sample size (n=24), the data provided evidence that the portable PID can be a valuable instrument for assessing personal exposure to mixtures based on the ACGIH TLV equations for mixtures. For all 24 samples the same exposure conclusion was reached by both methods with unity being the criteria for determining if the sample exceeded the TLV of the mixture. The high degree of correlation between the PID and GC mixture equation results provided additional evidence for the capability of the PID to assess TWA personal exposure to solvent mixtures.

To account for the varying sensitivity of the detector to specific chemicals, a method to evaluate the effect of PID correction (response) factors was attempted. The GC results were used to calculate a RF Predicted PID ppm response based on the GC solvent percent composition data and the PID solvent specific response factors. The regression analysis of the log PID ppm with the log response factor predicted PID PPM provided a final model of:

log PID ppm = -0.076 + 0.993 log RF Pred. PID ppm

The $R^2$ was 94.3 % for this regression model which was not improved from the first regression analysis (94.8 %). The PID response factors did not improve the correlation

of data; therefore, the response factors did not appear to be significant in the model for the response of the PID for complex mixtures. It should be noted that for simple mixtures such as found during pool painting, the PID response factors may be extremely important for assessing worker exposure.

The summary table (Table 14) lists the three regression analyses which were performed, thus providing the regression equation , the coefficient of determination ($R^2$), and the p-value for each analysis.

Table 14: Summary of regression analysis performed for the evaluation of the PID

| Y | X | $R^2$ | Equation | p |
|---|---|---|---|---|
| logPID ppm | logGC ppm | .95 | log PID ppm= 0.04 + 0.95 log GC ppm | <.001 |
| logPID ppm | logRF ppm | .94 | log PID ppm= -0.08 + 0.99 log RF ppm | <.001 |
| logPID mix | logGC mix | .94 | log PID mix = 0.07 + 1.02 log GC mix | <.001 |

The researcher expected the sampling results to be highly correlated since both methods were designed to measure TWA total solvent concentration from the vapor component of the mixture. The PID method provided a TWA total solvent concentration in isobutylene equivalent ppm, whereas, the GC-FID method provided a TWA total solvent concentration from the sum of all chemicals detected. Since the units of measure for the two methods are different, the PID response factors were applied to the GC-FID air concentrations and summed to obtain a PID predicted response in isobutylene equivalent ppm. Unexpectedly, the PID response factors did not improve the correlation of the data so their usefulness for mixtures must be questioned. Since PID correction factors are derived for single contaminants, the lack of research with solvent mixtures hinders the explanation of this result. Other investigators have developed a working linear range for the PID and determined correction factors for the solvent being measured (Chelton, et al. 1983). Thus, it would be preferable to determine correction factors for the instrument by generating and testing the response

for the solvent mixture to be measured. Due to the variability of solvent mixtures encountered during construction painting tasks, this option was not feasible.

Several researchers have evaluated solvent exposure by using a method similar to the ACGIH mixture equation which sums the ratios of the solvent concentrations over their TLV-TWA (Glass, et al. 1994; Riala, et al. 1984; Winder and Turner, 1992). This method has been employed for evaluation of exposure even though the air samples were not 8-hour samples. It should be noted that samples were not collected over an 8-hour period, thus comparing to the TLV-TWA may not be appropriate for assessing worker exposure. Solvent exposure for construction painting tasks may be more appropriately assessed by the use of TLV-STEL, but only a few organic solvents have TLV-STELs.

While there was a high degree of correlation between the two sampling methods, the PID method underestimated solvent exposure especially for the higher exposure tasks. The PID underestimation was probably due to the maximum value limitation and the linear range of the instrument. In addition, the GC-FID total solvent exposure may have included contribution from chemicals not detected by the PID. The PID coupled with the datalogger would provide a maximum value of 1009.9 ppm, thus high exposure tasks were not accurately measured. Therefore, the MiniRAE Professional PID coupled with extended data logger may underestimate TWA solvent exposure during tasks where the air concentration exceeds 1009.9 ppm.

Limitations of Project 2

Although the results provide evidence that the PID can be a useful industrial hygiene monitoring device for assessing exposure to solvent mixtures, there are several limitations of the research. While the GC analyses were the primary sampling method for quantifying specific solvents, there were several limitations with this method. The GC analyses were limited to the 18 chemicals used in calibration curve of the solvent scan; however, other components such as halogenated solvents with similar retention times may have been included as one of the 18 solvents. A halogenated solvent was

listed on the MSDS of two of the construction materials used during this research. As mentioned earlier due to similar retention times, MAK was reported as xylenes. Since these two compounds were not adequately separated by the column of the GC-FID, the more common paint solvent of xylene was reported. The other solvent not identified was V.M. & P naphtha because it was reported under the classification of petroleum distillates. The mineral spirits and petroleum distillates were analyzed by utilizing a range of numerous peaks of which the areas were summed. The standards and samples were not identical matches for the compounds of mineral spirits and petroleum distillates due to the variability from batch to batch in both paint products and standards. Due to the varying vapor pressures of mixture constituents, liquid standards may not be representative of vapors collected with an air pump and a charcoal tube.

By utilizing a single solvent (carbon disulfide) for desorption of charcoal samples, several chemicals exhibited desorption efficiencies less than 75 %, mainly the alcohols. By using an alternative solvent, the desorption efficiencies for the alcohols could have been improved.

The PID suffered from numerous limitations which limit the reliability of the response. The lack of specificity preclude the use of response factors to decipher the actual concentration of a chemical other than the calibrant. The evaluation of response factors for a complex mixture of chemicals is difficult and the research did not adequately address this question. Based on the results from this investigation, it appeared that for complex mixtures the response factors may not be as important as when dealing with less complex solvent mixtures. The pool painting task utilized a product which listed xylene as the only solvent on the MSDS so the PID correction factor was applied to these samples. Whenever utilizing a PID calibrated to the factory calibrant for air sampling of other compounds, the compound specific response factors in combination with the MSDS of the product should be used to assist with evaluating the response of the instrument.

The PID has been shown to be affected by high relative humidity (85-90%) reducing instrument response by a factor of two for most hydrocarbons (Barsky, et al. 1985). In this study, the linear regression analysis of log PID ppm and log GC ppm determined that relative humidity was not significant in the model. The maximum relative humidity encountered in this research was only 61 % which may explain this result. In work environments with RH greater than 80 %, the response of the PID may be affected.

Due to the engery of the UV lamp in the PID, the instrument will only respond to hydrocarbons with an ionization potential (IP) less than 10.2 eV. Since halogenated solvents and methanol have IP greater than 10.2 eV, this instrument should not be used to assess exposure for work tasks where these compounds are the predominant components. Neither method of air sampling was capable of assessing aerosol or dermal solvent exposure among construction painters, thus the sampling methods were limited to assessing the vapor component.

While this initial investigation provided justification for using a PID for assessing exposure to solvent mixtures, additional research is recommended. In order to strengthen this study, further research should be performed with other tasks involving solvent exposure such as hazardous waste operations. Due to the complexity of the solvent mixtures, the research could not evaluate the effect of the PID response factors. The manufacturers of these instruments should examine the relationship of PID response factors for solvent mixtures.

## Conclusions and Recommendations

The GC-FID and PID sampling methods identified painting tasks which resulted in TWA air concentration of greater than 100 ppm of organic solvents which were considered high exposure tasks. The tasks of spraying lacquer, spraying paint and pool painting were recognized as high exposure tasks by both GC-FID and PID sampling results. Without considering the reduction in exposure from the use of personal

protective equipment, these three tasks very often exceeded the TLV-TWA of the mixture determined by either sampling method. As noted earlier, the ACGIH TLV mixture calculation utilized TLV-TWA for the determination of exposure although the samples were not 8 hour samples. While the use of solvent-based coverings has been declining, this research showed that during special applications solvent exposures are quite high. The high exposure tasks require the implementation of control measures to reduce employee exposure to organic solvents. PID data suggests that the evaluation of solvent exposure during construction painting tasks may be more appropriately addressed with TLV-STELs.

By substituting high solvent products with water-borne equivalents, exposure to organic solvents can be minimized. This control method offers the most promising solution for reducing painters exposure to solvents. While product substitution can reduce the amount of solvent, this will not eliminate exposure to all solvents or other components of the paint. Therefore, in conjunction with the advent of new water-borne coverings other control measures must be implemented by the end-users.

All painters should provide adequate general ventilation when applying construction coverings to dilute air concentrations by the infiltration of fresh outside air. This control methods involves opening doors, windows and other openings to the outside environment. General ventilation should be provided for all painting tasks which involves the application of any construction covering not only solvent-based products. The fresh outside air will mix with all air contaminants, thereby reducing the air concentrations of the contaminants.

Most importantly, the mobile construction painter must use the proper personal protective equipment (PPE) in conjunction with other control methods to further reduce personal exposure. Respiratory protection is the most important aspect of a PPE program for construction painters. The development and implementation of a thorough PPE program should be mandatory for all painting establishments to properly control exposures.

Since high solvent concentrations are encountered for some painting applications, industrial hygiene air sampling should be conducted to monitor exposure and effectiveness of controls. This research provided evidence that a portable PID can be a useful industrial hygiene monitoring device for monitoring mixtures of solvents during construction painting tasks. The PID results displayed a high degree of correlation to the total ppm of solvents detected by GC-FID of the charcoal tube adjacent samples ($R^2$= 95 %). Furthermore, the comparison of the PID and GC data to the TLV of the mixture resulted in a high degree of correlation between the data ($R^2$= 94 %). Both linear regressions lend support to the usefulness of the portable PID for quantitatively assessing personal exposure to solvent mixtures of paint. In addition, air sampling with a direct-reading PID coupled with a data logger has several advantages over integrated sampling with charcoal tubes and GC-FID analysis.

The portable PID is capable of providing an immediate assessment of levels of solvents present in the work environment. This information can be useful to the construction painter for deciding if controls are warranted and if so what level of respiratory protection should be required. The PID with extended data logger can be used to evaluate TWA, STEL, and ceiling solvent concentrations from the same sampling data; whereas, with the charcoal tube/GC-FID method the same assessment would require multiple samples . Due to the variability of the work environment of the construction painter, the PID may be a useful and cost-effective sampling method for the industrial hygienists.

## Project 3. Comparison of Sampling Methods for Evaluating VOC Exposures During the Spray Application of Lacquer

Desorption Efficiency

Desorption efficiencies of nineteen paint solvents were determined by (1) injection standards directly on the small charcoal tube (SCT), (2) transferring the small charcoal tube contents into vials (SCTV), (3) transferring jumbo charcoal tube contents into vials (JCTV), and (4) direct injection on the passive sampler (PS).

Results of desorption efficiency of nineteen paint solvents were reported for hydrocarbons, ketones, esters, and alcohols. The summary of desorption efficiencies of the four groups of organic solvents on SCT, SCTV, JCTV and PS is shown in Table 15. The mean desorption efficiencies for aliphatic and aromatic hydrocarbons were close to 100 percent with all standard deviations being less than 7% for charcoal tubes and passive samplers and there were no significant differences between SCT, SCTV, JCTV and PS ($p > 0.05$). However, the desorption efficiencies of alcohols, ketones, and esters, especially of alcohols, were rather lower than those of aliphatic and aromatic hydrocarbons and there were significant differences between SCT, SCTV, JCTV and PS ($p < 0.05$). The passive sampler had significantly lower desorption efficiencies than charcoal tubes for ketones, esters, and alcohols ($p < 0.05$). This was expected because the passive sampler (SKC 575-001) used for this study was validated for more than 30 organic compounds but did not include any ketones, esters or alcohols.

For alcohols and esters, the technique of transferring the front section of a charcoal tube into a vial followed by spiking a known standard solution was not significantly different from the technique of direct spiking a standard solution on the front section of a charcoal tube and there was no significant difference between the jumbo tube and small tube. For ketones, no significant differences were found between the two

techniques on small charcoal tubes but there were differences between small tubes and jumbo tubes.

Table 15. Mean desorption efficiencies of hydrocarbons, ketones, esters and alcohols for JCTV, SCT, SCTV and PS.

| *Organic Solvents* | *Mean Desorption Efficiency (%)* | | | | *Significant Difference* | *p-Value* |
|---|---|---|---|---|---|---|
| | *JCTV*[a] | *SCT*[b] | *SCTV*[c] | *PS*[d] | | |
| Aliphatic and Aromatic Hydro-carbons | 98.75 | 97.08 | 98.90 | 99.60 | No Significant Difference | 0.1911 |
| Alcohols | 51.65 | 52.1 | 55.74 | 22.28 | SCTV=SCT= JCTV>PS | 0.0001 |
| Ketones | 79.32 | 84.92 | 88.65 | 64.71 | SCTV=SCT> SCT=JCTV> PS | 0.0001 |
| Esters | 86.25 | 92.75 | 93.89 | 76.74 | SCTV=SCT= JCTV>PS | 0.0013 |

[a]JCTV: Jumbo charcoal tube into vials (800/200 mg)
[b]SCT: Small charcoal tube (100/50 mg)
[c]SCTV: Small charcoal tube into vials
[d]PS: Passive sampler

Since the technique of transferring the front section of a charcoal tube into a vial followed by spiking a known standard solution was easier and more convenient, and was utilized in many laboratories (Krajewski, et al. 1980; Lopes, 1997; Salkin and Calpin, 1995) this technique was recommended for the determination of desorption efficiencies for charcoal tubes. Only ketones showed differences between small tubes

and jumbo tubes, therefore this should be taken into account when different tubes were used for collecting ketones.

Tables 16 to 19 show the desorption efficiencies of individual compounds of hydrocarbons, ketones, esters and alcohols. For aliphatic compounds, n-heptane and benzene, greater than 95 percent desorption efficiencies were found for each sampler at each loading except benzene on SCT. For aromatic compounds, toluene, ethyl benzene, m-, p-, and o-xylenes, greater than 98 percent desorption efficiencies were found for each sampler except that o-xylenes had desorption efficiencies approximately 93 percent for each sampler. The overall performances of charcoal tube and passive sampler for desorbing aliphatic and aromatic hydrocarbons were excellent. Recoveries reported here could be used to interpret field sampling results. Those recoveries which exceeded 100 percent were due to variability or errors in the test method as the samplers could not possibly be greater than 100 percent efficient. For those solvents where this occurred an efficiency of 100 percent was assumed.

The desorption efficiencies for four ketone compounds including acetone, methyl ethyl ketone, methyl isobutyl ketone, and 2-heptanone are given in Table 17. For the charcoal tubes, lower recoveries were found for ketones but most of them were greater than 80 percent. For the passive sampler, only 50 to 70 percent recoveries were found with the exception of methyl isobutyl ketone. Table 18 shows the desorption efficiencies for three ester compounds including isobutyl acetate, n-butyl acetate, and 2-butoxyethyl acetate. The desorption efficiencies for isobutyl acetate and n-butyl acetate were over 90 percent on charcoal tubes and over 80 percent on passive samplers.

The desorption efficiencies for five alcohol compounds including methanol, ethanol, isopropyl alcohol, isobutyl alcohol, and 2-butoxyethanol are shown in Table 19. The recoveries of different compounds ranged from 30 to 70 percent on charcoal tubes and from 20 to 30 percent on passive samplers. These results were relatively lower than the other organic compounds and the lowest recovery was found for 2-butoxyethanol. It also showed that the charcoal tube had lower desorption efficiency at lower loading

levels and relatively higher desorption efficiency at higher loading levels. This result is similar to a study conducted by Posner and Okenfuss (1981a). They predicted that at constant volume and constant weight of sorbent, equilibrium desorption efficiency should be increased with loading. The increase in loading should be greater at lower loading.

Carbon disulfide ($CS_2$) was an excellent extraction solvent for many hydrocarbons, but it yielded poor recovery for extraction of polar compounds such as ketones, esters, and alcohols (Burnett, 1976; Lopes, 1997; Posner and Okenfuss, 1981a; Posner and Okenfuss, 1981b). Some improved recoveries have been obtained by adding 1-5% of a polar compound such as methanol, propanol, butanol or acetone to the $CS_2$ (20,104). This technique has limited use for complex mixtures such as paint solvents since they required a different desorption solvent for polar and non-polar analytes or they required multiple samples. Lopes recommended that using a single extraction solvent, containing of 4% dimethyl sulfoxide (DMSO) in $CS_2$, giving satisfactory recovery (higher than 80%) for many commonly used paint solvents (Lopes, 1997). Langvardt and Melcher (1979) described a gas chromatographic procedure which was capable of measuring both polar and non-polar organic solvents. In their study airborne organics were collected on a single charcoal tube and desorbed with a two-phase (water/$CS_2$) desorption mixture. Organic and aqueous phases were analyzed separately on the same gas chromatographic column packed with Oronite NIW on Carbopack B. Recoveries for fifteen common solvents were greater than 90% with the exception of methyl ethyl ketone.

Comparison of Four Sampling Devices

Ten organic solvents were identified in the application of spraying lacquers using four sampling devices: charcoal tube (CT), pre-filtered charcoal tube (FC), vapor/aerosol sampler (VA) and passive sampler (PS). Since only four identified hydrocarbons including n-heptane, toluene, ethyl benzene, and xylenes were validated for the passive sampler, the mean measured concentrations for each of the four types of samplers were

reported for these four hydrocarbons (Tables 20 and 21). The mean measured concentrations of the other six identified solvents including ethanol, isopropyl alcohol, isobutyl alcohol, methyl ethyl ketone (MEK), isobutyl acetate, and 2-butoxyethanol were reported for the other three types of samplers (Tables 22 and 23). Results were shown for all samples combined into one data set, and then separately for each sampling trial.

Table 16. Mean desorption efficiencies of aliphatic and aromatic hydrocarbons for JCTV, SCT, SCTV and PS over three loading ranges.

| *Compound* | *Loading (μg)* | *JCTV*[a] | | *SCT*[b] | | *SCTV*[c] | | *PS*[d] | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD[e] | Mean | SD[e] | Mean | SD[e] | Mean | SD[e] |
| n-Heptane | 10 | 101.2 | 1.8 | 100.8 | 1.0 | 100.5 | 0.4 | 104.7 | 1.9 |
| | 100 | 104.3 | 2.8 | 96.7 | 3.8 | 102.9 | 3.3 | 103.0 | 1.5 |
| | 1000 | 105.7 | 1.1 | 95.7 | 6.9 | 101.1 | 0.4 | 107.9 | 1.1 |
| | **Mean** | **103.7** | **2.6** | **97.7** | **4.3** | **101.5** | **1.9** | **105.2** | **2.5** |
| Benzene | 5 | 96.4 | 1.1 | 101.0 | 1.0 | 100.2 | 0.4 | 98.3 | 1.6 |
| | 50 | 94.8 | 2.8 | 93.1 | 4.8 | 98.2 | 6.8 | 99.3 | 0.2 |
| | 500 | 96.8 | 0.4 | 89.0 | 0.1 | 96.4 | 1.1 | 98.1 | 0.1 |
| | **Mean** | **96.0** | **1.6** | **94.4** | **5.9** | **98.3** | **3.6** | **98.6** | **0.9** |
| Toluene | 5 | 96.8 | 3.1 | 98.9 | 3.5 | 100.7 | 1.8 | 101.9 | 1.8 |
| | 50 | 98.1 | 2.9 | 98.3 | 2.3 | 101.5 | 2.0 | 94.9 | 1.6 |
| | 500 | 100.5 | 1.1 | 95.2 | 6.3 | 96.6 | 4.3 | 100.3 | 0.6 |
| | **Mean** | **98.4** | **2.6** | **97.5** | **3.8** | **99.6** | **3.3** | **99.0** | **3.5** |
| Ethyl | 5 | 98.0 | 1.3 | 100.4 | 1.5 | 103.1 | 2.4 | 100.5 | 0.1 |
| Benzene | 50 | 100.4 | 0.2 | 101.2 | 1.7 | 102.6 | 3.4 | 104.3 | 0.1 |
| | 500 | 99.5 | 0.8 | 97.1 | 3.2 | 100.5 | 0.3 | 101.5 | 0.5 |
| | **Mean** | **99.3** | **1.3** | **99.6** | **2.6** | **102.0** | **2.2** | **102.1** | **1.8** |
| m-&p- | 10 | 96.7 | 3.3 | 97.8 | 1.7 | 97.1 | 1.2 | 102.3 | 2.7 |
| Xylenes | 100 | 98.4 | 2.7 | 100.0 | 2.5 | 101.8 | 1.7 | 95.9 | 1.3 |
| | 1000 | 100.8 | 1.0 | 96.7 | 6.5 | 97.0 | 4.1 | 100.4 | 0.3 |

Table 16. (cont)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Mean** | **98.6** | **2.7** | **98.2** | **3.5** | **98.7** | **3.2** | **99.5** | **3.2** |
| o-Xylenes | 5 | 91.2 | 3.7 | 87.2 | 2.1 | 86.2 | 2.1 | 90.0 | 2.6 |
| | 50 | 93.3 | 3.1 | 96.2 | 3.1 | 97.8 | 1.9 | 90.6 | 1.3 |
| | 500 | 96.5 | 0.9 | 94.0 | 6.2 | 94.2 | 3.9 | 95.9 | 0.2 |
| | **Mean** | **93.6** | **3.3** | **92.5** | **5.3** | **92.7** | **5.7** | **92.2** | **3.2** |

[a]JCTV: Jumbo charcoal tube into vial (800/200 mg)
[b]SCT: Small charcoal tube (100/50 mg)
[c]SCTV: Small charcoal tube into vial
[d]PS: Passive sampler
[e]SD: Standard deviation

Table 17. Mean desorption efficiencies of ketones for JCTV, SCT, SCTV and PS over three loading ranges.

| *Compound* | *Loading (μg)* | *JCTV*[a] | | *SCT*[b] | | *SCTV*[c] | | *PS*[d] | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD[e] | Mean | SD[e] | Mean | SD[e] | Mean | SD[e] |
| Acetone | 10 | 60.2 | 3.0 | 84.5 | 1.0 | 84.4 | 3.4 | 49.9 | 1.4 |
| | 100 | 67.8 | 0.6 | 72.6 | 3.2 | 80.8 | 2.7 | 54.3 | 1.2 |
| | 1000 | 87.0 | 0.7 | 77.4 | 0.1 | 86.4 | 0.3 | 68.0 | 0.7 |
| | **Mean** | **71.7** | **12.5** | **78.2** | **5.6** | **83.9** | **3.2** | **57.4** | **8.5** |
| Methyl Ethyl | 10 | 69.0 | 4.5 | 85.7 | 6.1 | 88.5 | 0.1 | 55.6 | 2.4 |
| Ketone | 100 | 69.3 | 7.9 | 75.9 | 1.5 | 83.0 | 3.4 | 43.5 | 0.4 |
| | 1000 | 96.0 | 1.3 | 87.0 | 5.0 | 90.7 | 2.2 | 74.5 | 0.8 |
| | **Mean** | **78.1** | **14.4** | **82.9** | **6.5** | **87.4** | **4.0** | **57.9** | **14.0** |
| Methyl | 10 | 76.9 | 1.1 | 93.4 | 0.1 | 94.8 | 0.8 | 68.6 | 1.5 |
| Isobutyl | 100 | 86.9 | 0.9 | 93.6 | 1.3 | 95.2 | 2.4 | 73.5 | 1.8 |
| Ketone | 1000 | 97.1 | 0.6 | 92.4 | 0.4 | 98.2 | 0.4 | 87.5 | 0.4 |
| | **Mean** | **87.0** | **9.0** | **93.1** | **0.8** | **96.1** | **2.0** | **76.5** | **8.9** |
| 2-Heptanone | 5 | 65.4 | 1.4 | 72.6 | 0.7 | 74.0 | 2.0 | 52.2 | 1.5 |
| | 50 | 80.3 | 1.5 | 89.8 | 0.4 | 90.5 | 1.7 | 65.5 | 2.1 |
| | 500 | 96.1 | 0.4 | 94.3 | 3.1 | 97.4 | 0.7 | 83.6 | 0.1 |
| | **Mean** | **80.6** | **13.8** | **85.5** | **10.3** | **87.3** | **10.8** | **67.1** | **14.1** |

[a]JCTV: Jumbo charcoal tube into vial (800/200 mg)
[b]SCT: Small charcoal tube (100/50 mg)
[c]SCTV: Small charcoal tube into vial
[d]PS: Passive sampler
[e]SD: Standard deviation

Table 18. Mean desorption efficiencies of esters for JCTV, SCT, SCTV and PS over three loading ranges.

| *Compound* | *Loading (μg)* | *JCTV*[a] | | *SCT*[b] | | *SCTV*[c] | | *PS*[d] | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD[e] | Mean | SD[e] | Mean | SD[e] | Mean | SD[e] |
| Isobutyl | 10 | 87.6 | 1.4 | 99.1 | 0.7 | 98.4 | 2.0 | 83.0 | 1.6 |
| Acetate | 100 | 95.0 | 0.0 | 98.3 | 1.2 | 100.6 | 2.5 | 86.9 | 1.3 |
| | 1000 | 100.0 | 0.4 | 94.5 | 0.9 | 100.2 | 0.4 | 95.2 | 0.3 |
| | **Mean** | **94.2** | **5.6** | **97.3** | **2.3** | **99.7** | **1.8** | **88.3** | **5.7** |
| n-Butyl | 10 | 81.1 | 1.7 | 96.1 | 2.3 | 96.2 | 0.6 | 83.3 | 0.2 |
| Acetate | 100 | 91.7 | 5.1 | 97.6 | 2.1 | 100.0 | 1.4 | 76.6 | 1.1 |
| | 1000 | 103.1 | 1.2 | 97.0 | 6.8 | 97.7 | 4.3 | 94.2 | 0.2 |
| | **Mean** | **92.0** | **10.1** | **96.9** | **3.4** | **98.0** | **2.7** | **84.7** | **8.0** |
| 2-Butoxy- | 5 | 50.2 | 4.0 | 71.0 | 8.6 | 67.6 | 4.0 | 48.1 | 1.8 |
| Ethyl Acetate | 50 | 70.8 | 3.3 | 86.1 | 2.3 | 86.7 | 0.2 | 46.6 | 2.6 |
| | 500 | 96.8 | 0.3 | 95.1 | 3.0 | 97.7 | 0.9 | 77.0 | 0.3 |
| | **Mean** | **72.6** | **21.0** | **84.1** | **11.7** | **84.0** | **13.7** | **57.2** | **15.4** |

[a]JCTV: Jumbo charcoal tube into vial (800/200 mg)
[b]SCT: Small charcoal tube (100/50 mg)
[c]SCTV: Small charcoal tube into vial
[d]PS: Passive sampler
[e]SD: Standard deviation

Table 19. Mean desorption efficiencies of alcohols for JCTV, SCT, SCTV and PS over three loading ranges.

| *Compound* | *Loading (μg)* | *JCTV*[a] | | *SCT*[b] | | *SCTV*[c] | | *PS*[d] | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD[e] | Mean | SD[e] | Mean | SD[e] | Mean | SD[e] |
| Methanol | 10 | 20.1 | 2.1 | 29.1 | 3.3 | 33.1 | 3.1 | 44.7 | 11.0 |
| | 100 | 51.9 | 1.2 | 28.2 | 3.7 | 33.9 | 3.4 | 14.5 | 0.8 |
| | 1000 | 54.7 | 2.9 | 45.5 | 7.6 | 52.2 | 10.4 | 16.8 | 0.9 |
| | **Mean** | **42.2** | **17.3** | **34.3** | **9.6** | **39.7** | **10.9** | **25.3** | **15.8** |
| Ethanol | 10 | 40.5 | 4.1 | 53.3 | 4.9 | 49.7 | 4.8 | 38.1 | 4.7 |
| | 100 | 58.6 | 0.2 | 47.6 | 1.0 | 51.4 | 2.0 | 19.7 | 0.5 |
| | 1000 | 69.5 | 2.0 | 62.1 | 4.8 | 70.4 | 4.5 | 24.0 | 0.5 |
| | **Mean** | **56.2** | **13.2** | **54.4** | **7.2** | **57.1** | **10.7** | **27.3** | **8.9** |
| Isopropyl | 5 | 46.7 | 2.0 | 60.5 | 1.2 | 62.9 | 0.5 | 25.4 | 0.9 |
| Alcohol | 50 | 57.8 | 4.8 | 57.6 | 0.0 | 64.5 | 6.8 | 20.7 | 1.1 |
| | 500 | 78.7 | 1.9 | 74.2 | 1.5 | 78.2 | 3.0 | 32.7 | 1.2 |
| | **Mean** | **61.1** | **14.8** | **64.1** | **8.0** | **68.5** | **8.2** | **26.3** | **5.5** |
| Isobutyl | 5 | 60.9 | 1.5 | 67.5 | 9.0 | 69.8 | 3.9 | 9.7 | 0.3 |
| Alcohol | 50 | 64.8 | 0.3 | 67.0 | 2.4 | 67.9 | 4.0 | 27.5 | 1.7 |
| | 500 | 84.2 | 0.4 | 78.8 | 3.5 | 86.4 | 2.3 | 39.3 | 0.3 |
| | **Mean** | **69.9** | **11.2** | **71.1** | **7.5** | **74.7** | **9.5** | **25.5** | **13.4** |
| 2-Butoxy- | 5 | 3.8 | 0.6 | 19.1 | 1.0 | 21.3 | 0.2 | 1.7 | 0.2 |
| ethanol | 50 | 17.8 | 1.4 | 25.4 | 2.8 | 27.7 | 5.3 | 5.6 | 0.4 |
| | 500 | 65.1 | 1.6 | 65.6 | 1.3 | 66.9 | 5.8 | 13.7 | 1.0 |
| | **Mean** | **28.9** | **28.7** | **36.7** | **22.6** | **38.6** | **22.4** | **7.0** | **5.5** |

[a]JCTV: Jumbo charcoal tube into vial (800/200 mg)
[b]SCT: Small charcoal tube (100/50 mg)
[c]SCTV: Small charcoal tube into vial
[d]PS: Passive sampler
[e]SD: Standard deviation

When all samples were combined into one data set for the four types of samplers as shown in Table 20, there were significant differences between CT, FC, VA and PS for n-heptane, toluene, ethyl benzene, and xylenes. For n-heptane, results indicated thatconcentrations measured by PS were greater than those measured by FC and CT , but VA, FC and CT results did not differ. For toluene, concentrations measured by PS were greater than those measured by VA and CT, but VA, FC and CT results were not different. For ethyl benzene and xylenes, concentrations measured by PS were greater than those measured by VA, FC and CT, but VA, FC and CT results did not differ. When results for these four hydrocarbons were combined, PS results were higher than the other three types samplers, but there were no differences between the three samplers.

Table 20. Mean airborne concentrations of four lacquer solvent constituents monitored during 13 field trials of spraying operations measured with four sampling technologies.

| *Compound* | *Mean Concentration ($mg/m^3$)* | | | | *Significant* | *p-Value* |
|---|---|---|---|---|---|---|
| | *CT*[a] | *FC*[b] | *VA*[c] | *PS*[d] | *Difference* | |
| n-Heptane | 45.4 | 47.1 | 50.5 | 65.3 | PS=VA>VA=FC=CT | 0.0484 |
| Toluene | 636.8 | 731.8 | 654.5 | 809.5 | PS=FC>FC=VA=CT | 0.0016 |
| Ethyl Benzene | 25.0 | 25.2 | 25.8 | 37.7 | PS>VA=FC=CT | 0.0260 |
| Xylenes | 139.6 | 143.2 | 143.0 | 236.0 | PS>FC=VA=CT | 0.0175 |
| 4 Compound Total | 846.8 | 883.7 | 873.8 | 1148.6 | PS>FC=VA=CT | 0.0021 |

[a]CT: Charcoal sorbent tube
[b]FC: pre-Filtered charcoal tube
[c]VA: Vapor/aerosol sampler
[d]PS: Passive sampler

The nature of exposure during spray painting was such that concentrations can be expected to fluctuate rapidly. If the passive sampler was unable to response quickly enough, this could add to the variability. As shown in Table 21 which provided the measured concentrations for each sampling trial, the PS results were up to 2 to 3 times higher than the concentrations measured by other samplers in some trials. These problems with extreme variability in environmental conditions have been pointed out by Coker (1987) and may explain our results. Coker has described occasional a "wild" result in field trials with, in some trials, up to 10% of PS measurements differing by a factor of more than 2 from CT measurements. Therefore, we tried to exclude the data of trial no. 8 since it seemed to be "wild" results, but only toluene showed different

results. It showed that PS and FC results were not different but they were higher than VA and CT. So accounting for the outliers did not fully explain the overall results.

The higher concentrations measured by PS than by other three types of samplers for the four hydrocarbons occurred in most trials as shown in Table 21. Similar problems have been reported by Bjϕrseth et al. (1987) and Cohen et al. (1992). The study performed by Bjϕrseth et al. (1987) was conducted in an oil mist contaminated environment. Results showed that use of diffusive samplers for hydrocarbon sampling gave higher concentrations than CT. In their laboratory tests the three diffusive samplers indicated approximately twice the concentration of CT. The authors suggested that these results were possibly due to the construction of the samplers and the handling procedures of the adsorbent between sampling and analyzing. In particular, the SKC sampler, with a thick porous membrane which was not removed after sampling, seemed to be sensitive to oil droplets and allowed transfer of hydrocarbons to the adsorbent after sampling. In the study performed by Cohen et al. (1992) sampling was conducted during spray painting of automobiles where both vapors and aerosols were produced. Results showed that diffusive monitors collected higher concentrations of xylenes in clear coat, and of toluene in all cases than CT. Their explanations for this were the bias in the sampling rates provided by the supplier and diffusion membrane damage caused by liquid solvent in droplets.

Table 21. Airborne concentrations of four lacquer solvent constituents for each trial of spraying operation measured with four sampling technologies.

| *Compound* | *Trial No.* | *Airborne Concentration ($mg/m^3$)* | | | |
|---|---|---|---|---|---|
| | | *CT*[a] | *FC*[b] | *VA*[c] | *PS*[d] |
| **n-Heptane** | 1 | 0.25 | 0.37 | 0.31 | 0 |
| | 2 | 45.82 | 46.52 | 48.38 | 56.22 |
| | 3 | 101.17 | 79.89* | 82.82 | 99.09 |
| | 4 | 10.12 | 10.99 | 10.96 | 10.67 |
| | 5 | 93.12 | 89.69 | 83.33 | 113.67 |
| | 6 | 84.14 | 100.32 | 95.80 | 120.01 |
| | 7 | 80.06 | 83.82 | 92.27 | 111.29 |
| | 8 | 124.65 | 142.78 | 145.00 | 262.30 |
| | 9 | 40.34 | 38.42 | 39.76 | 60.26 |
| | 10 | 1.29 | 1.50 | 1.66 | 1.57 |
| | 11 | 0.63 | 0.76 | 0.84 | 2.70 |
| | 12 | 2.23 | 2.59 | 2.72 | 7.66 |
| | 13 | 3.48 | 3.73 | 3.67 | 3.71 |
| **Toluene** | 1 | 328.82 | 283.79 | 266.46 | 339.65 |
| | 2 | 178.75 | 169.28 | 172.83 | 215.52 |
| | 3 | 268.49 | 218.28 | 221.76 | 293.37 |
| | 4 | 29.51 | 47.79 | 33.46 | 40.69 |
| | 5 | 399.07 | 381.29 | 342.88 | 477.29 |
| | 6 | 353.49 | 420.64 | 393.28 | 494.44 |
| | 7 | 334.71 | 340.36 | 372.04 | 479.66 |
| | 8 | 524.35 | 596.21 | 577.05 | 1125.23 |
| | 9 | 202.08 | 183.79 | 182.95 | 303.38 |
| | 10 | 317.89 | 369.14 | 373.45 | 451.69 |
| | 11 | 137.76 | 156.70 | 153.08 | 192.78 |
| | 12 | 1592.78 | 1777.55 | 1762.42 | 2272.67 |
| | 13 | 3610.78 | 3884.03 | 3483.90 | 3836.64 |

Table 21. (cont)

| *Compound* | *Trial No.* | *Airborne Concentration ($mg/m^3$)* | | | |
|---|---|---|---|---|---|
| | | *CT*[a] | *FC*[b] | *VA*[c] | *PS*[d] |
| **Ethyl Benzene** | 1 | 7.34 | 6.28 | 5.83 | 5.87 |
| | 2 | 23.62 | 22.47 | 21.72 | 28.29 |
| | 3 | 37.84 | 30.38 | 29.94 | 38.55 |
| | 4 | 5.73 | 6.83 | 6.39 | 5.80 |
| | 5 | 32.34 | 30.25 | 27.25 | 39.15 |
| | 6 | 28.56 | 33.94 | 31.42 | 43.34 |
| | 7 | 26.15 | 25.91 | 28.01 | 36.48 |
| | 8 | 40.54 | 45.14 | 41.78 | 129.23 |
| | 9 | 20.99 | 18.37 | 18.36 | 28.29 |
| | 10 | 6.43 | 7.42 | 7.61 | 8.50 |
| | 11 | 3.46 | 4.04 | 4.10 | 3.98 |
| | 12 | 27.58 | 30.00 | 31.10 | 44.39 |
| | 13 | 64.35 | 66.90 | 60.81 | 78.86 |
| **Xylenes** | 1 | 40.80 | 34.51 | 31.83 | 30.88 |
| | 2 | 77.29 | 72.41 | 71.02 | 92.98 |
| | 3 | 117.80 | 90.98 | 90.07 | 119.76 |
| | 4 | 18.81 | 23.76 | 21.23 | 20.39 |
| | 5 | 196.68 | 184.46 | 162.10 | 261.50 |
| | 6 | 183.99 | 218.01 | 201.85 | 296.02 |
| | 7 | 166.23 | 167.98 | 177.17 | 255.63 |
| | 8 | 264.52 | 296.81 | 276.36 | 923.42 |
| | 9 | 144.91 | 123.17 | 122.96 | 199.06 |
| | 10 | 38.66 | 43.77 | 45.5 | 58.43 |
| | 11 | 21.94 | 25.28 | 25.83 | 28.86 |
| | 12 | 168.07 | 180.92 | 183.98 | 281.31 |
| | 13 | 375.28 | 399.23 | 377.82 | 500.11 |

[a]CT: Charcoal sorbent tube
[b]FC: pre-Filtered charcoal tube
[c]VA: Vapor/aerosol sampler
[d]PS: Passive sampler
*: Breakthrough sample

The reported flow rate for the passive monitors has been questioned for toluene and styrene (Cohen, et al. 1992; Geuskens, et al. 1990). In the case of toluene, the sampling rate of the passive sampler appeared to be considerably lower than the value supplied by the manufacturer and required to be corrected by a factor about 1.8 (Cohen, et al. 1992). In the case of styrene, it was suggested that the uptake rate was about 1.2 times that reported by the manufacturer (Geuskens, et al. 1990). Our data suggested that, under our sampling conditions, the sampling rates should be corrected by a factor of 1.4, 1.3, 1.5, and 1.7 for n-heptane, toluene, ethyl benzene, and xylenes, respectively. These numbers were calculated by using the mean TWA concentrations obtained from the passive samplers divided by those obtained from the charcoal tubes for these four compounds.

When measurements with the FC, VA and CT samplers were compared (Table 22), it showed that no significant differences between the three samplers with the exception of MEK. These results were unexpected. Since a lot of droplets were present during the process of spraying lacquers, these droplets should have been collected by the large collection surface area (prefilter) of FC and VA. Therefore, when monitoring aerosol/vapor mixtures, FC and VA would be expected to provide higher solvent concentrations than CT. In our results, FC and VA did have higher TWA concentrations than CT except for ethanol and 2-butoxyethanol, but their differences were not significant. This was unlike the findings of the Cohen et al. (1992) investigation. Their study showed that filters followed by charcoal tubes (F-CST) had significantly higher xylenes and toluene concentrations than charcoal sorbent tubes (CST) in most cases. They determined that droplets would hold up to 50 percent of the airborne xylenes, as estimated from the overall mean concentrations of xylenes. However, their measured concentrations of xylenes and toluene averaged about 2.0 and 0.1 ppm for base coat and clear coat applications. These concentrations were well below the TLV-TWA of 100 ppm for these solvents. Our sampling was conducted in a workplace at much higher solvent concentrations than their study and resulted in an average of 174.6 ppm for toluene and 33.8 ppm for xylene. Perhaps these higher levels

were indicative of rapid vaporization of aerosolized paint aerosols and caused different results between the two study, however, this requires further investigation.

Table 22. Mean airborne concentrations of six lacquer solvent constituents monitored during 13 field trials of spraying operations measured with three sampling technologies.

| *Compound* | *Mean Concentration ($mg/m^3$)* | | | *Significant Difference* | *p-Value* |
|---|---|---|---|---|---|
| | *CT*[a] | *FC*[b] | *VA*[c] | | |
| Ethanol | 2.17 | 1.92 | 1.94 | NSD[d] | 0.2521 |
| Isopropyl Alcohol | 391.8 | 415.5 | 413.8 | NSD[d] | 0.2471 |
| Isobutyl Alcohol | 297.9 | 315.4 | 308.7 | NSD[d] | 0.2621 |
| Methyl Ethyl Ketone | 12.8 | 14.8 | 13.0 | FC>VA=CT | 0.0227 |
| Isobutyl Acetate | 907.4 | 948.3 | 952.2 | NSD[d] | 0.2889 |
| 2-Butoxyethanol | 4.33 | 4.97 | 3.69 | NSD[d] | 0.0570 |

[a]CT: Charcoal sorbent tube
[b]FC: pre-Filtered charcoal tube
[c]VA: Vapor/aerosol sampler
[d]NSD: No significant difference

The other possible explanation of no significant differences between CT results and FC/VA results could be the particle collection efficiency of charcoal tubes. Charcoal tubes have been reported to capture not only vapor molecules but also particles in the environment containing vapors and particulates (Brosseau, et al. 1992; Fairchild and Tillery, 1977). Brosseau et al. (1992) found that the collection efficiency for charcoal tubes increased with particle size. They ranged from 10 percent for 0.5 μm particles to 100 percent for particles greater than 2 μm. Fairchild and Tillery (1977) reported that the particle collection efficiency of charcoal tubes ranged from 70 % for 1.0 μm

particles to greater than 90 percent for 5.7 μm particles. Particle size distribution of overspray generated during spray painting has been reported to be ranged from 20 to 60 μm which were much greater than 2 μm (Brosseau, et al. 1992; Burkholz, et al. 1977; Chan, et al. 1986). Therefore, the particle collection efficiency of charcoal tubes should be 100 percent for paint overspray aerosols.

Our data showed that there was no significant differences between FC and VA and there was no consistency indicating which one has higher value (Table 22 and 23). As shown in Appendix II (Trails 1-13) which listed the raw data of GC analytical results for each sampling device at each sampling trial, the masses of solvents collected by the filters of FC and VA were extremely low compared to the masses collected by the follow-up charcoal tubes. It is possible that the solvent droplets of the spray evaporated so fast that by the time they reached the sampler only dried paint was collected on the filters. In the publication of Cohen et al., no data on the masses of solvents (toluene and xylenes) collected by the filters was provided. Whether the solvents collected by the filters caused the different results in two studies was unknown. However, sample losses by the filters or wall losses in sampler chambers of the FC and VA were very possible during and after sampling procedures. It has been indicated that electrostatic attraction to the cassette inlet and walls reduced the amount collected onto the filter, especially if the cassette was constructed of nonconducting material (Willeke and Baron, 1990). The loss increased with the number of electrical charges on the aerosol particles and on the sampler and decreased with sampling rate. The IOM sampler was all constructed of nonconducting material but it operated with a higher sampling rate (2 L/min) than vapor/aerosol sampler. So we did not know which sampler had more loss from the filter. Since there is no available data (published or unpublished) indicating the filter or wall losses of the IOM sampler and the vapor/aerosol sampler in similar field sampling, this potential source of error needs to be further studied.

Worker Exposure Levels

The measured TWA concentrations of the ten identified solvents and their exceeded TLV for each sampling trial were shown in Table 24. The lacquer spraying application resulted in a mean total solvent concentration of 822 ppm (ranging from 69.7 to 3537.1 ppm). Computation of the ACGIH mixture calculation revealed that 92 percent (12/13) of the samples exceeded the TLV based on the additive effect of the solvents. The exceeded TLV ranged from 1.5 to 37 times the TLV-TWA. This high exposure for spraying lacquer task has been shown in Project 2. The study showed that spraying lacquers resulted in a mean total solvent concentration of 355 ppm which was the highest mean exposure task among seven tasks being tested. It also revealed that 93% of the lacquering samples exceeded the TLV-TWA which was identical to our study.

Table 23. Airborne concentrations of six lacquer solvent constituents for each trial of spraying operation measured with three sampling technologies.

| *Compound* | *Trial No.* | *Airborne Concentration ($mg/m^3$)* | | |
|---|---|---|---|---|
| | | *CT*[a] | *FC*[b] | *VA*[c] |
| **Ethanol** | 1 | - | - | - |
| | 2 | 3.74 | 2.94 | 2.82 |
| | 3 | 7.44 | 5.63* | 6.41* |
| | 4 | 0.76 | 2.06 | 0.59 |
| | 5 | 1.41 | 1.45 | 1.24 |
| | 6 | 1.96* | 1.56 | 1.80 |
| | 7 | 2.14* | 1.80 | 2.05 |
| | 8 | 2.97* | 2.47 | 2.60 |
| | 9 | 0.96 | 0.64 | 0.77 |
| | 10 | 0.32 | 0.36 | 0.38 |
| | 11 | 0.14 | 0.14 | 0.12 |
| | 12 | 1.36 | 1.63 | 1.71 |
| | 13 | 2.88* | 2.41* | 2.78 |
| **Isopropyl Alcohol** | 1 | 166.99 | 147.92 | 123.54 |
| | 2 | 137.58 | 123.95 | 115.66 |
| | 3 | 230.40 | 205.80* | 209.70 |
| | 4 | 21.17 | 17.27* | 18.68 |
| | 5 | 281.37 | 292.17 | 248.66 |
| | 6 | 239.16 | 320.33 | 290.89 |
| | 7 | 233.23 | 255.96 | 265.30 |
| | 8 | 397.52 | 474.70 | 458.31 |
| | 9 | 124.75 | 108.94 | 102.91 |
| | 10 | 181.83 | 230.45 | 226.65 |
| | 11 | 68.69 | 71.88 | 65.23 |

Table 23. (cont)

| | | | | |
|---|---|---|---|---|
| | 12 | 983.70 | 1167.59 | 1199.62 |
| | 13 | 2027.45* | 1984.27* | 2054.74 |
| **Isobutyl alcohol** | 1 | 62.24 | 57.05 | 48.19 |
| | 2 | 195.49 | 180.47 | 173.92 |
| | 3 | 322.22 | 280.99* | 286.22 |
| | 4 | 38.48 | 34.21 | 37.14 |
| | 5 | 435.44 | 432.51 | 382.83 |
| | 6 | 387.78 | 493.31 | 454.74 |
| | 7 | 358.20 | 375.09 | 402.13 |
| | 8 | 587.79 | 679.67 | 655.97 |
| | 9 | 243.34 | 210.57 | 201.51 |
| | 10 | 73.35 | 90.29 | 89.24 |
| | 11 | 34.21 | 37.91 | 33.98 |
| | 12 | 356.87 | 407.88 | 422.03 |
| | 13 | 776.87 | 820.26* | 825.06 |
| **Methyl Ethyl Ketone** | 1 | 2.83* | 0.99* | 1.90* |
| | 2 | 17.66 | 22.95 | 19.53 |
| | 3 | 36.91 | 39.72 | 43.87 |
| | 4 | 1.66 | 2.17 | 2.23 |
| | 5 | 17.97 | 17.78 | 15.73 |
| | 6 | 18.12 | 21.62 | 19.26 |
| | 7 | 17.18 | 17.68 | 11.16 |
| | 8 | 25.27 | 29.42 | 25.80 |
| | 9 | 2.40 | 4.39 | 2.24 |
| | 10 | 0.73 | 1.07 | 0.96 |
| | 11 | 0.33 | 0.36 | 0.35 |
| | 12 | 7.05 | 10.46 | 7.14 |
| | 13 | 18.25* | 23.57* | 9.14 |

Table 23. (cont)

| | | | | |
|---|---|---|---|---|
| **Isobutyl acetate** | 1 | 303.88 | 264.16 | 246.76 |
| | 2 | 455.99 | 427.16 | 431.29 |
| | 3 | 706.72 | 557.84 | 577.17 |
| | 4 | 93.61 | 107.72 | 98.73 |
| | 5 | 968.83 | 921.79 | 844.26 |
| | 6 | 888.96 | 1070.37 | 1016.02 |
| | 7 | 807.57 | 84.89 | 917.46 |
| | 8 | 1290.92 | 1451.70 | 1410.33 |
| | 9 | 634.55 | 547.77 | 549.18 |
| | 10 | 357.14 | 415.58 | 426.12 |
| | 11 | 178.01 | 205.51 | 198.75 |
| | 12 | 1658.19 | 1806.06 | 1967.83 |
| | 13 | 3451.77 | 3727.04 | 3695.28 |
| **2-Butoxyethanol** | 1 | 0.72 | 0.94 | 0.42 |
| | 2 | - | - | - |
| | 3 | - | - | - |
| | 4 | - | - | - |
| | 5 | - | - | - |
| | 6 | - | - | - |
| | 7 | - | - | - |
| | 8 | - | - | - |
| | 9 | - | - | - |
| | 10 | 0.76 | 0.94 | 0.65 |
| | 11 | 0.44 | 0.41 | 0.20 |
| | 12 | 5.69 | 7.01 | 4.99 |
| | 13 | 14.05 | 15.57 | 12.19 |

[a]CT: Charcoal sorbent tube
[b]FC: pre-Filtered charcoal tube
[c]VA: Vapor/aerosol sampler
*: Breakthrough sample
-: below detection limit

Table 25 showed the mean exposure measurements and the highest exposure concentrations of the ten identified solvents for spraying lacquer application. It showed that isopropyl alcohol, isobutyl alcohol, toluene and isobutyl acetate were the compounds that exceeded their applicable TLVs.

