HETA 95-0308-2611
Ohio Department of Transportation
Columbus, Ohio

Daniel Hewett, CIH

PREFACE

The Hazard Evaluations and Technical Assistance Branch of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene and technical assistance (TA) to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Daniel Hewett, CIH, of the Respiratory Disease Hazard Evaluations and Technical Assistance Program, Clinical Investigations Branch, Division of Respiratory Disease Studies. Field assistance was provided by Patrick Hintz, Environmental Investigations Branch, Emily Allen, Clinical Investigations Branch. Desktop publishing by Terry Stewart.

Copies of this report have been sent to employee and management representatives at the Ohio Department of Transportation; Mr. Gene Frissora, Shop Steward, Ohio Civil Service Employee Association; U.S. Department of Labor/OSHA Region V, Columbus Area Office, and the OSHA Regional Office. This report is not copyrighted and may be freely reproduced. Single copies of this report will be available for a period of three years from the date of this report. To expedite your request, include a self-addressed mailing label along with your written request to:

NIOSH Publications Office
4676 Columbia Parkway
Cincinnati, Ohio 45226
800-356-4674

After this time, copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161. Information regarding the NTIS stock number may be obtained from the NIOSH Publications Office at the Cincinnati address.

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Health Hazard Evaluation Report 95-0308
Ohio Department of Transportation
Columbus, Ohio
November 1996

Daniel Hewett

SUMMARY

In August 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Ohio Department of Transportation (ODOT) Traffic Maintenance Shop (TMS) for technical assistance in the performance of a safety and health evaluation in the TMS silk screening department. The requestors asked NIOSH to evaluate workers' exposures to vapors and gases during silk screen printing of highway signs. Silk screening department workers reported a feeling of lethargy and a feeling of inebriation which the workers associate with exposures to high-intensity inks.

On September 6 and 7, 1995, NIOSH investigators performed quantitative area and personal air sampling for three chemicals; cyclohexanone, xylene, and 2-methoxyethanol. A qualitative screen for hydrocarbons was also performed with thermal desorption tubes. Material safety data sheets (MSDSs) of products used in the silk screening department were reviewed, ingredient information was obtained from manufacturers, and ODOT plans for ventilation system modifications were reviewed.

On November 20, 1995, NIOSH investigators issued an interim report which recommended changes in the TMS respiratory protection program for the silk screening department, and changes in work practices. On February 28, 1996, a second interim report was issued to report the results of environmental sampling performed on September 6 and 7, 1995. None of three chemicals sampled were present above occupational exposure evaluation criteria. The NIOSH review of the proposed ventilation system design indicated that the design would likely reduce worker exposures to air contaminants generated by the silk screening process.

Potential chemical exposures to halogenated hydrocarbons, ketones, naphthas, and esters were determined from information gathered after the September 6 and 7, 1995, surveys. On March 27 and 28, 1996, NIOSH investigators returned to ODOT to perform quantitative personal and area air sampling for these chemicals.

A total of 16 time-weighted average (TWA) personal breathing zone (PBZ) samples, and 10 TWA area samples were collected and analyzed for 1,2-dichloroethylene, 1,1,1-trichloroethane, 2-ethoxyethyl acetate (2EEA), n-pentane, acetone, toluene, methyl isobutyl ketone, Stoddard solvent, n-propyl acetate, methyl ethyl ketone, and isophorone.

Four of five full-shift personal breathing zone (PBZ) samples measured 2EEA concentrations which exceeded the full-shift TWA NIOSH recommended exposure limit (REL) of 0.5 parts per million (ppm); the concentrations ranged from 0.52 to 0.87 ppm.

Concentrations of a mixture of 2EGEEA, isophorone, and Stoddard solvent contributed to effective exposures for mixtures which exceeded unity (i.e., exceeded the threshold limit value (TLV®) for a mixture as defined by the American Conference of Governmental Industrial Hygienists (ACGIH)).

Screen printers were exposed to occupationally significant concentrations of 2EGEEA up to 1.7 times the TWA NIOSH REL of 0.5 ppm. If properly maintained, the full-facepiece, powered air-purifying respirators (PAPRs) with organic vapor cartridges (OVCs) worn by the screen printers provide adequate respiratory protection for up to 50 times the NIOSH REL for 2EGEEA. If respiratory exposures to 2EGEEA solvent vapors occur, the potential exists for the reproductive effects of 2EGEEA to occur rather than nervous system effects that could lead to feelings of lethargy and inebriation. The feelings of lethargy and inebriation experienced by workers are not likely to be associated with the exposure levels of the sampled chemicals, assessed individually, or as a mixture.

Recommendations are made to continue respirator use pending the installation of ventilation system improvements, institute worker exposure and exposure control monitoring, and to consider job design changes intended to reduce worker boredom.