Most published solvent exposure studies conducted during spraying paint showed that when conducted in a well-controlled spray booth most solvent-spraying activities did not produce serious exposures (Riala, et al. 1984; Whitehead, et al. 1984; Winder and Turner, 1992; Winder and Yeung, 1991). Our study indicates that in the construction environment use of spray booths is impossible and exposures to solvents may be excessive. Without considering the reduction in exposure from the use of personal protective equipment, other control methods such as ventilation and substituting the spray-painting guns could be possible methods to minimize the solvent exposure.

Our data indicates that ventilation had a crucial impact on the concentration of solvent vapor. In sampling trial no. 12 and 13, while painters were spraying final lacquers on doors, the two highest solvent exposures were obtained with the total solvent concentrations of 1654 and 3537 ppm, respectively (Table 25). It was observed that all doors and windows were totally closed and the room was full of the droplets produced by the application during these two sampling trials. Results from Riala et al. (1984) indicate that when a strong draft through the room existed by opening the doors and windows, the painters' exposure was diminished to about one-third of the levels measured when the windows were closed.

Table 24. TWA concentrations obtained from charcoal tube sampling methods of the ten lacquer solvent constituents during 13 field trials of spraying operations.

| | *Ethanol* | *Isopropyl Alcohol* | *MEK* | *Isobutyl Alcohol* | *n-Heptane* | *Toluene* | *Isobutyl Acetate* | *Ethyl Benzene* | *Xylenes* | *2Butoxy ethanol* | *Total ppm* | *Exceeded TLV*[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *TLV (ppm)* | 1000 | 400 | 200 | 50 | 400 | 50 | 150 | 100 | 100 | 25 | | |
| *Trial* | *Measured TWA Concentration (ppm)* | | | | | | | | | | | |
| 1 | - | 106.98 | 1.16 | 28.93 | 0.06 | 91.44 | 65.79 | 1.69 | 9.88 | 0.41 | 306.34 | 3.25 |
| 2 | 3.67 | 88.14 | 7.23 | 90.86 | 11.95 | 49.76 | 98.72 | 5.46 | 18.71 | - | 374.5 | 4.00 |
| 3 | 7.30 | 147.60 | 15.12 | 149.77 | 24.78 | 74.73 | 153.00 | 8.74 | 28.52 | - | 609.55 | 6.40 |
| 4 | 0.74 | 13.56 | 0.68 | 17.89 | 2.48 | 8.21 | 20.27 | 1.32 | 4.55 | - | 69.7 | 0.76 |
| 5 | 1.39 | 180.25 | 7.36 | 202.39 | 22.8 | 111.08 | 209.74 | 7.47 | 47.62 | - | 790.11 | 8.76 |
| 6 | 1.93 | 153.21 | 7.42 | 180.24 | 20.61 | 98.39 | 192.46 | 6.60 | 44.54 | - | 705.39 | 7.84 |
| 7 | 2.10 | 149.41 | 7.04 | 166.49 | 19.61 | 93.17 | 174.83 | 6.04 | 40.24 | - | 658.93 | 7.28 |
| 8 | 2.91 | 254.66 | 10.35 | 273.20 | 30.53 | 145.95 | 279.48 | 9.36 | 64.04 | - | 1070.5 | 11.75 |
| 9 | 0.95 | 79.92 | 0.98 | 113.10 | 9.88 | 56.25 | 137.38 | 4.85 | 35.08 | - | 438.38 | 4.93 |
| 10 | 0.32 | 116.48 | 0.30 | 34.09 | 0.32 | 88.49 | 77.32 | 1.48 | 9.36 | 0.43 | 328.59 | 3.39 |
| 11 | 0.13 | 44.01 | 0.14 | 15.90 | 0.15 | 38.34 | 38.54 | 0.80 | 5.31 | 0.25 | 143.57 | 1.52 |
| 12 | 1.34 | 630.18 | 2.89 | 165.87 | 0.55 | 443.35 | 358.99 | 6.37 | 40.69 | 3.23 | 1653.5 | 16.77 |
| 13 | 2.83 | 1298.8 | 7.48 | 361.08 | 0.85 | 1005.1 | 747.29 | 14.86 | 90.86 | 7.97 | 3537.1 | 36.97 |

[a]The TLV of mixture = C1/T1+C2/T2+C3/T3+....., where C1 indicates the observed air concentration and T1 the corresponding threshold limit. If the sum exceeds unity, then the threshold limit of the mixture is exceeded.

Conventional airless spray-painting guns were reported to have a transfer efficiency of 25 to 35% and high volume/low pressure (HVLP) guns are believed to have a transfer efficiency of at least 65% (Marg, 1989). A study conducted in autobody repair shops showed that a 50% reduction in the particulate overspray exposure and a 30% increase in the ratio of paint film thickness to mass of paint applied can be obtained by substituting HVLP spray-painting guns for conventional spray-painting guns (Heitbrink, et al. 1995). Another study also showed that use of HVLP spray-painting gun appeared to reduce the painter's solvent exposure by a factor of 2 (Heitbrink, et al. 1996).

Table 25. Mean TWA concentrations and the highest TWA concentrations of the ten lacquer solvent constituents during 13 field trials of spraying operations.

| *Compound* | *TLV-TWA (ppm)* | *Mean TWA Concentration (ppm)* | *Multiple of TLV* | *Highest TWA Concentration (ppm)* | *Multiple of TLV* |
|---|---|---|---|---|---|
| Ethanol | 1000 | 2.2 | | 7.3 | |
| Isopropyl Alcohol | 400 | 250.9 | | 1299 | 3.2 |
| Methyl Ethyl Ketone | 200 | 5.3 | | 15.1 | |
| Isobutyl Alcohol | 50 | 138.5 | 2.8 | 361.1 | 7.2 |
| n-Heptane | 400 | 11.1 | | 30.5 | |
| Toluene | 50 | 174.6 | 3.5 | 1005.1 | 20.1 |
| Isobutyl Acetate | 150 | 196.5 | 1.31 | 747.3 | 5.0 |
| Ethyl Benzene | 100 | 5.8 | | 14.9 | |
| Xylenes | 100 | 33.8 | | 90.9 | |
| 2-Butoxyethanol | 25 | 2.5 | | 8.0 | |

Conclusions and Recommendations

Ten organic solvents were identified in the application of spraying lacquers using four sampling devices: charcoal tube, pre-filtered charcoal tube, vapor/aerosol sampler and passive sampler. The TWA concentrations measured by passive samplers were significantly higher than those measured by the other three samplers for n-heptane, toluene, ethyl benzene, and xylene. The concentrations measured by passive samplers were up to 2 to 3 times higher than the concentrations measured by other samplers in some trials. Our data suggested that, under our sampling conditions, the sampling rates should be corrected by a factor of 1.4, 1.3, 1.5, and 1.7 for n-heptane, toluene, ethyl benzene, and xylenes, respectively.

The mean desorption efficiencies for aliphatic and aromatic hydrocarbons including n-heptane, benzene, toluene, ethyl benzene, and xylene were close to 100 percent for charcoal tubes and passive samplers. The overall performances of charcoal tubes and passive samplers for desorbing aliphatic and aromatic hydrocarbons were excellent. However, the desorption efficiencies of alcohols, ketones, and esters, especially of alcohols, were lower than those of aliphatic and aromatic hydrocarbons. The results suggest that carbon disulfide was an excellent extraction solvent for many hydrocarbons, but it yielded poor recovery for extraction of polar compounds such as ketones, esters, and alcohols.

The charcoal tube sampling methods identified spraying lacquer which resulted in a mean TWA air concentration of 822 ppm of organic solvents which is exceedingly high. The concentrations of specific contaminants ranged from 1.5 to 37 times the TLV-TWA. In such high exposure environment, none of observed workers were wearing any personal protective equipment. The implementation of control measures to reduce employee exposure to organic solvents was recommended. Without considering the reduction in exposure from the use of personal protective equipment, other control methods such as ventilation and substituting the spray-painting guns could be possible methods to minimize the solvent exposure.

## Project 4. Task Exposure Matrix and Questionnaire Data

The primary goals of project 4 were to characterize VOC exposures by work task, obtain an estimate of long term exposures to tasks with potential VOC exposures, and describe possible adverse symptoms reported by construction painters.

Study Population

Representatives from 376 painting contractors in Colorado were contacted by mail, telephone or in person and invited to participate in the study. Of these initial contacts, 162 companies were not interested in the study and refused to participate. Of the 214 remaining companies, 93 were contacted three or more additional times by telephone and were either too busy or otherwise reluctant to participate. Twenty additional companies were not studied because the general contractor would not allow researchers on their worksites. Of the remaining 101 companies, logistical difficulties and refusals of individual workers to participate (n=17) reduced the sample size to 62 companies with 85 employees participating.

Commercial workers were especially difficult to access for a variety of reasons. General contractors most often cited insurance and liability as reasons for their reluctance to allow monitoring to be conducted. Interference with the work process, and the possibility of upsetting employees was a concern for both commercial and residential contractors. It should be noted that permission was granted from a painting contractor and his employees to participate in the study, yet the general contractor working on sites at Colorado State University refused access.

Recruiting painting contractors by mail and telephone was less successful than expected. The return rate for mailed consent forms was 3% (6/220) and attempts were made to make telephone contact with nonrespondents to improve this rate. However, the majority of

companies contacted by telephone did not return our calls[1]. Not leaving the reason for calling improved the call-back response but the refusal rate remained high. The procedure that resulted in the highest response rate (>85%) was in-person contact with painters at the worksite. However, this resulted in a very large proportion of our sample being residential construction painters as the in-person contact with painters at commercial projects was not possible. This contact protocol also improved the likelihood that the general contractor would grant us permission to conduct the air monitoring.

Of the 62 companies that participated in the study, air monitoring was performed for 46 companies who were working at residential construction projects (6 at residential remodels, 40 at new residential). Painting contractors who were performing commercial work at the time of monitoring numbered 16 (7 at commercial new projects, 4 at remodels, 5 at road construction/maintenance). As expected contractors performing commercial work employed a larger number of employees and typically had more employees at the worksites monitored. Residential construction painting contractors usually employed one to three crews of two to three workers. At residential worksites most often the more experienced worker applied paint by spray while the one or two other employees assisted, prepared surfaces, or applied paint by other methods.

Air Monitoring Results

Personal air monitoring was successfully completed on 85 workers performing 107 painting processes. A total of 62 charcoal tube samples were analyzed (geometric mean (GM) VOC, 54.8 ppm; geometric standard deviation (GSD), 8.1) and 69 time-weighted average values were obtained from a PID (MiniRAE) (GM VOC, 50.2 ppm, GSD, 6.9). Painting processes ranged from 15 minutes to 8 hours, 55 minutes in length (mean, 2.7 hrs). Observed tasks and process were coded according to the definitions in Tables 26 and 27.

[1] The majority of telephone calls to painting contractors required us to leave a message on an answering machine.

Table 26. Painting processes

| **Residential Painting Processes** | **Commercial/Industrial Painting Processes** |
|---|---|
| 1=staining/lacquering of doors; 2=staining/lacquering of indoor woodwork (wood paneling/moldings, etc.); 3=staining/lacquering of cabinets only; 4=staining/lacquering of outdoor woodwork; 5=staining/lacquering/varnishing/painting of decks only; 6=painting of doors and door trim; 7=painting of doors only; 8=painting of exterior trim; 9=exterior painting - residential noc; 10=painting of floors; 11=painting of interior residential noc; 12="touch-up" of residential (interior or exterior); 13=Faux finish - residential; 14=Wallpaper hanging | 31=staining/lacquering of doors; 32=staining/lacquering of indoor woodwork; 33=staining/lacquering of cabinets only; 34=staining/lacquering of outdoor woodwork; 35=staining/lacquering/varnishing/painting of decks only; 36=painting of doors and door trim; 37=painting of doors only; 38=painting of exterior trim; 39=exterior painting - commercial/industrial noc; 40=painting of floors; 41=painting of interior commercial/industrial noc; 42="touch-up" of commercial/industrial (interior or exterior); 43=Faux finish - commercial |

Table 27. Painting tasks

| **Preparation** | **Application** | **Cleanup** |
|---|---|---|
| 1=prep for staining of wood (refers to wood paneling, doors, any wood product - activities include taping, getting product ready, no major VOC exposure (does not include sanding)); 2=prep for painting/priming of residence interior; 3=prep for painting/priming of residence exterior; 4=prep for application of wallpaper; 5=prep for painting of floors; 6=prep for painting of metal surfaces (doors, trim, siding); 7= 10=sanding before any coating is applied - interior; 11=sanding after an initial coating applied - interior; 12=sanding before any coating is applied - exterior; 13=sanding after an initial coating is applied - exterior | 20=application of stain to wood - first coating; 21=staining of wood - 2nd or 3rd application; 22=application of a sealer to wood; 23=application of a primer to any surface; 24=application of lacquer to wood first application; 25=application of lacquer 2nd or 3rd application; 26=application of paint to any surface - first application; 27=application of paint - 2nd or later application | 50=cleanup of brushes, rollers, tools - solvent based; 51=cleanup of brushes, rollers, tools - water based; 52=cleanup of spray equipment - solvent based; 53=cleanup of spray equipment - water based; 54=providing general assistance to painter/applicator; 55=wallpaper hanging |

Exposures to VOC depends largely on the products used (paints, lacquers, solvents) and the application processes. In addition to coding the applicable task and painting process, one or more tools, paint supply, and materials codes were selected from the definitions in Table 28.

Table 28. Application processes and products

| Tools Used | Paint Supply | Material |
|---|---|---|
| 0=nothing; 1=brush; 2=roller smooth; 3=roller rough; 4=pressure roller; 5=airless sprayer; 6=high vol low press sprayer; 7=convential sprayer; 8=spray roller; 9=spray can; 10=application cloth/pad; 11=sponge; 12=other; 13=spray pot-compressed air | 0=no paint/solvent used; 1=open 5-gal pail; 2=open 5-gal pail with roller insert; 3=open 1gal can; 4=roller tray; 5=closed spray system-or spray system in which paint supply is located far from the worker; 6=closed spray system-<1 gal; 9=other | 1=latex; 2=alkyd paint/enamel; 3=alkyd primer; 3=lacquer sealer; 4=lacquer; 5=stain; 6=mineral spirits; 7=stoddard solvent; 8=petroleum distilates; 9=petroleum naphtha; 10=turpentine; 11=paint thinner; 12-=lacquer thinner; 13=toluene; 14=gasoline; 15=other |

Air monitoring for VOCs was conducted using either a PID (MiniRAE), active sampling with charcoal sorbent tubes, or passive diffusion sampling. All passive samples were collected side-by-side with charcoal sorbent tube samples therefore only sorbent tube data was entered in the database. Sometimes both PID and sorbent tube sampling was conducted on a worker and only sorbent tube data was used in analyses. The time-weighted average VOC concentration data from both charcoal tube and PID samples were nonnormal in distribution. When all available VOC time-weighted average data were combined, the distribution was also nonnormal (Figure 8) and required transformation prior to analysis using parametric methods. The log of the TWA VOC value was most appropriate although the distribution was not perfectly normal (Figure 9).

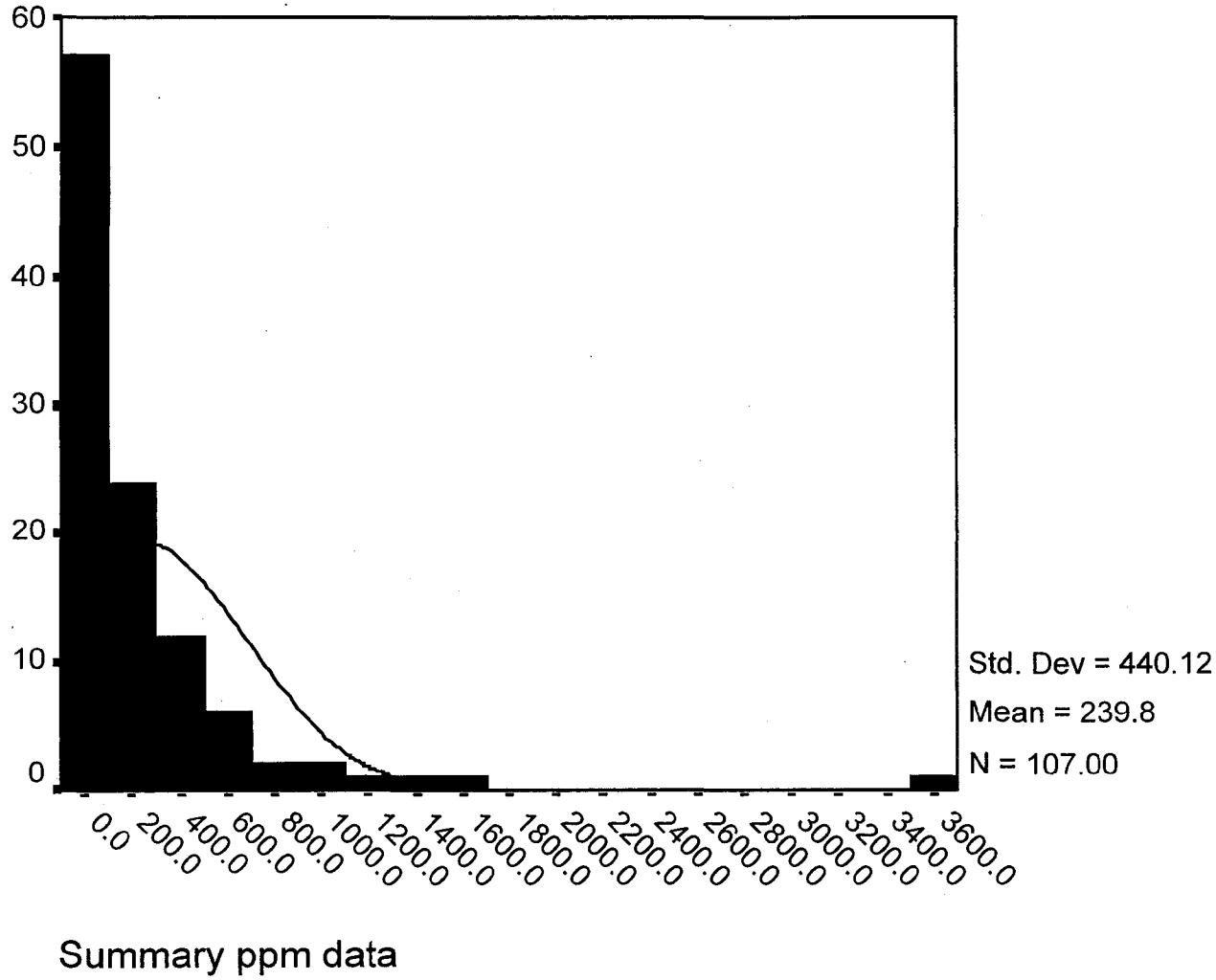



Figure 8. Summary ppm data

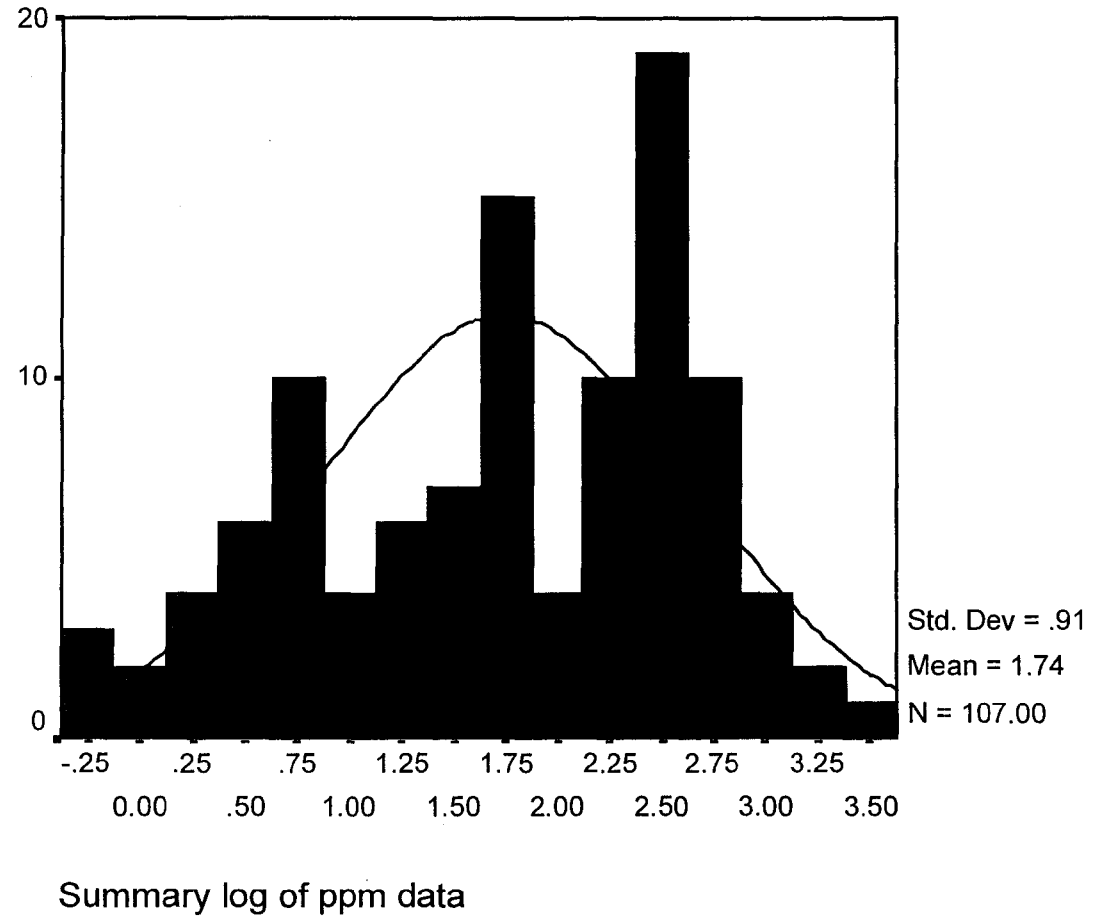



Figure 9. Summary of log transformed ppm data

The geometric mean TWA VOC concentration for all 107 painting processes monitored was 54.8 ppm (GSD, 8.1). When the data were grouped into those from residential versus commercial construction sites, geometric means of 96.6 ppm (n=67) and 19.3 ppm (n=38), respectively, were obtained (p=0.0001). When no solvent borne products were used by the painter during the painting process the geometric mean VOC exposure was 15.8 ppm (n=10) as compared to a GM TWA of 93.8 ppm (n=70) when solvent based products were used through the duration of the process.

Geometric mean values of TWA VOC concentrations by project type are shown in Table 29. The lowest GM values for TWA VOC concentration was for painting of lines on new highways (5.8 ppm). Although this type of project used a highly volatile product (toluene based), exposures were low because almost all work was conducted outdoors. Ceiling VOC values were highest in samples from commercial new construction (GM, 864.4 ppm) and lowest in commercial remodeling (GM, 347.0 ppm). VOC concentrations averaged over 15-minutes (15-min TWA) were recorded for all samples obtained with a PID and the means of the highest 15-min TWA concentrations for each process are also shown in Table 29. Ceiling values represent the highest VOC concentration averaged over 3 seconds for each sampling period.

Table 29. Geometric mean (GM) and geometric standard deviations (GSD) of TWA, STEL and ceiling VOC concentrations (ppm) by project type.

| Project Type | TWA GM | TWA GSD | STEL GM | STEL GSD | Ceiling GM | Ceiling GSD |
|---|---|---|---|---|---|---|
| Residential | | | | | | |
| New (n=52) | 122.7 | 6.84 | 174.0 | 7.09 | 661.4 | 3.15 |
| Remodel (n=15) | 42.0 | 7.39 | 67.4 | 7.77 | 400.1 | 3.32 |
| Commercial | | | | | | |
| New (n=9) | 10.7 | 6.84 | 446.3 | 1.42 | 864.4 | 1.26 |
| Remodel (n=23) | 33.2 | 7.14 | 59.3 | 4.95 | 347.0 | 3.66 |
| Highway (n=6) | 5.8 | 1.38 | 12.55 | 1.96 | 549.0 | 1.13 |

When the mean VOC TWA data were grouped by processes the differences in means were significantly different ($p=0.0106$) (Table 30). The highest TWA VOC concentration recorded (1007.7 ppm) was from one charcoal tube sample obtained over 3.03 hours during the spray application of alkyd paint on doors and wood trim (process 6). This data provides a good example of typical painting work practices in home building which are not appropriate. The application took place in the basement of a new home during the winter. Since the upstairs doors were open, the furnace in the basement was operating continuously and painting took

place within 15 feet of the open flame. In addition to high airborne levels of VOCs (the ceiling and 15-min TWA values were above the maximum values that could be recorded on the PID), open containers totaling 10 gallons of solvent based material (5 gal. alkyd paint; 5 gal. toluene) presented a spill hazard. Lacquers and sander sealers were also often applied in the basement and similar hazards were observed.

Very high exposures during the application of stain and lacquer to doors (process 1), both in terms of TWA (314.3 ppm), STEL (490.1 ppm) and ceiling values (904.9 ppm), were recorded. Application of stain and lacquer to indoor woodwork produced higher exposures during residential construction processes (88.2 ppm TWA) as compared to commercial painting processes (32.2 ppm TWA). Commercial painting using stains and lacquers generally was conducted in larger, more open rooms which diluted the concentrations of the VOCs.

Table 30. Geometric mean values by painting process (ppm)

| Painting process (see Table 26) | TWA GM | TWA GSD | STEL GM | STEL GSD | Ceiling GM | Ceiling GSD |
|---|---|---|---|---|---|---|
| Residential processes | | | | | | |
| 1 | 314.3 | 4.24 | 490.1 | 2.21 | 904.9 | 4.28 |
| 2 | 88.2 | 5.78 | 115.2 | 6.65 | 734.9 | 1.61 |
| 4 | 339.6 | 1.00 | 548.7 | 1.00 | 1009 | 1.00 |
| 6 | 1007 | | 1009 | | 1009 | |
| 9 | 39.0 | 17.45 | 95.4 | 17.89 | 610.0 | 2.36 |
| 11 | 143.8 | 5.17 | 187.4 | 5.33 | 695.4 | 2.21 |
| 12 | 2.90 | | 6.20 | | 84.0 | |
| 13 | 6.12 | 1.00 | 8.60 | 1.00 | 40.1 | 1.00 |
| 17 | 2.90 | | 6.20 | | 84.0 | |
| 20 | 6.21 | | | | 787.0 | |
| Commercial | | | | | | |
| 32 | 32.2 | 9.45 | 281.6 | 1.88 | 710.1 | 2.26 |
| 36 | 29.2 | 1.59 | 32.5 | 1.00 | 631.0 | 1.00 |
| 39 | 6.91 | 1.68 | 13.6 | | | |
| 41 | 23.2 | 9.16 | 65.9 | 6.74 | 310.2 | 4.50 |
| 44 | 76.8 | | 139 | | 905.0 | |

When the data were grouped according to specific tasks the means were significantly different ($p=0.0001$). Highest geometric mean VOC concentrations, presented in Table 31, were for the application of lacquer (241.7 and 387.8 ppm for first and second coatings) and the application of sander sealer (397.9 ppm). When similar tasks were combined (Table 32), the geometric mean TWA VOC for lacquer and sander sealer application was significantly higher than the means for other task groups (300.2 ppm) ($p<0.05$ Least Significant Difference Test). Tasks that involved surface preparation were associated with considerable VOC exposure (31.2 ppm) most likely because the mixing or application of solvent based coatings often took place concurrently.

Table 31. Geometric mean VOC values by painting task (ppm)

| Painting task (see Table 27) | n | TWA GM | TWA GSD |
|---|---|---|---|
| Preparation | | | |
| 1 | 9 | 122.9 | 2.95 |
| 2 | 2 | 26.2 | 22.74 |
| 4 | 1 | 6.30 | |
| 6 | 1 | 2.86 | |
| 10 | 1 | 76.8 | |
| 11 | 3 | 1.62 | 1.08 |
| Application | | | |
| 20 | 23 | 44.1 | 5.91 |
| 22 | 9 | 397.9 | 2.22 |
| 23 | 7 | 14.3 | 9.48 |
| 24 | 14 | 241.7 | 6.18 |
| 25 | 2 | 387.8 | 1.79 |
| 26 | 21 | 41.3 | 8.74 |
| 27 | 3 | 6.89 | 4.38 |
| Cleanup | | | |
| 54 | 3 | 129.3 | 3.39 |

Table 32. Geometric mean VOC values by grouped painting tasks (ppm)

| Painting task (see Table 27) | n | TWA GM | TWA GSD |
|---|---|---|---|
| Preparation | 17 | 31.2 | 8.29 |
| Staining | 23 | 44.1 | 5.91 |
| Priming | 7 | 14.3 | 9.48 |
| Lacquer and sealer | 25 | 300.2 | 4.24 |
| Painting | 24 | 33.0 | 8.64 |
| Helper | 3 | 129.3 | 3.39 |
| Total | 99 | 60.0 | 8.13 |

Relationship of Exposure to Task Related Variables

A number of variables were developed which were related to painting work tasks and the environment in which the painting took place. Analysis of variance and linear regression were performed to determine if these variables were associated with personal exposure to VOCs. When the data were grouped by type of paint supply, statistically significant differences in geometric mean concentrations between using an open 5-gallon pail of paint (158.6 ppm), a one gallon pail (37.9 ppm), and using a sealed paint supply system (127.1 ppm) were found. The contents of the material applied also was associated with exposure ($p=0.009$). The highest geometric mean VOC TWA concentrations were obtained during the application of alkyd paint (48.4 ppm), lacquer (400.6 ppm), sander sealer (103.9 ppm), and stain (51.9 ppm). GM exposures were linearly correlated to the VOC content of the product in g/L obtained from the material safety data sheets ($p<0.05$).

Most painters applying lacquer and sander sealers used airless sprayers with a tip size that allowed for the application of between 0.1 and 0.2 gallons per minute. VOC exposures using the very common 411 tip were significantly higher (525.4 ppm, GM) than those obtained when the 311 tip was used (317.2 ppm, GM). Painters were asked the approximate rate of coating

application in gallons per hour; however, this data was not associated with GM VOC exposures ($p=0.050$), however a trend of increasing exposure with increasing application rate was observed.

When all data were grouped by the location where painting was conducted, differences in GM concentrations between jobs conducted indoors (82.0 ppm) and outdoors (36.7 ppm) were statistically significant. Average dry bulb temperature during the painting task was correlated to TWA GM VOC exposures, with exposures increasing with increasing temperature. Most painting was performed in rooms in which no mechanical ventilation was operating. Although levels of VOC were higher in non-ventilated rooms as compared to rooms with functioning air systems, the difference in means was not statistically significant. Airflow at the point of application, degree of enclosure, and area of open doors and windows were not significant predictors of personal exposure to VOCs.

Questionnaire Responses

Although personal air monitoring was conducted on 85 workers, only 74 completed the questionnaire. The questionnaire took about 15 minutes to complete and, in most instances, were completed on the job site during the lunch break. Fifteen questionnaires were not completed on site and were mailed back to the investigators. The mean number of years that individuals reported working as a painter was 9.12. Ten individuals reported that they had not used solvent-based products in the 52 weeks prior to completing the questionnaire. Of the 60 who reported working with solvent based products in the last year, the mean number of weeks of use of solvent containing materials was 20.35. Of the 59 painters who reported solvent based product use in the preceding 30 days, the mean number of days of use was 10.25 (SD, 9.28).

The reported solvent use in the sample population is heavily weighted to residential construction and is in agreement with anecdotal information gained from discussions with painting contractors. Most non-industrial commercial painting projects require very little

solvent borne coatings. Latex paints are applied to most surfaces in new office buildings. Some commercial projects are specifying water borne products for applications that have traditionally required solvent based products, such as clear coating on wood doors and trim and coating of metal door frames. Residential construction painting is unique in that there are painting processes which still exclusively require the use of solvent borne products.

The typical new house (2500-3000 $ft^2$) requires the equivalent of approximately 80 person-hours to completely paint. With a two or three person crew, painters spend, at maximum, two days preparing for, and applying, solvent based products in a new house. This is reflected in our data in which painters using solvent based products reported on average 10.25 days a month using solvent based coatings. The range of reported days of using solvent based coatings was from 1 to 30 and 32 % of solvent exposed painters reported over 20 days of solvent product use. The large proportion of painters with over 20 days of solvent exposure reflects work practices of construction painters. Although only 2 of 5 days of work on a new residence requires the use of solvent based products, precise application of the coating is necessary and the work is left to the experienced spray painter. Painters who are skilled at applying lacquer usually spray one to three houses per week while less experienced members of the crew perform activities that involve less exposure to VOCs.

Thirty five percent of respondents reported that they spend less than one half of their time actually painting. This finding is similar to results of a previous study of construction and maintenance painters in which 40 % of painters reported that they spent less than half their time painting (Riala et al., 1984). In our investigation, 56.9% of the respondents reported they worked indoors at least one half the time. This is similar to the finding of the Riala et al. (1984) investigation in which 87% reported that they mainly worked indoors. The application of coatings by spray was the most commonly reported method of paint application with 27.5 % of respondents reporting that over 75% of the painting they performed was spraying. Brushing was the next most common method of application and 10% of the painters reported that over 75% of their painting used this method. Four percent of the respondents indicated that over 75% of their painting was performed using a roller. Over fifty percent of respondents reported

that they perform some applications by rag or sponge, however most reported that this application method was infrequently employed.

A number of items on the questionnaire pertained to respirator use. Less than seven percent of the respondents reported to have used supplied air respirators in the past. Chemical cartridge respirators were most often reported to be worn during spray applications, especially during lacquering. Over 22% of respondents reported using disposable dust/mist respirators during the spray application of latex paints. Just over 5% of the painters reported the use of respiratory protection when applying coatings using a brush.

Of the 62 companies where personal air monitoring was conducted, only 5 had a respiratory protection program with written standard operating procedures. All of these five companies employed at least 10 individuals. Although the majority of the other companies provided respirators to their employees, their respiratory protection programs were unstructured. Most respirators were purchased from paint distributors. Even though little formal training was given to workers, for the most part, painters used the appropriate respirator for the hazard in a manner which likely provided adequate protection. For workers who used respirators, they were used appropriately over 80% of the time (correct respirator worn properly). Wearing a respirator and not being clean shaven was the primary reason for classifying respirator use as inappropriate.

Symptoms

Frequencies of reported symptoms are provided in tables in Appendix IV. In each of the tables "0" corresponds to "not at all", "1" to "sometimes", "2" to "often" and "3" to "very often". To determine the relationship of symptom scores to solvent exposure, respondents were grouped according to the following categories of total VOC exposure: low (0-10 ppm), slight (10-100 ppm), moderate (100-300 ppm), and high (over 300 ppm). Differences in mean symptom scores grouped by total VOC exposure were significant for "been feeling run down", "getting edgy or bad tempered", and "felt high or intoxicated at work" (Table 33). With the exception of "getting edgy or bad tempered", symptom scores increased with increasing level of VOC exposure.

For the symptoms in which the mean symptom scores were significantly different when grouped by exposure level, there were also trends when the exposure data were grouped by symptom score. Individuals who reported not at all "feeling run down" were exposed to TWA geometric mean VOC concentration of 29.8 ppm. Those who reported sometimes and often had TWA GM VOC exposures of 52.4 and 88.2 ppm, respectively. Those who reported not at all "feeling intoxicated or high at work" were exposed to a TWA GM VOC of 32.5 ppm while those reporting they sometimes and often feeling this way had GM exposure of 51.9 and 451.6 ppm, respectively.

A number of non-significant trends were also observed in the data when grouped by symptom score. For the symptom "trouble remembering", TWA GM exposures were 35.2, 49.0, and 69.7 ppm for those reporting "not at all", "sometimes", and "often", respectively. For the symptom "feeling tired at work", TWA GM exposures were 25.9 and 53.0 ppm for those reporting "not at all", and "sometimes", respectively. Over 38% of respondents reported they "sometimes" or "often" feeling dizzy at work and the TWA GM concentration for those often feeling dizzy was 226.4 ppm.

**Table 33. ANOVA of mean symptom score and VOC exposure category**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| FELT ILL RECENTLY | Between Groups | 2.278 | 3 | .759 | 1.878 | .149 |
| | Within Groups | 15.769 | 39 | .404 | | |
| | Total | 18.047 | 42 | | | |
| BEEN FEELING RUN DOWN | Between Groups | 3.990 | 3 | 1.330 | 3.632 | .021 |
| | Within Groups | 13.915 | 38 | .366 | | |
| | Total | 17.905 | 41 | | | |
| NOT BEEN ABLE TO CONCENTRATE | Between Groups | .765 | 3 | .255 | .423 | .738 |
| | Within Groups | 24.144 | 40 | .604 | | |
| | Total | 24.909 | 43 | | | |
| HAD TROUBLE REMEMBERING | Between Groups | .917 | 3 | .306 | .869 | .465 |
| | Within Groups | 14.061 | 40 | .352 | | |
| | Total | 14.977 | 43 | | | |
| HAD TROUBLE SLEEPING | Between Groups | .424 | 3 | .141 | .723 | .544 |
| | Within Groups | 7.826 | 40 | .196 | | |
| | Total | 8.250 | 43 | | | |
| LOST SLEEP OVER WORRY | Between Groups | .510 | 3 | .170 | .442 | .724 |
| | Within Groups | 15.376 | 40 | .384 | | |
| | Total | 15.886 | 43 | | | |
| FEELING CONSTANTLY UNDER STRAIN | Between Groups | 3.093 | 3 | 1.031 | 2.111 | .114 |
| | Within Groups | 19.543 | 40 | .489 | | |
| | Total | 22.636 | 43 | | | |
| GETTING EDGY OR BAD TEMPER | Between Groups | 3.722 | 3 | 1.241 | 5.698 | .002 |
| | Within Groups | 8.710 | 40 | .218 | | |
| | Total | 12.432 | 43 | | | |
| FEELING NERVOUS | Between Groups | .328 | 3 | .109 | .496 | .687 |
| | Within Groups | 8.831 | 40 | .221 | | |
| | Total | 9.159 | 43 | | | |
| HAD DIFFUCULTY BREATHING | Between Groups | .309 | 3 | .103 | .724 | .544 |
| | Within Groups | 5.551 | 39 | .142 | | |
| | Total | 5.860 | 42 | | | |
| DEVELOPED HEADACHES AT WORK | Between Groups | .396 | 3 | .132 | .324 | .808 |
| | Within Groups | 15.883 | 39 | .407 | | |
| | Total | 16.279 | 42 | | | |
| BEEN FEELING TIRED AT WORK | Between Groups | 3.336 | 3 | 1.112 | 1.520 | .224 |
| | Within Groups | 28.525 | 39 | .731 | | |
| | Total | 31.860 | 42 | | | |
| FELT UNCOORDINATED AR CLUMSY AT WORK | Between Groups | 1.459 | 3 | .486 | 1.356 | .270 |
| | Within Groups | 13.983 | 39 | .359 | | |
| | Total | 15.442 | 42 | | | |
| FELT DIZZY AT WORK | Between Groups | .466 | 3 | .155 | .371 | .775 |
| | Within Groups | 15.938 | 38 | .419 | | |
| | Total | 16.405 | 41 | | | |
| FELT HIGH OR INTOXICATED AT WORK | Between Groups | 3.623 | 3 | 1.208 | 3.585 | .024 |
| | Within Groups | 11.456 | 34 | .337 | | |
| | Total | 15.079 | 37 | | | |
| DEVELOPED A SKIN RASH OR IRRITATION | Between Groups | .424 | 3 | .141 | 1.287 | .298 |
| | Within Groups | 3.076 | 28 | .110 | | |
| | Total | 3.500 | 31 | | | |
| EXPERIENCED ANY OTHE HEALTH PROBLEMS | Between Groups | .230 | 3 | 7.677E-02 | 1.220 | .322 |
| | Within Groups | 1.636 | 26 | 6.294E-02 | | |
| | Total | 1.867 | 29 | | | |

Conclusion

The geometric mean TWA concentration of 54.8 ppm for all samples indicates that painters have substantial exposures to VOCs. The use of solvents throughout the duration of the painting process was associated with even higher exposures to VOCs (GM, 96.6 ppm). Because of high exposures during the spray application of lacquers, samples obtained on painters in residential construction were higher than those obtained on workers on other projects. When the data were grouped by painting process or by specific work tasks, the differences in means were statistically significant. Application of lacquer and sander sealer were associated with very high exposures both in residential and commercial construction projects.

The variability in sampling results was high and few independent variables related to the task were statistically significant in models in which log ppm concentration was the dependent variable. Geometric mean VOC exposures were linearly correlated with the VOC content of the coating materials applied. Analysis of variance comparing the GM VOC concentration obtained from samples in which painting was performed outdoors was significantly different than those from indoor samples. Other variables describing the painting environment, such as degree of enclosure and airflow, were not significant predictors of painters' exposure to VOCs.

Of the 74 painters who completed the self-administered questionnaire, 10 reported not having used solvent based products in the preceding 52 weeks. For painters who reported using solvent based products in the preceding month, the mean number of days of use in the month was 10.5. Most respondents reported they spend less than one half of their time actually applying paint. The most commonly reported method of applications was spray painting. Many painters thought that the spray application of lacquer was the worst in terms of exposure to organic vapors.

Data from on-site air monitoring surveys showed that only the largest painting contractors had effective respiratory protection programs. Most smaller companies did supply their employees

with respirators but took no steps to ensure they were maintained, cleaned, or worn appropriately. Fortunately, paint suppliers provide seminars and offer advice on the use and care of the respirators they sell. Additionally, the type of respirator usually used by painters is the paint spray respirator (1/2 mask, organic vapor cartridges with prefilters) which is the appropriate respirator for almost all exposure incurred in construction painting.

Exposures to VOC categorized into levels 0-10, 10-100, 100-300, and over 300 to determine its relationship to symptom scores. The likert-type responses to "been feeling run down" and "felt high or intoxicated at work" were significantly positively associated with exposure level. These symptom scores increased with increasing level of VOC exposure. Other symptom scores were not related to VOC exposure.

Overall, painters have the potential to have elevated exposures to VOCs during the course of their work. Painter who work in residential construction on average have 10 days per month when they work with solvent based products. Although TWA exposures over the workweek are likely below applicable standards, ceiling and STEL exposures may often exceed occupational exposure limits. Respiratory protection programs are poor for most painters in Colorado so there is concern that workers may have intermittent exposures to very high concentrations of organic vapors. Exposures were high enough for there to be a correlation between exposure and two specific symptoms reflective of a biological effect.

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## 6. Acknowledgements

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## 7. Publications and Presentations

Colgan, C. *Assessment of Wood Stain Inhalation Exposure Using the Video Exposure Monitoring Technique.* Masters Degree Thesis, 1995, Colorado State University, Fort Collins, CO.

Coy, J. *Field Evaluation of a Portable Photoionization Detector for Assessing Exposure to Solvent Mixtures.* Masters Degree Thesis, 1996, Colorado State University, Fort Collins, CO.

Jinn, J. *Field Comparison of Different Sampling Methods for Evaluating Construction Painters' Exposure to Organic Solvents.* Masters Degree Thesis,1997, Colorado State University, Fort Collins, CO.

Colgan, C., Bigelow, P., Buchan, R., Parnell, J. A Case Study of Video Exposure Monitoring - Identifying the Exposure Sources of Occupational Air Contaminants. Platform

presentation at the American Industrial Hygiene Conference and Exposition, Kansas City, MI, May 22-26, 1995.

Jinn, J., Bigelow, P., Johnson, C., and Tessari, J. (accepted) Field Comparison of Different Sampling Methods for Evaluating Exposure to Volatile Organic Compounds during Spray Application of Lacquer in Residential Construction. *Applied Occupational and Environmental Hygiene.*

Coy, J. D., Bigelow, P., Rong-Jinn, J., and Tessari, J. (under review) Field Evaluation of a Portable Photoionization Detector for Assessing Exposure to Solvent Mixtures. *Applied Occupational and Environmental Hygiene.*

## 8. Planned Publications

Bigelow, P., and Buchan, R. (in preparation) Exposures to organic solvents and acute neurobehavioural effects in a population of construction painters in Colorado. *Applied Occupational and Environmental Hygiene.*

Bigelow, P., and Buchan, R. (in preparation) Safety and health concerns of applying lacquer in residential construction. *Professional Painting Contractor.*

Kelly, K. *Permeation and surface adsorption losses of volatile organic compounds during sampling using Tedlar and 5-layer bags.* Masters Degree Thesis, 1998, Colorado State University, Fort Collins, CO.

## 9. Inventions and Patents

Not applicable to this grant.

## 10. Appendix

See attached (Appendix I to IV).

# Appendix I

# Study of Exposures in Construction Painting – Painter's Consent Form

Principal Investigator: Philip L. Bigelow, Department of Environmental Health,
Co–Investigator: Roy M. Buchan, Department of Environmental Health,
Colorado State University, 110 Veterinary Sciences Building,
Fort Collins, CO, 80523
Phone (303) 491-1405; FAX (303) 491-7778

The purpose of this research project is to assess exposures to contaminants during construction painting, to improve the methods of assessing occupational exposures to painters, and to determine the prevalence of specific health complaints among construction painters. The study is funded by the Department of Health and Human Services, National Institute for Occupational Safety and Health.

Since this study involves observation of normal work procedures there is little risk in participation. The risk due to a break in confidentiality will be minimized by using unique identifiers, not names, for data collection. No reports or documents arising from the study will contain information in which individuals or companies could be identified. Videotapes will be erased upon completion of the study. I understand that it is not possible to identify all potential risks in an experimental procedure, but I believe that reasonable safeguards have been takes to minimize both the known and the potential, but unknown, risks. There are no expected benefits from participation in the study with the exception of possible improvement in the working environment.

Because Colorado State University is a publicly-funded, state institution, it may have only limited legal responsibility for injuries incurred as a result of participation in this study under a Colorado law known as the Colorado Government Immunity Act (Colorado Revised Statutes, Section 24–10–101, et seq.). In addition, under Colorado Law, you must file any claim against the University within 180 days after the date of the injury.

In light of these laws, you are encouraged to evaluate your own health and disability insurance to determine whether you are covered for any injuries you might sustain by participating in this research, since it may be necessary to rely on your individual coverage for any such injuries. If you sustain injuries which you believe were caused by Colorado State University or its employees, we advise you to consult an attorney.

Questions concerning treatment of subjects' rights may be directed to Celia S. Walker at 303-491-1563.

Having read this form I, _____of (company)_____ , hereby give my consent to participate in the Study of Exposures in Construction Painting (An Exposure Matrix for Construction Painters). I understand that the nature of my participation will be to provide written answers to standard questions (Study of Exposures in Construction Painting – Questionnaire) and to allow research associates from Colorado State University to conduct air monitoring and video taping of work that I conduct. I am aware that the video tapes will be erased upon completion of the study and that all information obtained will be strictly confidential. Names of individuals or companies will not be used in any reports or documents to ensure confidentiality.

 Initials_____ Date_____

I understand that my participation in this research is voluntary. If I decide to participate in the study, I may withdraw my consent and stop participating at any time without penalty or loss of benefits to which I am otherwise entitled.