Keywords: SIC 2759 (Commercial Printing, Not Elsewhere Classified), silk screen, printing, inks, solvents, halogenated hydrocarbons, ketones, naphthas, ethers, highway signs, inebriation, lethargy, boredom, 2-ethoxyethyl acetate, mixtures.

TABLE OF CONTENTS

Preface ii

Acknowledgments and Availability of Report ii

Summary iii

Keywords iv

Introduction 2

Background 2

Methods 3

Evaluation Criteria 5

Observations 6

Results 7
- Full-shift Area Samples 7
- Full-shift Personal Samples 7
- Partial-shift Personal Samples 8
- Mixture Calculations 8

Discussion 8
- Chemical Mixtures 9
- Worker Lethargy 9

Conclusions 10

Recommendations 10

References 12

Table 1 13

Table 2 14

Table 3 15

Table 4 16

Table 5 17

Table 6 18

Table 7 19

Table 8 20

INTRODUCTION

In August 1995, the National Institute for Occupational Safety and Health (NIOSH) received a request from the management of the Ohio Department of Transportation (ODOT) Traffic Maintenance Shop (TMS) for technical assistance (TA) in the performance of a safety and health evaluation in the TMS silk screening department. The TMS, in Columbus, Ohio, manufactures and prints a variety of highway signs.

The request was initiated by reports of lethargy and a feeling of inebriation among silk screening department workers. The workers associate the symptoms with silk screening using high-intensity inks, but not when using engineering-grade inks. The workers were also concerned with a lack of progress in updating the current ventilation system. One worker was concerned about changes in his skin pigmentation. Workers were concerned that several material safety data sheets (MSDSs) did not report all of the chemicals in the products they use. Workers were also concerned that the rapid-drying characteristics of some inks make it necessary to restrict air movement in the vicinity of silk screening operations. Therefore, the ventilation system was sometimes shut off to improve sign quality. In addition, the employees reported heat stress during warm weather, particularly when wearing respiratory protection.

In response to this TA request, NIOSH investigators initially performed quantitative air sampling for three chemicals; cyclohexanone, xylene, and 2-methoxyethanol. A qualitative screen for hydrocarbons was also performed with thermal desorption tubes. The sampling was performed during a walk-through survey of the silk screening department during September 6 and 7, 1995. In addition, MSDSs of products used in the silk screening department were reviewed, ingredient information was obtained from manufacturers, and ODOT plans for a future ventilation system were reviewed by engineers in the NIOSH Division of Physical Sciences and Engineering (DPSE), Engineering Control Technology Branch.

As a result of the September 6 and 7, 1995, survey, two interim reports were issued. The first report, dated November 20, 1995, recommended changes in the TMS respiratory protection program for the silk screening department, and changes in work practices. The second interim report, dated February 28, 1996, reported the results of environmental sampling from September 6 through September 7, 1995, and the results of the DPSE review of the future ventilation system. None of three chemicals sampled were present above occupational exposure evaluation criteria. The DPSE review indicated that the proposed ventilation system design would likely reduce worker exposures to air contaminants generated by the silk screening process.

After the second interim report was issued, a list of chemicals likely to be present in the silk screening environmental was compiled. The list was obtained from MSDSs provided by ODOT, the results of the qualitative hydrocarbon screen that was performed on September 6 and 7, 1995, and from information provided by manufacturers of products in use in the silk screening department.

On March 27 and 28, 1996, NIOSH investigators returned to ODOT to perform quantitative air sampling for four classes of chemicals (halogenated hydrocarbons, ketones, naphthas, and esters). The purpose of this report is to provide the results of air sampling performed on March 27 and 28, 1996, and offer conclusions and recommendations based on the results of the survey. This is the final report of this NIOSH safety and health evaluation.

BACKGROUND

The ODOT TMS silk screening department, in Columbus, Ohio, is a large, enclosed room at one corner of the TMS. Five workers are assigned to the department; a supervisor and four silk screen operators (hereafter referred to as "screen printers"). One other TMS employee prepares the screens by using a photographic process to affix a stencil to a screen.

The four screen printers work in the silk screening department from 7:00 a.m. to 2:30 p.m., five days per week. One to three workers operate a single silk screening table, depending on the work load and type of table used. The sign fabrication equipment in use is variable and depends on the sign orders being processed.

The current silk screening department contains an automatic silk screen table, two large manual silk screening tables, one large silk screen cleaning table that substitutes as a manual silk screening table, and a small manual silk screening table. The room also contains a ventilated chamber for air-drying wet highway signs, a gas-fired oven for hot air-drying of wet highway signs, a solvent and ink storage/mixing and stencil drying room, and a screen storage area.

The main silk screening department ventilation system is a general exhaust and supply air system. It consists of four freely suspended plain circular opening exhaust ducts positioned approximately 8 feet above the floor, an exhaust plenum in the ventilated sign drying chamber, 10 supply air diffusers, a supply air plenum in the ventilated sign drying chamber, and a slotted local exhaust hood positioned at the ends of the silk screen cleaning table. The main supply air system dilutes chemical vapors with outside air and heats the air using natural gas. Another general exhaust system (with an exhaust fan and duct separate from the main system) provides exhaust ventilation in the solvent and ink storage/mixing and stencil drying room.

Silk screens are created in a film room, where a light-exposed emulsion is affixed to a screen in a pattern created from a stencil. Screen printers prepare the screen for printing by adding paper centers to letters (if necessary), and attaching the screen to a stationary silk screening table. Metal highway sign blanks (either engineering-grade or high-intensity) are correctly positioned below the screen by a temporary jig. Inks are mixed and thinned according to the requirements of the job, for example, the drying characteristics of the ink on both the silk screen and the sign blank. High intensity or engineering-grade inks are prepared for printing on the same grade of sign blank.

Mixed ink is poured onto the screen and collected with a trowel before it is spread across and forced through the screen. A screen printer positions a metal blank on top of the table and underneath the screen, lowers the screen onto the blank, lowers a counter-weighted bar with a squeegee attached to one end down onto the screen, and pushes ink across the screen. The squeegee is lifted from the screen, the hinged screen is raised, and the freshly printed sign is removed by hand and placed on a nearby drying rack. This process continues until a batch of signs are printed and racked.

After a batch of signs is printed, unused ink is gathered and scooped from the screen with a trowel and poured into a can of used ink. The screen is then cleaned at the silk screening table, or moved to the ventilated silk screen cleaning table. Cleaning is performed with either pure xylene or Stoddard solvent applied to the screen with rags. The solvent is poured directly from a safety solvent dispenser onto the rags. Hardened inks may be removed with special cleaners, if necessary. Used, ink-contaminated rags are discarded in metal rag cans with foot-operated metal lids which close automatically. Racked, wet signs are dried by rolling the rack into a large ventilated sign drying chamber which resembles a narrow garage with three garage-door type openings, or positioned inside a gas-fired oven which typically operates at 100 to 180 degrees Fahrenheit (^{N}F) for 60 to 105 minutes.

METHODS

A list of chemicals in products likely to be used at ODOT during silk screening and screen cleaning was compiled. The chemical information was obtained from MSDSs, from manufacturers of inks and solvents, and from a list of chemicals detected with thermal desorption tubes during a NIOSH survey on September 7, 1995.

A group of chemicals was selected from the list that met the following criteria:

- Exposures can cause nervous system effects that could result in the feeling of inebriation reported by the screen printers.

- Chemical has a low occupational exposure limit and high vapor pressure relative to other chemicals likely to be present.

- Chemical has a NIOSH analytical method to support environmental sampling.

Based on the above criteria, the following 11 chemicals were selected for environmental air sampling at ODOT during the March 27 and 28, 1996, survey: acetone, n-pentane, *cis* and *trans*-1,2-dichloroethylene, methyl ethyl ketone, 1,1,1-trichloroethane, n-propyl acetate, methyl isobutyl ketone, toluene, 2-ethoxyethyl- acetate, Stoddard solvent, and isophorone.

Two types of air samples were collected to determine worker exposures: personal breathing zone (PBZ) samples and area samples. Sampling periods were full-shift, and partial-shift (task length or less). Sampling periods did not include lunch or break periods; these breaks were taken outside of the silk screening department.

All environmental samples were collected on charcoal tubes using battery-operated sampling pumps calibrated at a flow rate of either 40 cubic centimeters of air per minute (cc/min) for full-shift samples or 200 cc/min for partial-shift samples.

Five full-shift area samples were collected on March 27; three full-shift and two partial-shift samples were collected on the 28th. See Figure 1 on the next page for the locations of the area samples (locations #1 through #5) in relation to the silk screening tables. Area samples were collected at a height of approximately five feet.

Full-shift PBZ samples were collected from four screen printers (workers #1 through #4) on March 27. Full-shift and partial-shift PBZ samples were collected from workers #1, #3, and #4 on the 28th.

Six partial-shift, short-term PBZ samples were collected from four screen printers (workers #1 through #4) on March 27. The six personal samples were collected during screen printing. One short term sample was collected on March 27 from the PBZ of a silk screen preparation worker (worker #5) while the worker cleaned a screen with Easi-Solv 201 Screen Wash.

Two partial-shift personal samples were collected in the PBZ of workers #1 and #3 on the 28th. These two samples were task-length; the samples were collected from the start to the completion of printing a small batch of signs. The collection period included set-up of the silk screen printing table, sign printing, and removal and cleaning of the silk screen.