I have read and understand the information stated and willingly sign this consent form. My signature also acknowledges that I have received, on the date signed, a copy of this document containing 2 pages.

_____ _____

Name of Subject (Please Print) Date

_____ _____

Signature of Subject Date

Do you grant permission for the use of the exposure data and video recording of your work to be used for training purposes at your company then subsequently erased ?

Yes ❒ No ❒

_____ _____

Signature of Investigator or Co-Investigator Date

 Initials_____ Date_____

# Study of Exposures in Construction Painting – Employer Consent Form

Principle Investigator: Philip L. Bigelow, Department of Environmental Health,
Co–Investigator: Roy M. Buchan, Department of Environmental Health,
Colorado State University, 110 Veterinary Sciences Building,
Fort Collins, CO, 80523
Phone (303) 491-1405; FAX (303) 491-7778

The purpose of this research project is to assess exposures to contaminants during construction painting, to improve the methods of assessing occupational exposures to painters, and to determine the prevalence of specific health complaints among construction painters. The study is funded by the Department of Health and Human Services, National Institute for Occupational Safety and Health.

Since this study involves observation of normal work procedures there is little risk in participation. The risk due to a break in confidentiality will be minimized by using unique identifiers, not names, for data collection. No reports or documents arising from the study will contain information in which individuals or companies could be identified. Videotapes will be erased upon completion of the study. I understand that it is not possible to identify all potential risks in an experimental procedure, but I believe that reasonable safeguards have been takes to minimize both the known and the potential, but unknown, risks. There are no expected benefits from participation in the study with the exception of possible improvement in the working environment.

Because Colorado State University is a publicly-funded, state institution, it may have only limited legal responsibility for injuries incurred as a result of participation in this study under a Colorado law known as the Colorado Government Immunity Act (Colorado Revised Statutes, Section 24–10–101, et seq.). In addition, under Colorado Law, you must file any claim against the University within 180 days after the date of the injury.

In light of these laws, you are encouraged to evaluate your own health and disability insurance to determine whether you are covered for any injuries you might sustain by participating in this research, since it may be necessary to rely on your individual coverage for any such injuries. If you sustain injuries which you believe were caused by Colorado State University or its employees, we advise you to consult an attorney.

Questions concerning treatment of subjects' rights may be directed to Celia S. Walker at 303-491-1563.

Having read this form I, _____of (company)_____ , hereby give my consent for this company to participate in the Study of Exposures in Construction Painting (An Exposure Matrix for Construction Painters). I understand that the nature of the company's participation will be to allow research associates from Colorado State University to conduct air monitoring and video taping of painters at the jobsites listed below. I am aware that individual painters who volunteer will fill out questionnaires as part of the study. I am aware that I have the right to refuse to participate or withdraw from the study at any time.

 Initials_____ Date_____

I give the investigators the permission to enter the jobsites listed below in order to complete their data collection. (Please list active jobsites for which you would allow this research to be conducted).

Active Jobsites:

| Job Location | Dates of Work | Number of Painters on Site |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

_____ _____

Signature of Company Representative Date

Would you like to be informed of the results of monitoring conducted at the above jobsites ?

Yes ❒ No ❒

_____ _____

Signature of Investigator or Co-Investigator Date

 Initials_____ Date_____

# Development of an Exposure Matrix For Painters Based on Specific Work Tasks

## Project Description

Painters are exposed to a wide variety of substances that may cause acute and chronic adverse health effects. Relatively little work has focused on this occupational group despite the extent of exposure, the large population of workers, and the potential for severe effects -neurotoxicity, increased accident rates, cancer, reproductive disorders, and respiratory disease. The investigation will provide much needed quantitative information on exposures in painting. By focusing on specific work tasks, a new methodology will be developed in which exposures can be accurately estimated on the basis of self reports of work activity. This exposure assessment technique will be valuable when dealing with workers who perform tasks at different jobsites or who perform a variety of activities. The new technique will enhance the capabilities of health scientists in the assessment of exposure of individuals that in the past have been difficult to characterize.

The major hypothesis of the study is that by studying specific job tasks, a painter's overall occupational exposure can be estimated. In order to test this hypothesis, methods are under development to standardize the measurement of organic vapor exposures during specific painting tasks. Another important objective of the study is to determine the relationships between occupational exposures and variables that characterize the work environment. Through the analysis of data collected during this investigation a method will be developed that will allow the prediction of overall occupational exposures based on descriptions of work tasks and characteristics of the occupational environment.

## Volunteer Participation

Participation of painting contractors and painters is essential for successful completion of the project. All information obtained during the study will be strictly confidential. Confidentiality will be maintained through the use of unique identifiers. Company names or the names of individuals will not recorded on any data files. Participation, by companies and individuals, is voluntary and can be terminated at any time. The reports submitted to the National Institute for Occupational Safety and Health will not contain information that will disclose the identity of any company or individual. The results of the study will not be made available to any regulatory agency.

## Methods

All data for the study will be collected while at specific job sites. Data collection at a specific jobsite will normally be completed by two research associates from Colorado State University within an eight hour period. At the worksite employees will be approached individually and invited to participate in the study. They will be given a consent form and a short questionnaire which takes about 15 minutes to complete. After

the form is signed and the questionnaire completed, the worker will be instructed to perform his or her tasks as normal. Routine industrial hygiene monitoring will be conducted during each specific work task to characterize exposure. The research associates, both trained in industrial hygiene, will determine the amount of monitoring required for each work task. It should be noted that this type of exposure assessment is routinely performed in industry and does not interfere with the work process. Depending on the complexity of the specific work tasks, exposure assessments for work conducted by up to four painters may be completed at each job site.

Since the results of monitoring conducted at your jobsites may be of importance in your health and safety program, this information will be made available if requested.

**Funding Agency**

Department of Health and Human Services, Public Health Service, National Institute for Occupational Safety and Health

**Personnel**

Principal Investigator: Phil Bigelow, Ph.D., CIH
Assistant Professor, Department of Environmental Health
Occupational Health and Safety Section
Colorado State University,
153 Environmental Health Building
Fort Collins, CO 80523
Phone (970) 491-6151 FAX (970) 491-7778

Co-Investigator: Roy M. Buchan, Dr. of Public Health, CIH
Professor, Department of Environmental Health
Head, Occupational Health and Safety Section
Colorado State University

Research Associates: Jim Coy, B.S. (Environmental Health)
Research Associate, Department of Environmental Health
Colorado State University

Kimberly Kelley, B.S. (Chemistry)
Research Associate, Department of Environmental Health
Colorado State University

Jia-Rong Jinn, B.S. (Food Science)
Research Associate, Department of Environmental Health
Colorado State University

If you would like further information about the project or would like to participate, please call Phil Bigelow or Kim Kelley at (970) 491-6151.

# Worksite Assessment

Location:_____ +Project Type:_____ Contractor: _____ Sub:_____ Initials:

Describe Paintin g Project (or Job):_____ Completion Date:_____
Painting

**Worker A** ID:_____ Name (opt):_____ +Job Classification:_____
(i.e., modyyr-A)
Rae Start T:_____ Rae Stop T:_____ Pump SN:_____ Media:_____ Pump Start T:_____ Stop T:_____
(CK/BG)

**Worker B** ID:_____ Name (opt):_____ +Job Classification:_____

Pump SN:_____ Media:_____ Pump Start T:_____ Stop T:_____
(CK/BG)

**Worker C** ID:_____ Name (opt):_____ +Job Classification:_____

Pump SN:_____ Media:_____ Pump Start T:_____ Stop T:_____
(CK/BG)

**Worker D** ID:_____ Name (opt):_____ +Job Classification:_____

Pump SN:_____ Media:_____ Pump Start T:_____ Stop T:_____
(CK/BG)

**Worker E** ID:_____ Name (opt):_____ +Job Classification:_____

Pump SN:_____ Media:_____ Pump Start T:_____ Stop T:_____
(CK/BG)

Shift Start/End:_____ Is this normal?_____ Workweek:_____

Company Name: _____ Attn: _____

Address: _____ City: _____ ZIP: _____

NOTES / COMMENTS: _____

**Respiratory Protection Program:** 1. Program administrator_____ 2. Written SOP?_____

3. Physical Exam?_____ 4. Respirator selection - i.e., hazard assessment_____

5. Training? Annual? _____ 6. Fit testing_____

7. Maintenance_____ 8. Inspection_____ 9. Storage_____

Comments _____

**Task#__ Descript&Process_____Worker_____**

Task Start T:_____Task Stop T:_____ Rae PBZ; Bag PBZ; Ck PBZ; rae area; bag area; hnu area PreFilt Y

Tool Types:_____ Tool size:_____Extension:_____Size open pail:_____
brush; roller; spray gun; spray can; cloth; inch brush/roller inches gallons

Pre - Post-Wght

Material1:_____ _____ VOCmax_____
all chemicals - attach MSDS - Bulk collected?

Material2_____ _____ VOCmax_____

Material3_____ _____ VOCmax_____

Spray pres:_____Tip Size or #_____Airless / HVLP / Air Brand_____ AC / gas GPM_____

+Surface Type:_____ Surface Area:_____
material; roughness to be painted SqFt

Break Times:(1)_____ (2)_____ (3)_____ Break Exposure:(1)_____ (2)_____ (3)_____
list (9:00:9:10) zero / low / medium or PID reading

Application Rate:_____ Is this Normal Application Rate:_____
gal/hr Ask - low; med; high

"Duty Cycle"_____Duration of Application_____Total Observation T_____Avg Single Application T_____

Indoors/Out:_____Describe Location:_____

Outside Wind fpm____,____Direction:_____Work area: DB_____RH_____(average of values below)

Time/Temp/RH Data:_____

Rooms Painted

Room(ft): L_____W_____H_____ or # rooms _____Sq Ft House_____ _____

Degree of Enclosure:_____Area Open Windows & Doors($ft^2$):_____Average airflow(fpm):_____
6=6 surfaces; 5=5 surfaces.... ft/min doors and windows

Time/Vent Data:_____

Ventilation:_____ Ventilation effectiveness:_____Airflow at work_____
LEV; Mech; Natl; None

PPE: +Respirator:_____ Brand_____ TC -_____Fit Tested?_____Assigned?_____Condition_____

Respirator Use_____+Clothing Type:_____ +Hand:_____ +Eyes:_____ Other:_____

Dermal:_____Hand Dermal: _____ Body Dermal: _____
0=little; 1=moderate; 2=high Body - contaminated clothing skin

Work Practices to Reduce Exposure:_____

Mix/thinning task included? No if yes → Times_____Work Practice_____Dermal =

Cleaning task included? No if yes → Time:_____ Work Practice_____ Dermal =

Other Trades Exposed? No Yes_____#_____ Other hazards:_____

**Monitoring data** **Sorbent Tube Data**

| Bag # | Start | End | Rae/HNU/ Pump # | Pump# | Start | End | Tube #s worker ID-W-1 | Pre Flow | Post (time) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | x- | | |
| | | | | | | | y- | | |
| | | | | | | | z- | | |
| | | | | | | | | | |

Note: X Y Z are positions on the manifold dy/mo/yr A is worker ID

| Start Time | Stop | **Activity** (1=as per task; 2=mixing thinning; 3=cleaning; 4=sanding; 5=surf. prep; 6=alternate application method; 7=cutting; .....20=repair of spray equipment; 21=adjusting equipment (spray) |
|---|---|---|
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**Monitoring data**

| Bag # | Start | End | Rae/HNU/ Pump # |
|---|---|---|---|
| | | | |

Note: X Y Z are positions on the manifold dy/mo/yr A is worker ID

**Sorbent Tube Data**

| Pump# | Start | End | Tube #s worker ID-W-1 | Pre Flow | Post (time) |
|---|---|---|---|---|---|
| | | | x- | | |
| | | | y- | | |
| | | | z- | | |
| | | | - | | |

| Start Time | Stop | **Activity** (1=as per task; 2=mixing thinning; 3=cleaning; 4=sanding; 5=surf. prep; 6=alternate application method; 7=cutting; .....20=repair of spray equipment; 21=adjusting equipment (spray) |
|---|---|---|
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**Monitoring data**

| Bag # | Start | End | Rae/HNU/ Pump # |
|---|---|---|---|
| | | | |

Note: X Y Z are positions on the manifold dy/mo/yr A is worker ID

**Sorbent Tube Data**

| Pump# | Start | End | Tube #s worker ID-W-1 | Pre Flow | Post (time) |
|---|---|---|---|---|---|
| | | | x- | | |
| | | | y- | | |
| | | | z- | | |
| | | | - | | |

| Start Time | Stop | **Activity** (1=as per task; 2=mixing thinning; 3=cleaning; 4=sanding; 5=surf. prep; 6=alternate application method; 7=cutting; .....20=repair of spray equipment; 21=adjusting equipment (spray) |
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**Monitoring data** **Sorbent Tube Data**

| Bag # | Start | End | Rae/HNU/ Pump # | Pump# | Start | End | Tube #s worker ID-W-1 | Pre Flow | Post (time) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | x- | | |
| | | | | | | | y- | | |
| | | | | | | | z- | | |
| | | | | | | | - | | |

Note: X Y Z are positions on the manifold dy/mo/yr A is worker ID

| Start Time | Stop | **Activity** (1=as per task; 2=mixing thinning; 3=cleaning; 4=sanding; 5=surf. prep; 6=alternate application method; 7=cutting; .....20=repair of spray equipment; 21=adjusting equipment (spray) |
|---|---|---|
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**Monitoring data** **Sorbent Tube Data**

| Bag # | Start | End | Rae/HNU/ Pump # | Pump# | Start | End | Tube #s worker ID-W-1 | Pre Flow | Post (time) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | x- | | |
| | | | | | | | y- | | |
| | | | | | | | z- | | |
| | | | | | | | - | | |

Note: X Y Z are positions on the manifold dy/mo/yr A is worker ID

| Start Time | Stop | **Activity** (1=as per task; 2=mixing thinning; 3=cleaning; 4=sanding; 5=surf. prep; 6=alternate application method; 7=cutting; .....20=repair of spray equipment; 21=adjusting equipment (spray) |
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# Study of Exposures in Painting – Questionnaire

Thank-you for agreeing to participate in this investigation to assess occupational exposures to painters. Please fill out this questionnaire as completely as you can.

1. **What is your current occupation ?**

   _____

2. **How many years have you painted ?** _____

3. **How many years have you painted with solvent paints ?** _____

4. **During the years that you have painted with solvent paints, how much of your time were you actually painting (as opposed to doing other jobs in the trade or not working) ?**

   All ❒ Almost All ❒ Over Half ❒

   About Half ❒ Less than Half ❒ A Little ❒ Never ❒

5. **During that time, when you have painted, how much of the time have you painted <u>out of doors</u> ?**

   All ❒ Almost All ❒ Over Half ❒

   About Half ❒ Less than Half ❒ A Little ❒ Never ❒

6. **During the <u>past year</u>, when you have painted, how much of the time have you painted <u>out of doors</u> ?**

   All ❒ Almost All ❒ Over Half ❒

   About Half ❒ Less than Half ❒ A Little ❒ Never ❒

7. **Within the <u>past year</u>, estimate the number of weeks you have worked using solvent paints.** _____

8. **Within the <u>past month</u>, estimate the number of days you have worked using solvent based paints.** _____

9. **How long ago has it been since you last used solvent paints ?**

   Currently using ❒ 1 week ❒ 2 to 4 weeks ❒

   1 month ❒ 2 to 6 months ❒ 7 to 12 months ❒

   Over 1 year ❒ → If over 1 year, how many ? _____

10. **During the time you have painted, what percentage of the time have you used each of the following application methods ?**

| | Never | Less than 25 % | 25 to 50 % | 50 to 75 % | Over 75 % |
|---|---|---|---|---|---|
| SPRAY | ❒ | ❒ | ❒ | ❒ | ❒ |
| ROLLER | ❒ | ❒ | ❒ | ❒ | ❒ |
| BRUSH | ❒ | ❒ | ❒ | ❒ | ❒ |
| RAG / SPONGE | ❒ | ❒ | ❒ | ❒ | ❒ |

11. **During the time you have painted, what has been you average rate of application per hour for each application method ? (Gallons per hour)**

| | $\frac{1}{2}$ to 1 | 1 to 2 | 2 to 4 | 4 to 6 | 6 to 9 | Over 9 |
|---|---|---|---|---|---|---|
| SPRAY | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ROLLER | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| BRUSH | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| RAG / SPONGE | ❒ | ❒ | ❒ | ❒ | | |

12. **During the <u>past year</u>, what percentage of the time have you used each of the following application methods ?**

| | Never | Less than 25 % | 25 to 50 % | 50 to 75 % | Over 75 % |
|---|---|---|---|---|---|
| SPRAY | ❒ | ❒ | ❒ | ❒ | ❒ |
| ROLLER | ❒ | ❒ | ❒ | ❒ | ❒ |
| BRUSH | ❒ | ❒ | ❒ | ❒ | ❒ |
| RAG / SPONGE | ❒ | ❒ | ❒ | ❒ | ❒ |

13. **During the <u>past year</u>, what has been you average rate of application per hour for each application method ? (Gallons per hour)**

| | $\frac{1}{2}$ to 1 | 1 to 2 | 2 to 4 | 4 to 6 | 6 to 9 | Over 9 |
|---|---|---|---|---|---|---|
| SPRAY | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| ROLLER | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| BRUSH | ❒ | ❒ | ❒ | ❒ | ❒ | ❒ |
| RAG / SPONGE | ❒ | ❒ | ❒ | ❒ | | |

14. **How many times per month do you perform similar tasks to those you performed today?**_____

15. **What task for you is the worst in terms of exposure?**_____

16. **During the time you have worked as a painter, what <u>percentage</u> of the time have you used the following types of respirators while spraying, rolling, and brushing ?**

| | Dust mask | Chemical Cartridge | Supplied Air | None |
|---|---|---|---|---|
| **SPRAY** | _____ | _____ | _____ | _____ |
| **ROLLER** | _____ | _____ | _____ | _____ |
| **BRUSH** | _____ | _____ | _____ | _____ |

17. **During the <u>past year</u>, what <u>percentage</u> of the time have you used the following types of respirators while spraying, rolling, and brushing ?**

| | Dust mask | Chemical Cartridge | Supplied Air | None |
|---|---|---|---|---|
| **SPRAY** | _____ | _____ | _____ | _____ |
| **ROLLER** | _____ | _____ | _____ | _____ |
| **BRUSH** | _____ | _____ | _____ | _____ |

18. **What <u>percentage</u> of the time do you wear a respirator when working with the following solvent (or oil) containing products ?**

| lacquers | stains | varnishes | exterior alkyds | interior alkyds | enamels | primers |
|---|---|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ | _____ | _____ |

**other - please list:**

| | | | | |
|---|---|---|---|---|
| _____ | _____ | _____ | _____ | _____ |

19. **Do you currently smoke ?**

Yes ❒ No ❒

→ If yes, how much of the following do you smoke per day ?

Cigarettes _____ Pipe / Cigar _____ Chewing _____ Other _____

20. **Do you currently drink alcoholic beverages ?**

Yes ❒ No ❒

→ If yes, how many drinks do you have per week ? _____

21. **Do you currently use marijuana ?**

Yes ❒ No ❒

→ If yes, how many times per week ? _____

22. **Do you currently use cocaine, downers, uppers, heroin, or any other drugs?**

Yes ❒ No ❒

→ If yes, how many times per week ? _____→, please circle the type(s) above.

For the following questions please circle the most appropriate response.

**Have you recently:**

| | | | | |
|---|---|---|---|---|
| felt that you are ill ? | Not at all | Sometimes | Often | Very often |
| been feeling run down ? | Not at all | Sometimes | Often | Very often |
| not been able to concentrate on whatever you're doing ? | Not at all | Sometimes | Often | Very often |
| had trouble remembering ? | Not at all | Sometimes | Often | Very often |
| had difficulty in falling asleep ? | Not at all | Sometimes | Often | Very often |
| lost much sleep over worry ? | Not at all | Sometimes | Often | Very often |
| been feeling constantly under strain ? | Not at all | Sometimes | Often | Very often |
| been getting edgy and bad tempered ? | Not at all | Sometimes | Often | Very often |
| been feeling nervous and uptight all the time ? | Not at all | Sometimes | Often | Very often |
| had difficulty breathing or respiratory problems ? | Not at all | Sometimes | Often | Very often |
| developed headaches while at work ? | Not at all | Sometimes | Often | Very often |
| been feeling tired at work ? | Not at all | Sometimes | Often | Very often |
| felt uncoordinated or clumsy while at work ? | Not at all | Sometimes | Often | Very often |
| felt dizzy at work ? | Not at all | Sometimes | Often | Very often |
| felt intoxicated or "high" while at work ? | Not at all | Sometimes | Often | Very often |
| developed a skin rash or skin irritation ? | Not at all | Sometimes | Often | Very often |
| experienced any other health problems related to your work? | Not at all | Sometimes | Often | Very often |

→If so, please describe:_____

| | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
|---|---|---|---|---|---|---|---|
| 7 – 8 AM | | | | | | | |
| 8 – 9 | | | | | | | |
| 9 – 10 | | | | | | | |
| 10 – 11 | | | | | | | |
| 11 – 12 | | | | | | | |
| 12 – 1 PM | | | | | | | |
| 1 – 2 | | | | | | | |
| 2 – 3 | | | | | | | |
| 3 – 4 | | | | | | | |
| 4 – 5 | | | | | | | |
| 5 – 6 | | | | | | | |
| Oil Based or solvent products used and amounts (gallons) | | | | | | | |

Please provide task names for all tasks performed today and all tasks performed within the last week. If you used any alkyd, oil based, solvents, or any other product with VOCs please list them in the space provided along with an estimate of the volume used (gallons).

# Appendix II

Appendix : Field Monitoring Data Form

**Company Name and Address:**_____

**Monitored Location:**_____

**Monitored worker:** _____ **Date:**_____

**Tool Type:**_____(brush, roller, spray)

**Material:** _____all chemicals-attach MSDS

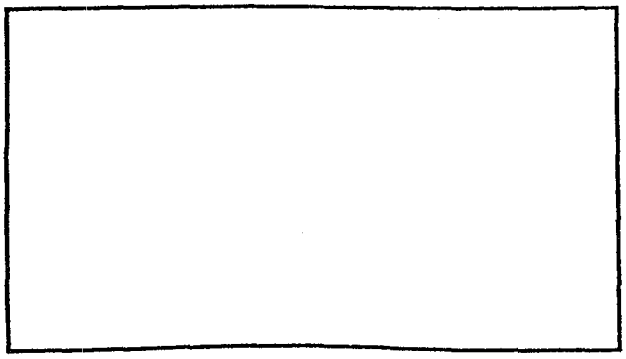
Spray pres.:_____Tip size:_____Airless/HVLP/AirBrand_____AC/gas GMP_____

Surface Type:_____Surface Area:_____Sqft

**Air Temperature:**_____**Relative Humidity:**_____**Air velocity:**_____fpm

| Sampler | Pump No. | Id. (i.e. date -sampler -filter/ct -front/rear) | Start Time | Stop Time | Total Sample Time (min) | Average Flow rate (ml/min) | Volume Sampled (mL) |
|---|---|---|---|---|---|---|---|
| CT | | | | | | | |
| PS | | | | | | | |
| FC | | | | | | | |
| | | | | | | | |
| VA | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| Field Notes: CT: charcoal tube; PS: passive sampler; FC: filter-charcoal tube; VA: vapor-aerosol sampler | | | | | | | |
| | | | | | | | |

Room Size & Sampler Location

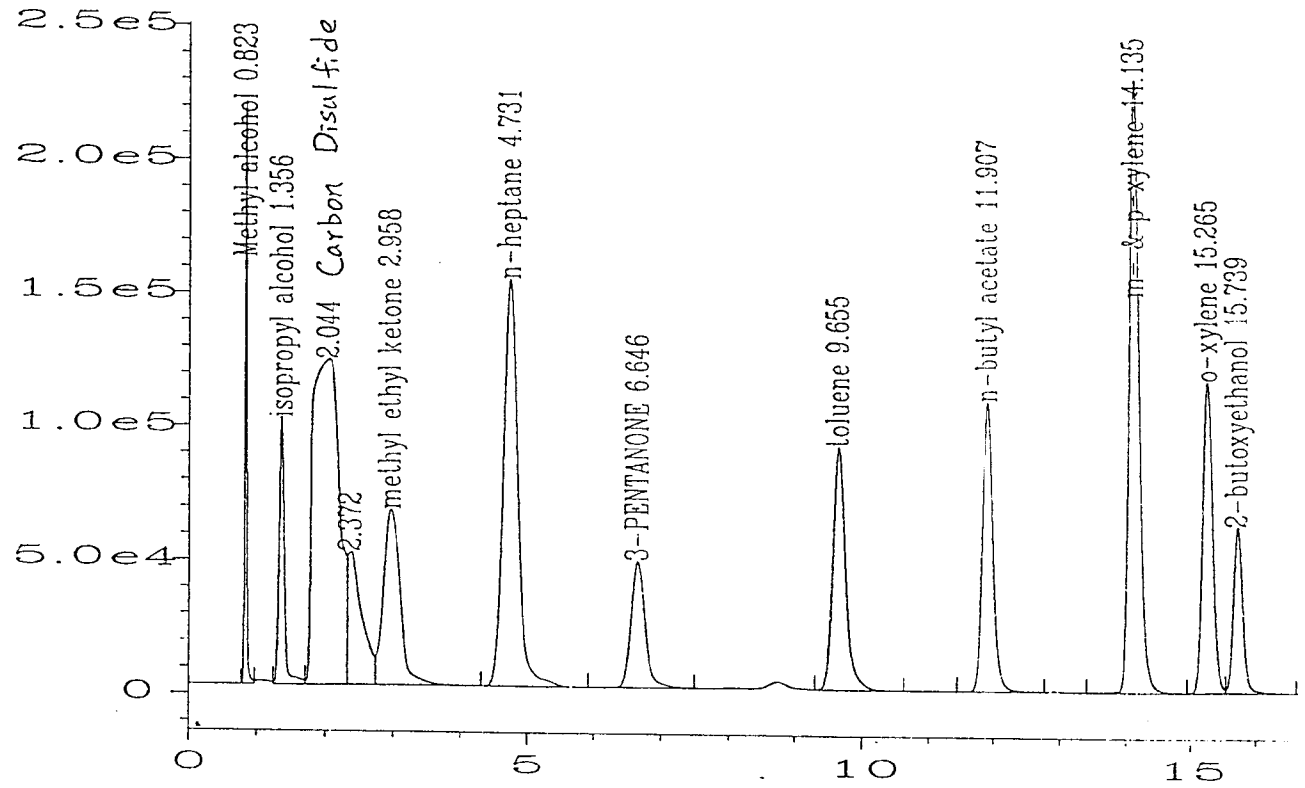


## Appendix Calibration Data Form

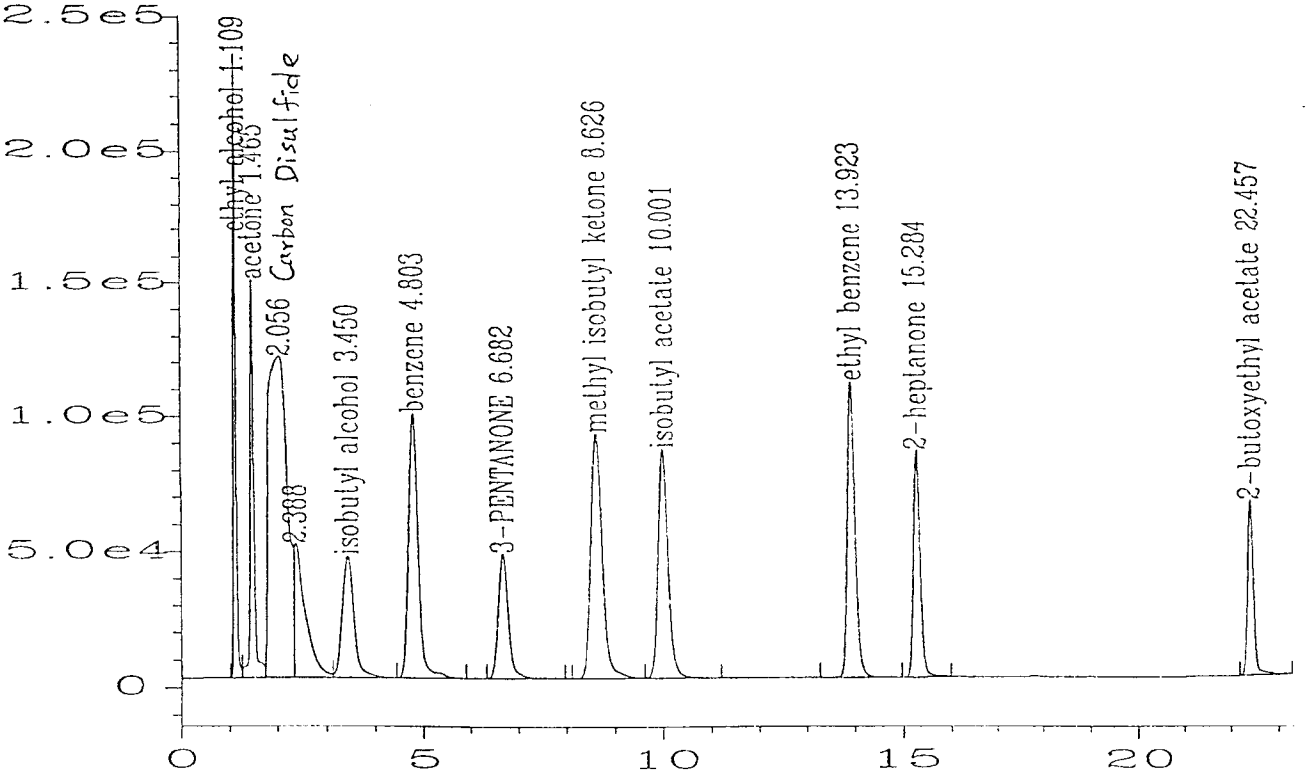
| | |
|---|---|
| Name and Location of Calibration:<br>Calibration Conducted by:<br>Calibration Instruments:Gilibrator<br>Air Sampling Pumps: CST-Gilian low flow<br>F-CST, VAS-SKC Airchek | Date Calibration Conducted:<br><br>Air Temperature:<br>Relative Humidity: |

| Pump Serial No. | Collection Medium in line | Pre-Sampling Calibration Flow Rate (ml/min) | | | | Post-Sampling Calibration Flow Rate (ml/min) | | | | Time Used (min) | % difference |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | Avg | 1 | 2 | 3 | Avg | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

**Appendix : Chromatograms of Mixture Standard I and II**




(a) Mixture Standard I




(b) Mixture Standard II

**Appendix : Calibration Curve: Concentration Range and Correlation Coefficient**

| | High Concentration Range | | Low Concentration Range | |
|---|---|---|---|---|
| Compounds | Amount range (ug/ml $CS_2$) | Correlation coefficient ($r^2$) | Amount range (ug/ml $CS_2$) | Correlation coefficient ($r^2$) |
| Methanol | 10-2002 | 0.994 | 0.4-100 | 1.000 |
| Ethanol | 10-2004 | 0.999 | 1.0-100 | 1.000 |
| Isopropyl Alcohol | 5-1005 | 1.000 | 0.2-50 | 1.000 |
| Acetone | 10-2001 | 1.000 | 1.0-100 | 1.000 |
| Methyl Ethyl Ketone | 10-2005 | 0.999 | 4.0-100 | 1.000 |
| Isobutyl alcohol | 5-1008 | 1.000 | 0.5-5 | 1.000 |
| n-Heptane | 10-2004 | 1.000 | 2.0-10 | 1.000 |
| Benzene | 5-1002 | 0.999 | 1.0-5 | 1.000 |
| Methyl Isobutyl Ketone | 10-2000 | 1.000 | 1.0-100 | 1.000 |
| Toluene | 5-1006 | 1.000 | 0.2-50 | 1.000 |
| Isobutyl Acetate | 10-2003 | 1.000 | 1.0-100 | 1.000 |
| n-Butyl Acetate | 10-2004 | 1.000 | 0.4-100 | 1.000 |
| Ethyl Benzene | 5-1004 | 1.000 | 0.5-50 | 1.000 |
| m- and p- Xylene | 10-2010 | 1.000 | 0.4-100 | 1.000 |
| o-Xylene | 5-1000 | 1.000 | 0.2-56 | 1.000 |
| 2- Heptanone | 5-1007 | 1.000 | 0.5-50 | 1.000 |
| 2- Butoxyethanol | 5-1000 | 0.999 | 0.2-50 | 1.000 |
| 2-Butoxyethyl Acetate | 5-1008 | 1.000 | 0.5-50 | 1.000 |

**Appendix : Relative Retention Time and Detection Limits**

| Compounds | **Relative Retention Time** (as $CS_2$ being 1.000) | **Detection Limits** (ppb) (ng/mL $CS_2$) |
|---|---|---|
| Methanol | 0.403 | 2.0 |
| Ethanol | 0.539 | 5.0 |
| Isopropyl Alcohol | 0.663 | 1.0 |
| Acetone | 0.713 | 5.0 |
| Methyl Ethyl Ketone | 1.447 | 10.0 |
| Isobutyl alcohol | 1.678 | 2.5 |
| n-Heptane | 2.315 | 2.0 |
| Benzene | 2.336 | 2.5 |
| Methyl Isobutyl Ketone | 4.196 | 5.0 |
| Toluene | 4.724 | 1.0 |
| Isobutyl Acetate | 4.864 | 5.0 |
| n-Butyl Acetate | 5.825 | 2.0 |
| Ethyl Benzene | 6.772 | 2.5 |
| m- and p- Xylene | 6.915 | 2.0 |
| o-Xylene | 7.468 | 1.0 |
| 2- Heptanone | 7.434 | 2.5 |
| 2- Butoxyethanol | 7.700 | 1.0 |
| 2-Butoxyethyl Acetate | 10.923 | 2.5 |

# Appendix II: Trial # 1

| GC Analytical Results (for Filtered-Charcoal Tube) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 6/30/97 | | Total time: | | 7 | min | | | | | |
| Sample ID: | 630-FC | | Avg flow: | | 2020 | mL/min | | | | | |
| Sampler: | IOM followed by charcoal tube | | Total Volume: | | 14140 | mL | | | | | |
| Tool Type: | SPRAY | | Desb Vol: | | 3 | mL for CT(400/200), 3mL for filter | | | | | |
| | | | | | | | | | | | |
| | | **Charcoal Tube** | | **Filter** | **Gas** | **Particul** | **Total** | | | | |
| | | Front | Back | Mass | Conc. | Conc. | Conc. | | | | |
| | | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) | | | | |
| 1 | Methanol | | | | | | | | | | |
| 2 | Ethanol | | | | | | | | | | |
| 3 | Isopropyl Alcohol | 2091.339 | | 0.2529 | 147.90 | 0.018 | 147.920 | | | | |
| 4 | Acetone | | | | | | | | | | |
| 5 | MEK | 5.208 | 4.392 | 4.326 | 0.679 | 0.306 | 0.985 | | | | |
| 6 | Isobutyl Alcohol | 805.524 | | 1.173 | 56.968 | 0.083 | 57.051 | | | | |
| 7 | n-Heptane | 5.208 | | | 0.368 | 0.000 | 0.368 | | | | |
| 8 | Benzene | | | | | | | | | | |
| 9 | MIBK | | | | | | | | | | |
| 10 | Toluene | 4012.401 | 0.1764 | 0.2112 | 283.77 | 0.015 | 283.790 | | | | |
| 11 | Isobutyl Acetate | 3731.271 | | 4.005 | 263.88 | 0.283 | 264.164 | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | | |
| 13 | Ethyl Benzene | 88.785 | | | 6.279 | | 6.279 | | | | |
| 14 | Xylenes (m-,o-&p-) | 487.668 | 0.1176 | 0.1938 | 34.497 | 0.014 | 34.511 | | | | |
| 15 | 2-Heptanone | | | | | | | | | | |
| 16 | 2-Butoxyethanol | 12.519 | | 0.744 | 0.885 | 0.053 | 0.938 | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | | |

| GC Analytical Results (for Charcoal Tube) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 6/30/97 | | Total time: | | 7 | min | | | | | |
| Sample ID: | 630-CT | | Avg flow: | | 206.4 | mL/min | | | | | |
| Sampler: | charcoal tube | | Total Volume: | | 1444.8 | mL | | | | | |
| Tool Type: | spray | | Desb Vol: | | 1 | mL for CT(100/50) | | | | | |
| | | | | | | | | | | | |
| | | **Charcoal Tube** | | **Total** | | | | | | | |
| | | Front | Back | Conc. | | | | | | | |
| | | (ug) | (ug) | (mg/m3) | | | | | | | |
| 1 | Methanol | | | | | | | | | | |
| 2 | Ethanol | | | | | | | | | | |
| 3 | Isopropyl Alcohol | 241.265 | | 166.989 | | | | | | | |
| 4 | Acetone | | | | | | | | | | |
| 5 | MEK | 2.412 | 1.682 | 2.834 | | | | | | | |
| 6 | Isobutyl Alcohol | 89.927 | | 62.242 | | | | | | | |
| 7 | n-Heptane | 0.366 | | 0.253 | | | | | | | |
| 8 | Benzene | | | | | | | | | | |
| 9 | MIBK | | | | | | | | | | |
| 10 | Toluene | 474.244 | 0.395 | 328.515 | | | | | | | |
| 11 | Isobutyl Acetate | 439.039 | | 303.875 | | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | | |
| 13 | Ethyl Benzene | 10.6 | | 7.337 | | | | | | | |
| 14 | Xylenes (m-,o-&p-) | 58.952 | | 40.803 | | | | | | | |
| 15 | 2-Heptanone | | | | | | | | | | |
| 16 | 2-Butoxyethanol | 1.04 | | 0.720 | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | | |

# Appendix II: Trial # 1

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **GC Analytical Results (for Vapor-Aerosol Sampler)** | | | | | | | | | | |
| Date: | 6/30/97 | | Total time: | | 7 | min | | | | |
| Sample ID: | 630-VA | | Flow rate: | Qv= | 1022 | Qp= | 1019 | Qo= | 2017 | mL/min |
| Sampler: | vapor-aerosol sampler | | Volume: | Vv= | 7154 | Vp= | 7133 | Vo= | 14119 | mL |
| Tool Type: | spray | | Desorb vol: 3 mL for CT(400/200), 3 mL for filter | | | | | | | |
| | | **Front Charcoal** | | **Back Charcoal** | | **Filter** | **Particulate** | **Gas phase** | **Particulate** | **Total** |
| | | Front | Back | Front | Back | Mass | Mass | Conc. | phase conc. | Conc. |
| | | (ug) | (ug) | (ug) | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) |
| 1 | Methanol | | | | | | | | | |
| 2 | Ethanol | | | | | | | | | |
| 3 | Isopropyl Alcohol | 871.128 | | 893.64 | | | 25.069 | 121.768 | 1.776 | 123.544 |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 7.008 | 4.377 | 7.38 | 4.359 | 4.002 | 4.389 | 1.591 | 0.311 | 1.902 |
| 6 | Isobutyl Alcohol | 341.298 | | 346.989 | | 0.1296 | 6.822 | 47.707 | 0.483 | 48.191 |
| 7 | n-Heptane | 2.052 | | 2.322 | | | 0.276 | 0.287 | 0.020 | 0.306 |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 1903.296 | 0.1827 | 1903.059 | 0.1869 | 0.1875 | 5.542 | 266.072 | 0.393 | 266.464 |
| 11 | Isobutyl Acetate | 1755.252 | | 1769.109 | | 0.798 | 19.807 | 245.353 | 1.403 | 246.755 |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 41.379 | | 41.892 | | | 0.634 | 5.784 | 0.045 | 5.829 |
| 14 | Xylenes (m-,o-&p-) | 225.384 | | 229.281 | | | 4.559 | 31.505 | 0.323 | 31.827 |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | 2.94 | | 2.787 | | 0.2979 | 0.154 | 0.411 | 0.011 | 0.422 |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |
| | | | | | | | | | | |
| **GC Analytical Results (for Passive Sampler)** | | | | | | | | | | |
| Date: | 6/30/97 | | Total time: | | 7 | min | | | | |
| Sample ID: | 630-PS | | Desb Vol: | | 2 | mL for PS | | | | |
| Sampler: | passive sampler | | Tool Type: | | spray | | | | | |
| | | **Passive** | **Sampling** | **Sample** | **Total** | | | | | |
| | | Mass | Rate | volume | Conc. | | | | | |
| | | (ug) | (mL/min) | (mL) | (mg/m3) | | | | | |
| 1 | Methanol | | | | | | | | | |
| 2 | Ethanol | | | | | | | | | |
| 3 | Isopropyl Alcohol | 5.942 | | | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 3.232 | | | | | | | | |
| 6 | Isobutyl Alcohol | 0.932 | | | | | | | | |
| 7 | n-Heptane | 0 | 13.9 | 97.3 | 0.000 | | | | | |
| 8 | Benzene | | 16 | 112 | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 34.474 | 14.5 | 101.5 | 339.65 | | | | | |
| 11 | Isobutyl Acetate | 24.384 | | | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 0.53 | 12.9 | 90.3 | 5.869 | | | | | |
| 14 | Xylenes (m-,o-&p-) | 2.68 | 12.4 | 86.8 | 30.876 | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |

# Appendix II: Trial # 2

| GC Analytical Results (for Filtered-Charcoal Tube) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/1/97 | | Total time: | | 9.47 | min | | | | |
| Sample ID: | 701-1-FC | | Avg flow: | | 2020 | mL/min | | | | |
| Sampler: | IOM followed by charcoal tube | | Total Vol: | | 19129.4 | mL | | | | |
| Tool Type: | SPRAY | | Desb Vol: | | 3 | mL for CT(400/200), 3mL for filter | | | | |
| | | **Charcoal Tube** | | **Filter** | **Gas phas** | **Particul** | **Total** | | | |
| | | Front | Back | Mass | Conc. | phase co | Conc. | | | |
| | | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) | | | |
| 1 | Methanol | 171.852 | 121.098 | 1.14 | 15.314 | 0.060 | 15.374 | | | |
| 2 | Ethanol | 54.777 | 0.861 | 0.507 | 2.909 | 0.027 | 2.935 | | | |
| 3 | Isopropyl Alcohol | 2370.741 | 0.1278 | 0.2868 | 123.938 | 0.015 | 123.953 | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 436.626 | 1.209 | 1.236 | 22.888 | 0.065 | 22.953 | | | |
| 6 | Isobutyl Alcohol | 3451.716 | | 0.585 | 180.440 | 0.031 | 180.471 | | | |
| 7 | n-Heptane | 889.851 | | | 46.517 | | 46.517 | | | |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 3235.425 | 2.667 | 0.2175 | 169.273 | 0.011 | 169.284 | | | |
| 11 | Isobutyl Acetate | 8167.077 | 2.703 | 1.431 | 427.080 | 0.075 | 427.155 | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 429.582 | 0.1542 | | 22.465 | | 22.465 | | | |
| 14 | Xylenes (m-,o-&p-) | 1384.518 | 0.5751 | 0.0861 | 72.407 | 0.005 | 72.411 | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

| GC Analytical Results (for Charcoal Tube) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/1/97 | | Total time: | | 9.47 | min | | | | |
| Sample ID: | 701-1-CT | | Avg flow: | | 206.4 | mL/min | | | | |
| Sampler: | charcoal tube | | Total Vol: | | 1954.608 | mL | | | | |
| Tool Type: | spray | | Desb Vol: | | 1 | mL for CT(100/50) | | | | |
| | | **Charcoal Tube** | | **Total** | | | | | | |
| | | Front | Back | Conc. | | | | | | |
| | | (ug) | (ug) | (mg/m3) | | | | | | |
| 1 | Methanol | 59.173 | 27.356 | 44.269 | | | | | | |
| 2 | Ethanol | 7.025 | 0.286 | 3.740 | | | | | | |
| 3 | Isopropyl Alcohol | 268.738 | 0.181 | 137.58 | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 34.087 | 0.421 | 17.655 | | | | | | |
| 6 | Isobutyl Alcohol | 381.997 | 0.103 | 195.49 | | | | | | |
| 7 | n-Heptane | 95.416 | | 48.816 | | | | | | |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 347.827 | 1.561 | 178.75 | | | | | | |
| 11 | Isobutyl Acetate | 889.966 | 1.31 | 455.99 | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 46.117 | 0.0578 | 23.624 | | | | | | |
| 14 | Xylenes (m-,o-&p-) | 150.927 | 0.1457 | 77.291 | | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

# Appendix II: Trial # 2

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **GC Analytical Results (for Vapor-Aerosol Sampler)** | | | | | | | | | | |
| Date: | 7/1/97 | | Total time: | | 9.47 | min | | | | |
| Sample ID: | 701-1-VA | | Flow rate | Qv= | 1022 | Qp= | 1019 | Qo= | 2017 | mL/min |
| Sampler: | vapor-aerosol sampler | | Volume: | Vv= | 9678.34 | Vp= | 9649.93 | Vo= | 19100.99 | mL |
| Tool Type: | spray | | Desorb vol: 3 mL for CT(400/200), 3 mL for filter | | | | | | | |
| | | **Front Charcoal** | | **Back Charcoal** | | **Filter** | **Particulate** | **Gas phase** | **Particulate** | **Total** |
| | | Front | Back | Front | Back | Mass | Mass | Conc. | phase conc. | Conc. |
| | | (ug) | (ug) | (ug) | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) |
| 1 | Methanol | 155.31 | 98.706 | 191.112 | 102.693 | 0.951 | 41.486 | 26.246 | 2.172 | 28.418 |
| 2 | Ethanol | 26.982 | 0.552 | 25.959 | 0.495 | 0.54 | -0.459 | 2.845 | -0.024 | 2.821 |
| 3 | Isopropyl Alcohol | 1156.878 | 0.1455 | 1078.87 | 0.0948 | 0.312 | -74.354 | 119.548 | -3.893 | 115.655 |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 190.749 | 1.227 | 182.94 | 1.305 | 1.251 | -5.916 | 19.836 | -0.310 | 19.526 |
| 6 | Isobutyl Alcohol | 1725.912 | | 1636.36 | | 0.366 | -84.121 | 178.327 | -4.404 | 173.923 |
| 7 | n-Heptane | 472.479 | | 462.642 | | | -8.450 | 48.818 | -0.442 | 48.376 |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 1690.905 | 2.433 | 1645.89 | 1.446 | 0.2415 | -40.793 | 174.962 | -2.136 | 172.826 |
| 11 | Isobutyl Acetate | 4224.342 | 2.217 | 4108.12 | 1.41 | 1.242 | -103.384 | 436.703 | -5.413 | 431.290 |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 210.396 | 0.1284 | 209.07 | 0.1344 | | -0.702 | 21.752 | -0.037 | 21.715 |
| 14 | Xylenes (m-,o-&p-) | 685.35 | 0.3993 | 686.409 | 0.312 | 0.0936 | 3.078 | 70.854 | 0.161 | 71.015 |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |
| | | | | | | | | | | |
| **GC Analytical Results (for Passive Sampler)** | | | | | | | | | | |
| Date: | 7/1/97 | | Total time: | | 9.47 | min | | | | |
| Sample ID: | 701-1-PS | | Desb Vol: | | 2 | mL for PS | | | | |
| Sampler: | passive sampler | | Tool Type: | | spray | | | | | |
| | | **Passive** | **Samplin** | **Sample** | **Total** | | | | | |
| | | Mass | Rate | volume | Conc. | | | | | |
| | | (ug) | (mL/min) | (mL) | (mg/m3) | | | | | |
| 1 | Methanol | 3.428 | | | | | | | | |
| 2 | Ethanol | | | | | | | | | |
| 3 | Isopropyl Alcohol | 7.354 | | | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 2.128 | | | | | | | | |
| 6 | Isobutyl Alcohol | 12.758 | | | | | | | | |
| 7 | n-Heptane | 7.4 | 13.9 | 131.633 | 56.217 | | | | | |
| 8 | Benzene | | 16 | 151.52 | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 29.594 | 14.5 | 137.315 | 215.519 | | | | | |
| 11 | Isobutyl Acetate | 57.272 | | | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 3.456 | 12.9 | 122.163 | 28.290 | | | | | |
| 14 | Xylenes (m-,o-&p-) | 10.918 | 12.4 | 117.428 | 92.976 | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |

# Appendix II: Trial # 3

| GC Analytical Results (for Filtered-Charcoal Tube) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/1/97 | | Total time: | | 5.2 | min | | | | |
| Sample ID: | 701-2-FC | | Avg flow: | | 2066 | mL/min | | | | |
| Sampler: | IOM followed by charcoal tube | | Total Vol: | | 10743.2 | mL | | | | |
| Tool Type: | SPRAY | | Desb Vol: | | 1 | mL for CT(100/50),3 mL for filter | | | | |
| | | | | | | | | | | |
| | | **Charcoal Tube** | | **Filter** | **Gas pha** | **Particul** | **Total** | | | |
| | | Front mas | ack mas | Mass | Conc. | phase co | Conc. | | | |
| | | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) | | | |
| 1 | Methanol | 48.926 | 115.195 | 0.645 | 15.277 | 0.060 | 15.337 | | | |
| 2 | Ethanol | 21.662 | 38.395 | 0.42 | 5.590 | 0.039 | 5.629 | | | |
| 3 | Isopropyl Alcohol | 1199.848 | 1010.95 | 0.1932 | 205.79 | 0.018 | 205.804 | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 290.861 | 134.572 | 1.278 | 39.600 | 0.119 | 39.719 | | | |
| 6 | Isobutyl Alcohol | 2320.447 | 697.766 | 0.501 | 280.94 | 0.047 | 280.988 | | | |
| 7 | n-Heptane | 762.818 | 95.465 | | 79.891 | | 79.891 | | | |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 2228.256 | 116.644 | 0.1632 | 218.27 | 0.015 | 218.283 | | | |
| 11 | Isobutyl Acetate | 5610.324 | 381.508 | 1.146 | 557.73 | 0.107 | 557.839 | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 322.811 | 3.53 | | 30.377 | | 30.377 | | | |
| 14 | Xylenes (m-,o-&p-) | 973.111 | 4.268 | 0.0777 | 90.977 | 0.007 | 90.984 | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

| GC Analytical Results (for Charcoal Tube) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/1/97 | | Total time: | | 5.2 | min | | | | |
| Sample ID: | 701-2-CT | | Avg flow: | | 206 | mL/min | | | | |
| Sampler: | charcoal tube | | Total Vol: | | 1071.2 | mL | | | | |
| Tool Type: | spray | | Desb Vol: | | 1 | mL for CT(100/50) | | | | |
| | | | | | | | | | | |
| | | **Charcoal Tube** | | **Total** | | | | | | |
| | | Front | Back | Conc. | | | | | | |
| | | (ug) | (ug) | (mg/m3) | | | | | | |
| 1 | Methanol | 77.455 | 49.533 | 118.547 | | | | | | |
| 2 | Ethanol | 7.838 | 0.129 | 7.437 | | | | | | |
| 3 | Isopropyl Alcohol | 246.607 | 0.194 | 230.397 | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 39.069 | 0.473 | 36.914 | | | | | | |
| 6 | Isobutyl Alcohol | 345.056 | 0.11 | 322.224 | | | | | | |
| 7 | n-Heptane | 108.369 | | 101.166 | | | | | | |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 286.781 | 0.82 | 268.485 | | | | | | |
| 11 | Isobutyl Acetate | 756.59 | 0.452 | 706.723 | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 40.534 | | 37.840 | | | | | | |
| 14 | Xylenes (m-,o-&p-) | 126.191 | | 117.803 | | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

# Appendix II: Trial # 3

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **GC Analytical Results (for Vapor-Aerosol Sampler)** | | | | | | | | | | |
| Date: | 7/1/97 | | Total time: | | 5.2 | min | | | | |
| Sample ID: | 701-2-VA | | Flow rat | Qv= | 1067 | Qp= | 1087 | Qo= | 2066 | mL/min |
| Sampler: | vapor-aerosol sampler | | Volume: | Vv= | 5548.4 | Vp= | 5652.4 | Vo= | 10743.2 | mL |
| Tool Type: | spray | | Desorb vol: 1 mL for CT(100/50), 3 mL for filter | | | | | | | |
| | | **Front Charcoal** | | **Back Charcoal** | | **Filter** | **Particulate** | **Gas phase** | **Particulate** | **Total** |
| | | Front | Back | Front | Back | Mass | Mass | Conc. | phase conc. | Conc. |
| | | (ug) | (ug) | (ug) | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) |
| 1 | Methanol | 96.848 | 131.366 | 92.577 | 102.567 | 0.525 | -36.823 | 41.131 | -3.428 | 37.704 |
| 2 | Ethanol | 27.594 | 7.419 | 29.77 | 6.552 | 0.396 | 1.049 | 6.310 | 0.098 | 6.408 |
| 3 | Isopropyl Alcohol | 1107.211 | 55.245 | 1163.172 | 22.918 | 0.1812 | 2.026 | 209.512 | 0.189 | 209.701 |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 240.252 | 1.427 | 247.324 | 0.788 | 1.416 | 3.319 | 43.558 | 0.309 | 43.867 |
| 6 | Isobutyl Alcohol | 1585.763 | 15.851 | 1602.279 | 2.78 | 0.327 | -26.249 | 288.662 | -2.443 | 286.219 |
| 7 | n-Heptane | 467.344 | 1.412 | 459.423 | 0.225 | | -17.894 | 84.485 | -1.666 | 82.819 |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 1251.384 | 2.413 | 1230.035 | 1.816 | 0.1665 | -45.281 | 225.975 | -4.215 | 221.760 |
| 11 | Isobutyl Acetate | 3254.771 | 7.003 | 3204.499 | 2.432 | 0.921 | -115.061 | 587.877 | -10.710 | 577.166 |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 168.756 | 0.08 | 166.654 | 0.0861 | | -5.261 | 30.430 | -0.490 | 29.940 |
| 14 | Xylenes (m-,o-&p-) | 507.414 | 0.104 | 501.718 | 0.2203 | | -15.093 | 91.471 | -1.405 | 90.066 |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |
| | | | | | | | | | | |
| **GC Analytical Results (for Passive Sampler)** | | | | | | | | | | |
| Date: | 7/1/97 | | Total time: | | 5.2 | min | | | | |
| Sample ID: | 701-2-PS | | Desb Vol: | | 2 | mL for PS | | | | |
| Sampler: | passive sampler | | Tool Type: | | spray | | | | | |
| | | **Passive** | **Samplin** | **Sample** | **Total** | | | | | |
| | | Mass | Rate | volume | Conc. | | | | | |
| | | (ug) | (mL/min | (mL) | (mg/m3) | | | | | |
| 1 | Methanol | 3.59 | | | | | | | | |
| 2 | Ethanol | | | | | | | | | |
| 3 | Isopropyl Alcohol | 6.688 | | | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 2.376 | | | | | | | | |
| 6 | Isobutyl Alcohol | 11.266 | | | | | | | | |
| 7 | n-Heptane | 7.162 | 13.9 | 72.28 | 99.087 | | | | | |
| 8 | Benzene | | 16 | 83.2 | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 22.12 | 14.5 | 75.4 | 293.37 | | | | | |
| 11 | Isobutyl Acetate | 44.298 | | | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 2.586 | 12.9 | 67.08 | 38.551 | | | | | |
| 14 | Xylenes (m-,o-&p-) | 7.722 | 12.4 | 64.48 | 119.76 | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |

# Appendix II: Trial # 4

| GC Analytical Results (for Filtered-Charcoal Tube) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/1/97 | | Total time: | | 15.8 | min | | | | |
| Sample ID: | 701-3-FC | | Avg flow: | | 2020 | mL/min | | | | |
| Sampler: | IOM followed by charcoal tube | | Total Vol: | | 31916 | mL | | | | |
| Tool Type: | SPRAY | | Desb Vol: | | 3 | mL for CT(400/200), | | 3 | mL for filter | |
| | | | | | | | | | | |
| | | **Charcoal Tube** | | **Filter** | **Total** | | | | | |
| | | Front | Back | Mass | Conc. | | | | | |
| | | (ug) | (ug) | (ug) | (mg/m3) | | | | | |
| 1 | Methanol | 63.678 | 60.105 | 0.393 | 3.891 | | | | | |
| 2 | Ethanol | 61.632 | 3.879 | 0.357 | 2.064 | | | | | |
| 3 | Isopropyl Alcohol | 497.199 | 53.643 | 0.465 | 17.274 | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 66.666 | 1.233 | 1.212 | 2.165 | | | | | |
| 6 | Isobutyl Alcohol | 1060.16 | 31.689 | | 34.210 | | | | | |
| 7 | n-Heptane | 348.864 | 1.824 | | 10.988 | | | | | |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 1258.34 | 266.772 | 0.1353 | 47.789 | | | | | |
| 11 | Isobutyl Acetate | 3230.23 | 207.237 | 0.597 | 107.722 | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 208.83 | 9.159 | | 6.830 | | | | | |
| 14 | Xylenes (m-,o-&p-) | 707.475 | 50.697 | | 23.755 | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |
| | | | | | | | | | | |
| **GC Analytical Results (for Charcoal Tube)** | | | | | | | | | | |
| Date: | 7/1/97 | | Total time: | | 15.8 | min | | | | |
| Sample ID: | 701-3-CT | | Avg flow: | | 206.4 | mL/min | | | | |
| Sampler: | charcoal tube | | Total Vol: | | 3261.12 | mL | | | | |
| Tool Type: | spray | | Desb Vol: | | 1 | mL for CT(100/50) | | | | |
| | | | | | | | | | | |
| | | **Charcoal Tube** | | **Total** | | | | | | |
| | | Front | Back | Conc. | | | | | | |
| | | (ug) | (ug) | (mg/m3) | | | | | | |
| 1 | Methanol | 12.983 | 9.015 | 6.746 | | | | | | |
| 2 | Ethanol | 2.321 | 0.14 | 0.755 | | | | | | |
| 3 | Isopropyl Alcohol | 69.025 | | 21.166 | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 4.938 | 0.468 | 1.658 | | | | | | |
| 6 | Isobutyl Alcohol | 125.5 | | 38.484 | | | | | | |
| 7 | n-Heptane | 32.996 | | 10.118 | | | | | | |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 95.96 | 0.272 | 29.509 | | | | | | |
| 11 | Isobutyl Acetate | 304.993 | 0.263 | 93.605 | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 18.63 | 0.044 | 5.726 | | | | | | |
| 14 | Xylenes (m-,o-&p-) | 61.266 | 0.0849 | 18.813 | | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

# Appendix II: Trial # 4

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **GC Analytical Results (for Vapor-Aerosol Sampler)** | | | | | | | | | | |
| Date: | 7/1/97 | | Total time: | | 15.8 | min | | | | |
| Sample ID: | 701-3-VA | | Flow rate | Qv= | 1022 | Qp= | 1019 | Qo= | 2017 | mL/min |
| Sampler: | vapor-aerosol sampler | | Volume: | Vv= | 16147.6 | Vp= | 16100.2 | Vo= | 31868.6 | mL |
| Tool Type: | spray | | Desorb vol: 3 mL for CT(400/200), 3 mL for filter | | | | | | | |
| | | **Front Charcoal** | | **Back Charcoal** | | **Filter** | **Particulate** | **Gas phase** | **Particulate** | **Total** |
| | | Front | Back | Front | Back | Mass | Mass | Conc. | phase conc. | Conc. |
| | | (ug) | (ug) | (ug) | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) |
| 1 | Methanol | 24.321 | 24.144 | 35.079 | 33.753 | 0.2589 | 20.768 | 3.001 | 0.652 | 3.653 |
| 2 | Ethanol | 9.285 | 0.2997 | 8.748 | 0.327 | 0.306 | -0.176 | 0.594 | -0.006 | 0.588 |
| 3 | Isopropyl Alcohol | 318.312 | | 284.511 | | | -32.867 | 19.713 | -1.031 | 18.681 |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 35.451 | 0.1206 | 35.097 | 0.1317 | 1.245 | 1.007 | 2.203 | 0.032 | 2.234 |
| 6 | Isobutyl Alcohol | 620.631 | | 577.233 | | 0.366 | -41.210 | 38.435 | -1.293 | 37.142 |
| 7 | n-Heptane | 177.351 | | 175.959 | | | -0.871 | 10.983 | -0.027 | 10.956 |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 545.127 | 0.369 | 533.394 | 0.351 | | -10.150 | 33.782 | -0.318 | 33.463 |
| 11 | Isobutyl Acetate | 1615.03 | 0.456 | 1567.94 | 0.441 | 0.333 | -42.028 | 100.045 | -1.319 | 98.726 |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 103.893 | 0.1209 | 102.105 | | | -1.604 | 6.441 | -0.050 | 6.391 |
| 14 | Xylenes (m-,o-&p-) | 345.267 | 0.2661 | 338.892 | 0.2292 | | -5.398 | 21.398 | -0.169 | 21.229 |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |
| | | | | | | | | | | |
| **GC Analytical Results (for Passive Sampler)** | | | | | | | | | | |
| Date: | 7/1/97 | | Total time: | | 15.8 | min | | | | |
| Sample ID: | 701-3-PS | | Desb Vol: | | 2 | mL for PS | | | | |
| Sampler: | passive sampler | | Tool Type: | | spray | | | | | |
| | | **Passive** | **Samplin** | **Sample** | **Total** | | | | | |
| | | Mass | Rate | volume | Conc. | | | | | |
| | | (ug) | (mL/min) | (mL) | (mg/m3) | | | | | |
| 1 | Methanol | 2.16 | | | | | | | | |
| 2 | Ethanol | | | | | | | | | |
| 3 | Isopropyl Alcohol | 2.318 | | | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 1.414 | | | | | | | | |
| 6 | Isobutyl Alcohol | 3.658 | | | | | | | | |
| 7 | n-Heptane | 2.344 | 13.9 | 219.62 | 10.673 | | | | | |
| 8 | Benzene | | 16 | 252.8 | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 9.322 | 14.5 | 229.1 | 40.690 | | | | | |
| 11 | Isobutyl Acetate | 20.726 | | | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 1.182 | 12.9 | 203.82 | 5.799 | | | | | |
| 14 | Xylenes (m-,o-&p-) | 3.994 | 12.4 | 195.92 | 20.386 | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |

# Appendix II: Trial # 5

| GC Analytical Results (for Filtered-Charcoal Tube) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 18.3 | min | | | | | |
| Sample ID: | 717-1-FC | | Avg flow: | | 1993.7 | mL/min | | | | | |
| Sampler: | IOM followed by charcoal tube | | Total Vol: | | 36484.7 | mL | | | | | |
| Tool Type: | SPRAY | | Desb Vol: | | 10 | mL for front CT(800/200),5 mL for back CT,3mL for filter | | | | | |
| | | | | | | | | | | | |
| | | **Charcoal Tube** | | **Filter** | **Gas phas** | **Particula** | **Total** | | | | |
| | | Front | Back | Mass | Conc. | phase con | Conc. | | | | |
| | | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) | | | | |
| 1 | Methanol | 508.43 | 218.455 | 1.092 | 19.923 | 0.030 | 19.953 | | | | |
| 2 | Ethanol | 50.57 | 1.82 | 0.447 | 1.436 | 0.012 | 1.448 | | | | |
| 3 | Isopropyl Alcohol | 10658.2 | 0.332 | 1.239 | 292.136 | 0.034 | 292.170 | | | | |
| 4 | Acetone | | | | | | | | | | |
| 5 | MEK | 648.44 | | 0.1281 | 17.773 | 0.004 | 17.776 | | | | |
| 6 | Isobutyl Alcohol | 15776.2 | 0.234 | 3.498 | 432.413 | 0.096 | 432.509 | | | | |
| 7 | n-Heptane | 3272.3 | | | 89.690 | | 89.690 | | | | |
| 8 | Benzene | | | | | | | | | | |
| 9 | MIBK | | | | | | | | | | |
| 10 | Toluene | 13908 | 2.61 | 0.648 | 381.273 | 0.018 | 381.291 | | | | |
| 11 | Isobutyl Acetate | 33620 | 2.16 | 9.201 | 921.540 | 0.252 | 921.792 | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | | |
| 13 | Ethyl Benzene | 1103.34 | | 0.132 | 30.241 | 0.004 | 30.245 | | | | |
| 14 | Xylenes (m-,o-&p-) | 6728.54 | 0.735 | 0.7215 | 184.441 | 0.020 | 184.461 | | | | |
| 15 | 2-Heptanone | | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | | |

| GC Analytical Results (for Charcoal Tube) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 18.3 | min | | | | | |
| Sample ID: | 717-1-CT | | Avg flow: | | 203.3 | mL/min | | | | | |
| Sampler: | charcoal tube | | Total Vol: | | 3720.39 | mL | | | | | |
| Tool Type: | spray | | Desb Vol: | | 1 | mL for CT(100/50) | | | | | |
| | | | | | | | | | | | |
| | | **Charcoal Tube** | | **Total** | | | | | | | |
| | | Front mas | ack mas | Conc. | | | | | | | |
| | | (ug) | (ug) | (mg/m3) | | | | | | | |
| 1 | Methanol | 111.905 | 124.504 | 63.544 | | | | | | | |
| 2 | Ethanol | 4.888 | 0.371 | 1.414 | | | | | | | |
| 3 | Isopropyl Alcohol | 1046.66 | 0.162 | 281.373 | | | | | | | |
| 4 | Acctonc | | | | | | | | | | |
| 5 | MEK | 66.869 | | 17.974 | | | | | | | |
| 6 | Isobutyl Alcohol | 1619.93 | 0.0795 | 435.442 | | | | | | | |
| 7 | n-Heptane | 346.439 | | 93.119 | | | | | | | |
| 8 | Benzene | | | | | | | | | | |
| 9 | MIBK | | | | | | | | | | |
| 10 | Toluene | 1483.79 | 0.896 | 399.066 | | | | | | | |
| 11 | Isobutyl Acetate | 3603.93 | 0.486 | 968.827 | | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | | |
| 13 | Ethyl Benzene | 120.325 | | 32.342 | | | | | | | |
| 14 | Xylenes (m-,o-&p-) | 731.653 | 0.0873 | 196.684 | | | | | | | |
| 15 | 2-Heptanone | | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | | |

# Appendix II: Trial # 5

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **GC Analytical Results (for Vapor-Aerosol Sampler)** | | | | | | | | | | |
| Date: | 7/17/97 | | Total time: | | 18.3 | min | | | | |
| Sample ID: | 717-1-VA | | Flow rate | Qv= | 1017.4 | Qp= | 1014.5 | Qo= | 2007.8 | mL/min |
| Sampler: | vapor-aerosol sampler | | Volume: | Vv= | 18618.4 | Vp= | 18565.35 | Vo= | 36742.74 | mL |
| Tool Type: | spray | | Desorb vol: 6 mL for front CT(800/200), 3 mL for back CT, 3 mL for filter | | | | | | | |
| | | **Front Charcoal** | | **Back Charcoal** | | **Filter** | **Particulate** | **Gas phase** | **Particulate** | **Total** |
| | | Front | Back | Front | Back | Mass | Mass | Conc. | phase conc. | Conc. |
| | | (ug) | (ug) | (ug) | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) |
| 1 | Methanol | 577.554 | 193.221 | 602.418 | 206.382 | 1.365 | 41.587 | 41.399 | 1.132 | 42.530 |
| 2 | Ethanol | 25.116 | 0.411 | 19.806 | 0.435 | 0.465 | -4.748 | 1.371 | -0.129 | 1.242 |
| 3 | Isopropyl Alcohol | 5237.47 | 0.411 | 4021.82 | 0.411 | 0.516 | -1200.202 | 281.328 | -32.665 | 248.663 |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 338.544 | 0.1242 | 247.056 | 0.1407 | 0.1626 | -90.344 | 18.190 | -2.459 | 15.731 |
| 6 | Isobutyl Alcohol | 8055.15 | 0.2175 | 6200.28 | 0.324 | 1.026 | -1830.776 | 432.656 | -49.827 | 382.829 |
| 7 | n-Heptane | 1740.38 | | 1362.47 | | | -372.949 | 93.476 | -10.150 | 83.326 |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 7203.11 | 2.853 | 5559.4 | 3.333 | 0.429 | -1622.257 | 387.034 | -44.152 | 342.882 |
| 11 | Isobutyl Acetate | 17710 | 2.325 | 13721.3 | 2.352 | 3.96 | -3934.308 | 951.335 | -107.077 | 844.258 |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 573.564 | 0.24 | 440.826 | 0.1539 | | -131.189 | 30.819 | -3.570 | 27.249 |
| 14 | Xylenes (m-,o-&p-) | 3435.35 | 1.227 | 2599.88 | 0.5751 | 0.3675 | -825.953 | 184.579 | -22.479 | 162.100 |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |
| **GC Analytical Results (for Passive Sampler)** | | | | | | | | | | |
| Date: | 7/17/97 | | Total time: | | 18.3 | min | | | | |
| Sample ID: | 717-1-PS | | Desb Vol: | | 2 | mL for PS | | | | |
| Sampler: | passive sampler | | Tool Type: | | spray | | | | | |
| | | **Passive** | **Samplin** | **Sample** | **Total** | | | | | |
| | | Mass | Rate | volume | Conc. | | | | | |
| | | (ug) | (mL/min) | (mL) | (mg/m3) | | | | | |
| 1 | Methanol | 9.644 | | | | | | | | |
| 2 | Ethanol | 5.004 | | | | | | | | |
| 3 | Isopropyl Alcohol | 27.374 | | | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 1.766 | | | | | | | | |
| 6 | Isobutyl Alcohol | 61.384 | | | | | | | | |
| 7 | n-Heptane | 28.914 | 13.9 | 254.37 | 113.669 | | | | | |
| 8 | Benzene | | 16 | 292.8 | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 126.65 | 14.5 | 265.35 | 477.294 | | | | | |
| 11 | Isobutyl Acetate | 236.448 | | | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 9.242 | 12.9 | 236.07 | 39.149 | | | | | |
| 14 | Xylenes (m-,o-&p-) | 59.34 | 12.4 | 226.92 | 261.502 | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | 0.276 | | | | | | | | |

# Appendix II: Trial # 6

| GC Analytical Results (for Filtered-Charcoal Tube) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 13.5 | min | | | | |
| Sample ID: | 717-2-FC | | Avg flow: | | 1986 | mL/min | | | | |
| Sampler: | IOM followed by charcoal tube | | Total Vol: | | 26811 | mL | | | | |
| Tool Type: | SPRAY | | Desb Vol: | | 10 | mL for front CT(800/200),2 mL for back CT,3 mL for filter | | | | |
| | | | | | | | | | | |
| | | **Charcoal Tube** | | **Filter** | **Gas phas** | **Particula** | **Total** | | | |
| | | Front | Back | Mass | Conc. | phase con | Conc. | | | |
| | | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) | | | |
| 1 | Methanol | 295.83 | 88.612 | 2.694 | 14.339 | 0.100 | 14.439 | | | |
| 2 | Ethanol | 40.36 | 1.17 | 0.399 | 1.549 | 0.015 | 1.564 | | | |
| 3 | Isopropyl Alcohol | 8585.71 | 0.238 | 2.403 | 320.240 | 0.090 | 320.329 | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 575.33 | 4.238 | 0.1308 | 21.617 | 0.005 | 21.622 | | | |
| 6 | Isobutyl Alcohol | 13215.5 | | 10.545 | 492.914 | 0.393 | 493.307 | | | |
| 7 | n-Heptane | 2689.71 | | | 100.321 | 0.000 | 100.321 | | | |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 11270.9 | 5.078 | 1.716 | 420.571 | 0.064 | 420.635 | | | |
| 11 | Isobutyl Acetate | 28677.9 | 3.536 | 16.107 | 1069.77 | 0.601 | 1070.366 | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 909.63 | 0.218 | 0.2031 | 33.936 | 0.008 | 33.943 | | | |
| 14 | Xylenes (m-,o-&p-) | 5842.9 | 0.9758 | 1.1508 | 217.966 | 0.043 | 218.009 | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | 0.0942 | 0.000 | 0.004 | 0.004 | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

| GC Analytical Results (for Charcoal Tube) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 13.5 | min | | | | |
| Sample ID: | 717-2-CT | | Avg flow: | | 203.9 | mL/min | | | | |
| Sampler: | charcoal tube | | Total Vol: | | 2752.65 | mL | | | | |
| Tool Type: | spray | | Desb Vol: | | 1 | mL for CT(100/50) | | | | |
| | | | | | | | | | | |
| | | **Charcoal Tube** | | **Total** | | | | | | |
| | | Front | Back | Conc. | | | | | | |
| | | (ug) | (ug) | (mg/m3) | | | | | | |
| 1 | Methanol | 81.003 | 68.461 | 54.298 | | | | | | |
| 2 | Ethanol | 4.81 | 0.591 | 1.962 | | | | | | |
| 3 | Isopropyl Alcohol | 658.248 | 0.0707 | 239.158 | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 47.809 | 2.078 | 18.123 | | | | | | |
| 6 | Isobutyl Alcohol | 1067.42 | | 387.780 | | | | | | |
| 7 | n-Heptane | 231.609 | | 84.140 | | | | | | |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 971.919 | 1.105 | 353.486 | | | | | | |
| 11 | Isobutyl Acetate | 2446.52 | 0.477 | 888.960 | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 78.62 | | 28.562 | | | | | | |
| 14 | Xylenes (m-,o-&p-) | 506.318 | 0.141 | 183.990 | | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

# Appendix II: Trial # 6

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **GC Analytical Results (for Vapor-Aerosol Sampler)** | | | | | | | | | | |
| Date: | 7/17/97 | | Total time: | | 13.5 | min | | | | |
| Sample ID: | 717-2-VA | | Flow rate | Qv= | 1056 | Qp= | 1034.4 | Qo= | 2046.5 | mL/min |
| Sampler: | vapor-aerosol sampler | | Volume: | Vv= | 14256 | Vp= | 13964.4 | Vo= | 27627.75 | mL |
| Tool Type: | spray | | Desorb vol: 10 mL for front CT(800/200), 2 mL for back CT, 3 mL for filter | | | | | | | |
| | | **Front Charcoal** | | **Back Charcoal** | | **Filter** | **Particulate** | **Gas phase** | **Particulate** | **Total** |
| | | Front | Back | Front | Back | Mass | Mass | Conc. | phase conc. | Conc. |
| | | (ug) | (ug) | (ug) | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) |
| 1 | Methanol | 350.15 | 108.228 | 390.8 | 104.56 | 1.467 | 47.825 | 32.153 | 1.731 | 33.884 |
| 2 | Ethanol | 19.6 | 1.044 | 29.47 | | 0.417 | 9.665 | 1.448 | 0.350 | 1.798 |
| 3 | Isopropyl Alcohol | 4025.01 | 0.212 | 4177.74 | 0.218 | 0.717 | 235.787 | 282.353 | 8.534 | 290.887 |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 266.64 | 3.88 | 268.12 | 4.554 | 0.1446 | 7.832 | 18.976 | 0.283 | 19.259 |
| 6 | Isobutyl Alcohol | 6347.91 | | 6478.22 | | 1.14 | 261.294 | 445.280 | 9.458 | 454.738 |
| 7 | n-Heptane | 1344.11 | | 1358.5 | | | 41.883 | 94.284 | 1.516 | 95.800 |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 5518.79 | 5.374 | 5566.04 | 4.2 | 0.561 | 159.631 | 387.497 | 5.778 | 393.275 |
| 11 | Isobutyl Acetate | 14206.2 | 2.882 | 14444 | 2.99 | 4.938 | 533.497 | 996.710 | 19.310 | 1016.02 |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 440.06 | 0.262 | 445.85 | 0.1676 | | 14.702 | 30.887 | 0.532 | 31.419 |
| 14 | Xylenes (m-,o-&p-) | 2811.28 | 1.1094 | 2880.05 | 0.7916 | 0.4491 | 126.427 | 197.278 | 4.576 | 201.854 |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |
| **GC Analytical Results (for Passive Sampler)** | | | | | | | | | | |
| Date: | 7/17/97 | | Total time: | | 13.5 | min | | | | |
| Sample ID: | 717-2-PS | | Desb Vol: | | 2 | mL for PS | | | | |
| Sampler: | passive sampler | | Tool Type: | | spray | | | | | |
| | | **Passive** | **Samplin** | **Sample** | **Total** | | | | | |
| | | Mass | Rate | volume | Conc. | | | | | |
| | | (ug) | (mL/min) | (mL) | (mg/m3) | | | | | |
| 1 | Methanol | 8.332 | | | | | | | | |
| 2 | Ethanol | 1.742 | | | | | | | | |
| 3 | Isopropyl Alcohol | 23.248 | | | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 1.12 | | | | | | | | |
| 6 | Isobutyl Alcohol | 51.472 | | | | | | | | |
| 7 | n-Heptane | 22.52 | 13.9 | 187.65 | 120.011 | | | | | |
| 8 | Benzene | | 16 | 216 | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 96.786 | 14.5 | 195.75 | 494.437 | | | | | |
| 11 | Isobutyl Acetate | 207.124 | | | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 7.548 | 12.9 | 174.15 | 43.342 | | | | | |
| 14 | Xylenes (m-,o-&p-) | 49.554 | 12.4 | 167.4 | 296.022 | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |

# Appendix II: Trial # 7

| GC Analytical Results (for Filtered-Charcoal Tube) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 10.6 | min | | | | |
| Sample ID: | 717-3-FC | | Avg flow: | | 1993.7 | mL/min | | | | |
| Sampler: | IOM followed by charcoal tube | | Total Vol: | | 21133.2 | mL | | | | |
| Tool Type: | SPRAY | | Desb Vol: | | 10 | mL for front CT(800/200),2 mL for back CT,3 mL for filter | | | | |
| | | **Charcoal Tube** | | **Filter** | **Gas phas** | **Particula** | **Total** | | | |
| | | Front | Back | Mass | Conc. | phase con | Conc. | | | |
| | | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) | | | |
| 1 | Methanol | 400.2 | 110.768 | 1.272 | 24.178 | 0.060 | 24.239 | | | |
| 2 | Ethanol | 37.59 | | 0.405 | 1.779 | 0.019 | 1.798 | | | |
| 3 | Isopropyl Alcohol | 5408.35 | 0.36 | 0.537 | 255.934 | 0.025 | 255.959 | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 369.08 | 4.506 | 0.1341 | 17.678 | 0.006 | 17.684 | | | |
| 6 | Isobutyl Alcohol | 7925.37 | | 1.38 | 375.020 | 0.065 | 375.085 | | | |
| 7 | n-Heptane | 1771.28 | | | 83.815 | 0.000 | 83.815 | | | |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 7187.79 | 4.65 | 0.489 | 340.338 | 0.023 | 340.361 | | | |
| 11 | Isobutyl Acetate | 17425.3 | 2.188 | 5.067 | 824.650 | 0.240 | 824.890 | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 547.34 | 0.1602 | | 25.907 | 0.000 | 25.907 | | | |
| 14 | Xylenes (m-,o-&p-) | 3548.82 | 0.655 | 0.4797 | 167.957 | 0.023 | 167.980 | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

| GC Analytical Results (for Charcoal Tube) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 10.6 | min | | | | |
| Sample ID: | 717-3-CT | | Avg flow: | | 203.3 | mL/min | | | | |
| Sampler: | charcoal tube | | Total Vol: | | 2154.98 | mL | | | | |
| Tool Type: | spray | | Desb Vol: | | 1 | mL for CT(100/50) | | | | |
| | | **Charcoal Tube** | | **Total** | | | | | | |
| | | Front | Back | Conc. | | | | | | |
| | | (ug) | (ug) | (mg/m3) | | | | | | |
| 1 | Methanol | 94.866 | 80.989 | 81.604 | | | | | | |
| 2 | Ethanol | 3.554 | 1.052 | 2.137 | | | | | | |
| 3 | Isopropyl Alcohol | 502.425 | 0.184 | 233.231 | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 34.671 | 2.352 | 17.180 | | | | | | |
| 6 | Isobutyl Alcohol | 771.915 | | 358.201 | | | | | | |
| 7 | n-Heptane | 172.532 | | 80.062 | | | | | | |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 719.005 | 2.284 | 334.708 | | | | | | |
| 11 | Isobutyl Acetate | 1739.17 | 1.123 | 807.569 | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 56.358 | | 26.152 | | | | | | |
| 14 | Xylenes (m-,o-&p-) | 358.005 | 0.2087 | 166.226 | | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

# Appendix II: Trial # 7

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **GC Analytical Results (for Vapor-Aerosol Sampler)** | | | | | | | | | | |
| Date: | 7/17/97 | | Total time: | | 10.6 | min | | | | |
| Sample ID: | 717-3-VA | | Flow rate | Qv= | 1017.4 | Qp= | 1014.5 | Qo= | 2007.8 | mL/min |
| Sampler: | vapor-aerosol sampler | | Volume: | Vv= | 10784.4 | Vp= | 10753.7 | Vo= | 21282.68 | mL |
| Tool Type: | spray | | Desorb vol: 10 mL for front CT(800/200), 2 mL for back CT, 3 mL for filter | | | | | | | |
| | | **Front Charcoal** | | **Back Charcoal** | | **Filter** | **Particulate** | **Gas phase** | **Particulate** | **Total** |
| | | Front | Back | Front | Back | Mass | Mass | Conc. | phase conc. | Conc. |
| | | (ug) | (ug) | (ug) | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) |
| 1 | Methanol | 418.84 | 120.59 | 400.15 | 107.078 | 0.978 | -29.686 | 50.005 | -1.395 | 48.611 |
| 2 | Ethanol | 20.78 | | 22.91 | | 0.435 | 2.624 | 1.926 | 0.123 | 2.050 |
| 3 | Isopropyl Alcohol | 2913.73 | 0.782 | 2801.44 | 0.574 | 0.447 | -103.743 | 270.176 | -4.875 | 265.302 |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 120.91 | | 119.31 | 0.0756 | 0.1314 | -1.048 | 11.208 | -0.049 | 11.159 |
| 6 | Isobutyl Alcohol | 4388.65 | 0.628 | 4274.49 | 0.28 | 0.726 | -101.271 | 406.888 | -4.758 | 402.129 |
| 7 | n-Heptane | 1003.39 | | 984.58 | | | -15.950 | 93.015 | -0.749 | 92.265 |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 4057.55 | 6.924 | 3947.35 | 4.348 | 0.396 | -100.795 | 376.778 | -4.736 | 372.042 |
| 11 | Isobutyl Acetate | 9992.3 | 4.846 | 9765.63 | 2.69 | 2.739 | -197.591 | 926.739 | -9.284 | 917.455 |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 306.12 | 0.244 | 296.97 | 0.1408 | | -8.380 | 28.400 | -0.394 | 28.006 |
| 14 | Xylenes (m-,o-&p-) | 1944.72 | 0.9758 | 1871.39 | 0.5078 | 0.2205 | -68.031 | 180.367 | -3.197 | 177.170 |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **GC Analytical Results (for Passive Sampler)** | | | | | | |
| Date: | 7/17/97 | Total time: | | 10.6 | min | |
| Sample ID: | 717-3-PS | Desb Vol: | | 2 | mL for PS | |
| Sampler: | passive sampler | Tool Type: | | spray | | |
| | | **Passive** | **Samplin** | **Sample** | **Total** | |
| | | Mass | Rate | volume | Conc. | |
| | | (ug) | (mL/min) | (mL) | (mg/m3) | |
| 1 | Methanol | 7.204 | | | | |
| 2 | Ethanol | 4.324 | | | | |
| 3 | Isopropyl Alcohol | 18.512 | | | | |
| 4 | Acetone | | | | | |
| 5 | MEK | 1.332 | | | | |
| 6 | Isobutyl Alcohol | 35.678 | | | | |
| 7 | n-Heptane | 16.398 | 13.9 | 147.34 | 111.294 | |
| 8 | Benzene | | 16 | 169.6 | | |
| 9 | MIBK | | | | | |
| 10 | Toluene | 73.724 | 14.5 | 153.7 | 479.662 | |
| 11 | Isobutyl Acetate | 141.33 | | | | |
| 12 | n-Butyl Acetate | | | | | |
| 13 | Ethyl Benzene | 4.988 | 12.9 | 136.74 | 36.478 | |
| 14 | Xylenes (m-,o-&p-) | 33.6 | 12.4 | 131.44 | 255.630 | |
| 15 | 2-Heptanone | | | | | |
| 16 | 2-Butoxyethanol | | | | | |

# Appendix II: Trial # 8

| GC Analytical Results (for Filtered-Charcoal Tube) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 13.3 | min | | | | |
| Sample ID: | 717-4-FC | | Avg flow: | | 1986 | mL/min | | | | |
| Sampler: | IOM followed by charcoal tube | | Total Vol: | | 26413.8 | mL | | | | |
| Tool Type: | SPRAY | | Desb Vol: | | 10 | mL for front CT(800/200),2 mL for back CT,3 mL for filter | | | | |
| | | | | | | | | | | |
| | | **Charcoal Tube** | | **Filter** | **Gas phas** | **Particula** | **Total** | | | |
| | | Front | Back | Mass | Conc. | phase con | Conc. | | | |
| | | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) | | | |
| 1 | Methanol | 547.76 | 203.96 | 3.693 | 28.459 | 0.140 | 28.599 | | | |
| 2 | Ethanol | 61.72 | 3.062 | 0.354 | 2.453 | 0.013 | 2.466 | | | |
| 3 | Isopropyl Alcohol | 12533.1 | 3.698 | 1.977 | 474.629 | 0.075 | 474.704 | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 776.98 | | 0.2145 | 29.416 | 0.008 | 29.424 | | | |
| 6 | Isobutyl Alcohol | 17944.9 | 0.288 | 7.497 | 679.387 | 0.284 | 679.671 | | | |
| 7 | n-Heptane | 3771.29 | | | 142.777 | 0.000 | 142.777 | | | |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 15740.3 | 6.402 | 1.425 | 596.153 | 0.054 | 596.207 | | | |
| 11 | Isobutyl Acetate | 38326.9 | 3.986 | 14.022 | 1451.17 | 0.531 | 1451.701 | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 1191.87 | 0.276 | 0.1944 | 45.133 | 0.007 | 45.141 | | | |
| 14 | Xylenes (m-,o-&p-) | 7836.91 | 1.736 | 1.131 | 296.763 | 0.043 | 296.806 | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | 0.1119 | 0.000 | 0.004 | 0.004 | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |
| | | | | | | | | | | |
| **GC Analytical Results (for Charcoal Tube)** | | | | | | | | | | |
| Date: | 7/17/97 | | Total time: | | 13.3 | min | | | | |
| Sample ID: | 717-4-CT | | Avg flow: | | 203.9 | mL/min | | | | |
| Sampler: | charcoal tube | | Total Vol: | | 2711.87 | mL | | | | |
| Tool Type: | spray | | Desb Vol: | | 1 | mL for CT(100/50) | | | | |
| | | | | | | | | | | |
| | | **Charcoal Tube** | | **Total** | | | | | | |
| | | Front | Back | Conc. | | | | | | |
| | | (ug) | (ug) | (mg/m3) | | | | | | |
| 1 | Methanol | 140.388 | 144.262 | 104.964 | | | | | | |
| 2 | Ethanol | 6.677 | 1.373 | 2.968 | | | | | | |
| 3 | Isopropyl Alcohol | 1077.65 | 0.374 | 397.521 | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 68.521 | | 25.267 | | | | | | |
| 6 | Isobutyl Alcohol | 1593.89 | 0.107 | 587.786 | | | | | | |
| 7 | n-Heptane | 338.025 | | 124.646 | | | | | | |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 1420.1 | 1.865 | 524.349 | | | | | | |
| 11 | Isobutyl Acetate | 3499.85 | 0.973 | 1290.92 | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 109.859 | 0.0662 | 40.535 | | | | | | |
| 14 | Xylenes (m-,o-&p-) | 717.067 | 0.2654 | 264.516 | | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

# Appendix II: Trial # 8

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **GC Analytical Results (for Vapor-Aerosol Sampler)** | | | | | | | | | | |
| Date: | 7/17/97 | | Total tim | 13.3 | min | | | | | |
| Sample ID: | 717-4-VA | | Flow rate | Qv= | 1056 | Qp= | 1034.4 | Qo= | 2046.5 | mL/min |
| Sampler: | vapor-aerosol sampler | | Volume: | Vv= | 14044.8 | Vp= | 13757.52 | Vo= | 27218.45 | mL |
| Tool Type: | spray | | Desorb vol: 10 mL for front CT(800/200), 2 mL for back CT, 3 mL for filter | | | | | | | |
| | | **Front Charcoal** | | **Back Charcoal** | | **Filter** | **Particulate** | **Gas phase** | **Particulate** | **Total** |
| | | Front | Back | Front | Back | Mass | Mass | Conc. | phase conc. | Conc. |
| | | (ug) | (ug) | (ug) | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) |
| 1 | Methanol | 874.29 | 231.258 | 852.73 | 244.24 | 1.527 | 15.562 | 78.716 | 0.572 | 79.288 |
| 2 | Ethanol | 38.84 | | 33.15 | | 0.423 | -4.473 | 2.765 | -0.164 | 2.601 |
| 3 | Isopropyl Alcohol | 6306.19 | 0.524 | 6429.08 | 0.314 | 0.57 | 252.251 | 449.043 | 9.268 | 458.310 |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 355.33 | | 361.43 | | 0.144 | 13.512 | 25.300 | 0.496 | 25.796 |
| 6 | Isobutyl Alcohol | 9041.6 | 0.54 | 9187.03 | 0.1476 | 1.095 | 331.085 | 643.807 | 12.164 | 655.971 |
| 7 | n-Heptane | 2007.97 | | 2022.07 | | | 55.172 | 142.969 | 2.027 | 144.996 |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 7988.93 | 6.186 | 8037.62 | 5.592 | 0.417 | 212.049 | 569.258 | 7.791 | 577.049 |
| 11 | Isobutyl Acetate | 19419.9 | 4.36 | 19763.3 | 2.89 | 4.161 | 743.405 | 1383.019 | 27.313 | 1410.33 |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 587.88 | 0.304 | 573.21 | 0.256 | 0.1098 | -2.577 | 41.879 | -0.095 | 41.784 |
| 14 | Xylenes (m-,o-&p-) | 3805.18 | 1.522 | 3872.04 | 1.1452 | 0.3681 | 144.716 | 271.040 | 5.317 | 276.357 |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **GC Analytical Results (for Passive Sampler)** | | | | | | |
| Date: | 7/17/97 | | Total time: | 13.3 | min | |
| Sample ID: | 717-4-PS | | Desb Vol: | 2 | mL for PS | |
| Sampler: | passive sampler | | Tool Type: | spray | | |
| | | **Passive** | **Samplin** | **Sample** | **Total** | |
| | | Mass | Rate | volume | Conc. | |
| | | (ug) | (mL/min) | (mL) | (mg/m3) | |
| 1 | Methanol | 15.754 | | | | |
| 2 | Ethanol | 1.628 | | | | |
| 3 | Isopropyl Alcohol | 56.37 | | | | |
| 4 | Acetone | | | | | |
| 5 | MEK | 2.034 | | | | |
| 6 | Isobutyl Alcohol | 153.194 | | | | |
| 7 | n-Heptane | 48.492 | 13.9 | 184.87 | 262.303 | |
| 8 | Benzene | | 16 | 212.8 | | |
| 9 | MIBK | | | | | |
| 10 | Toluene | 217 | 14.5 | 192.85 | 1125.23 | |
| 11 | Isobutyl Acetate | 646.722 | | | | |
| 12 | n-Butyl Acetate | | | | | |
| 13 | Ethyl Benzene | 22.172 | 12.9 | 171.57 | 129.230 | |
| 14 | Xylenes (m-,o-&p-) | 152.29 | 12.4 | 164.92 | 923.417 | |
| 15 | 2-Heptanone | | | | | |
| 16 | 2-Butoxyethanol | | | | | |

# Appendix II: Trial # 9

| GC Analytical Results (for Filtered-Charcoal Tube) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 8.2 | min | | | | | |
| Sample ID: | 717-5-FC | | Avg flow: | | 1993.7 | mL/min | | | | | |
| Sampler: | IOM followed by charcoal tube | | Total Vol: | | 16348.3 | mL | | | | | |
| Tool Type: | SPRAY | | Desb Vol: | | 6 | mL for front CT(800/200),2 mL for back CT,3 mL for filter | | | | | |
| | | | | | | | | | | | |
| | | **Charcoal Tube** | | **Filter** | **Gas phas** | **Particula** | **Total** | | | | |
| | | Front | Back | Mass | Conc. | phase con | Conc. | | | | |
| | | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) | | | | |
| 1 | Methanol | 119.694 | 40.354 | 1.047 | 9.790 | 0.064 | 9.854 | | | | |
| 2 | Ethanol | 10.062 | | 0.441 | 0.615 | 0.027 | 0.642 | | | | |
| 3 | Isopropyl Alcohol | 1780.21 | 0.346 | 0.444 | 108.914 | 0.027 | 108.941 | | | | |
| 4 | Acetone | | | | | | | | | | |
| 5 | MEK | 71.694 | | 0.1266 | 4.385 | 0.008 | 4.393 | | | | |
| 6 | Isobutyl Alcohol | 3440.94 | 0.338 | 1.107 | 210.497 | 0.068 | 210.565 | | | | |
| 7 | n-Heptane | 628.02 | | | 38.415 | 0.000 | 38.415 | | | | |
| 8 | Benzene | | | | | | | | | | |
| 9 | MIBK | | | | | | | | | | |
| 10 | Toluene | 2997.97 | 6.282 | 0.474 | 183.765 | 0.029 | 183.794 | | | | |
| 11 | Isobutyl Acetate | 8946.76 | 4.502 | 3.879 | 547.534 | 0.237 | 547.771 | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | | |
| 13 | Ethyl Benzene | 299.934 | 0.296 | | 18.365 | 0.000 | 18.365 | | | | |
| 14 | Xylenes (m-,o-&p-) | 2011.58 | 1.68 | 0.3924 | 123.148 | 0.024 | 123.172 | | | | |
| 15 | 2-Heptanone | | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | | |

| GC Analytical Results (for Charcoal Tube) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 8.2 | min | | | | | |
| Sample ID: | 717-5-CT | | Avg flow: | | 203.3 | mL/min | | | | | |
| Sampler: | charcoal tube | | Total Vol: | | 1667.06 | mL | | | | | |
| Tool Type: | spray | | Desb Vol: | | 1 | mL for CT(100/50) | | | | | |
| | | | | | | | | | | | |
| | | **Charcoal Tube** | | **Total** | | | | | | | |
| | | Front | Back | Conc. | | | | | | | |
| | | (ug) | (ug) | (mg/m3) | | | | | | | |
| 1 | Methanol | 41.422 | 29.455 | 42.516 | | | | | | | |
| 2 | Ethanol | 1.606 | | 0.963 | | | | | | | |
| 3 | Isopropyl Alcohol | 207.887 | 0.0748 | 124.748 | | | | | | | |
| 4 | Acetone | | | | | | | | | | |
| 5 | MEK | 3.997 | | 2.398 | | | | | | | |
| 6 | Isobutyl Alcohol | 405.6 | 0.0689 | 243.344 | | | | | | | |
| 7 | n-Heptane | 67.251 | | 40.341 | | | | | | | |
| 8 | Benzene | | | | | | | | | | |
| 9 | MIBK | | | | | | | | | | |
| 10 | Toluene | 335.199 | 1.676 | 202.077 | | | | | | | |
| 11 | Isobutyl Acetate | 1057.08 | 0.76 | 634.554 | | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | | |
| 13 | Ethyl Benzene | 34.99 | | 20.989 | | | | | | | |
| 14 | Xylenes (m-,o-&p-) | 241.42 | 0.155 | 144.911 | | | | | | | |
| 15 | 2-Heptanone | | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | | |

# Appendix II: Trial # 9

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **GC Analytical Results (for Vapor-Aerosol Sampler)** | | | | | | | | | | |
| Date: | 7/17/97 | | Total time: | | 8.2 | min | | | | |
| Sample ID: | 717-5-VA | | Flow rate | Qv= | 1017.4 | Qp= | 1014.5 | Qo= | 2007.8 | mL/min |
| Sampler: | vapor-aerosol sampler | | Volume: | Vv= | 8342.68 | Vp= | 8318.9 | Vo= | 16463.96 | mL |
| Tool Type: | spray | | Desorb vol: 6 mL for front CT(800/200), 2 mL for back CT, 3 mL for filter | | | | | | | |
| | | **Front Charcoal** | | **Back Charcoal** | | **Filter** | **Particulate** | **Gas phase** | **Particulate** | **Total** |
| | | Front | Back | Front | Back | Mass | Mass | Conc. | phase conc. | Conc. |
| | | (ug) | (ug) | (ug) | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) |
| 1 | Methanol | 147.96 | 50.638 | 153.132 | 49.312 | 0.543 | 4.955 | 23.805 | 0.301 | 24.106 |
| 2 | Ethanol | 6.426 | | 5.952 | | 0.453 | -0.003 | 0.770 | 0.000 | 0.770 |
| 3 | Isopropyl Alcohol | 871.776 | 0.1726 | 842.586 | 0.1438 | 0.2853 | -26.448 | 104.517 | -1.606 | 102.910 |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 18.612 | | 18.534 | | 0.1284 | 0.103 | 2.231 | 0.006 | 2.237 |
| 6 | Isobutyl Alcohol | 1697.45 | 0.34 | 1659.45 | 0.1374 | 0.414 | -32.947 | 203.506 | -2.001 | 201.505 |
| 7 | n-Heptane | 320.322 | | 341.796 | | | 22.387 | 38.396 | 1.360 | 39.755 |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 1545.77 | 5.856 | 1490.77 | 6.228 | 0.2571 | -49.950 | 185.987 | -3.034 | 182.953 |
| 11 | Isobutyl Acetate | 4582.75 | 2.984 | 4559.12 | 3.68 | 1.77 | -8.091 | 549.671 | -0.491 | 549.180 |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 156.564 | 0.284 | 148.716 | 0.342 | | -7.343 | 18.801 | -0.446 | 18.355 |
| 14 | Xylenes (m-,o-&p-) | 1029.37 | 1.6224 | 1015.78 | 1.812 | 0.159 | -10.303 | 123.581 | -0.626 | 122.955 |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **GC Analytical Results (for Passive Sampler)** | | | | | | | | | | |
| Date: | 7/17/97 | | Total time: | | 8.2 | min | | | | |
| Sample ID: | 717-5-PS | | Desb Vol: | | 2 | mL for PS | | | | |
| Sampler: | passive sampler | | Tool Type: | | spray | | | | | |
| | | **Passive** | **Samplin** | **Sample** | **Total** | | | | | |
| | | Mass | Rate | volume | Conc. | | | | | |
| | | (ug) | (mL/min) | (mL) | (mg/m3) | | | | | |
| 1 | Methanol | 5.506 | | | | | | | | |
| 2 | Ethanol | 6.346 | | | | | | | | |
| 3 | Isopropyl Alcohol | 7.38 | | | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 0.488 | | | | | | | | |
| 6 | Isobutyl Alcohol | 15.87 | | | | | | | | |
| 7 | n-Heptane | 6.868 | 13.9 | 113.98 | 60.256 | | | | | |
| 8 | Benzene | | 16 | 131.2 | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 36.072 | 14.5 | 118.9 | 303.381 | | | | | |
| 11 | Isobutyl Acetate | 77.908 | | | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 2.992 | 12.9 | 105.78 | 28.285 | | | | | |
| 14 | Xylenes (m-,o-&p-) | 20.24 | 12.4 | 101.68 | 199.056 | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | | | | | | | | | |

# Appendix II: Trial # 10

| GC Analytical Results (for Filtered-Charcoal Tube) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 14.6 | min | | | | |
| Sample ID: | 717-6-FC | | Avg flow: | | 1993.7 | mL/min | | | | |
| Sampler: | IOM followed by charcoal tube | | Total Vol: | | 29108 | mL | | | | |
| Tool Type: | SPRAY | | Desb Vol: | | 6 | mL for front CT(800/200),1 mL for back CT,3 mL for filter | | | | |
| | | | | | | | | | | |
| | | **Charcoal Tube** | | **Filter** | **Gas phas** | **Particula** | **Total** | | | |
| | | Front | Back | Mass | Conc. | phase con | Conc. | | | |
| | | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) | | | |
| 1 | Methanol | 18.09 | 2.999 | 0.378 | 0.725 | 0.013 | 0.737 | | | |
| 2 | Ethanol | 10.056 | | 0.393 | 0.345 | 0.014 | 0.359 | | | |
| 3 | Isopropyl Alcohol | 6706.18 | 0.115 | 1.56 | 230.393 | 0.054 | 230.447 | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 30.894 | | 0.1407 | 1.061 | 0.005 | 1.066 | | | |
| 6 | Isobutyl Alcohol | 2626.04 | 0.0823 | 2.001 | 90.220 | 0.069 | 90.289 | | | |
| 7 | n-Heptane | 43.728 | | | 1.502 | 0.000 | 1.502 | | | |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 10737.5 | 6.256 | 1.128 | 369.100 | 0.039 | 369.139 | | | |
| 11 | Isobutyl Acetate | 12085.1 | 2.266 | 9.465 | 415.259 | 0.325 | 415.584 | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 215.658 | 0.245 | | 7.417 | 0.000 | 7.417 | | | |
| 14 | Xylenes (m-,o-&p-) | 1272.21 | 1.468 | 0.3027 | 43.757 | 0.010 | 43.767 | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | 26.904 | | 0.519 | 0.924 | 0.018 | 0.942 | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

| GC Analytical Results (for Charcoal Tube) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 14.6 | min | | | | |
| Sample ID: | 717-6-CT | | Avg flow: | | 203.3 | mL/min | | | | |
| Sampler: | charcoal tube | | Total Vol: | | 2968.18 | mL | | | | |
| Tool Type: | spray | | Desb Vol: | | 1 | mL for CT(100/50) | | | | |
| | | | | | | | | | | |
| | | **Charcoal Tube** | | **Total** | | | | | | |
| | | Front | Back | Conc. | | | | | | |
| | | (ug) | (ug) | (mg/m3) | | | | | | |
| 1 | Methanol | 3.894 | 2.873 | 2.280 | | | | | | |
| 2 | Ethanol | 0.959 | | 0.323 | | | | | | |
| 3 | Isopropyl Alcohol | 539.61 | 0.0914 | 181.829 | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 2.157 | | 0.727 | | | | | | |
| 6 | Isobutyl Alcohol | 217.682 | 0.0444 | 73.354 | | | | | | |
| 7 | n-Heptane | 3.836 | | 1.292 | | | | | | |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 942.06 | 1.504 | 317.893 | | | | | | |
| 11 | Isobutyl Acetate | 1059.72 | 0.322 | 357.135 | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 19.086 | | 6.430 | | | | | | |
| 14 | Xylenes (m-,o-&p-) | 114.699 | 0.0534 | 38.661 | | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | 2.259 | | 0.761 | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

# Appendix II: Trial # 10

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **GC Analytical Results (for Vapor-Aerosol Sampler)** | | | | | | | | | | |
| Date: | 7/17/97 | | Total time: | | 14.6 | min | | | | |
| Sample ID: | 717-6-VA | | Flow rate | Qv= | 1017.4 | Qp= | 1014.5 | Qo= | 2007.8 | mL/min |
| Sampler: | vapor-aerosol sampler | | Volume: | Vv= | 14854 | Vp= | 14811.7 | Vo= | 29313.88 | mL |
| Tool Type: | spray | | Desorb vol: 6 mL for front CT(800/200), 2 mL for back CT, 3 mL for filter | | | | | | | |

| | | **Front Charcoal** | | **Back Charcoal** | | **Filter** | **Particulate** | **Gas phase** | **Particulate** | **Total** |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Front | Back | Front | Back | Mass | Mass | Conc. | phase conc. | Conc. |
| | | (ug) | (ug) | (ug) | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) |
| 1 | Methanol | 18.846 | 3.07 | 16.842 | 2.988 | 0.3 | -1.724 | 1.475 | -0.059 | 1.417 |
| 2 | Ethanol | 5.58 | | 5.34 | | 0.378 | 0.154 | 0.376 | 0.005 | 0.381 |
| 3 | Isopropyl Alcohol | 3378.43 | 0.106 | 3344.7 | 0.121 | 0.543 | -23.544 | 227.449 | -0.803 | 226.646 |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 14.154 | | 14.256 | | 0.1326 | 0.275 | 0.953 | 0.009 | 0.962 |
| 6 | Isobutyl Alcohol | 1331.38 | 0.0607 | 1315.36 | 0.101 | 0.477 | -11.708 | 89.635 | -0.399 | 89.235 |
| 7 | n-Heptane | 25.194 | | 23.97 | | | -1.152 | 1.696 | -0.039 | 1.657 |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 5573.35 | 4.117 | 5496.72 | 4.485 | 0.603 | -59.763 | 375.485 | -2.039 | 373.446 |
| 11 | Isobutyl Acetate | 6404.59 | 1.159 | 6232.9 | 1.944 | 2.412 | -150.240 | 431.246 | -5.125 | 426.121 |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 115.662 | 0.117 | 109.992 | 0.139 | | -5.318 | 7.794 | -0.181 | 7.613 |
| 14 | Xylenes (m-,o-&p-) | 692.79 | 0.4249 | 656.442 | 0.4535 | 0.1041 | -34.239 | 46.668 | -1.168 | 45.500 |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | 12.228 | | 6.81 | | 0.2961 | -5.087 | 0.823 | -0.174 | 0.650 |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

| **GC Analytical Results (for Passive Sampler)** | | | | | | |
|---|---|---|---|---|---|---|
| Date: | 7/17/97 | Total time: | | 14.6 | min | |
| Sample ID: | 717-6-PS | Desb Vol: | | 2 | mL for PS | |
| Sampler: | passive sampler | Tool Type: | | spray | | |

| | | **Passive** | **Samplin** | **Sample** | **Total** |
|---|---|---|---|---|---|
| | | Mass | Rate | volume | Conc. |
| | | (ug) | (mL/min) | (mL) | (mg/m3) |
| 1 | Methanol | 2.168 | | | |
| 2 | Ethanol | 3.714 | | | |
| 3 | Isopropyl Alcohol | 19.176 | | | |
| 4 | Acetone | | | | |
| 5 | MEK | 0.272 | | | |
| 6 | Isobutyl Alcohol | 9.092 | | | |
| 7 | n-Heptane | 0.318 | 13.9 | 202.94 | 1.567 |
| 8 | Benzene | | 16 | 233.6 | |
| 9 | MIBK | | | | |
| 10 | Toluene | 95.622 | 14.5 | 211.7 | 451.686 |
| 11 | Isobutyl Acetate | 95.152 | | | |
| 12 | n-Butyl Acetate | | | | |
| 13 | Ethyl Benzene | 1.6 | 12.9 | 188.34 | 8.495 |
| 14 | Xylenes (m-,o-&p-) | 10.578 | 12.4 | 181.04 | 58.429 |
| 15 | 2-Heptanone | | | | |
| 16 | 2-Butoxyethanol | | | | |

# Appendix II: Trial # 11

| GC Analytical Results (for Filtered-Charcoal Tube) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 17.3 | min | | | | | |
| Sample I | 717-7-FC | | Avg flow: | | 1986 | mL/min | | | | | |
| Sampler: | IOM followed by charcoal tube | | Total Vol: | | 34357.8 | mL | | | | | |
| Tool Ty | SPRAY | | Desb Vol: | | 6 | mL for front CT(800/200),1 mL for back CT,3 mL for filter | | | | | |
| | | | | | | | | | | | |
| | | **Charcoal Tube** | | **Filter** | **Gas phas** | **Particula** | **Total** | | | | |
| | | Front | Back | Mass | Conc. | phase con | Conc. | | | | |
| | | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) | | | | |
| 1 | Methanol | 10.854 | 2.142 | 0.2817 | 0.378 | 0.008 | 0.386 | | | | |
| 2 | Ethanol | 4.362 | | 0.387 | 0.127 | 0.011 | 0.138 | | | | |
| 3 | Isopropyl Alcohol | 2469.32 | 0.129 | 0.2295 | 71.875 | 0.007 | 71.881 | | | | |
| 4 | Acetone | | | | | | | | | | |
| 5 | MEK | 12.312 | | 0.1464 | 0.358 | 0.004 | 0.363 | | | | |
| 6 | Isobutyl Alcohol | 1302.34 | 0.108 | 0.1725 | 37.908 | 0.005 | 37.913 | | | | |
| 7 | n-Heptane | 26.178 | | | 0.762 | 0.000 | 0.762 | | | | |
| 8 | Benzene | | | | | | | | | | |
| 9 | MIBK | | | | | | | | | | |
| 10 | Toluene | 5377.92 | 5.625 | 0.342 | 156.691 | 0.010 | 156.701 | | | | |
| 11 | Isobutyl Acetate | 7057.36 | 2.491 | 1.116 | 205.480 | 0.032 | 205.513 | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | | |
| 13 | Ethyl Benzene | 138.45 | 0.204 | | 4.036 | 0.000 | 4.036 | | | | |
| 14 | Xylenes (m-,o-&p-) | 867.264 | 1.293 | | 25.280 | 0.000 | 25.280 | | | | |
| 15 | 2-Heptanone | | | | | | | | | | |
| 16 | 2-Butoxyethanol | 13.812 | | 0.1893 | 0.402 | 0.006 | 0.408 | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | | |

| GC Analytical Results (for Charcoal Tube) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 17.3 | min | | | | | |
| Sample I | 717-7-CT | | Avg flow: | | 203.9 | mL/min | | | | | |
| Sampler: | charcoal tube | | Total Vol: | | 3527.47 | mL | | | | | |
| Tool Ty | spray | | Desb Vol: | | 1 | mL for CT(100/50) | | | | | |
| | | | | | | | | | | | |
| | | **Charcoal Tube** | | **Total** | | | | | | | |
| | | Front | Back | Conc. | | | | | | | |
| | | (ug) | (ug) | (mg/m3) | | | | | | | |
| 1 | Methanol | 2.311 | 1.162 | 0.985 | | | | | | | |
| 2 | Ethanol | 0.48 | | 0.136 | | | | | | | |
| 3 | Isopropyl Alcohol | 242.227 | 0.0807 | 68.692 | | | | | | | |
| 4 | Acetone | | | | | | | | | | |
| 5 | MEK | 1.163 | | 0.330 | | | | | | | |
| 6 | Isobutyl Alcohol | 120.593 | 0.0809 | 34.210 | | | | | | | |
| 7 | n-Heptane | 2.217 | | 0.628 | | | | | | | |
| 8 | Benzene | | | | | | | | | | |
| 9 | MIBK | | | | | | | | | | |
| 10 | Toluene | 484.324 | 1.603 | 137.755 | | | | | | | |
| 11 | Isobutyl Acetate | 627.487 | 0.452 | 178.014 | | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | | |
| 13 | Ethyl Benzene | 12.215 | | 3.463 | | | | | | | |
| 14 | Xylenes (m-,o-&p-) | 77.329 | 0.0613 | 21.939 | | | | | | | |
| 15 | 2-Heptanone | | | | | | | | | | |
| 16 | 2-Butoxyethanol | 1.555 | | 0.441 | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | | |

# Appendix II: Trial # 11

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **GC Analytical Results (for Vapor-Aerosol Sampler)** | | | | | | | | | | |
| Date: | 7/17/97 | | Total time: | | 17.3 | min | | | | |
| Sample I | 717-7-VA | | Flow rate | Qv= | 1056 | Qp= | 1034.4 | Qo= | 2046.5 | mL/min |
| Sampler: | vapor-aerosol sampler | | Volume: | Vv= | 18268.8 | Vp= | 17895.12 | Vo= | 35404.45 | mL |
| Tool Ty | spray | | Desorb vol: 6 mL for front CT(800/200), 1 mL for back CT, 3 mL for filter | | | | | | | |
| | | **Front Charcoal** | | **Back Charcoal** | | **Filter** | **Particulate** | **Gas phase** | **Particulate** | **Total** |
| | | Front | Back | Front | Back | Mass | Mass | Conc. | phase conc. | Conc. |
| | | (ug) | (ug) | (ug) | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) |
| 1 | Methanol | 8.148 | 1.647 | 11.178 | 1.966 | 0.312 | 3.861 | 0.536 | 0.109 | 0.645 |
| 2 | Ethanol | 1.746 | | 2.274 | | 0.375 | 0.939 | 0.096 | 0.027 | 0.122 |
| 3 | Isopropyl Alcohol | 1101.26 | 0.137 | 1253.35 | 0.136 | 0.2517 | 174.873 | 60.288 | 4.939 | 65.228 |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 5.76 | | 6.738 | | 0.1527 | 1.249 | 0.315 | 0.035 | 0.351 |
| 6 | Isobutyl Alcohol | 582.846 | 0.179 | 643.776 | 0.216 | 0.168 | 73.061 | 31.914 | 2.064 | 33.977 |
| 7 | n-Heptane | 14.964 | | 15.348 | | | 0.690 | 0.819 | 0.019 | 0.839 |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 2705.41 | 6.644 | 2814.46 | 5.445 | 0.306 | 163.631 | 148.453 | 4.622 | 153.075 |
| 11 | Isobutyl Acetate | 3572.51 | 2.99 | 3606.45 | 2.436 | 0.921 | 107.438 | 195.716 | 3.035 | 198.751 |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 72.522 | 0.263 | 75.114 | 0.196 | | 4.014 | 3.984 | 0.113 | 4.097 |
| 14 | Xylenes (m-,o-&p-) | 461.172 | 1.94 | 469.368 | 1.256 | | 16.985 | 25.350 | 0.480 | 25.830 |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | 3.03 | | 4.008 | | 0.1401 | 1.180 | 0.166 | 0.033 | 0.199 |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **GC Analytical Results (for Passive Sampler)** | | | | | | |
| Date: | 7/17/97 | Total time: | 17.3 | min | | |
| Sample I | 717-7-PS | Desb Vol: | 2 | mL for PS | | |
| Sampler: | passive sampler | Tool Type: | spray | | | |
| | | **Passive** | **Samplin** | **Sample** | **Total** | |
| | | Mass | Rate | volume | Conc. | |
| | | (ug) | (mL/min) | (mL) | (mg/m3) | |
| 1 | Methanol | 2.264 | | | | |
| 2 | Ethanol | 4.01 | | | | |
| 3 | Isopropyl Alcohol | 8.234 | | | | |
| 4 | Acetone | | | | | |
| 5 | MEK | 0.814 | | | | |
| 6 | Isobutyl Alcohol | 2.374 | | | | |
| 7 | n-Heptane | 0.648 | 13.9 | 240.47 | 2.695 | |
| 8 | Benzene | | 16 | 276.8 | | |
| 9 | MIBK | | | | | |
| 10 | Toluene | 48.358 | 14.5 | 250.85 | 192.777 | |
| 11 | Isobutyl Acetate | 48.72 | | | | |
| 12 | n-Butyl Acetate | | | | | |
| 13 | Ethyl Benzene | 0.888 | 12.9 | 223.17 | 3.979 | |
| 14 | Xylenes (m-,o-&p-) | 6.19 | 12.4 | 214.52 | 28.855 | |
| 15 | 2-Heptanone | | | | | |
| 16 | 2-Butoxyethanol | | | | | |

# Appendix II: Trial # 12

| GC Analytical Results (for Filtered-Charcoal Tube) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 11.1 | min | | | | |
| Sample ID: | 717-8-FC | | Avg flow: | | 1993.7 | mL/min | | | | |
| Sampler: | IOM followed by charcoal tube | | Total Vol: | | 22130.1 | mL | | | | |
| Tool Type: | SPRAY | | Desb Vol: | | 10 | mL for front CT(800/200),1 mL for back CT,3 mL for filter | | | | |
| | | | | | | | | | | |
| | | **Charcoal Tube** | | **Filter** | **Gas phas** | **Particula** | **Total** | | | |
| | | Front | Back | Mass | Conc. | phase con | Conc. | | | |
| | | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) | | | |
| 1 | Methanol | 32.39 | 6.642 | 0.501 | 1.764 | 0.023 | 1.786 | | | |
| 2 | Ethanol | 35.22 | 0.546 | 0.336 | 1.616 | 0.015 | 1.631 | | | |
| 3 | Isopropyl Alcohol | 25831.3 | 2.472 | 5.031 | 1167.36 | 0.227 | 1167.590 | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 231.25 | | 0.1464 | 10.450 | 0.007 | 10.456 | | | |
| 6 | Isobutyl Alcohol | 9020.14 | 0.335 | 5.985 | 407.612 | 0.270 | 407.882 | | | |
| 7 | n-Heptane | 57.3 | | | 2.589 | 0.000 | 2.589 | | | |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 39321.2 | 10.192 | 5.997 | 1777.28 | 0.271 | 1777.554 | | | |
| 11 | Isobutyl Acetate | 39940.7 | 5.365 | 22.149 | 1805.06 | 1.001 | 1806.061 | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 663.46 | 0.267 | 0.1506 | 29.992 | 0.007 | 29.999 | | | |
| 14 | Xylenes (m-,o-&p-) | 4001.43 | 1.391 | 0.987 | 180.877 | 0.045 | 180.922 | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | 153.08 | | 2.103 | 6.917 | 0.095 | 7.012 | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

| GC Analytical Results (for Charcoal Tube) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 11.1 | min | | | | |
| Sample ID: | 717-8-CT | | Avg flow: | | 203.3 | mL/min | | | | |
| Sampler: | charcoal tube | | Total Vol: | | 2256.63 | mL | | | | |
| Tool Type: | spray | | Desb Vol: | | 1 | mL for CT(100/50) | | | | |
| | | | | | | | | | | |
| | | **Charcoal Tube** | | **Total** | | | | | | |
| | | Front | Back | Conc. | | | | | | |
| | | (ug) | (ug) | (mg/m3) | | | | | | |
| 1 | Methanol | 5.203 | 4.917 | 4.485 | | | | | | |
| 2 | Ethanol | 2.636 | 0.44 | 1.363 | | | | | | |
| 3 | Isopropyl Alcohol | 2216.06 | 3.784 | 983.698 | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 15.912 | | 7.051 | | | | | | |
| 6 | Isobutyl Alcohol | 805.131 | 0.196 | 356.872 | | | | | | |
| 7 | n-Heptane | 5.031 | | 2.229 | | | | | | |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 3589.69 | 4.626 | 1592.78 | | | | | | |
| 11 | Isobutyl Acetate | 3739.66 | 2.265 | 1658.19 | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 62.173 | 0.053 | 27.575 | | | | | | |
| 14 | Xylenes (m-,o-&p-) | 379.131 | 0.1325 | 168.066 | | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | 12.839 | | 5.689 | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |

# Appendix II: Trial # 12

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **GC Analytical Results (for Vapor-Aerosol Sampler)** | | | | | | | | | | |
| Date: | 7/17/97 | | Total time: | | 11.1 | min | | | | |
| Sample ID: | 717-8-VA | | Flow rate | Qv= | 1012.7 | Qp= | 995.9 | Qo= | 1978.7 | mL/min |
| Sampler: | vapor-aerosol sampler | | Volume: | Vv= | 11241 | Vp= | 11054.49 | Vo= | 21963.57 | mL |
| Tool Type: | spray | | Desorb vol: 10 mL for front CT(800/200), 1 mL for back CT, 3 mL for filter | | | | | | | |
| | | **Front Charcoal** | | **Back Charcoal** | | **Filter** | **Particulate** | **Gas phase** | **Particulate** | **Total** |
| | | Front | Back | Front | Back | Mass | Mass | Conc. | phase conc. | Conc. |
| | | (ug) | (ug) | (ug) | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) |
| 1 | Methanol | 36.43 | 5.431 | 39.15 | 6.798 | 0.312 | 5.093 | 3.724 | 0.232 | 3.956 |
| 2 | Ethanol | 18.24 | | 19.46 | | 0.357 | 1.880 | 1.623 | 0.086 | 1.708 |
| 3 | Isopropyl Alcohol | 13248.4 | 0.41 | 13486.7 | 0.705 | 2.898 | 461.331 | 1178.614 | 21.004 | 1199.62 |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 83.24 | | 75.82 | | 0.1488 | -5.890 | 7.405 | -0.268 | 7.137 |
| 6 | Isobutyl Alcohol | 4690.08 | 0.276 | 4715.88 | 0.25 | 1.179 | 104.763 | 417.255 | 4.770 | 422.025 |
| 7 | n-Heptane | 29.7 | | 30.95 | | | 1.743 | 2.642 | 0.079 | 2.721 |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 19260.2 | 7.624 | 19996.5 | 9.738 | 3.921 | 1061.975 | 1714.070 | 48.352 | 1762.42 |
| 11 | Isobutyl Acetate | 22474.5 | 4.59 | 21389.1 | 5.957 | 10.155 | -701.025 | 1999.750 | -31.918 | 1967.83 |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 334.37 | 0.258 | 358.4 | | | 29.323 | 29.769 | 1.335 | 31.104 |
| 14 | Xylenes (m-,o-&p-) | 2044.69 | 1.839 | 2053.32 | 0.829 | 0.5205 | 42.091 | 182.060 | 1.916 | 183.976 |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | 53.08 | | 56.45 | | 1.725 | 5.976 | 4.722 | 0.272 | 4.994 |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |
| | | | | | | | | | | |
| **GC Analytical Results (for Passive Sampler)** | | | | | | | | | | |
| Date: | 7/17/97 | | Total time: | | 11.1 | min | | | | |
| Sample ID: | 717-8-PS | | Desb Vol: | | 2 | mL for PS | | | | |
| Sampler: | passive sampler | | Tool Type: | | spray | | | | | |
| | | **Passive** | **Samplin** | **Sample** | **Total** | | | | | |
| | | Mass | Rate | volume | Conc. | | | | | |
| | | (ug) | (mL/min) | (mL) | (mg/m3) | | | | | |
| 1 | Methanol | 3.122 | | | | | | | | |
| 2 | Ethanol | 2.308 | | | | | | | | |
| 3 | Isopropyl Alcohol | 76.396 | | | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 1.79 | | | | | | | | |
| 6 | Isobutyl Alcohol | 30.036 | | | | | | | | |
| 7 | n-Heptane | 1.182 | 13.9 | 154.29 | 7.661 | | | | | |
| 8 | Benzene | | 16 | 177.6 | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 365.786 | 14.5 | 160.95 | 2272.67 | | | | | |
| 11 | Isobutyl Acetate | 332.002 | | | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 6.356 | 12.9 | 143.19 | 44.389 | | | | | |
| 14 | Xylenes (m-,o-&p-) | 38.72 | 12.4 | 137.64 | 281.314 | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | 0.1062 | | | | | | | | |

# Appendix II: Trial # 13

| GC Analytical Results (for Filtered-Charcoal Tube) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 13 | min | | | | | |
| Sample ID: | 717-9-FC | | Avg flow: | | 1986 | mL/min | | | | | |
| Sampler: | IOM followed by charcoal tube | | Total Vol: | | 25818 | mL | | | | | |
| Tool Type: | SPRAY | | Desb Vol: | | 10 | mL for front CT(800/200),1 mL for back CT,3 mL for filter | | | | | |
| | | | | | | | | | | | |
| | | **Charcoal Tube** | | **Filter** | **Gas phas** | **Particula** | **Total** | | | | |
| | | Front | Back | Mass | Conc. | phase con | Conc. | | | | |
| | | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) | | | | |
| 1 | Methanol | 7.17 | 11.366 | 0.618 | 0.718 | 0.024 | 0.742 | | | | |
| 2 | Ethanol | 19.98 | 41.926 | 0.372 | 2.398 | 0.014 | 2.412 | | | | |
| 3 | Isopropyl Alcohol | 17637.2 | 33584.6 | 8.067 | 1983.96 | 0.312 | 1984.269 | | | | |
| 4 | Acetone | | | | | | | | | | |
| 5 | MEK | 227.47 | 380.625 | 0.465 | 23.553 | 0.018 | 23.571 | | | | |
| 6 | Isobutyl Alcohol | 15735.8 | 5428.73 | 12.861 | 819.759 | 0.498 | 820.257 | | | | |
| 7 | n-Heptane | 73.67 | 22.51 | | 3.725 | 0.000 | 3.725 | | | | |
| 8 | Benzene | | | | | | | | | | |
| 9 | MIBK | | | | | | | | | | |
| 10 | Toluene | 98232.2 | 2037.95 | 7.689 | 3883.73 | 0.298 | 3884.030 | | | | |
| 11 | Isobutyl Acetate | 93089.8 | 3100.03 | 34.803 | 3725.69 | 1.348 | 3727.035 | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | | |
| 13 | Ethyl Benzene | 1725.85 | 1.01 | 0.2727 | 66.886 | 0.011 | 66.896 | | | | |
| 14 | Xylenes (m-,o-&p-) | 10301.2 | 4.321 | 1.815 | 399.161 | 0.070 | 399.231 | | | | |
| 15 | 2-Heptanone | | | | | | | | | | |
| 16 | 2-Butoxyethanol | 398.1 | | 3.759 | 15.419 | 0.146 | 15.565 | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | | |

| GC Analytical Results (for Charcoal Tube) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date: | 7/17/97 | | Total time: | | 13 | min | | | | | |
| Sample ID: | 717-9-CT | | Avg flow: | | 203.9 | mL/min | | | | | |
| Sampler: | charcoal tube | | Total Vol: | | 2650.7 | mL | | | | | |
| Tool Type: | spray | | Desb Vol: | | 1 | mL for CT(100/50) | | | | | |
| | | | | | | | | | | | |
| | | **Charcoal Tube** | | **Total** | | | | | | | |
| | | Front | Back | Conc. | | | | | | | |
| | | (ug) | (ug) | (mg/m3) | | | | | | | |
| 1 | Methanol | 1.944 | 6.557 | 3.207 | | | | | | | |
| 2 | Ethanol | 1.625 | 6.018 | 2.883 | | | | | | | |
| 3 | Isopropyl Alcohol | 2425.46 | 2948.71 | 2027.45 | | | | | | | |
| 4 | Acetone | | | | | | | | | | |
| 5 | MEK | 31.116 | 17.253 | 18.248 | | | | | | | |
| 6 | Isobutyl Alcohol | 1883.72 | 175.545 | 776.874 | | | | | | | |
| 7 | n-Heptane | 8.638 | 0.587 | 3.480 | | | | | | | |
| 8 | Benzene | | | | | | | | | | |
| 9 | MIBK | | | | | | | | | | |
| 10 | Toluene | 9531.08 | 39.998 | 3610.77 | | | | | | | |
| 11 | Isobutyl Acetate | 9097.23 | 52.366 | 3451.77 | | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | | |
| 13 | Ethyl Benzene | 170.576 | | 64.351 | | | | | | | |
| 14 | Xylenes (m-,o-&p-) | 992.52 | 2.231 | 375.279 | | | | | | | |
| 15 | 2-Heptanone | | | | | | | | | | |
| 16 | 2-Butoxyethanol | 37.237 | | 14.048 | | | | | | | |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | | |

# Appendix II: Trial # 13

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **GC Analytical Results (for Vapor-Aerosol Sampler)** | | | | | | | | | | |
| Date: | 7/17/97 | | Total time: | | 13 | min | | | | |
| Sample ID: | 717-9-VA | | Flow rate | Qv= | 1056 | Qp= | 1034.4 | Qo= | 2046.5 | mL/min |
| Sampler: | vapor-aerosol sampler | | Volume: | Vv= | 13728 | Vp= | 13447.2 | Vo= | 26604.5 | mL |
| Tool Type: | spray | | Desorb vol: 10 mL for front CT(800/200), 1 mL for back CT, 3 mL for filter | | | | | | | |
| | | **Front Charcoal** | | **Back Charcoal** | | **Filter** | **Particulate** | **Gas phase** | **Particulate** | **Total** |
| | | Front | Back | Front | Back | Mass | Mass | Conc. | phase conc. | Conc. |
| | | (ug) | (ug) | (ug) | (ug) | (ug) | (ug) | (mg/m3) | (mg/m3) | (mg/m3) |
| 1 | Methanol | 27.47 | 6.557 | 26.34 | 5.56 | 0.381 | -1.050 | 2.479 | -0.039 | 2.439 |
| 2 | Ethanol | 34.55 | 1.548 | 37.68 | 1.2 | 0.348 | 3.868 | 2.630 | 0.145 | 2.775 |
| 3 | Isopropyl Alcohol | 27332.8 | 65.656 | 28398.4 | 4.849 | 2.736 | 1567.941 | 1995.806 | 58.935 | 2054.74 |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 256.71 | | 263.01 | | 0.1509 | 11.702 | 18.700 | 0.440 | 19.140 |
| 6 | Isobutyl Alcohol | 11171.3 | 0.86 | 11240.3 | 0.563 | 1.818 | 299.033 | 813.824 | 11.240 | 825.064 |
| 7 | n-Heptane | 50.44 | | 49.18 | 0.139 | | -0.089 | 3.674 | -0.003 | 3.671 |
| 8 | Benzene | | | | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 47378.7 | 14.243 | 47247.6 | 14.293 | 2.916 | 841.316 | 3452.280 | 31.623 | 3483.90 |
| 11 | Isobutyl Acetate | 50169.7 | 10.523 | 50197.8 | 9.264 | 9.888 | 1063.152 | 3655.317 | 39.961 | 3695.28 |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 810.88 | 0.419 | 839.8 | 0.389 | 0.1062 | 45.591 | 59.098 | 1.714 | 60.812 |
| 14 | Xylenes (m-,o-&p-) | 5141.21 | 3.036 | 5117.7 | 2.962 | 0.6447 | 82.284 | 374.727 | 3.093 | 377.819 |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | 160.1 | | 169.61 | | 1.125 | 13.910 | 11.662 | 0.523 | 12.185 |
| 17 | 2-Butoxyethyl Acetate | | | | | | | | | |
| | | | | | | | | | | |
| **GC Analytical Results (for Passive Sampler)** | | | | | | | | | | |
| Date: | 7/17/97 | | Total time: | | 13 | min | | | | |
| Sample ID: | 717-9-PS | | Desb Vol: | | 2 | mL for PS | | | | |
| Sampler: | passive sampler | | Tool Type: | | spray | | | | | |
| | | **Passive** | **Samplin** | **Sample** | **Total** | | | | | |
| | | Mass | Rate | volume | Conc. | | | | | |
| | | (ug) | (mL/min) | (mL) | (mg/m3) | | | | | |
| 1 | Methanol | 3.038 | | | | | | | | |
| 2 | Ethanol | 2.328 | | | | | | | | |
| 3 | Isopropyl Alcohol | 145.364 | | | | | | | | |
| 4 | Acetone | | | | | | | | | |
| 5 | MEK | 0.528 | | | | | | | | |
| 6 | Isobutyl Alcohol | 60.506 | | | | | | | | |
| 7 | n-Heptane | 0.67 | 13.9 | 180.7 | 3.708 | | | | | |
| 8 | Benzene | | 16 | 208 | | | | | | |
| 9 | MIBK | | | | | | | | | |
| 10 | Toluene | 723.206 | 14.5 | 188.5 | 3836.64 | | | | | |
| 11 | Isobutyl Acetate | 687.904 | | | | | | | | |
| 12 | n-Butyl Acetate | | | | | | | | | |
| 13 | Ethyl Benzene | 13.224 | 12.9 | 167.7 | 78.855 | | | | | |
| 14 | Xylenes (m-,o-&p-) | 80.618 | 12.4 | 161.2 | 500.112 | | | | | |
| 15 | 2-Heptanone | | | | | | | | | |
| 16 | 2-Butoxyethanol | 0.1712 | | | | | | | | |

# Appendix III

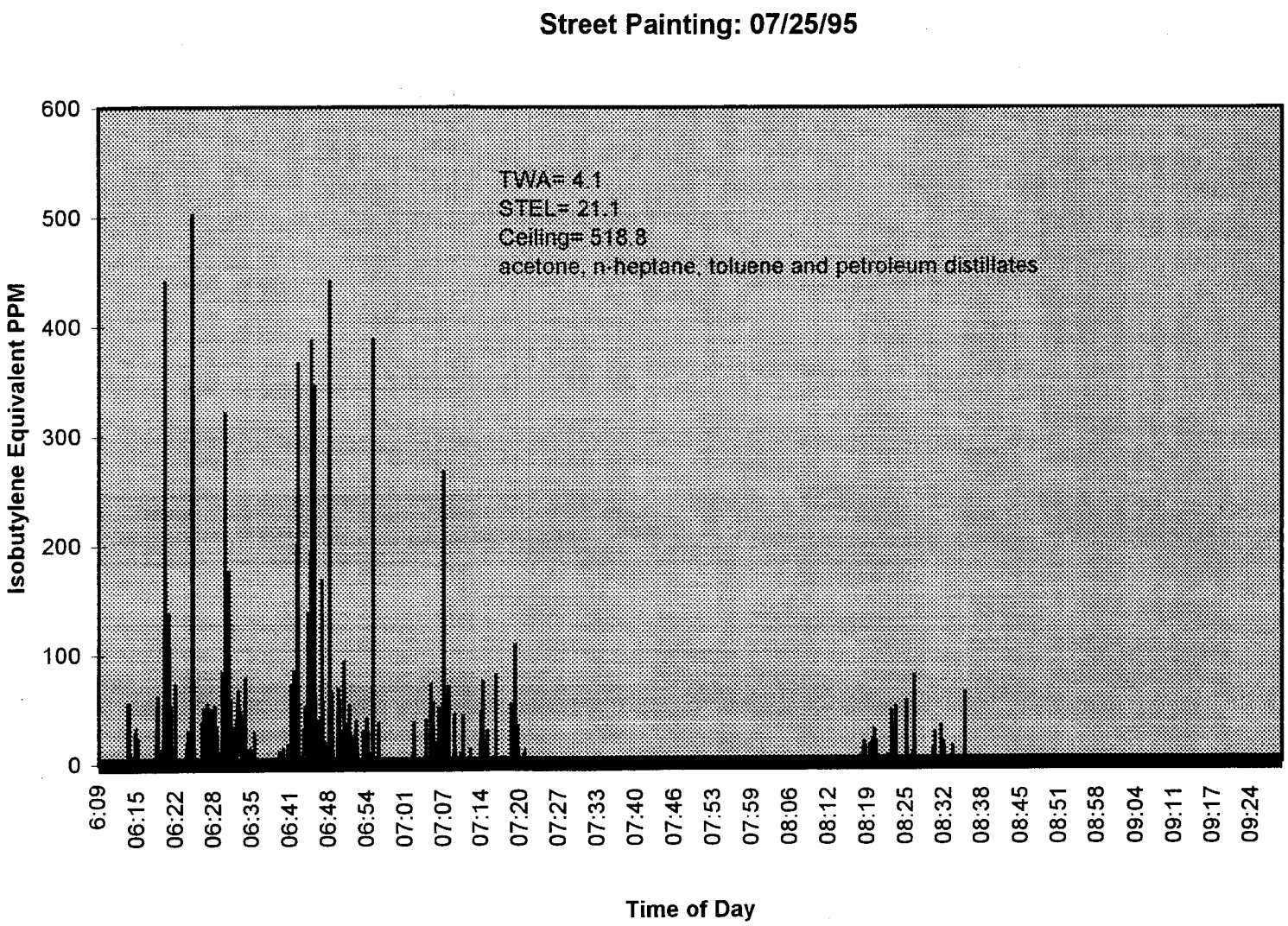

Street Painting: 07/25/95
TWA= 4.1
STEL= 21.1
Ceiling= 518.8
acetone, n-heptane, toluene and petroleum distillates
Isobutylene Equivalent PPM
600
500
400
300
200
100
0
6:09
06:15
06:22
06:28
06:35
06:41
06:48
06:54
07:01
07:07
07:14
07:20
07:27
07:33
07:40
07:46
07:53
07:59
08:06
08:12
08:19
08:25
08:32
08:38
08:45
08:51
08:58
09:04
09:11
09:17
09:24
Time of Day

Figure 1

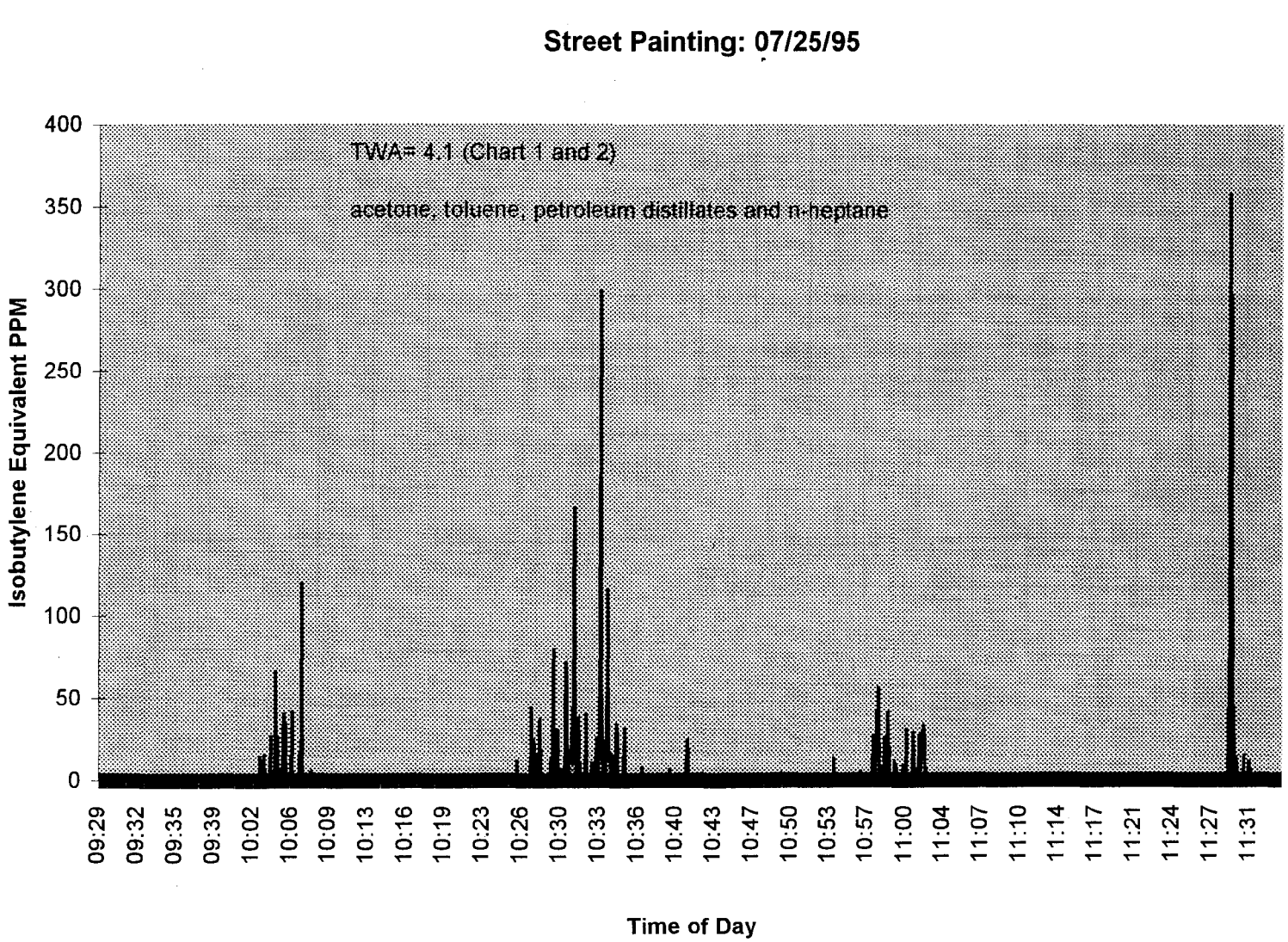

Street Painting: 07/25/95
TWA= 4.1 (Chart 1 and 2)
acetone, toluene, petroleum distillates and n-heptane
Isobutylene Equivalent PPM
400
350
300
250
200
150
100
50
0
09:29
09:32
09:35
09:39
10:02
10:06
10:09
10:13
10:16
10:19
10:23
10:26
10:30
10:33
10:36
10:40
10:43
10:47
10:50
10:53
10:57
11:00
11:04
11:07
11:10
11:14
11:17
11:21
11:24
11:27
11:31
Time of Day

Figure 2

## Brushing Doors: 08/01/95

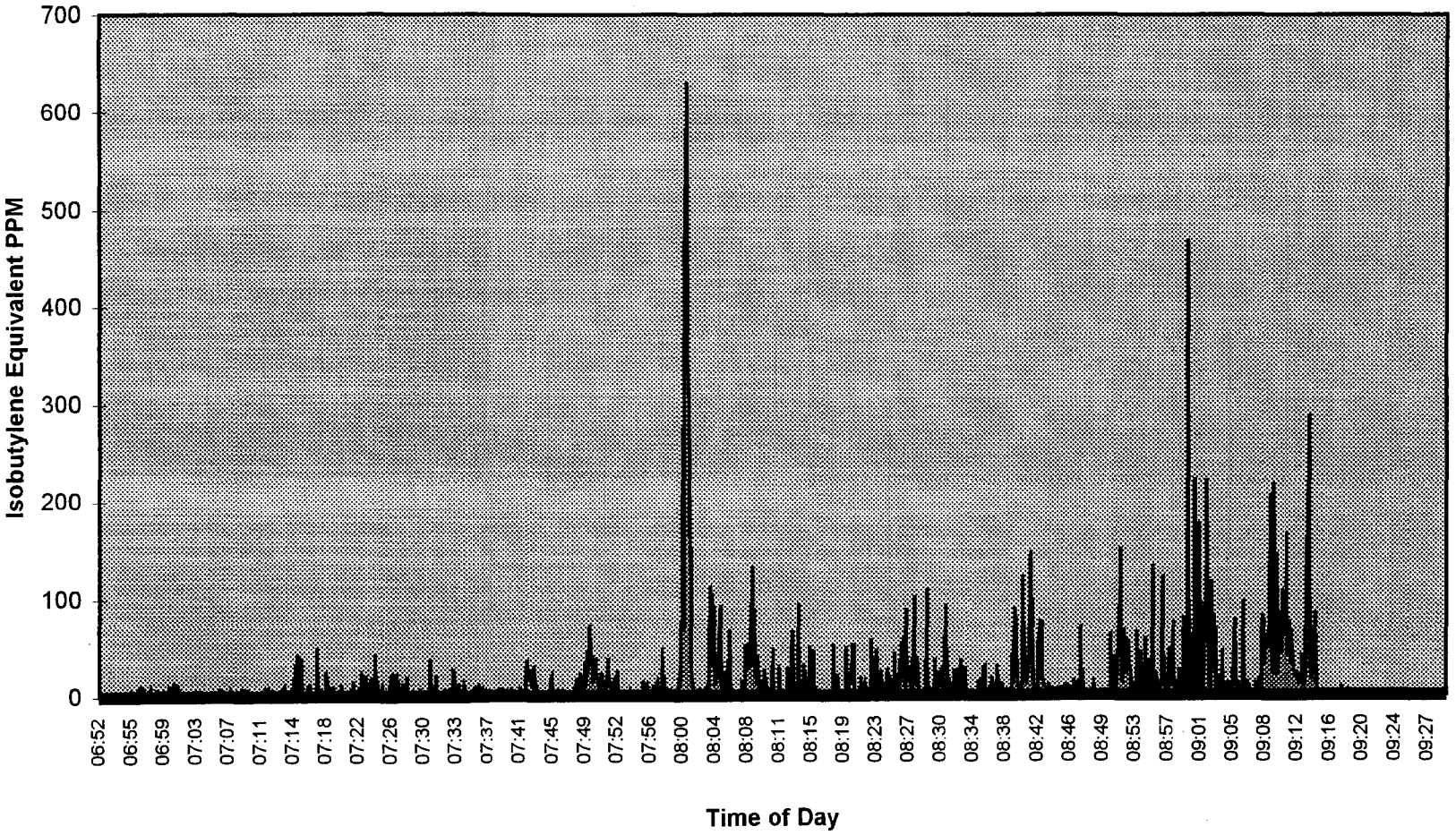



Figure 3

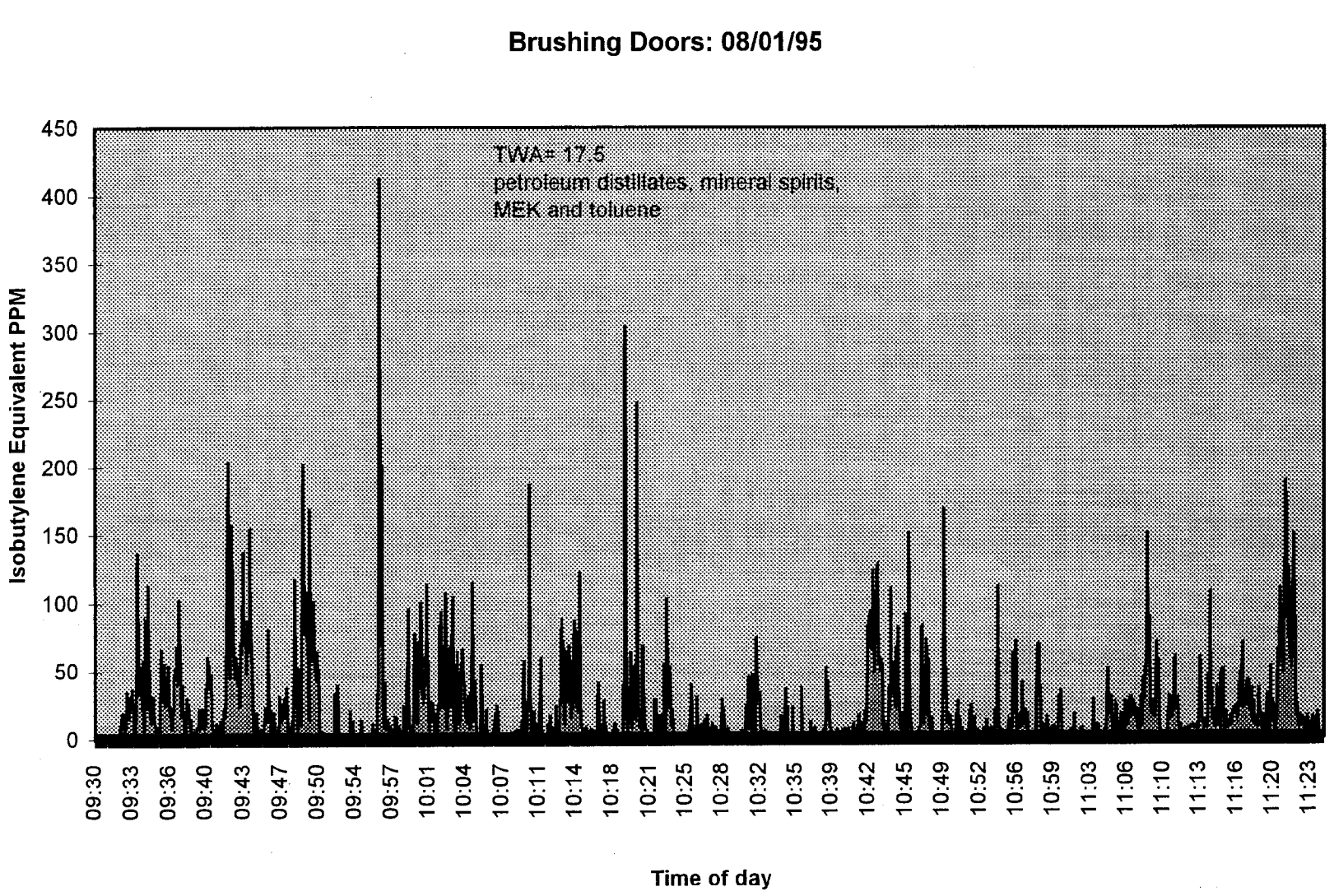

Brushing Doors: 08/01/95
TWA= 17.5
petroleum distillates, mineral spirits,
MEK and toluene
Isobutylene Equivalent PPM
450
400
350
300
250
200
150
100
50
0
09:30
09:33
09:36
09:40
09:43
09:47
09:50
09:54
09:57
10:01
10:04
10:07
10:11
10:14
10:18
10:21
10:25
10:28
10:32
10:35
10:39
10:42
10:45
10:49
10:52
10:56
10:59
11:03
11:06
11:10
11:13
11:16
11:20
11:23
Time of day

Figure 4

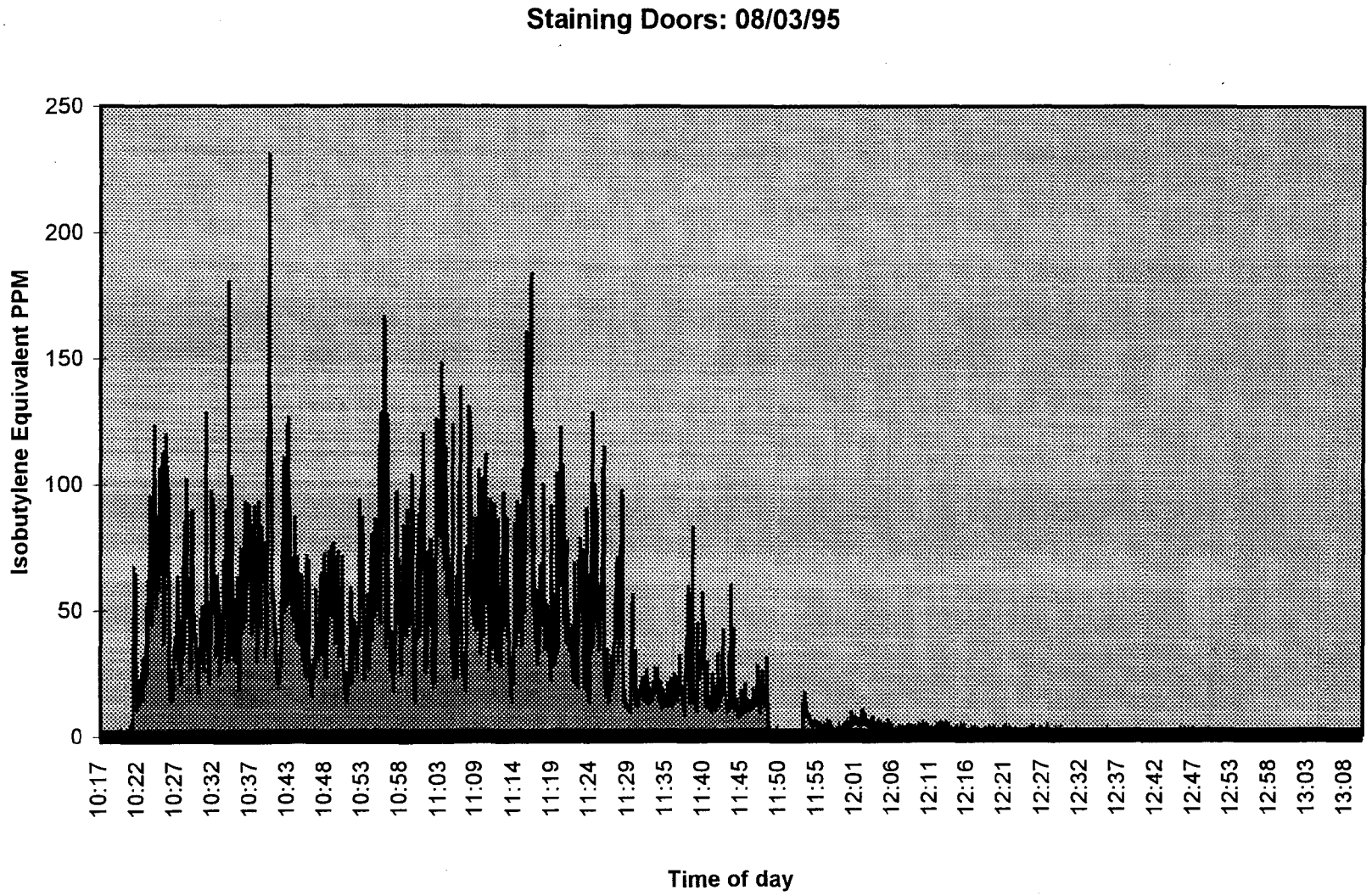

Staining Doors: 08/03/95
Isobutylene Equivalent PPM
250
200
150
100
50
0
10:17
10:22
10:27
10:32
10:37
10:43
10:48
10:53
10:58
11:03
11:09
11:14
11:19
11:24
11:29
11:35
11:40
11:45
11:50
11:55
12:01
12:06
12:11
12:16
12:21
12:27
12:32
12:37
12:42
12:47
12:53
12:58
13:03
13:08
Time of day

Figure 5

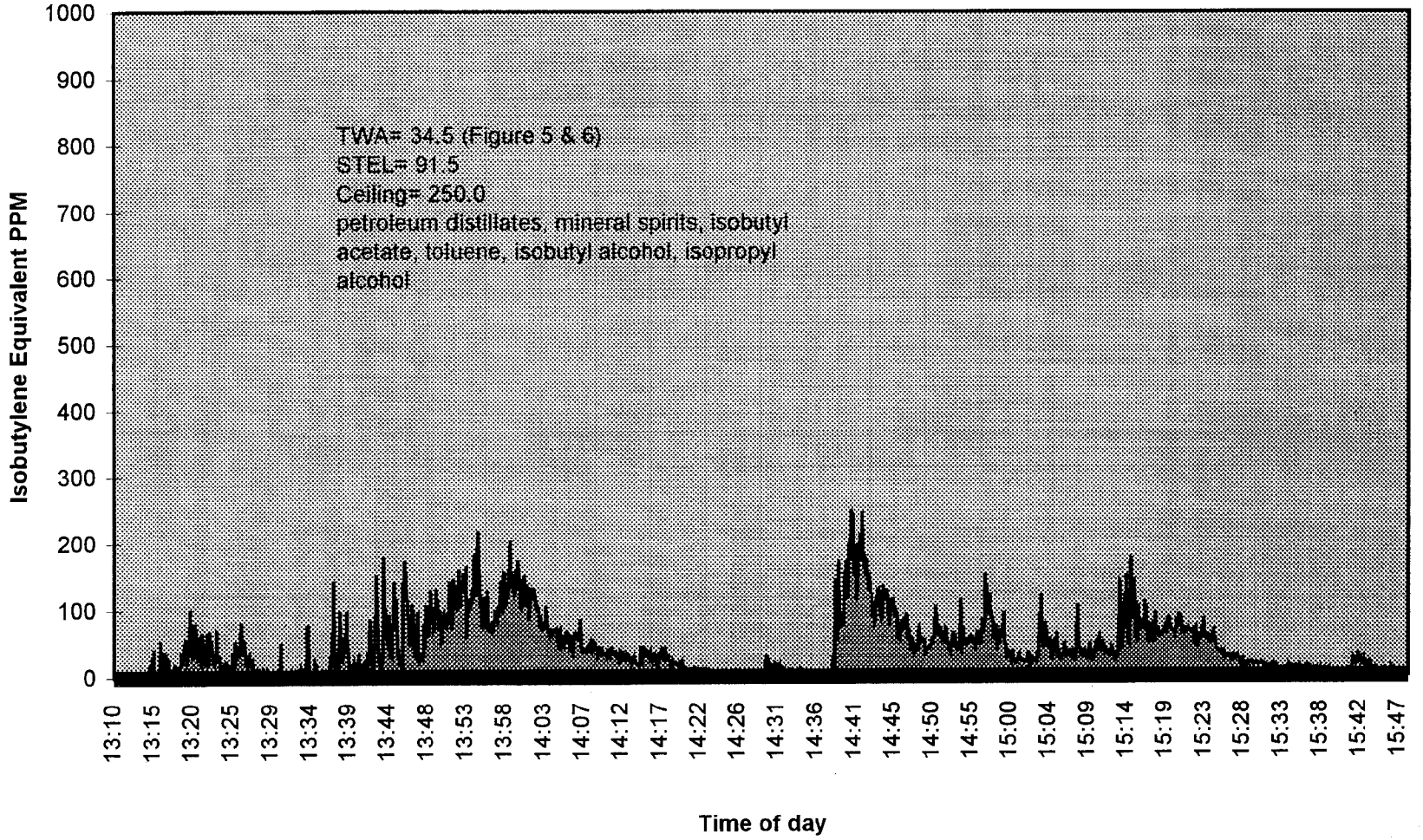

Staining While Lacquering: 08/03/95
Isobutylene Equivalent PPM
1000
900
800
700
600
500
400
300
200
100
0
TWA= 34.5 (Figure 5 & 6)
STEL= 91.5
Ceiling= 250.0
petroleum distillates, mineral spirits, isobutyl acetate, toluene, isobutyl alcohol, isopropyl alcohol
13:10
13:15
13:20
13:25
13:29
13:34
13:39
13:44
13:48
13:53
13:58
14:03
14:07
14:12
14:17
14:22
14:26
14:31
14:36
14:41
14:45
14:50
14:55
15:00
15:04
15:09
15:14
15:19
15:23
15:28
15:33
15:38
15:42
15:47
Time of day

Figure 6

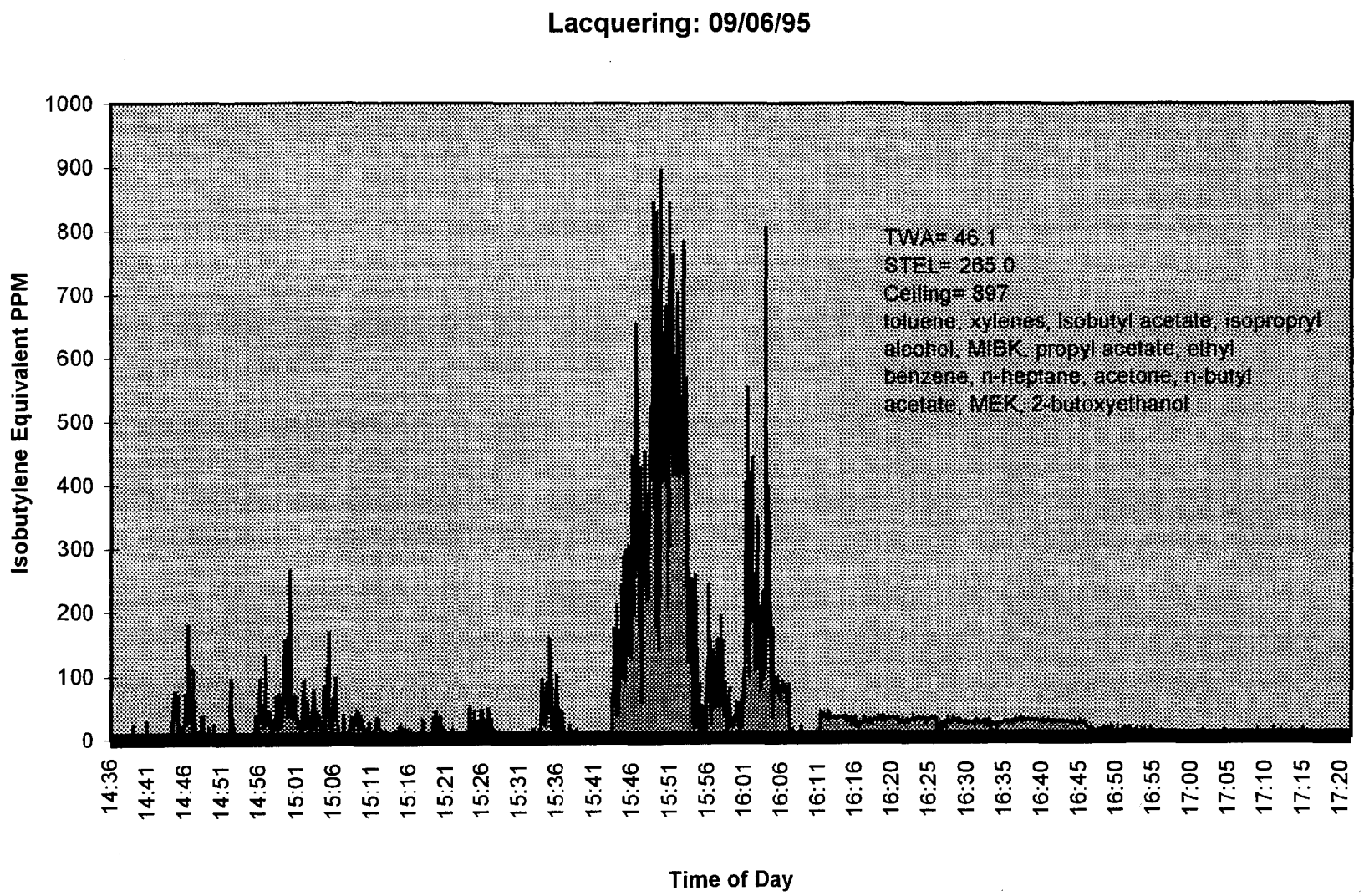

Lacquering: 09/06/95
Isobutylene Equivalent PPM
1000
900
800
700
600
500
400
300
200
100
0
14:36
14:41
14:46
14:51
14:56
15:01
15:06
15:11
15:16
15:21
15:26
15:31
15:36
15:41
15:46
15:51
15:56
16:01
16:06
16:11
16:16
16:20
16:25
16:30
16:35
16:40
16:45
16:50
16:55
17:00
17:05
17:10
17:15
17:20
Time of Day
TWA= 46.1
STEL= 265.0
Ceiling= 897
toluene, xylenes, isobutyl acetate, isopropyl alcohol, MIBK, propyl acetate, ethyl benzene, n-heptane, acetone, n-butyl acetate, MEK, 2-butoxyethanol

Figure 7

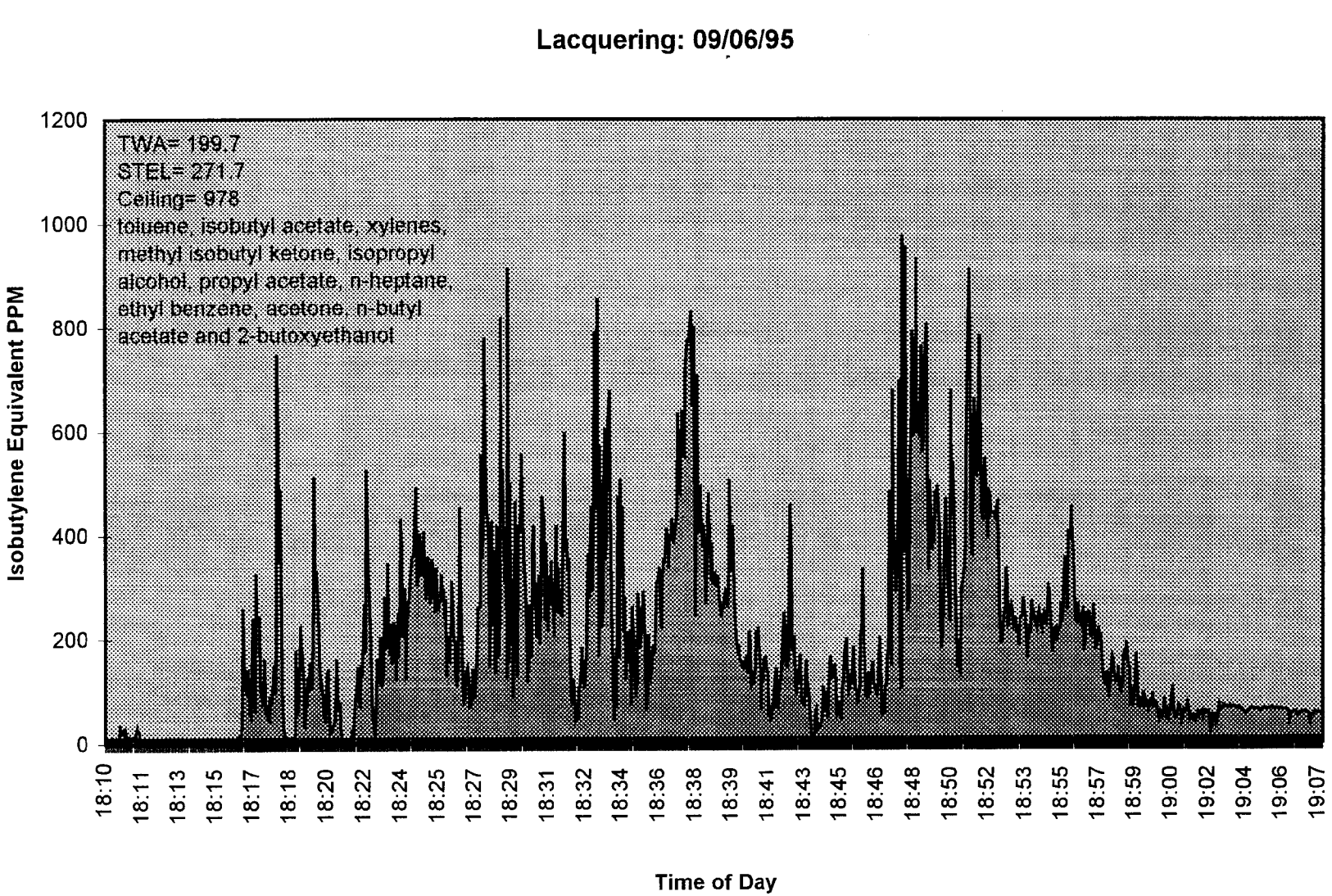

Lacquering: 09/06/95
TWA= 199.7
STEL= 271.7
Ceiling= 978
toluene, isobutyl acetate, xylenes, methyl isobutyl ketone, isopropyl alcohol, propyl acetate, n-heptane, ethyl benzene, acetone, n-butyl acetate and 2-butoxyethanol
Isobutylene Equivalent PPM
1200
1000
800
600
400
200
0
18:10
18:11
18:13
18:15
18:17
18:18
18:20
18:22
18:24
18:25
18:27
18:29
18:31
18:32
18:34
18:36
18:38
18:39
18:41
18:43
18:45
18:46
18:48
18:50
18:52
18:53
18:55
18:57
18:59
19:00
19:02
19:04
19:06
19:07
Time of Day

Figure 8

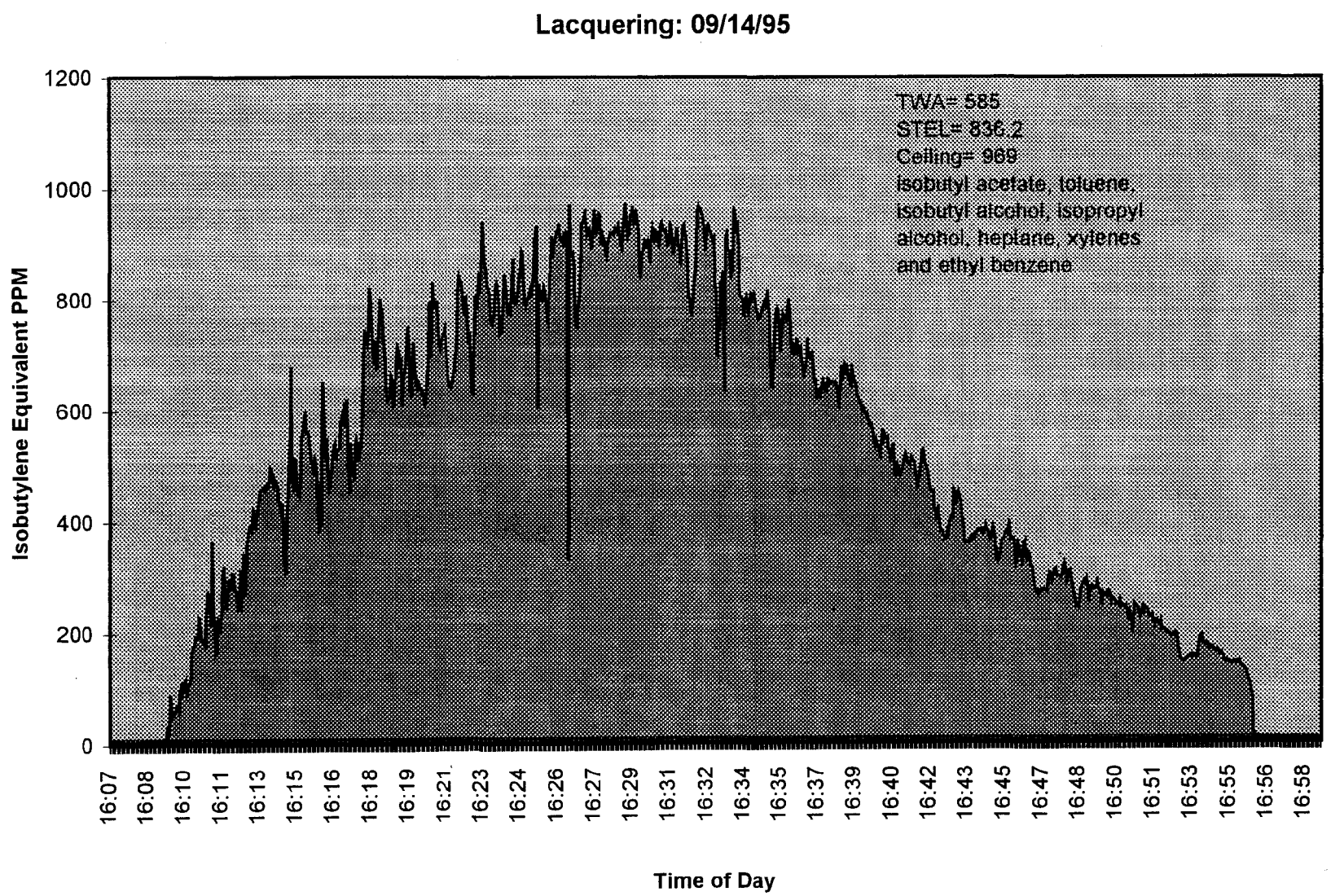

Lacquering: 09/14/95
TWA= 585
STEL= 836.2
Ceiling= 969
Isobutyl acetate, toluene, isobutyl alcohol, isopropyl alcohol, heptane, xylenes and ethyl benzene
Isobutylene Equivalent PPM
0
200
400
600
800
1000
1200
16:07
16:08
16:10
16:11
16:13
16:15
16:16
16:18
16:19
16:21
16:23
16:24
16:26
16:27
16:29
16:31
16:32
16:34
16:35
16:37
16:39
16:40
16:42
16:43
16:45
16:47
16:48
16:50
16:51
16:53
16:55
16:56
16:58
Time of Day

Figure 9

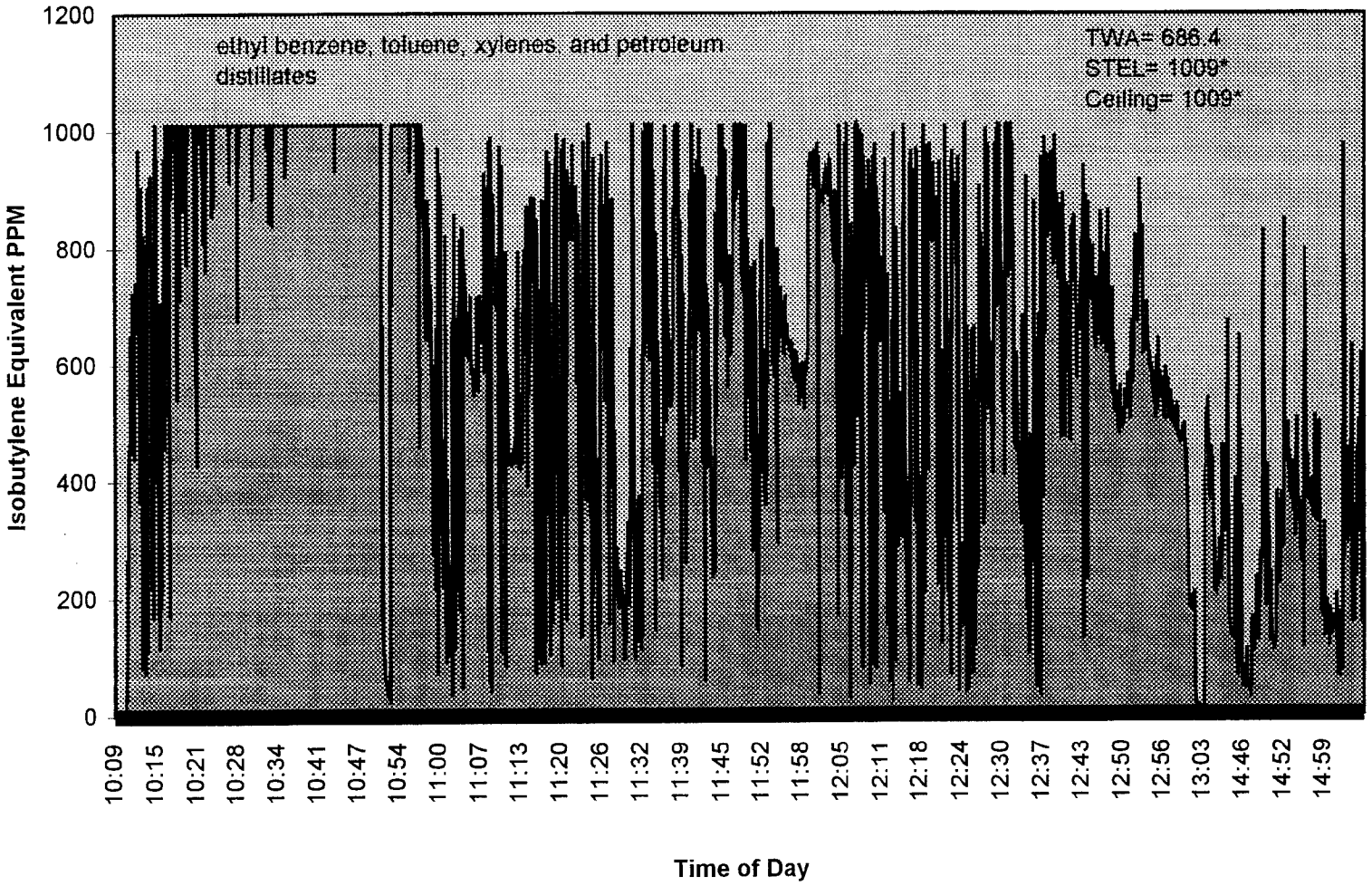

Spraying Paint on Doors: 02/29/96
ethyl benzene, toluene, xylenes, and petroleum distillates
TWA= 686.4
STEL= 1009*
Ceiling= 1009*
Isobutylene Equivalent PPM
1200
1000
800
600
400
200
0
10:09
10:15
10:21
10:28
10:34
10:41
10:47
10:54
11:00
11:07
11:13
11:20
11:26
11:32
11:39
11:45
11:52
11:58
12:05
12:11
12:18
12:24
12:30
12:37
12:43
12:50
12:56
13:03
14:46
14:52
14:59
Time of Day

Figure 10

## Staining while Lacquering: 03/07/96

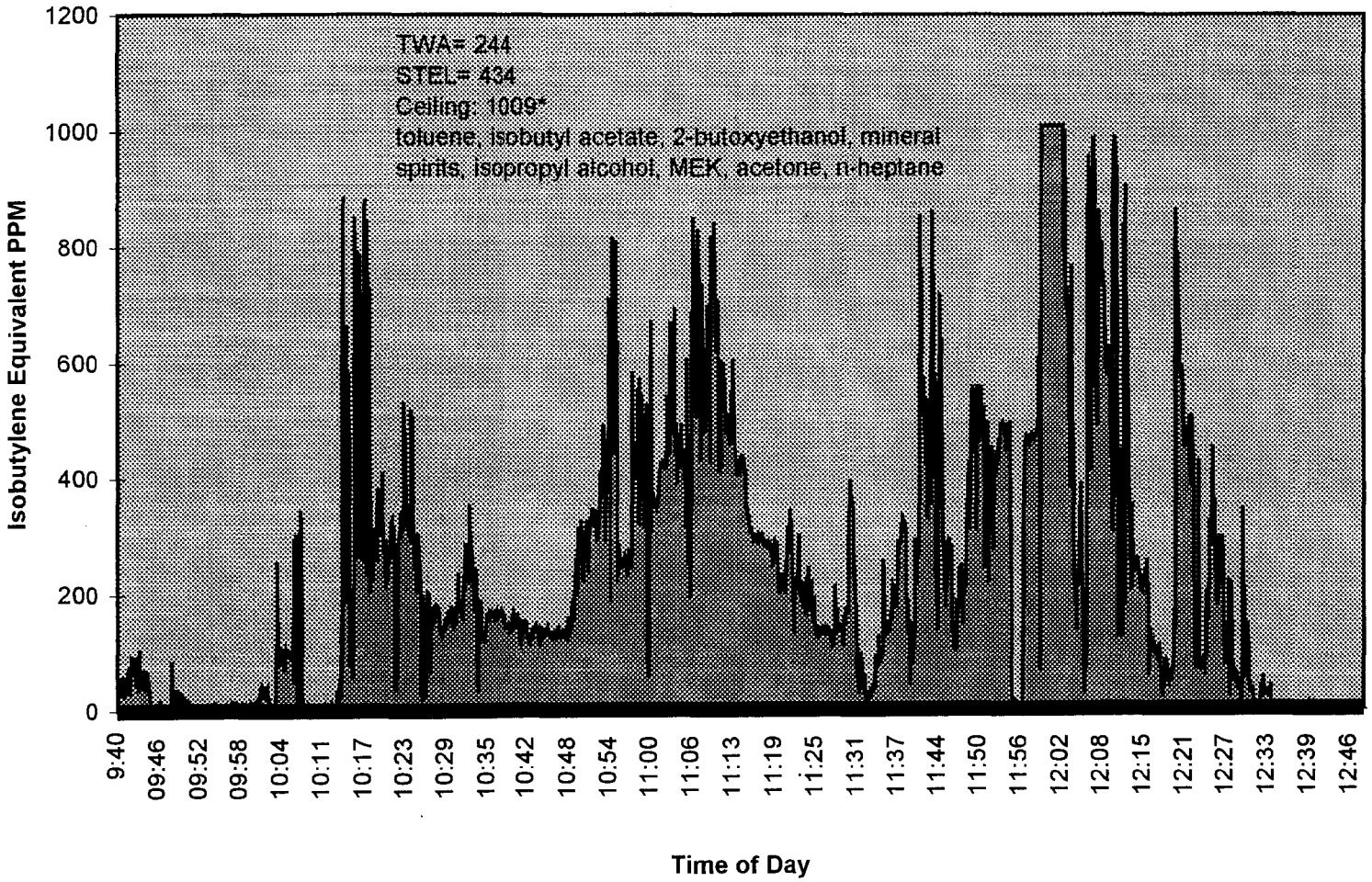



Figure 11

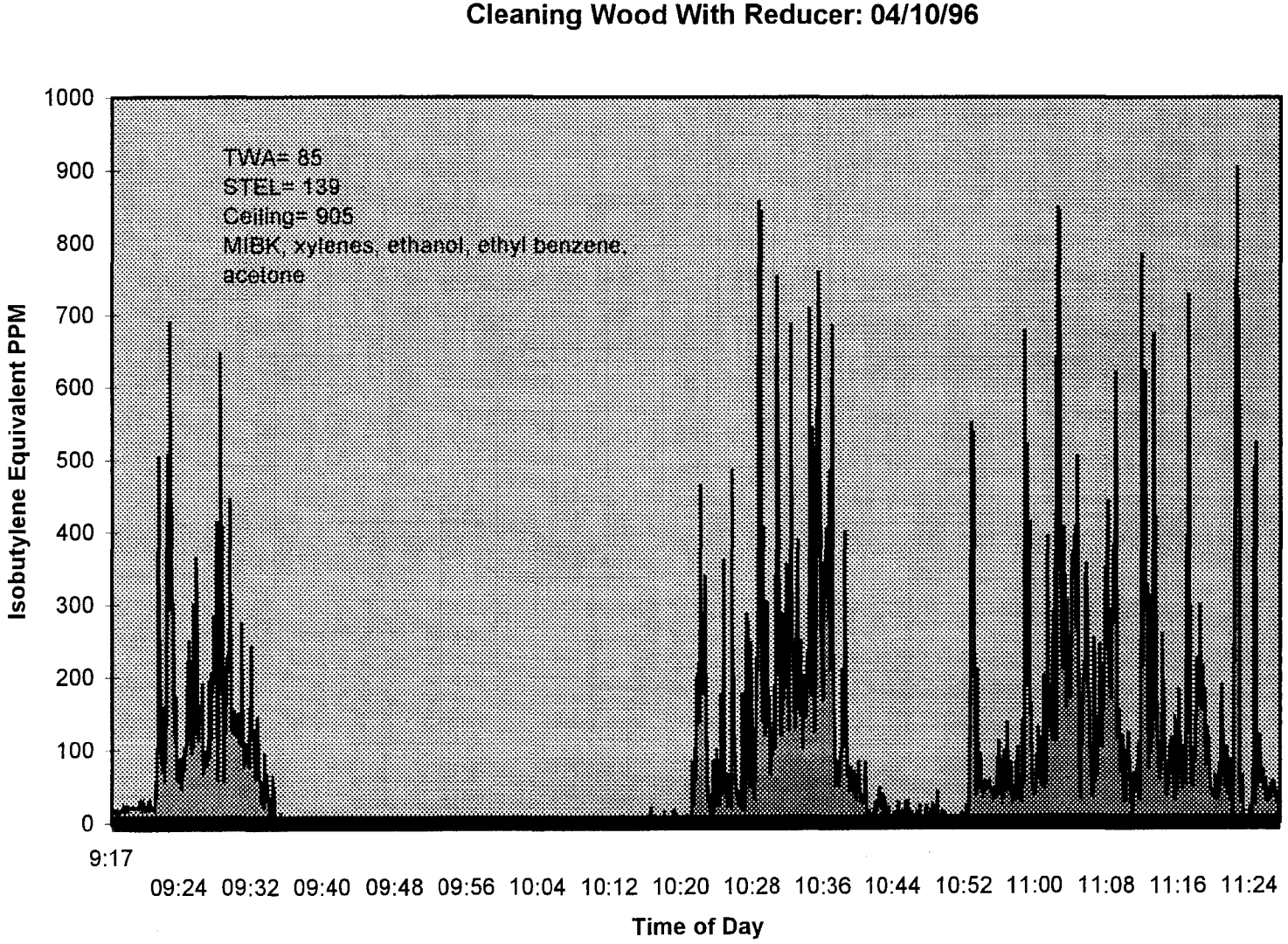

Cleaning Wood With Reducer: 04/10/96
TWA= 85
STEL= 139
Ceiling= 905
MIBK, xylenes, ethanol, ethyl benzene, acetone
Isobutylene Equivalent PPM
1000
900
800
700
600
500
400
300
200
100
0
9:17
09:24 09:32 09:40 09:48 09:56 10:04 10:12 10:20 10:28 10:36 10:44 10:52 11:00 11:08 11:16 11:24
Time of Day

Figure 12

## Wiping Stain and Reducer: 04/16/96

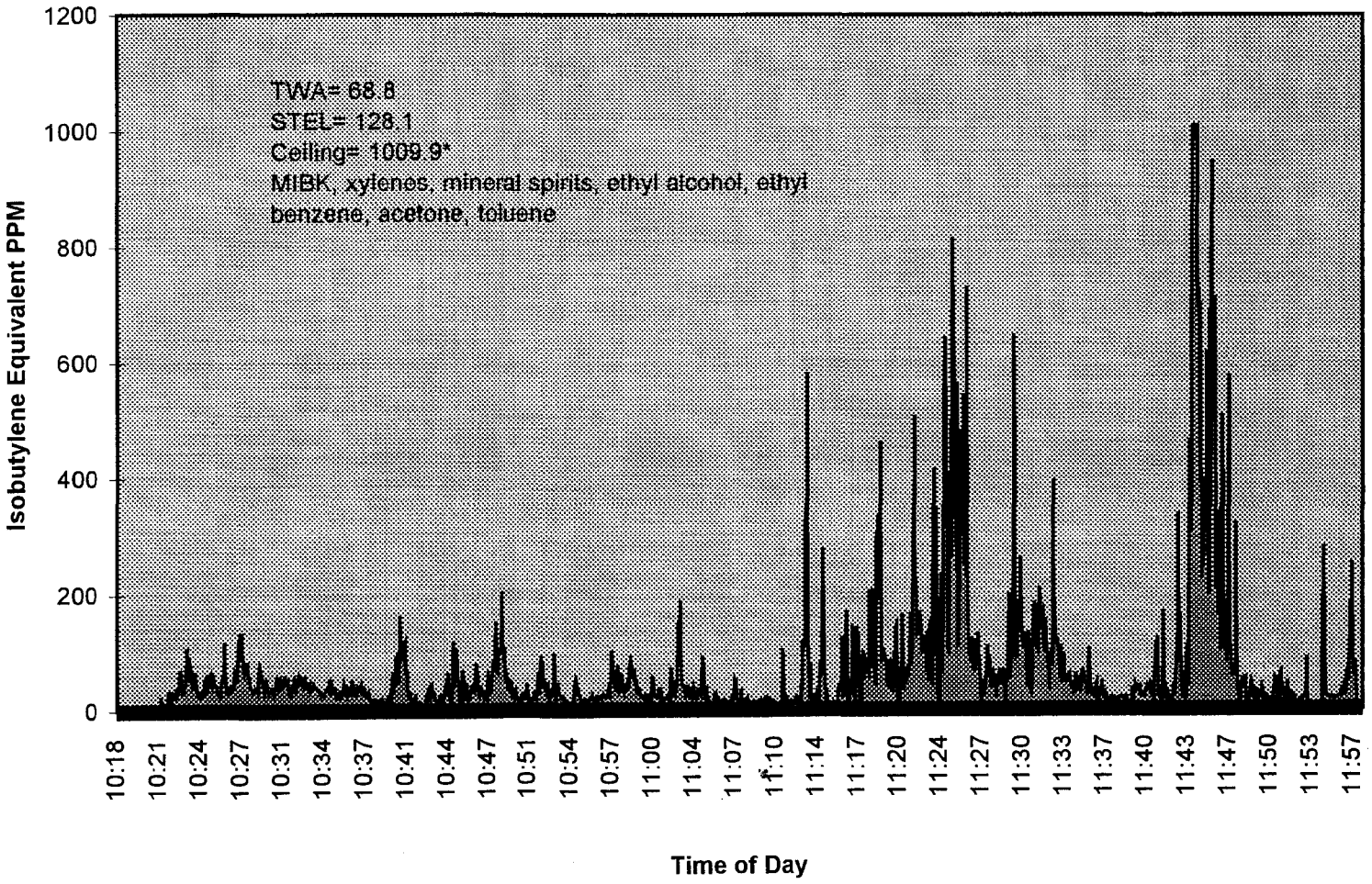



Figure 13

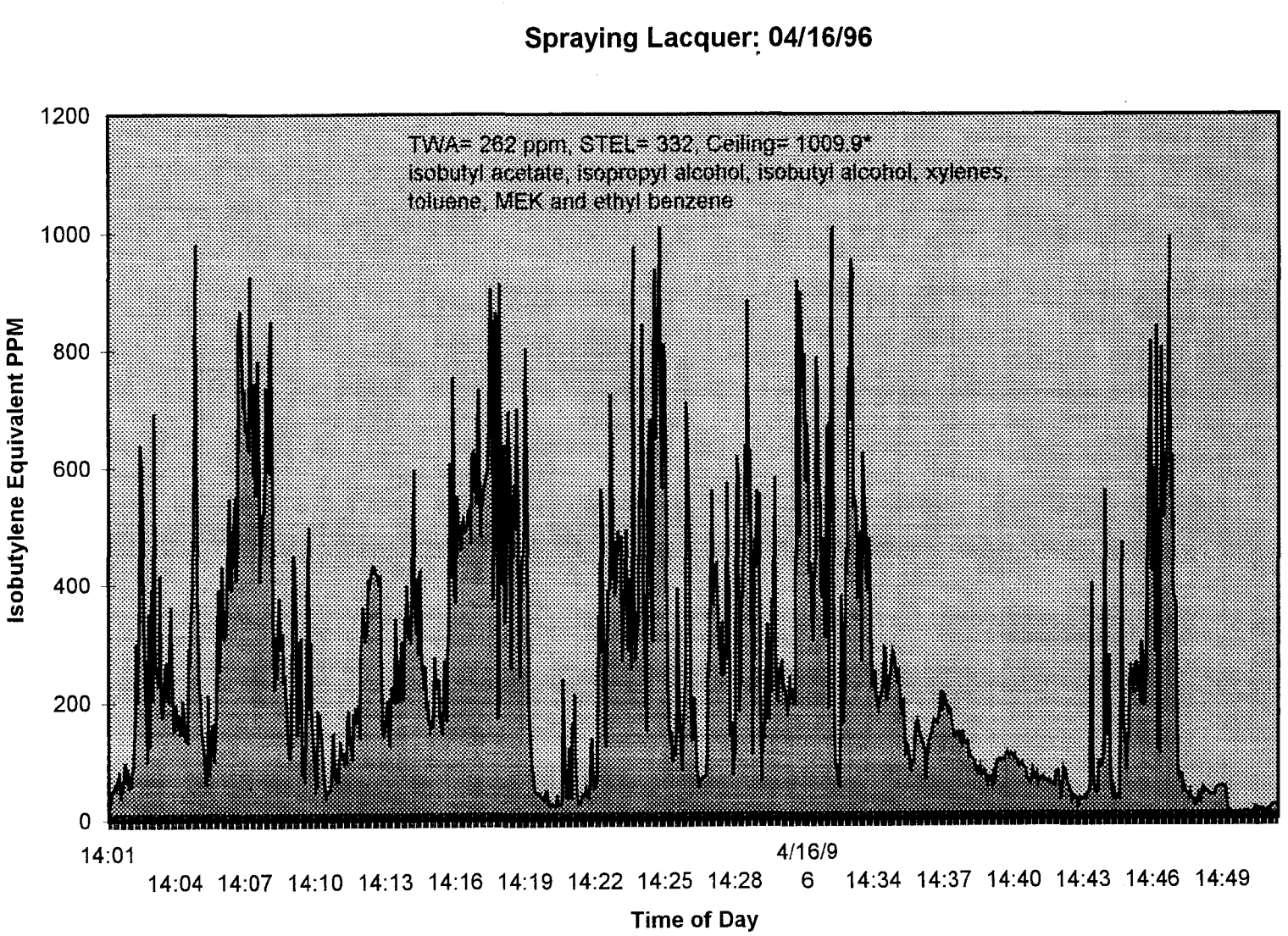

Spraying Lacquer: 04/16/96
TWA= 262 ppm, STEL= 332, Ceiling= 1009.9*
isobutyl acetate, isopropyl alcohol, isobutyl alcohol, xylenes,
toluene, MEK and ethyl benzene
Isobutylene Equivalent PPM
1200
1000
800
600
400
200
0
14:01
4/16/9
6
14:04 14:07 14:10 14:13 14:16 14:19 14:22 14:25 14:28 14:34 14:37 14:40 14:43 14:46 14:49
Time of Day

Figure 14

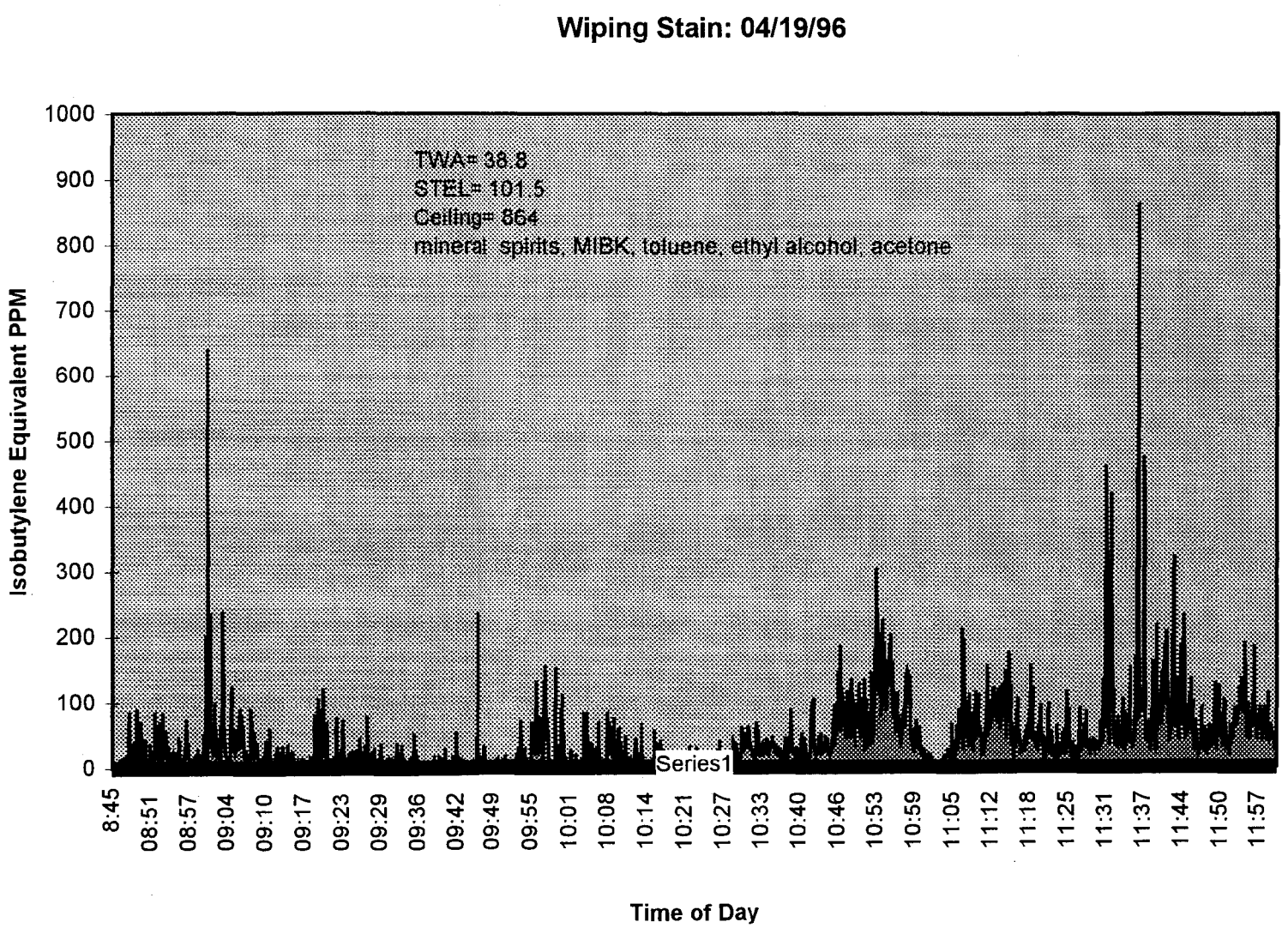

Wiping Stain: 04/19/96
TWA= 38.8
STEL= 101.5
Ceiling= 864
mineral spirits, MIBK, toluene, ethyl alcohol, acetone
Isobutylene Equivalent PPM
1000
900
800
700
600
500
400
300
200
100
0
Series1
8:45
08:51
08:57
09:04
09:10
09:17
09:23
09:29
09:36
09:42
09:49
09:55
10:01
10:08
10:14
10:21
10:27
10:33
10:40
10:46
10:53
10:59
11:05
11:12
11:18
11:25
11:31
11:37
11:44
11:50
11:57
Time of Day

Figure 15

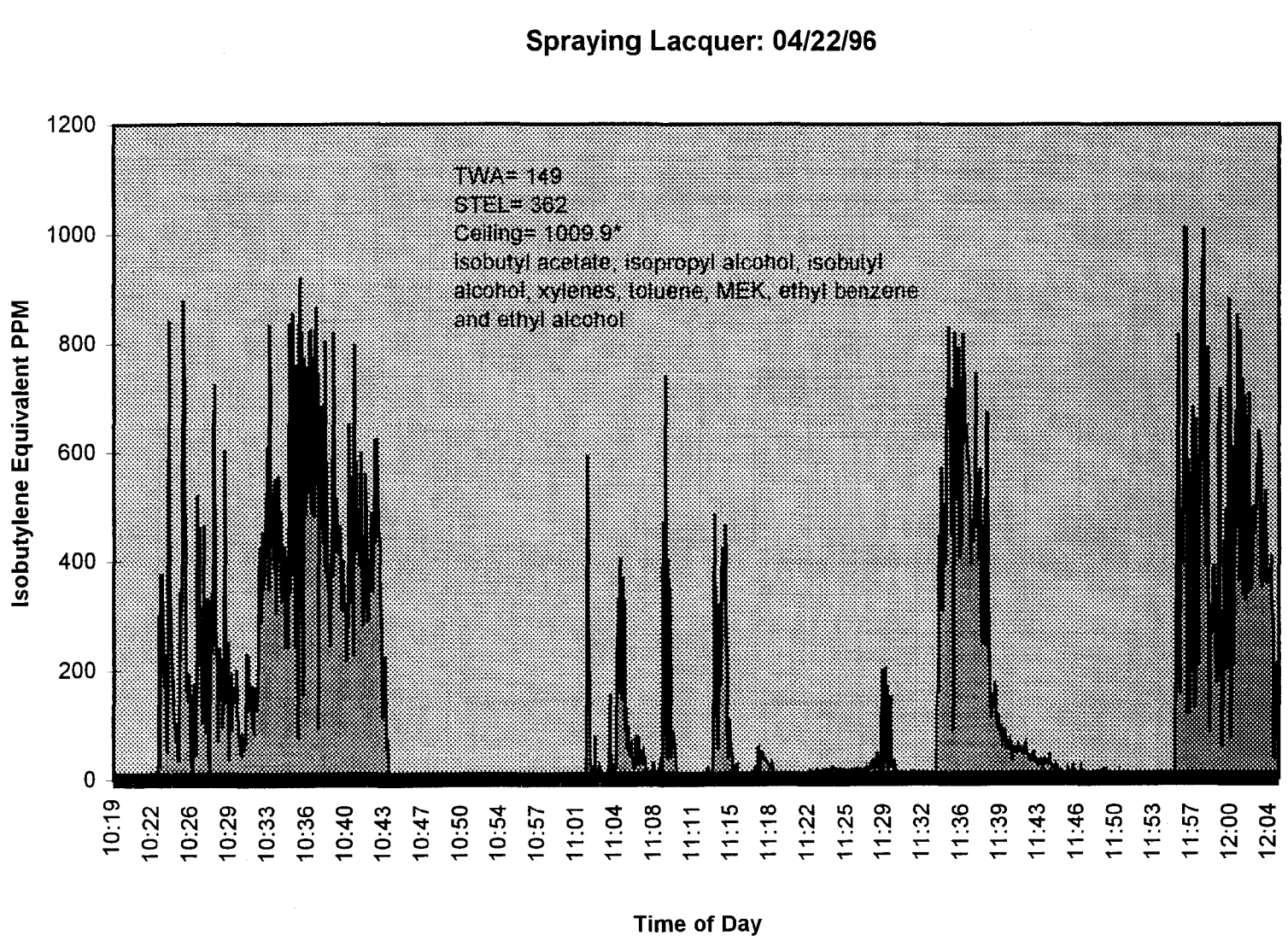

Spraying Lacquer: 04/22/96
TWA= 149
STEL= 362
Ceiling= 1009.9*
Isobutyl acetate, isopropyl alcohol, isobutyl alcohol, xylenes, toluene, MEK, ethyl benzene and ethyl alcohol
Isobutylene Equivalent PPM
1200
1000
800
600
400
200
0
10:19
10:22
10:26
10:29
10:33
10:36
10:40
10:43
10:47
10:50
10:54
10:57
11:01
11:04
11:08
11:11
11:15
11:18
11:22
11:25
11:29
11:32
11:36
11:39
11:43
11:46
11:50
11:53
11:57
12:00
12:04
Time of Day

Figure 16

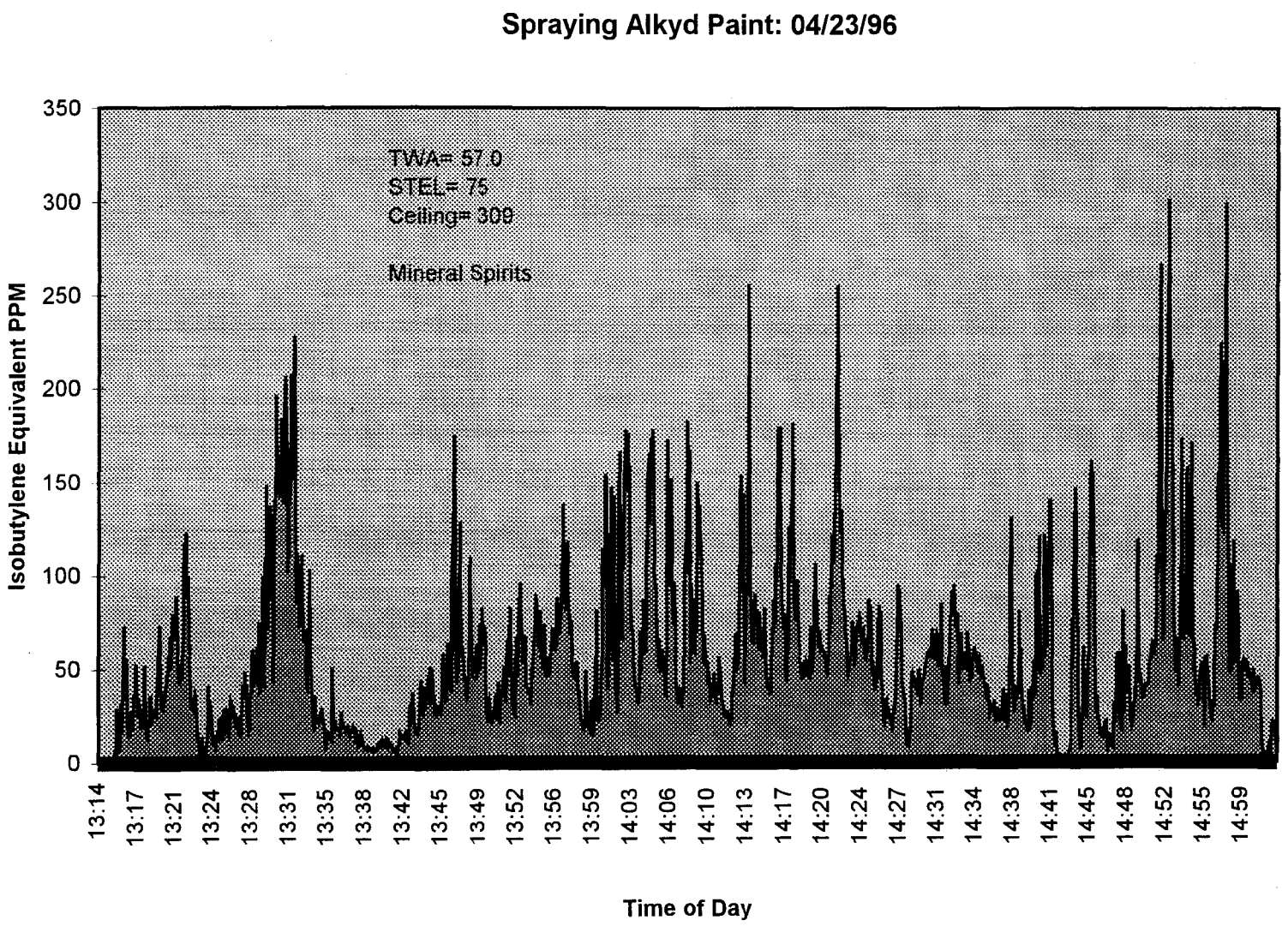

Spraying Alkyd Paint: 04/23/96
TWA= 57.0
STEL= 75
Ceiling= 309
Mineral Spirits
Isobutylene Equivalent PPM
350
300
250
200
150
100
50
0
13:14
13:17
13:21
13:24
13:28
13:31
13:35
13:38
13:42
13:45
13:49
13:52
13:56
13:59
14:03
14:06
14:10
14:13
14:17
14:20
14:24
14:27
14:31
14:34
14:38
14:41
14:45
14:48
14:52
14:55
14:59
Time of Day

Figure 17

## Spraying Alkyd Paint: 04/24/96

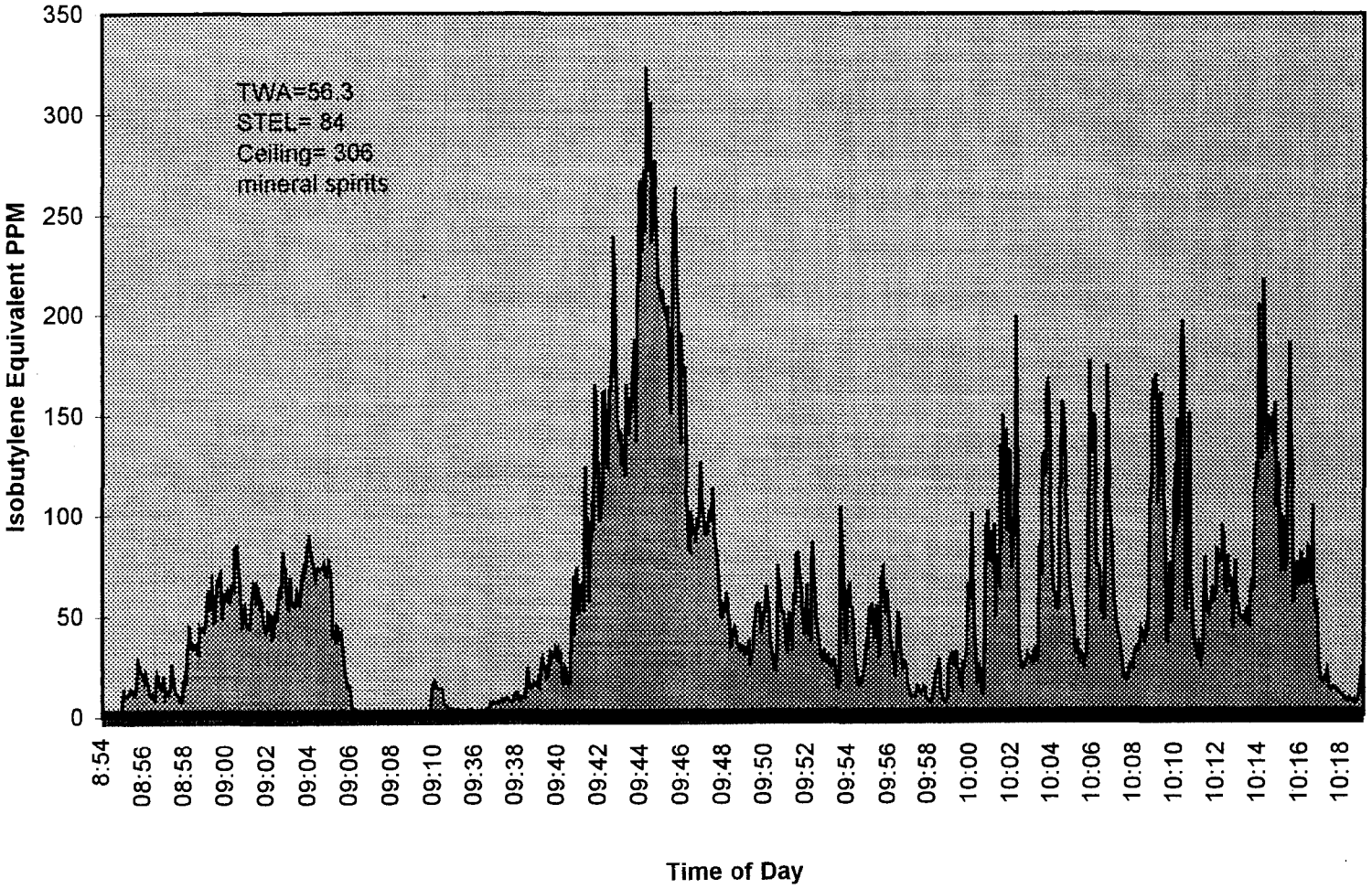



Figure 18

## Brushing Paint Outdoors: 05/29/96

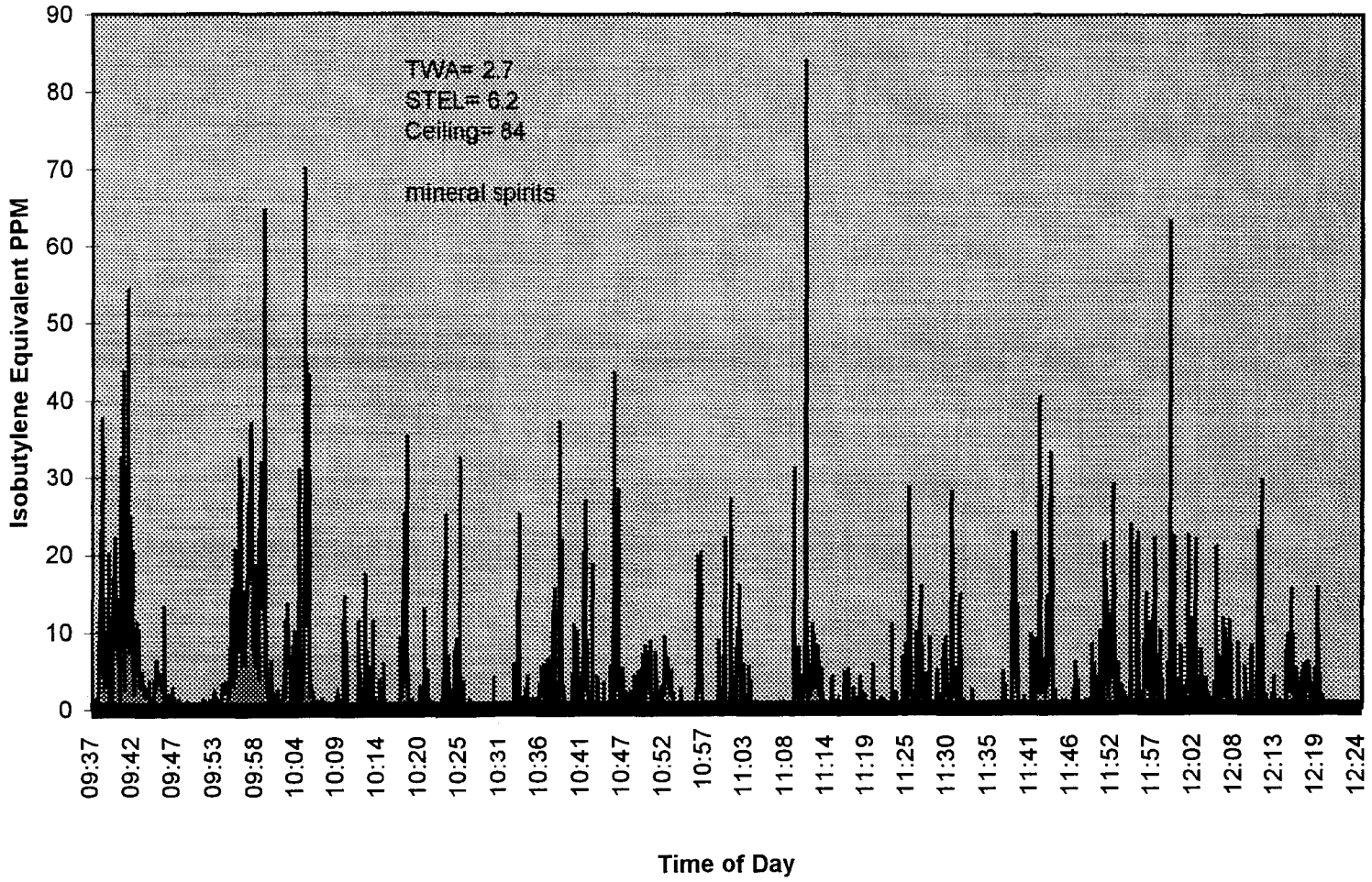



Figure 19

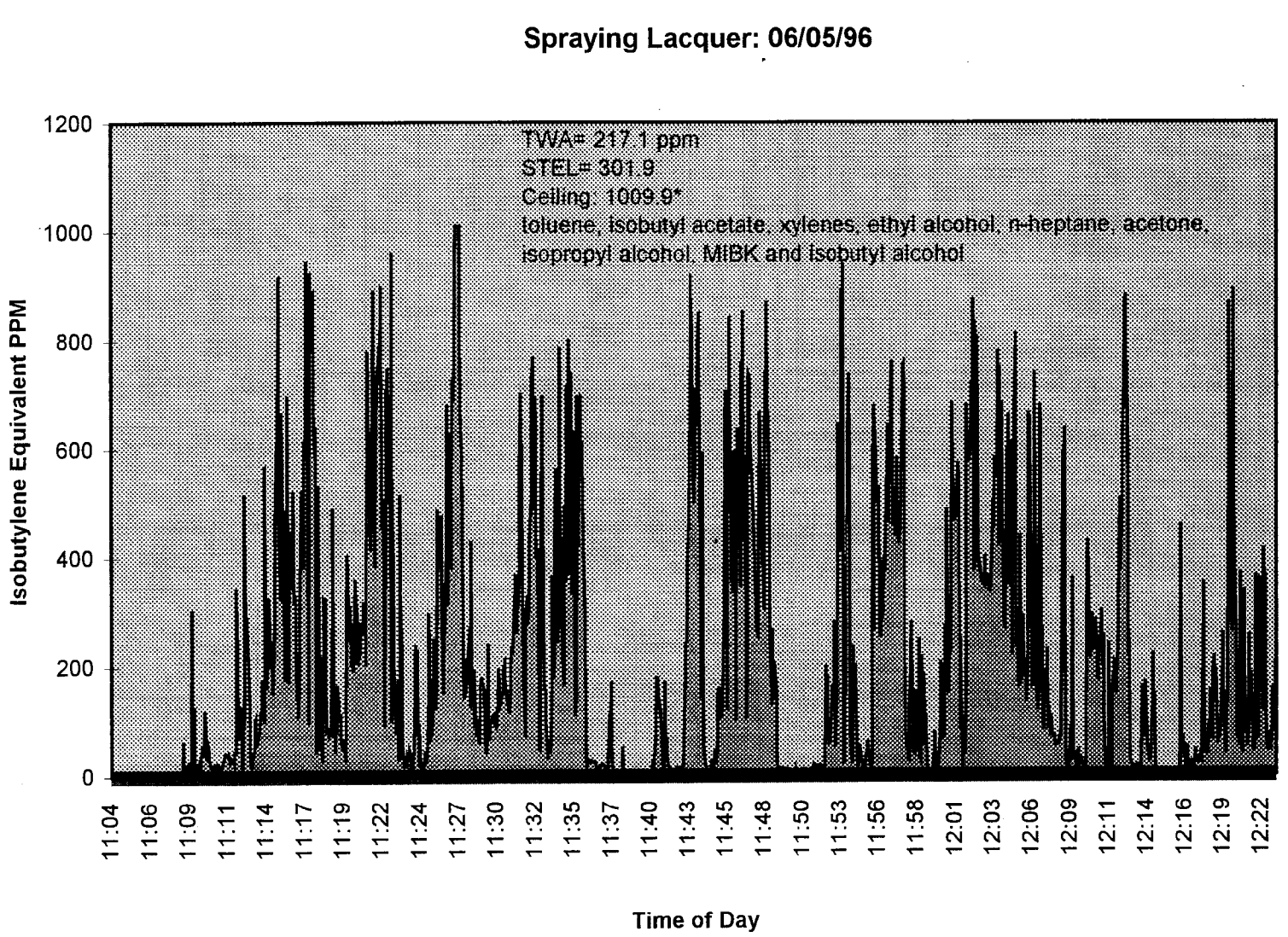

Spraying Lacquer: 06/05/96
TWA= 217.1 ppm
STEL= 301.9
Ceiling: 1009.9*
toluene, isobutyl acetate, xylenes, ethyl alcohol, n-heptane, acetone, isopropyl alcohol, MIBK and isobutyl alcohol
Isobutylene Equivalent PPM
1200
1000
800
600
400
200
0
11:04
11:06
11:09
11:11
11:14
11:17
11:19
11:22
11:24
11:27
11:30
11:32
11:35
11:37
11:40
11:43
11:45
11:48
11:50
11:53
11:56
11:58
12:01
12:03
12:06
12:09
12:11
12:14
12:16
12:19
12:22
Time of Day

Figure 20

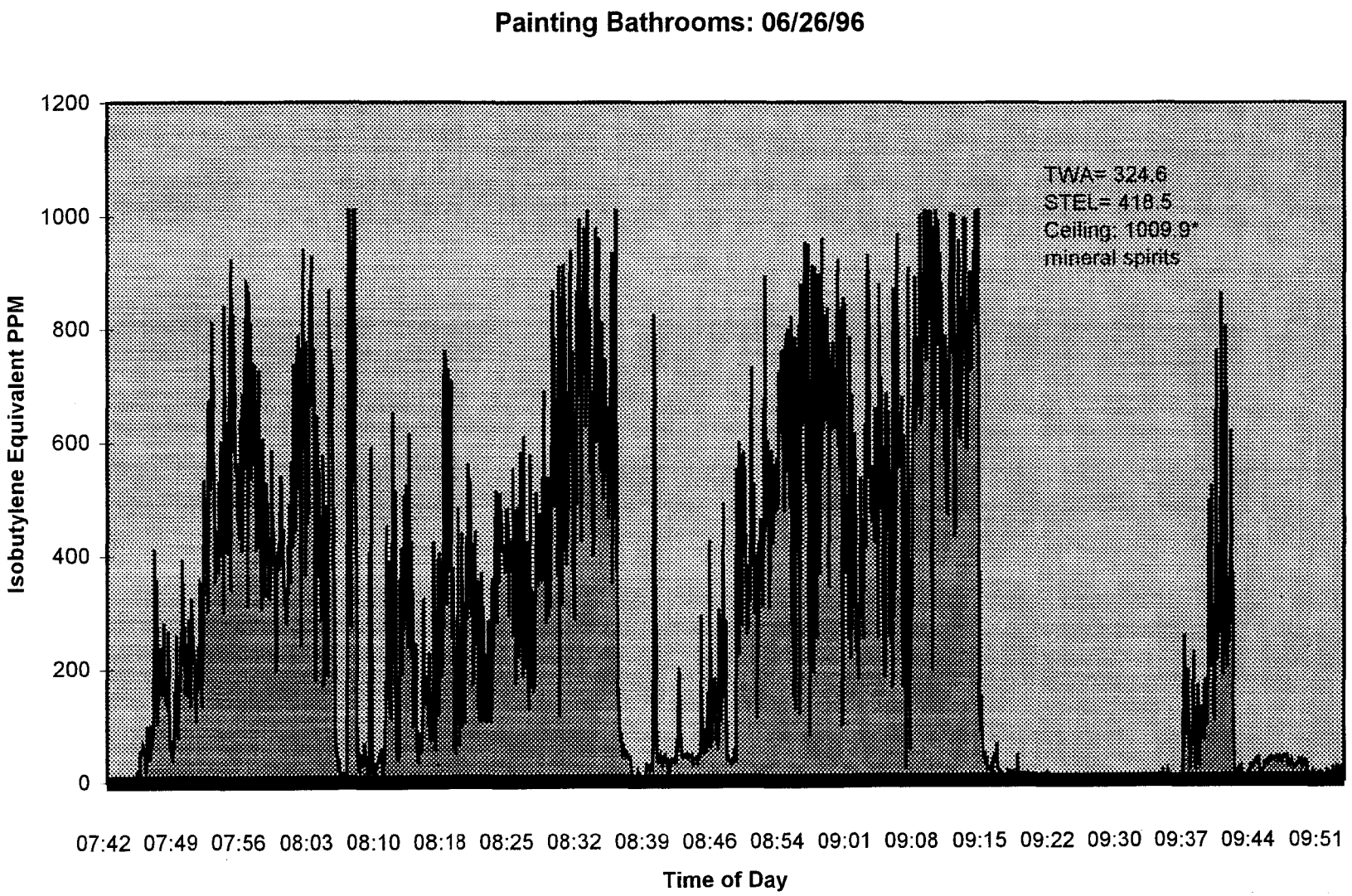

Painting Bathrooms: 06/26/96
Isobutylene Equivalent PPM
1200
1000
800
600
400
200
0
TWA= 324.6
STEL= 418.5
Ceiling: 1009.9*
mineral spirits
07:42 07:49 07:56 08:03 08:10 08:18 08:25 08:32 08:39 08:46 08:54 09:01 09:08 09:15 09:22 09:30 09:37 09:44 09:51
Time of Day

Figure 21

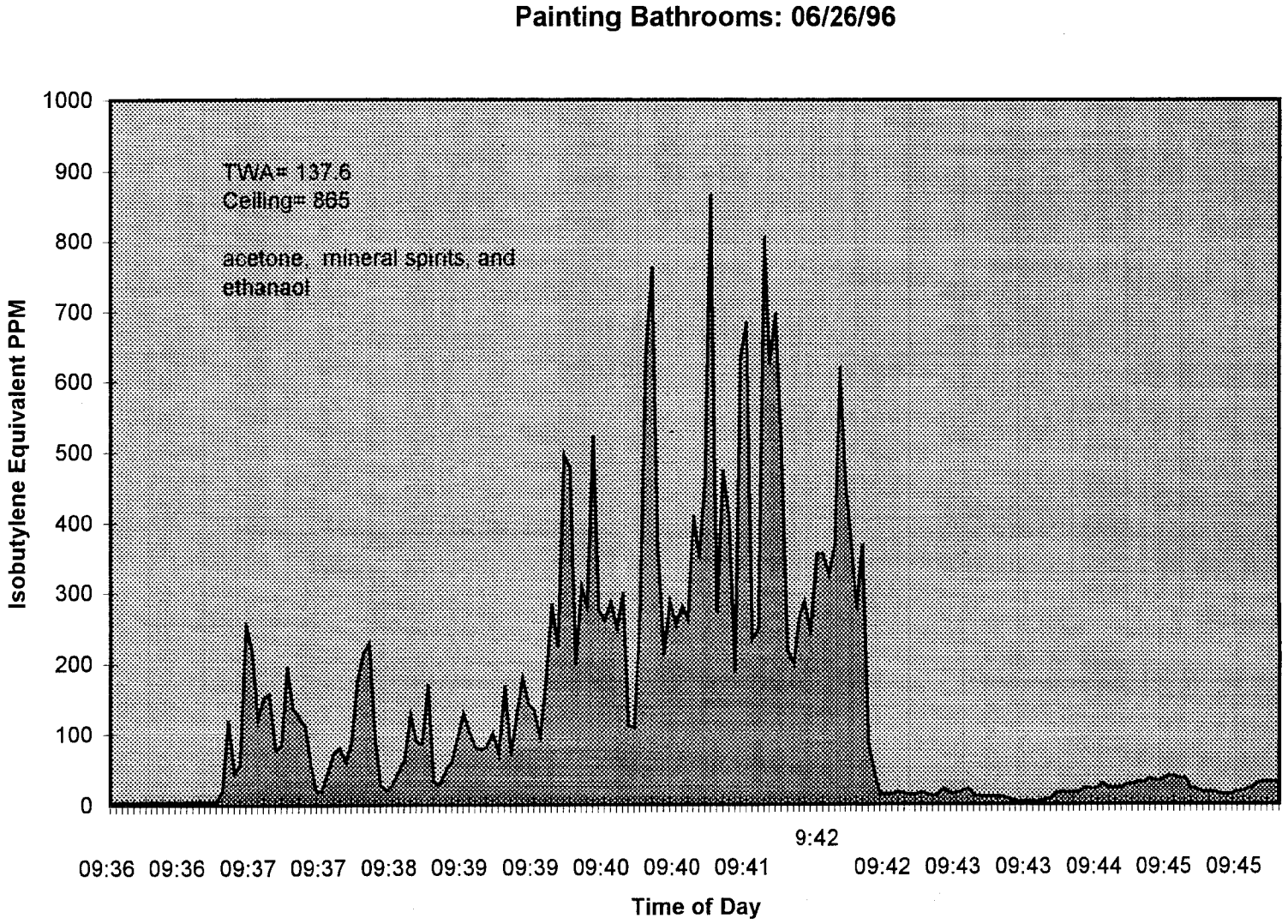

Painting Bathrooms: 06/26/96
TWA= 137.6
Ceiling= 865
acetone, mineral spirits, and ethanaol
Isobutylene Equivalent PPM
1000
900
800
700
600
500
400
300
200
100
0
09:36 09:36 09:37 09:37 09:38 09:39 09:39 09:40 09:40 09:41 9:42 09:42 09:43 09:43 09:44 09:45 09:45
Time of Day

Figure 22

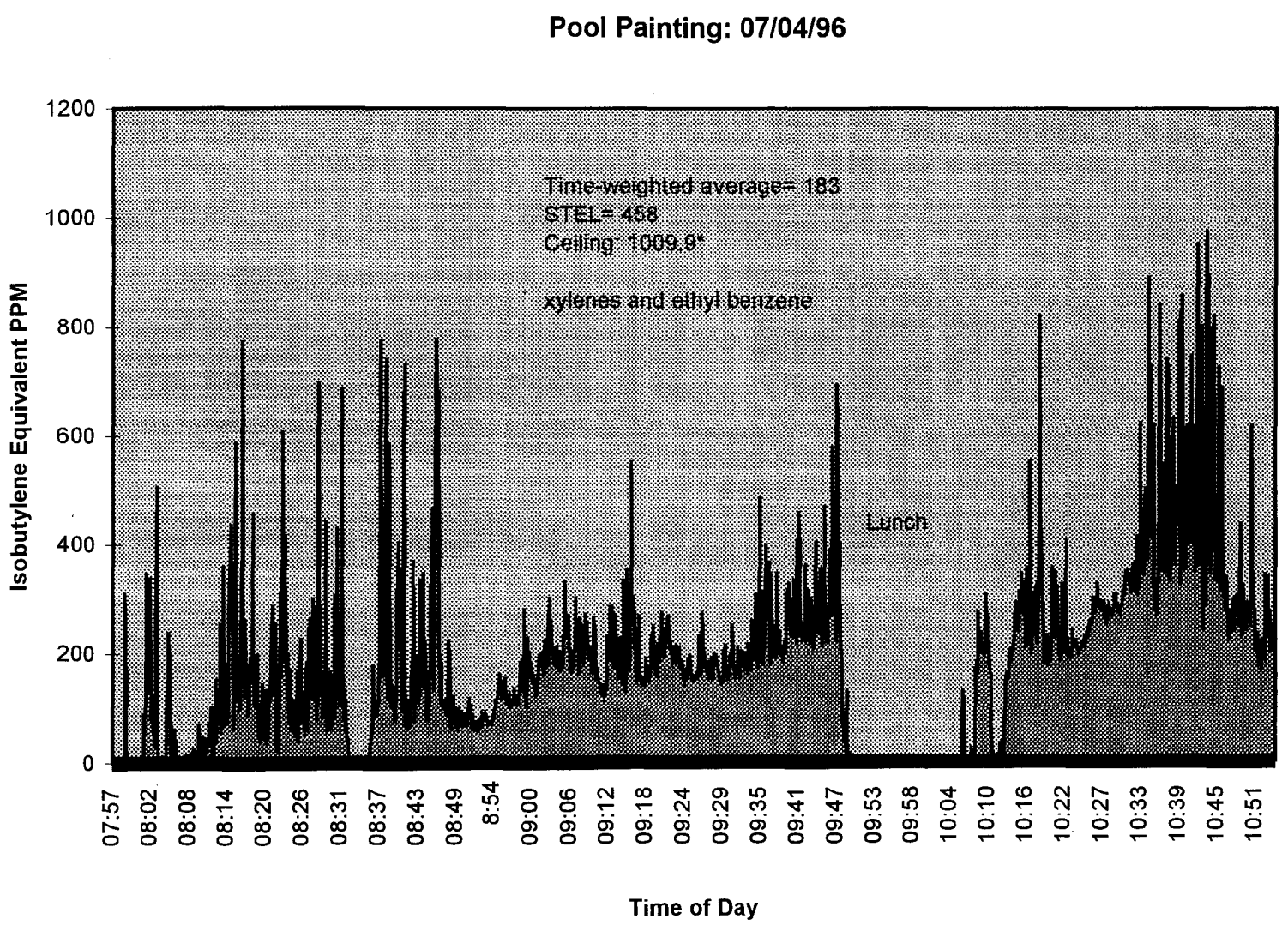

Pool Painting: 07/04/96
Isobutylene Equivalent PPM
1200
1000
800
600
400
200
0
Time-weighted average= 183
STEL= 458
Ceiling: 1009.9*
xylenes and ethyl benzene
Lunch
07:57
08:02
08:08
08:14
08:20
08:26
08:31
08:37
08:43
08:49
8:54
09:00
09:06
09:12
09:18
09:24
09:29
09:35
09:41
09:47
09:53
09:58
10:04
10:10
10:16
10:22
10:27
10:33
10:39
10:45
10:51
Time of Day

Figure 23

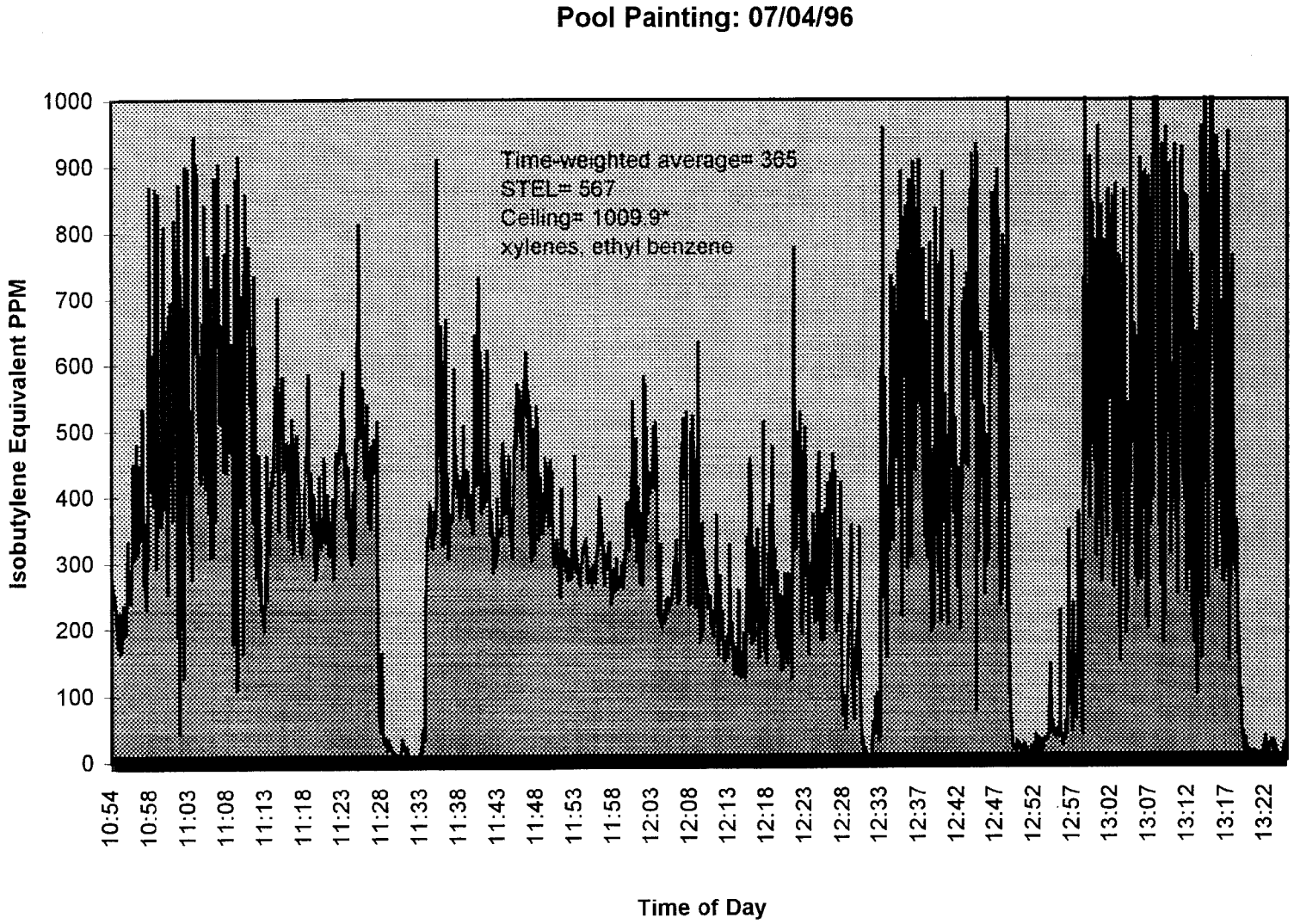

Pool Painting: 07/04/96
Time-weighted average= 365
STEL= 567
Ceiling= 1009.9*
xylenes, ethyl benzene
Isobutylene Equivalent PPM
1000
900
800
700
600
500
400
300
200
100
0
10:54
10:58
11:03
11:08
11:13
11:18
11:23
11:28
11:33
11:38
11:43
11:48
11:53
11:58
12:03
12:08
12:13
12:18
12:23
12:28
12:33
12:37
12:42
12:47
12:52
12:57
13:02
13:07
13:12
13:17
13:22
Time of Day

Figure 24

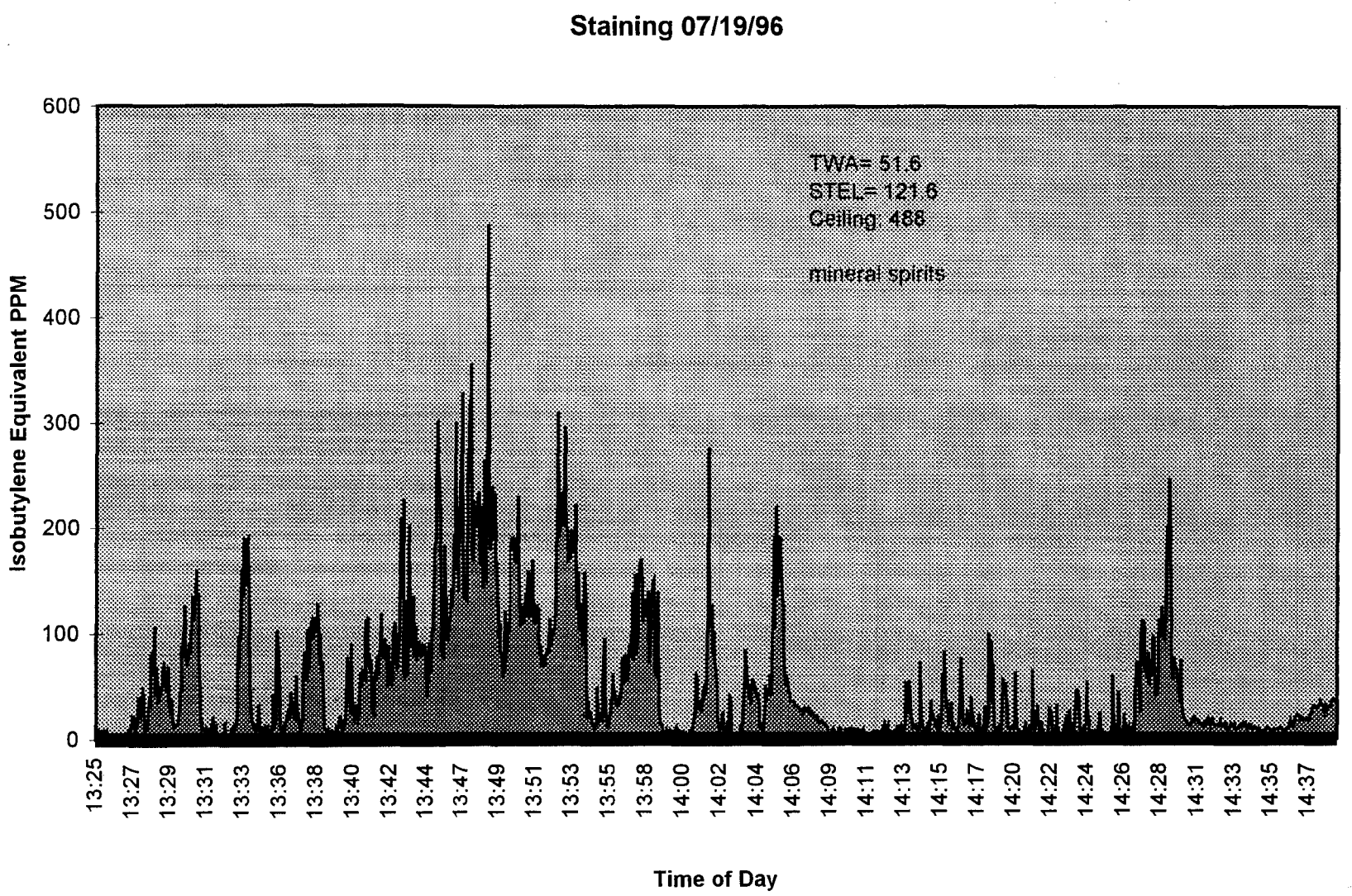

Staining 07/19/96
TWA= 51.6
STEL= 121.6
Ceiling 468
mineral spirits
Isobutylene Equivalent PPM
600
500
400
300
200
100
0
13:25
13:27
13:29
13:31
13:33
13:36
13:38
13:40
13:42
13:44
13:47
13:49
13:51
13:53
13:55
13:58
14:00
14:02
14:04
14:06
14:09
14:11
14:13
14:15
14:17
14:20
14:22
14:24
14:26
14:28
14:31
14:33
14:35
14:37
Time of Day

Figure 25

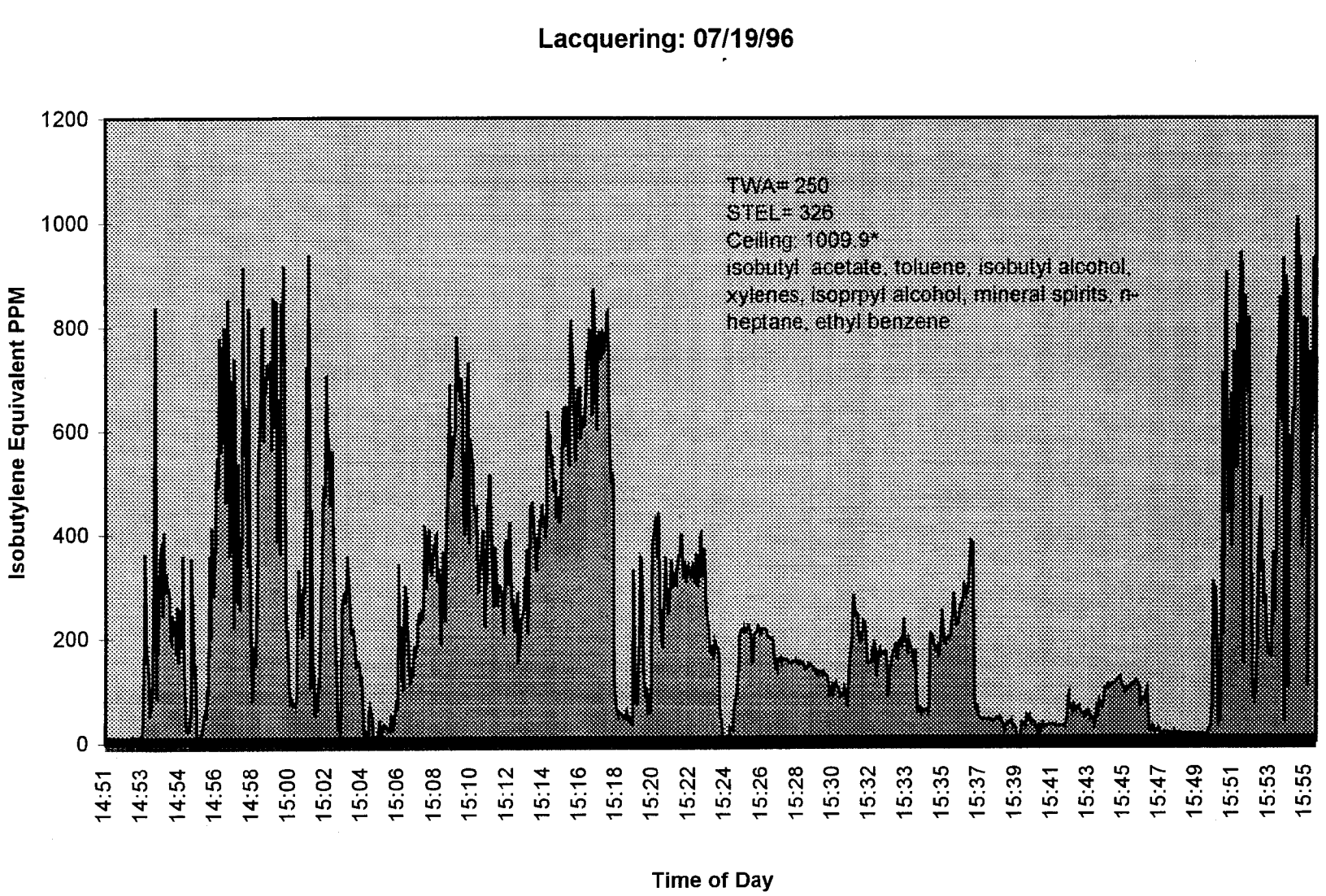

Lacquering: 07/19/96
Isobutylene Equivalent PPM
1200
1000
800
600
400
200
0
TWA= 250
STEL= 326
Ceiling: 1009.9*
isobutyl acetate, toluene, isobutyl alcohol, xylenes, isoprpyl alcohol, mineral spirits, n-heptane, ethyl benzene
14:51
14:53
14:54
14:56
14:58
15:00
15:02
15:04
15:06
15:08
15:10
15:12
15:14
15:16
15:18
15:20
15:22
15:24
15:26
15:28
15:30
15:32
15:33
15:35
15:37
15:39
15:41
15:43
15:45
15:47
15:49
15:51
15:53
15:55
Time of Day

Figure 26

Table I : GC-FID Analytical Results in PPM Solvent and Total PPM for Charcoal Tube Samples

| Sample # | PID | Task | Total PPM | acetone | but ace | ethanol | ethyl ben | heptane | isob acet | methanol | MEK | MIBK | isob alcoh | isop alcoh | toluene | xylenes | min spirit | pet distill | 2-butoxyet | prop acet | hex eqv |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 950801#3 | 0 | BPT | 45.32 | | | | | 0.31 | | 1.33 | 3.65 | | | | 13.02 | | 11.87 | 15.15 | | | |
| 950801#1 | 1 | BPT | 34.58 | | | | | | | | 0.73 | | | | 3.19 | | 15.87 | 14.80 | | | |
| 950801#2 | 0 | BPT | 33.13 | | | | | 0.15 | | 0.90 | 1.35 | | | | 5.76 | | 10.23 | 14.74 | | | |
| 960529A2X | 0 | BPT | 3.95 | | | | | | | | | | | | | | 3.95 | | | | |
| 960529A1X | 1 | BPT | 1.84 | | | | | | | | | | | | | | 1.84 | | | | |
| 960410A1Y | 1 | CI | 77.02 | 2.36 | 0.08 | 28.52 | 3.06 | | | 0.25 | | 29.30 | | | 0.23 | 13.22 | | | | | |
| 960305B2X | 0 | CI | 26.71 | 4.99 | | | 0.24 | 1.08 | | 4.90 | | | | 0.54 | 12.82 | 1.20 | | | 0.94 | | |
| 950914#2 | 0 | LQ | 1473.78 | | | | 20.79 | 102.31 | 352.75 | 77.78 | 1.49 | | 262.05 | 247.59 | 284.86 | 95.57 | | 28.58 | | | |
| 950914#1 | 1 | LQ | 1452.08 | | | | 20.19 | 102.63 | 351.67 | 66.14 | | | 243.30 | 240.09 | 277.90 | 94.11 | | 56.05 | | | |
| 960404A1X | 0 | LQ | 1103.24 | | | 27.00 | 28.33 | | 374.04 | | 29.81 | | 187.60 | 272.65 | 113.99 | 69.81 | | | | | |
| 960305A2X | 0 | LQ | 604.69 | | | 134.27 | 8.43 | | 63.92 | 5.85 | | 3.83 | 2.06 | 36.39 | 267.13 | 43.32 | | | 39.49 | | |
| 960607A1X | 0 | LQ | 422.11 | 6.71 | | | | | | 37.48 | 31.39 | | | 11.37 | 316.19 | | 18.98 | | | | |
| 960719A2X | 1 | LQ | 361.11 | | | | 4.93 | 6.98 | 96.96 | 24.86 | | | 60.25 | 45.22 | 82.17 | 24.09 | 15.65 | | | | |
| 960416B1X | 1 | LQ | 314.89 | | | | 8.47 | | 113.36 | | 15.82 | | 49.20 | 84.41 | 24.14 | 19.48 | | | | | |
| 960605A1X | 1 | LQ | 287.38 | 20.27 | | 55.96 | 3.39 | 13.49 | 33.06 | 18.50 | | 8.91 | 13.41 | 22.89 | 78.73 | 18.77 | | | | | |
| 960305A1X | 0 | LQ | 257.79 | 1.39 | | 7.85 | 0.23 | 5.07 | 59.56 | 2.39 | 30.04 | | | 65.86 | 69.89 | 1.16 | | | 14.34 | | |
| 960409A2X | 0 | LQ | 250.21 | | | 4.50 | 7.34 | | 90.79 | | 8.53 | | 41.44 | 69.36 | 11.26 | 16.99 | | | | | |
| 950906#2 | 1 | LQ | 248.59 | 5.91 | 3.07 | 6.32 | 5.27 | 5.54 | 33.51 | | 2.16 | 13.94 | | 28.91 | 105.55 | 25.02 | | | 2.92 | 10.48 | |
| 960422A1X | 1 | LQ | 231.42 | | | 7.43 | 5.75 | | 79.16 | | 8.35 | | 35.52 | 55.12 | 17.64 | 14.91 | | | | | 7.54 |
| 960229A2Y | 0 | LQ | 198.79 | 10.34 | | | 4.49 | 0.33 | 97.28 | | | 16.72 | | 25.40 | | 23.09 | | 21.15 | | | |
| 950906#1 | 1 | LQ | 57.08 | 1.25 | 0.71 | 0.78 | 1.29 | 1.12 | 6.64 | | 0.36 | 3.18 | | 6.73 | 24.73 | 5.94 | | | 0.44 | 2.61 | 1.30 |
| 960704B1X | 0 | PIPT | 338.27 | | | 0.31 | 58.89 | | | | | | | | 0.31 | 278.76 | | | | | |
| 960704A2Y | 1 | PIPT | 302.68 | | | | 50.20 | | | | | | | | 0.29 | 252.19 | | | | | |
| 960704A1Y | 1 | PIPT | 129.14 | | | | 22.71 | | | | | | | | 0.12 | 106.30 | | | | | |
| 960626A2X | 1 | SpPT | 1674.51 | 167.15 | | 11.08 | | | | 1436.62 | | | | | | - | 59.65 | | | | |
| 960229B1X | 1 | SpPT | 1007.71 | | | | 81.38 | 0.62 | | | | | | | 140.63 | 121.50 | | 663.57 | | | |
| 960626A1X | 1 | SpPT | 242.58 | | | | | | | | | | | | | | 242.58 | | | | |
| 960423A1X | 1 | SpPT | 51.34 | | | | | | | | | | | | | | 51.34 | | | | |
| 960424A1X | 1 | SpPT | 37.53 | | | | | | | | | | | | | | 37.53 | | | | |
| 960307C1X | 1 | ST | 161.98 | 10.09 | | 3.46 | | 2.90 | 30.77 | 10.60 | 8.72 | | | 20.28 | 53.56 | | 11.00 | | 10.60 | | |
| 960307A1X | 0 | ST | 127.46 | 6.23 | | 2.13 | | 1.89 | 28.96 | 8.48 | 6.31 | | | 14.07 | 39.18 | | 8.35 | | 11.86 | | |
| 960229A1Y | 0 | ST | 126.69 | 3.56 | | 43.96 | | | | | | 54.19 | | | | 24.97 | | | | | |
| 960307B1X | 0 | ST | 62.08 | | | | | | 13.74 | | | | | 15.33 | 18.30 | | 10.24 | | 4.47 | | |
| 960719A1X | 1 | ST | 59.16 | | | | | | | 0.98 | | | | | | | 58.18 | | | | |
| 960416A1Y | 1 | ST | 55.24 | 1.46 | | 13.49 | 0.63 | | | | | 18.55 | 0.32 | 0.32 | 1.18 | 11.23 | 8.07 | | | | |
| 960409A1X | 0 | ST | 36.12 | 1.03 | | | | | | | | 1.08 | | 0.77 | 7.39 | | 25.84 | | | | |
| 960419A1X | 1 | ST | 36.05 | 0.78 | | 3.20 | | | | | | 2.37 | | 0.39 | 3.47 | | 25.83 | | | | |
| 960604B1X | 0 | ST | 17.54 | 1.00 | | | | | | | | | | 0.30 | 0.61 | | 15.63 | | | | |
| 960604A1X | 0 | ST | 6.30 | | | | | | | | | | | | 0.72 | | 5.59 | | | | |
| 950803#1 | 1 | ST | 70.26 | | | | | 0.25 | 4.46 | | | | 2.78 | 2.30 | 3.43 | | 27.74 | 29.30 | | | |
| 950614A2 | 1 | StPT | 23.73 | | | | | 0.14 | | | | | | | 11.47 | | | 12.12 | | | |
| 950614A1 | 0 | StPT | 9.97 | 1.08 | | | | 0.11 | | | | | | | 3.71 | | | 5.06 | | | |
| 950620B | 1 | StPT | 6.82 | 1.12 | | | | 0.16 | | | | | | | 2.92 | | | 2.62 | | | |
| 950725B | 0 | StPT | 5.52 | | | | | 0.08 | | | | | | | 2.65 | | | 2.79 | | | |
| 950614B1 | 0 | StPT | 5.24 | 0.60 | | | | 0.14 | | 0.20 | | | | | 2.00 | | | 2.30 | | | |
| 950725A | 1 | StPT | 5.04 | 2.19 | | | | 0.05 | | | | | | | 1.82 | | | 0.99 | | | |
| 950614A3 | 1 | StPT | 5.04 | 0.42 | | | | 0.06 | | 0.49 | | | | | 1.97 | | | 2.10 | | | |
| 950620A | 0 | StPT | 4.79 | 0.75 | | | | 0.23 | | | 0.35 | | | | 2.57 | | | 0.90 | | | |

Table II: GC Summary Sampling Data of Total PPM and TLV Mixture Comparision

| Sample # | Task | Time(min) | PID Y/N | Total PPM | GC RF | Mixture Equation |
|---|---|---|---|---|---|---|
| 960529A1X | BPT | 157 | 1 | 1.84 | 2.25 | 0.02 |
| 960529A2X | BPT | 64 | 0 | 3.95 | 4.82 | 0.04 |
| 950801#2 | BPT | 564 | 0 | 33.13 | 36.16 | 0.34 |
| 950801#1 | BPT | 273 | 1 | 34.58 | 37.14 | 0.33 |
| 950801#3 | BPT | 494 | 0 | 45.32 | 55.70 | 0.50 |
| 960410A1Y | Cl | 127 | 1 | 77.02 | 61.76 | 0.70 |
| 960305B2X | Cl | 136 | 0 | 26.71 | 33.81 | 0.31 |
| 950906#1 | LQ | 165 | 1 | 57.08 | 73.92 | 0.66 |
| 960229A2Y | LQ | 59 | 0 | 198.79 | 116.31 | 1.38 |
| 960422A1X | LQ | 106 | 1 | 231.42 | 114.71 | 1.77 |
| 950906#2 | LQ | 56 | 1 | 248.59 | 317.17 | 2.88 |
| 960409A2X | LQ | 44 | 0 | 250.21 | 114.38 | 1.90 |
| 960305A1X | LQ | 141 | 0 | 257.79 | 207.89 | 2.44 |
| 960605A1X | LQ | 78 | 1 | 287.38 | 248.84 | 2.44 |
| 960416B1X | LQ | 50 | 1 | 314.89 | 163.10 | 2.50 |
| 960719A2X | LQ | 64 | 1 | 361.11 | 276.43 | 3.75 |
| 960607A1X | LQ | 110 | 0 | 422.11 | 700.02 | 6.16 |
| 960305A2X | LQ | 145 | 0 | 604.69 | 681.37 | 7.36 |
| 960404A1X | LQ | 33 | 0 | 1103.24 | 596.56 | 9.26 |
| 950914#1 | LQ | 42 | 1 | 1452.08 | 996.16 | 14.00 |
| 950914#2 | LQ | 42 | 0 | 1473.78 | 999.61 | 14.31 |
| 960704A1Y | PlPT | 176 | 1 | 129.14 | 256.53 | 1.16 |
| 960704A2Y | PlPT | 148 | 1 | 302.68 | 601.51 | 2.71 |
| 960704B1X | PlPT | 323 | 0 | 338.27 | 671.42 | 3.02 |
| 960626A1X | SpPT | 106 | 1 | 242.58 | 295.83 | 2.17 |
| 960626A2X | SpPT | 9 | 1 | 1674.51 | 225.63 | 7.16 |
| 960424A1X | SpPT | 85 | 1 | 37.53 | 45.77 | 0.34 |
| 960423A1X | SpPT | 106 | 1 | 51.34 | 62.61 | 0.46 |
| 960229B1X | SpPT | 182 | 1 | 1007.71 | 1154.99 | 10.26 |
| 960604A1X | ST | 277 | 0 | 6.30 | 8.25 | 0.06 |
| 960604B1X | ST | 277 | 0 | 17.54 | 21.25 | 0.15 |
| 960419A1X | ST | 193 | 1 | 36.05 | 41.46 | 0.34 |
| 960409A1X | ST | 94 | 0 | 36.12 | 48.26 | 0.39 |
| 960416A1Y | ST | 100 | 1 | 55.24 | 53.86 | 0.55 |
| 960719A1X | ST | 61 | 1 | 59.16 | 70.95 | 0.52 |
| 960307B1X | ST | 21 | 0 | 62.08 | 55.55 | 0.69 |
| 960229A1Y | ST | 15 | 0 | 126.69 | 102.01 | 1.24 |
| 960307A1X | ST | 185 | 0 | 127.46 | 113.76 | 1.48 |
| 960307C1X | ST | 173 | 1 | 161.98 | 153.58 | 1.77 |
| 950803#1 | ST/LQ | 327 | 1 | 70.26 | 63.25 | 0.65 |
| 950620A | StPT | 418 | 0 | 4.79 | 6.95 | 0.06 |
| 950614A3 | StPT | 188 | 1 | 5.04 | 5.84 | 0.06 |
| 950725A | StPT | 324 | 1 | 5.04 | 6.35 | 0.04 |
| 950614B1 | StPT | 376 | 0 | 5.24 | 6.24 | 0.06 |
| 950725B | StPT | 324 | 0 | 5.52 | 7.32 | 0.07 |
| 950620B | StPT | 416 | 1 | 6.82 | 8.80 | 0.08 |
| 950614A1 | StPT | 29 | 0 | 9.97 | 12.07 | 0.11 |
| 950614A2 | StPT | 69 | 1 | 23.73 | 31.65 | 0.31 |

Table III: PID Summary Air Sampling Data in Isobutylene Equivalent PPM Concentrations

| Sample # | Task | TWA | STEL | Ceiling | T (F) | RH (%) |
|---|---|---|---|---|---|---|
| 960529A1X | BPT | 3 | 6 | 84 | 69 | 51 |
| 950801#1 | BPT | 18 | 33 | 631 | 62 | 58 |
| 960410A1Y | Cl | 85 | 139 | 905 | 65 | 25 |
| 950906#1 | LQ | 46 | 265 | 897 | 81 | 40 |
| 960422A1X | LQ | 149 | 362 | 1010 | 65 | 27 |
| 950906#2 | LQ | 200 | 272 | 978 | 80 | 40 |
| 960605A1X | LQ | 217 | 302 | 1010 | 82 | 23 |
| 960416B1X | LQ | 263 | 332 | 1010 | 69 | 21 |
| 960719A2X | LQ | 250 | 327 | 1010 | 90 | 31 |
| 950914#1 | LQ | 585 | 836 | 969 | 78 | 40 |
| 960704A1Y | PlPT | 184 | 459 | 1010 | 78 | 43 |
| 960704A2Y | PlPT | 366 | 567 | 1010 | 82 | 39 |
| 960626A2X | SpPT | 138 | 138 | 865 | 72 | 61 |
| 960626A1X | SpPT | 325 | 419 | 1010 | 72 | 61 |
| 960424A1X | SpPT | 56 | 84 | 306 | 65 | 26 |
| 960423A1X | SpPT | 57 | 75 | 309 | 65 | 26 |
| 960229B1X | SpPT | 686 | 1009 | 1009 | 74 | 40 |
| 960419A1X | ST | 39 | 102 | 864 | 68 | 22 |
| 960416A1Y | ST | 69 | 128 | 1009 | 67 | 24 |
| 960719A1X | ST | 52 | 122 | 1010 | 90 | 32 |
| 960307C1X | ST | 245 | 434 | 1009 | 47 | 13 |
| 950803#1 | ST | 35 | 92 | 250 | 82 | 40 |
| 950614A3 | StPT | 3 | 4 | 278 | 88 | 40 |
| 950725A | StPT | 4 | 21 | 503 | 75 | 36 |
| 950620B | StPT | 6 | 12 | 326 | 71 | 51 |
| 950614A2 | StPT | 14 | 27 | 599 | 79 | 40 |

I. Statistical Analysis for PID PPM and GC PPM Data

A. Descriptive Statistics

| Variable | N | Mean | Median | TrMean | StDev | SEMean |
|---|---|---|---|---|---|---|
| GC PPM | 26 | 206.8 | 73.5 | 166.2 | 316.2 | 62.0 |
| PID PPM | 26 | 157.4 | 77.1 | 141.8 | 177.5 | 34.8 |
| log PID | 26 | 1.831 | 1.885 | 1.848 | 0.693 | 0.136 |
| log GC | 26 | 1.889 | 1.866 | 1.904 | 0.712 | 0.140 |

| Variable | Min | Max |
|---|---|---|
| GC PPM | 1.8 | 1385.9 |
| PID PPM | 2.7 | 686.4 |
| log PID | 0.431 | 2.837 |
| log GC | 0.266 | 3.142 |

Confidence Intervals

| Variable | N | Mean | StDev | SE Mean | 95.0 % C.I. |
|---|---|---|---|---|---|
| GC PPM | 26 | 206.8 | 316.2 | 62.0 | (79.1, 334.5) |
| PID PPM | 26 | 157.4 | 177.5 | 34.8 | (85.7, 229.1) |

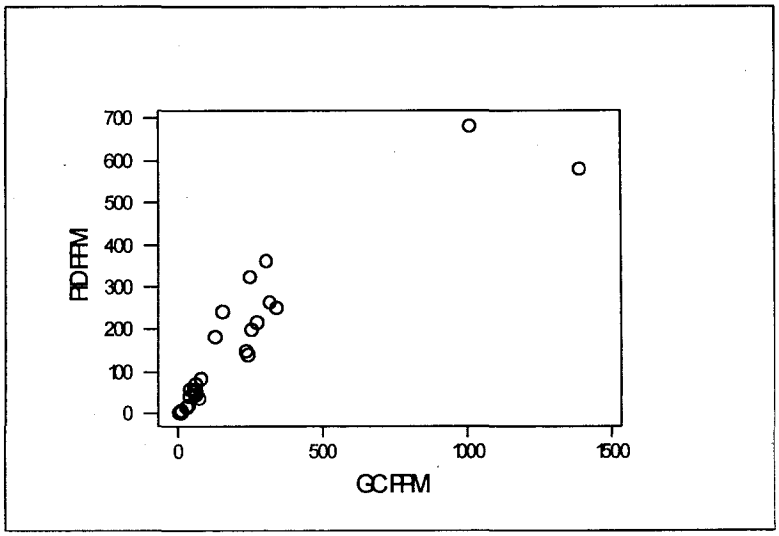



Figure 1: XY Scatter Plot of PID TWA PPM and GC TWA PPM for Side by Side Personal Breathing Zone Samples

Regression Analysis

The regression equation is

PID PPM = 51.9 + 0.510 GC PPM

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 51.93 | 17.89 | 2.90 | 0.008 |
| GC PPM | 0.50997 | 0.04799 | 10.63 | 0.000 |

s = 75.87 R-sq = 82.5% R-sq(adj) = 81.7%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 1 | 649860 | 649860 | 112.90 | 0.000 |
| Error | 24 | 138142 | 5756 | | |
| Total | 25 | 788003 | | | |

Unusual Observations

| Obs. | GC PPM | PID PPM | Fit | Stdev.Fit | Residual | St.Resid |
|---|---|---|---|---|---|---|
| 10 | 1386 | 585.0 | 758.7 | 58.5 | -173.7 | -3.60RX |
| 12 | 303 | 365.5 | 206.3 | 15.6 | 159.2 | 2.14R |
| 14 | 243 | 324.6 | 175.6 | 15.0 | 149.0 | 2.00R |
| 17 | 1008 | 686.4 | 565.8 | 41.2 | 120.6 | 1.89 X |

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

Test for Significance in the model

$$F = 112.9 > F_{1, 24} = 4.26$$

Therefore, the GC PPM is significant in the model.

C. Test the Assumption of Normality

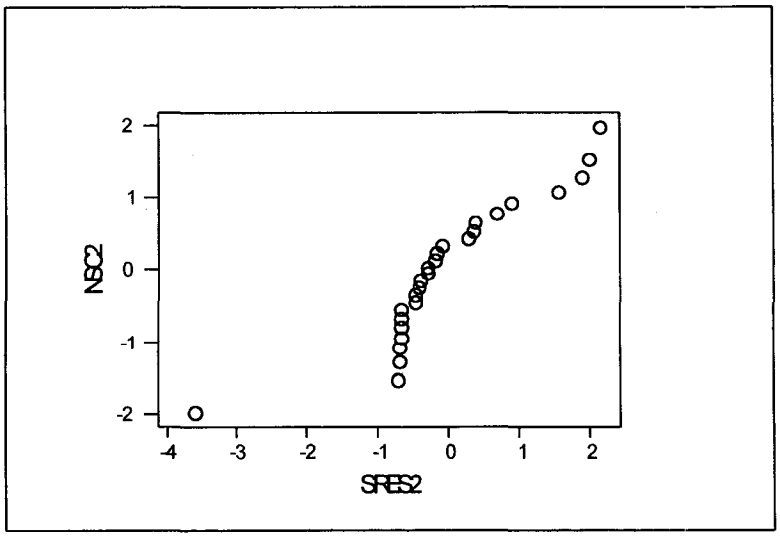



Figure 2: XY Plot of the Normal Scores of Residuals vs. Residuals for Regression of PID PPM with GC PPM Sample Data

Correlations (Pearson)
Correlation of SRES2 and NSC2 = 0.917
$r_{.05\ 26} = 0.9582 > 0.917$
Therefore the assumption of normality is rejected

The plot of the data distribution suggested the need for a logarthrimetric transformation of the both data sets.

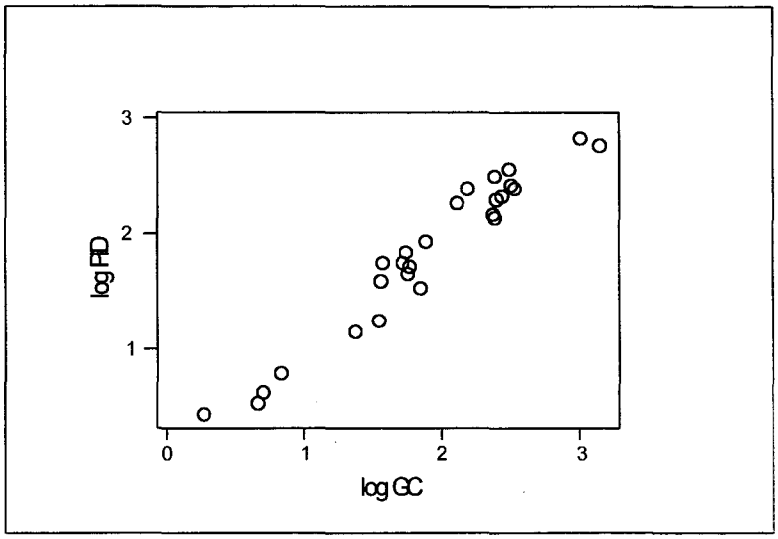


Figure 3: XY Scatter Plot of the log of PID PPM and the log of GC PPM

Regression Analysis
The regression equation is
log PID = 0.0408 + 0.948 log GC

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 0.04080 | 0.09091 | 0.45 | 0.658 |
| log GC | 0.94801 | 0.04515 | 21.00 | 0.000 |

s = 0.1608 R-sq = 94.8% R-sq(adj) = 94.6%

By the lognormal transformation of the data, the coefficeint of determination is improved.

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 1 | 11.402 | 11.402 | 440.91 | 0.000 |
| Error | 24 | 0.621 | 0.026 | | |
| Total | 25 | 12.023 | | | |

Unusual Observations

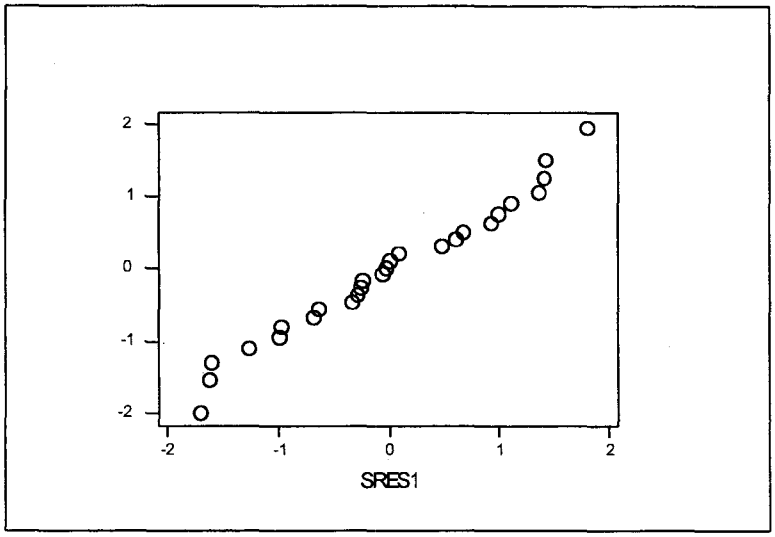
| Obs. | log GC | log PID | Fit | Stdev.Fit | Residual | St.Resid |
|---|---|---|---|---|---|---|
| 1 | 0.27 | 0.4314 | 0.2929 | 0.0798 | 0.1384 | 0.99 X |

X denotes an obs. whose X value gives it large influence.

Test for Significance in the Model

$F = 440.9 >> F_{1, 24} = 4.26$
Therefore the log of GC PPM is very significant in the model.

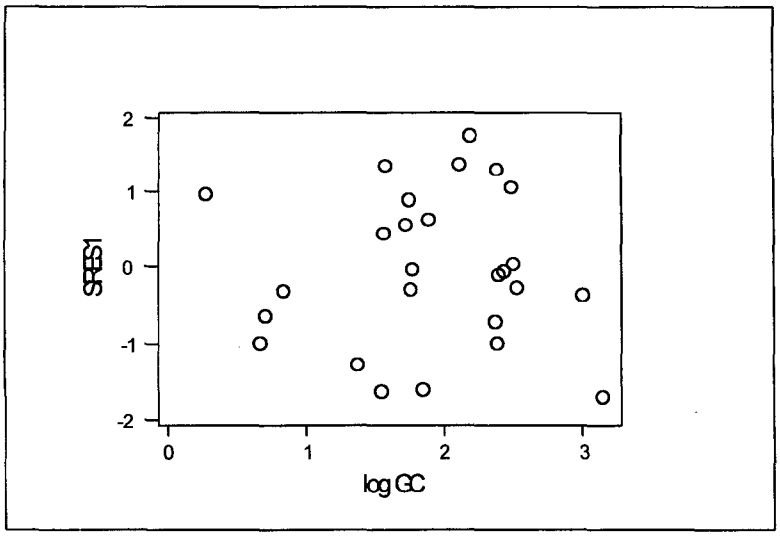
Assumption of Normality




Correlations (Pearson)

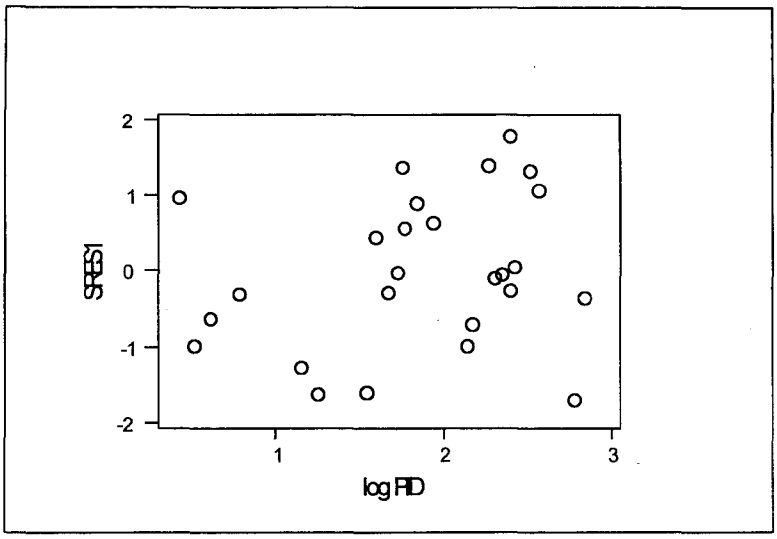
Correlation of NSC and SRES1 = 0.988
$0.988 > r_{.05\,26} = 0.9582$
Therefore the assumption of normality is accepted.

Test for Linearity




Assumption of linearity is accepted since no functional relationship is apparent.

Test for Homoscedacity




The assumption of homodecasity was accepted based on the XY scatter plot.

Lastly, the log of the GC PPM and relative humidity were entered into the model due to the known effects of humidity on the response of the PID.

Regression Analysis
The regression equation is
log PID = 0.220 + 0.936 log GC - 0.00429 RH

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 0.2196 | 0.1344 | 1.63 | 0.116 |
| log GC | 0.93631 | 0.04384 | 21.36 | 0.000 |
| RH | -0.004290 | 0.002453 | -1.75 | 0.094 |

s = 0.1543 R-sq = 95.4% R-sq(adj) = 95.0%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 2 | 11.4749 | 5.7374 | 240.89 | 0.000 |
| Error | 23 | 0.5478 | 0.0238 | | |
| Total | 25 | 12.0227 | | | |

| SOURCE | DF | SEQ SS |
|---|---|---|
| log GC | 1 | 11.4020 |
| RH | 1 | 0.0728 |

Unusual Observations

| Obs. | log GC | log PID | Fit | Stdev.Fit | Residual | St.Resid |
|---|---|---|---|---|---|---|
| 14 | 2.38 | 2.5113 | 2.1909 | 0.0734 | 0.3204 | 2.36R |

Test for Significance

$F = .0728/.0238 = 3.05 < F_{1, 23} = 4.28$

Therefore relative humidity was not included in the final model.

The final model was:
Regression Analysis
The regression equation is
log PID PPM = 0.0408 + 0.948 log GC PPM

s = 0.1608 R-sq = 94.8% R-sq(adj) = 94.6%

II. Statistical Analysis for log PID PPM and log of RF Predicted PID PPM Based on % Composition Data Obtained by GC.

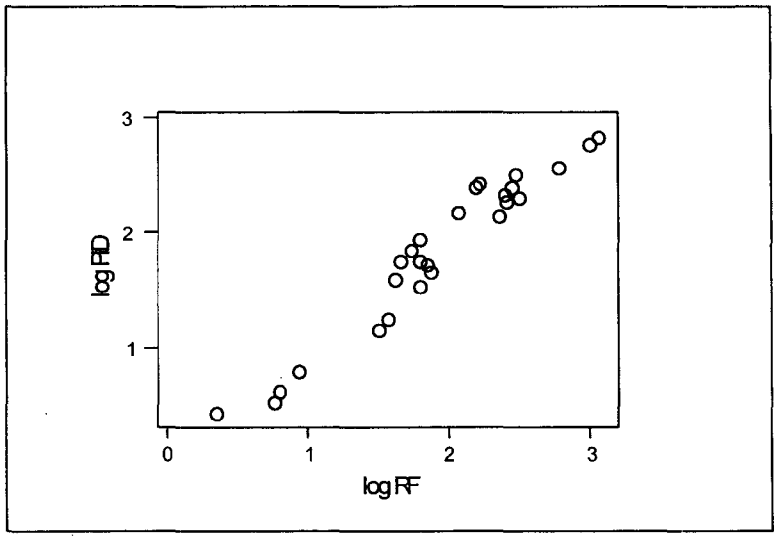



Figure 4: XY Scatter Plot of log PID PPM and Predicted PID PPM Corrected by Response Factors and % Composition Data from GC Analysis

Regression Analysis
The regression equation is
log PID PPM = - 0.076 + 0.993 log RF Predicted PID PPM

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | -0.0760 | 0.1016 | -0.75 | 0.462 |
| log RF | 0.99328 | 0.05002 | 19.86 | 0.000 |

s = 0.1695 R-sq = 94.3% R-sq(adj) = 94.0%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 1 | 11.333 | 11.333 | 394.30 | 0.000 |
| Error | 24 | 0.690 | 0.029 | | |
| Total | 25 | 12.023 | | | |

Unusual Observations

| Obs. | log RF | log PID | Fit | Stdev.Fit | Residual | St.Resid |
|---|---|---|---|---|---|---|
| 1 | 0.35 | 0.4314 | 0.2738 | 0.0852 | 0.1576 | 1.08 X |

X denotes an obs. whose X value gives it large influence.

The use of the response factor predicted PID PPM did not improve the correlation between the data. Therefore the model developed in the first regression was used in the final model.

III. Statistical Analysis of TLV Mixture Equation Comparision

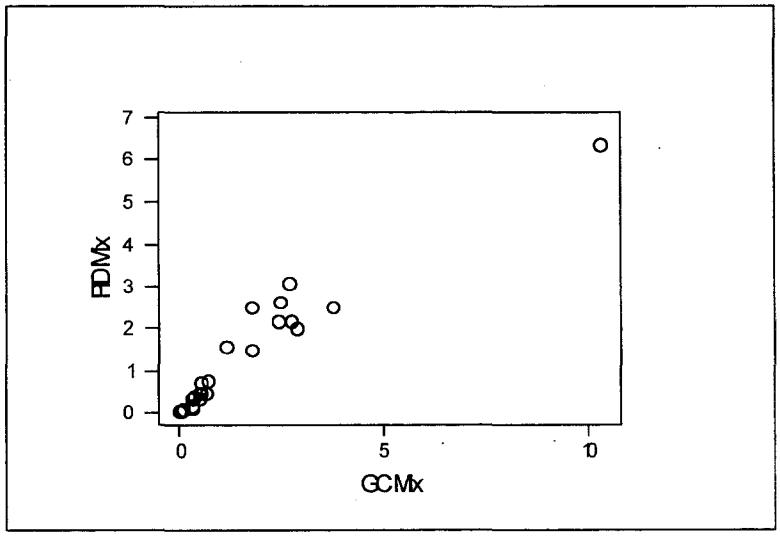



Figure 5: XY Scatter Plot of PID Mixture Equation and GC Mixture Equation

Regression Analysis

The regression equation is

PID Mix = 0.278 + 0.653 GC Mix

24 cases used 2 cases contain missing values

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | 0.2785 | 0.1119 | 2.49 | 0.021 |
| GC Mix | 0.65258 | 0.04260 | 15.32 | 0.000 |

s = 0.4445 R-sq = 91.4% R-sq(adj) = 91.0%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 1 | 46.358 | 46.358 | 234.68 | 0.000 |
| Error | 22 | 4.346 | 0.198 | | |
| Total | 23 | 50.704 | | | |

Unusual Observations

| Obs. | GC Mix | PID Mix | Fit | Stdev.Fit | Residual | St.Resid |
|---|---|---|---|---|---|---|
| 12 | 2.7 | 3.1000 | 2.0469 | 0.1036 | 1.0531 | 2.44R |
| 17 | 10.3 | 6.4000 | 7.0000 | 0.3842 | -0.6000 | -2.68RX |
| 21 | 1.8 | 2.5000 | 1.4335 | 0.0913 | 1.0665 | 2.45R |

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

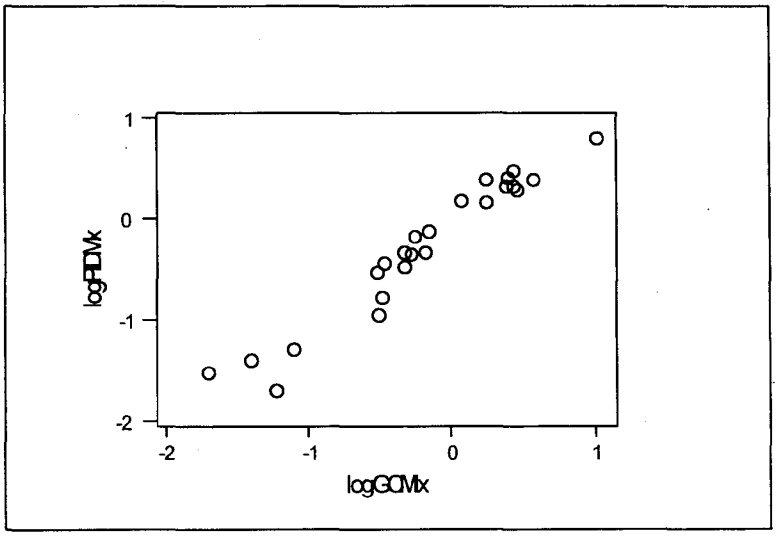



Figure 6: XY Scatter Plot of the log PID Mixture Equation Versus log GC Mixture Equation

Regression Analysis

The regression equation is
logPIDMx = - 0.0746 + 1.02 logGCMix

24 cases used 2 cases contain missing values

| Predictor | Coef | Stdev | t-ratio | p |
|---|---|---|---|---|
| Constant | -0.07455 | 0.03685 | -2.02 | 0.055 |
| logGCMix | 1.01685 | 0.05365 | 18.95 | 0.000 |

s = 0.1732 R-sq = 94.2% R-sq(adj) = 94.0%

Analysis of Variance

| SOURCE | DF | SS | MS | F | p |
|---|---|---|---|---|---|
| Regression | 1 | 10.769 | 10.769 | 359.18 | 0.000 |
| Error | 22 | 0.660 | 0.030 | | |
| Total | 23 | 11.428 | | | |

Unusual Observations

| Obs. | logGCMix | logPIDMx | Fit | Stdev.Fit | Residual | St.Resid |
|---|---|---|---|---|---|---|
| 1 | -1.70 | -1.5229 | -1.8022 | 0.0881 | 0.2793 | 1.87 X |
| 23 | -1.22 | -1.6990 | -1.3170 | 0.0655 | -0.3820 | -2.38R |
| 26 | -0.51 | -0.9586 | -0.5918 | 0.0392 | -0.3668 | -2.17R |

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

Test for Normality

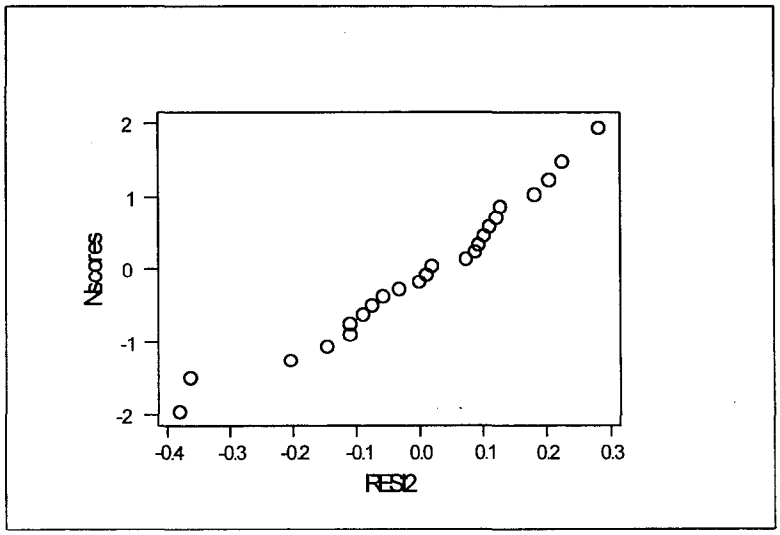



Figure 7: XY Scatter Plot of the Normal Scores Of the Standard Residuals Versus the Standard Residuals

Correlations (Pearson)

Correlation of RESI2 and Nscores = 0.979
$0.979 > r_{24} = 0.9582$ therefore accept the assumption of normality

Test the Assumption of Linearity

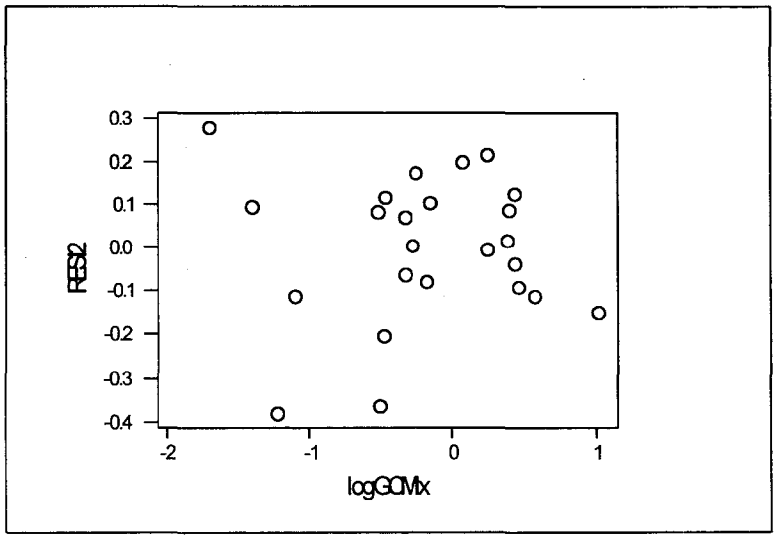



Figure 8: XY Scatter Plot of Standard Residuals Versus the X Variable

Since there is no apparent functional relationship between the standard residuals and the log GC mix equation, the assumption of linearity is accepted.

Test for Homoscedicity

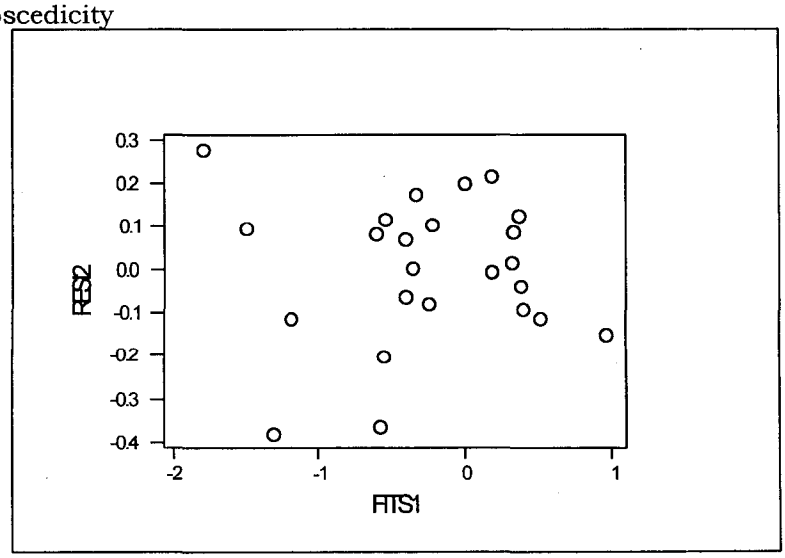



Figure 9: XY Scatter Plot of The Standard Residuals Versus the The Fits of the Y Variable

# Appendix IV

**Table 1. BEEN FEELING RUN DOWN**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 | 31 | 19.3 | 42.5 | 42.5 |
| | 1 | 36 | 22.4 | 49.3 | 91.8 |
| | 2 | 5 | 3.1 | 6.8 | 98.6 |
| | 3 | 1 | .6 | 1.4 | 100.0 |
| | Total | 73 | 45.3 | 100.0 | |
| Missing | System | 88 | 54.7 | | |
| Total | | 161 | 100.0 | | |

**Table 2. NOT BEEN ABLE TO CONCENTRATE**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 | 45 | 28.0 | 60.0 | 60.0 |
| | 1 | 24 | 14.9 | 32.0 | 92.0 |
| | 2 | 3 | 1.9 | 4.0 | 96.0 |
| | 3 | 3 | 1.9 | 4.0 | 100.0 |
| | Total | 75 | 46.6 | 100.0 | |
| Missing | System | 86 | 53.4 | | |
| Total | | 161 | 100.0 | | |

**Table 3. HAD TROUBLE REMEMBERING**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 | 43 | 26.7 | 57.3 | 57.3 |
| | 1 | 29 | 18.0 | 38.7 | 96.0 |
| | 2 | 3 | 1.9 | 4.0 | 100.0 |
| | Total | 75 | 46.6 | 100.0 | |
| Missing | System | 86 | 53.4 | | |
| Total | | 161 | 100.0 | | |

**Table 4. HAD TROUBLE SLEEPING**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 | 54 | 33.5 | 72.0 | 72.0 |
| | 1 | 19 | 11.8 | 25.3 | 97.3 |
| | 2 | 1 | .6 | 1.3 | 98.7 |
| | 3 | 1 | .6 | 1.3 | 100.0 |
| | Total | 75 | 46.6 | 100.0 | |
| Missing | System | 86 | 53.4 | | |
| Total | | 161 | 100.0 | | |

**Table 5. LOST SLEEP OVER WORRY**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 | 53 | 32.9 | 70.7 | 70.7 |
| | 1 | 14 | 8.7 | 18.7 | 89.3 |
| | 2 | 7 | 4.3 | 9.3 | 98.7 |
| | 3 | 1 | .6 | 1.3 | 100.0 |
| | Total | 75 | 46.6 | 100.0 | |
| Missing | System | 86 | 53.4 | | |
| Total | | 161 | 100.0 | | |

**Table 6. FEELING CONSTANTLY UNDER STRAIN**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 | 40 | 24.8 | 53.3 | 53.3 |
| | 1 | 26 | 16.1 | 34.7 | 88.0 |
| | 2 | 7 | 4.3 | 9.3 | 97.3 |
| | 3 | 2 | 1.2 | 2.7 | 100.0 |
| | Total | 75 | 46.6 | 100.0 | |
| Missing | System | 86 | 53.4 | | |
| Total | | 161 | 100.0 | | |

**Table 7. GETTING EDGY OR BAD TEMPER**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 | 31 | 19.3 | 41.3 | 41.3 |
| | 1 | 42 | 26.1 | 56.0 | 97.3 |
| | 2 | 2 | 1.2 | 2.7 | 100.0 |
| | Total | 75 | 46.6 | 100.0 | |
| Missing | System | 86 | 53.4 | | |
| Total | | 161 | 100.0 | | |

**Table 8. FEELING NERVOUS**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 | 55 | 34.2 | 73.3 | 73.3 |
| | 1 | 20 | 12.4 | 26.7 | 100.0 |
| | Total | 75 | 46.6 | 100.0 | |
| Missing | System | 86 | 53.4 | | |
| Total | | 161 | 100.0 | | |

**Table 9. HAD DIFFUCULTY BREATHING**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 | 60 | 37.3 | 83.3 | 83.3 |
| | 1 | 10 | 6.2 | 13.9 | 97.2 |
| | 2 | 1 | .6 | 1.4 | 98.6 |
| | 3 | 1 | .6 | 1.4 | 100.0 |
| | Total | 72 | 44.7 | 100.0 | |
| Missing | System | 89 | 55.3 | | |
| Total | | 161 | 100.0 | | |

**Table 10. DEVELOPED HEADACHES AT WORK**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 | 41 | 25.5 | 55.4 | 55.4 |
| | 1 | 28 | 17.4 | 37.8 | 93.2 |
| | 2 | 5 | 3.1 | 6.8 | 100.0 |
| | Total | 74 | 46.0 | 100.0 | |
| Missing | System | 87 | 54.0 | | |
| Total | | 161 | 100.0 | | |

**Table 11. BEEN FEELING TIRED AT WORK**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 | 30 | 18.6 | 40.5 | 40.5 |
| | 1 | 35 | 21.7 | 47.3 | 87.8 |
| | 2 | 4 | 2.5 | 5.4 | 93.2 |
| | 3 | 5 | 3.1 | 6.8 | 100.0 |
| | Total | 74 | 46.0 | 100.0 | |
| Missing | System | 87 | 54.0 | | |
| Total | | 161 | 100.0 | | |

**Table 12. FELT UNCOORDINATED AR CLUMSY AT WORK**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 | 54 | 33.5 | 73.0 | 73.0 |
| | 1 | 15 | 9.3 | 20.3 | 93.2 |
| | 2 | 5 | 3.1 | 6.8 | 100.0 |
| | Total | 74 | 46.0 | 100.0 | |
| Missing | System | 87 | 54.0 | | |
| Total | | 161 | 100.0 | | |

**Table 13. FELT DIZZY AT WORK**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 | 49 | 30.4 | 68.1 | 68.1 |
| | 1 | 18 | 11.2 | 25.0 | 93.1 |
| | 2 | 5 | 3.1 | 6.9 | 100.0 |
| | Total | 72 | 44.7 | 100.0 | |
| Missing | System | 89 | 55.3 | | |
| Total | | 161 | 100.0 | | |

**Table 14. FELT HIGH OR INTOXICATED AT WORK**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 | 45 | 28.0 | 68.2 | 68.2 |
| | 1 | 17 | 10.6 | 25.8 | 93.9 |
| | 2 | 4 | 2.5 | 6.1 | 100.0 |
| | Total | 66 | 41.0 | 100.0 | |
| Missing | System | 95 | 59.0 | | |
| Total | | 161 | 100.0 | | |

**Table 15. DEVELOPED A SKIN RASH OR IRRITATION**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 | 50 | 31.1 | 87.7 | 87.7 |
| | 1 | 7 | 4.3 | 12.3 | 100.0 |
| | Total | 57 | 35.4 | 100.0 | |
| Missing | System | 104 | 64.6 | | |
| Total | | 161 | 100.0 | | |

**Table 16. EXPERIENCED ANY OTHE HEALTH PROBLEMS RELATED TO W**

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | 0 | 50 | 31.1 | 92.6 | 92.6 |
| | 1 | 3 | 1.9 | 5.6 | 98.1 |
| | 2 | 1 | .6 | 1.9 | 100.0 |
| | Total | 54 | 33.5 | 100.0 | |
| Missing | System | 107 | 66.5 | | |
| Total | | 161 | 100.0 | | |