Chemicals collected on the charcoal tubes were quantitatively analyzed by gas chromatography using a modified combination of NIOSH Analytical Methods 1003, 1300, 1450, 1500, 1501, 1550, 2500, and 2508.[1]

In addition to environmental air sampling, plant processes and employee work practices were observed to identify potential workplace hazards not already addressed by the two interim reports mentioned in the Introduction Section.

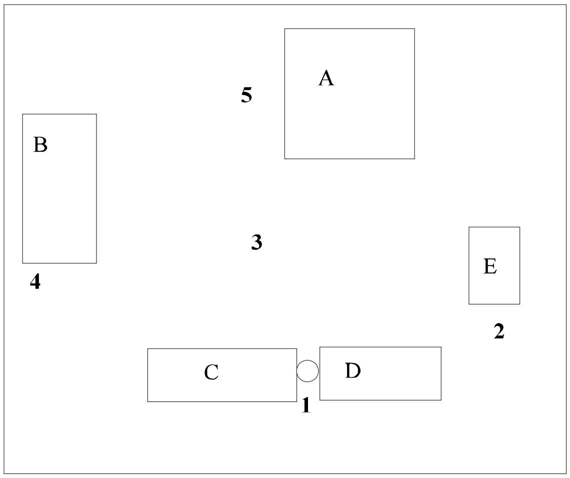

Figure 1
Silk Screen Department
HETA 95-0308

Numbers are Area Sample locations

A = Automatic Silk Screen Table
B = Large Silk Screen Table
C = Large Silk Screen Table
D = Silk Screen Cleaning Table
E = Small Silk Screen Table

EVALUATION CRITERIA

Table 1 (tables are located at the end of the report) lists the chemicals that were selected for sampling and specific health effects associated with the chemicals.[2] Sufficient worker exposures to these chemicals either collectively or singly could result in lethargy or a subjective feeling of inebriation due to central nervous system effects.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs)[2], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs®)[3], and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs)[4]. In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed in the current Code of Federal Regulations (CFR). The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet exposure limits specified by the OSHA standard, and that OSHA PELs included in this report reflect the 1971 values.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8 to 10-hour workday. Some substances have a short-term exposure limit (STEL) for a 10 to 15 minute exposure period, or a ceiling (C) exposure limit not to be exceeded for any amount of time. These STEL or C limits are intended to supplement an 8 to 10-hour TWA when there are recognized toxic effects from higher exposures over short time periods.

Table 2 lists the chemicals sampled and the NIOSH, ACGIH, and OSHA exposure criteria for each chemical. These exposure criteria have been derived from human and animal toxicological data and from industrial experience. The objective of these criteria is to establish levels of exposure to which most workers may be exposed, from 8 to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. Differences between the NIOSH RELs, OSHA PELs, and ACGIH TLVs® may exist because of different philosophies and interpretations of technical information.

Not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase overall exposures. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent becomes available. A "skin" notation in Table 2 indicates significant absorption of the chemical may occur through the skin.

Effects of chemicals in a mixture may be additive if the chemicals produce similar health effects. In the case of chemicals in Table 2, the similar health effects are nervous system effects. A formula referenced in the ACGIH TLV® booklet[3] was used to determine if exposures to the ingredients of a mixture of chemical vapors resulted in an overexposure to the mixture as a whole. This formula returns a value of 1.0 if the TLV® for the mixture has been equaled, a value less than 1.0 if the TLV® has not been exceeded, and a value greater than 1.0 if the TLV® has been exceeded.[5] The exposure limits chosen to calculate the mixture TLV® were the lowest of the standards proposed by NIOSH, the ACGIH, and OSHA.

OBSERVATIONS

During the March 27 and 28 NIOSH survey, all four screen printers wore N-DEX™ nitrile gloves, safety glasses, polymer aprons, and full-facepiece, Survivair® model 420010, powered air-purifying respirators (PAPR) fitted with three organic vapor cartridges (OVCs) while working. Under the protective equipment, the workers wore street clothes and shoes.

Immediately prior to silk screening, the screen printers actuated their PAPRs and the main ventilation system. The ventilation system remained on throughout the work shift. The screen printers produced a variety of signs in batches at the automatic silk screening table and at manual silk screening tables. The type, concentration, and duration of chemical exposures varied according to the proximity of the workers to specific inks, thinners, and solvents.

The following inks, thinners, and solvents were used during screen printing on March 27: 3M Brand Scotchlite 845 High Intensity Black Ink, 3M Brand 891 Thinner, Summit Brand K-24567 Engineering Grade Black Ink, Summit Brand K-14003 Thinner, Summit Brand 700 Black Ink, Summit Brand 41116 High Intensity Black Ink, Stoddard solvent, and xylene. On March 28, all of these inks, thinners, and solvents were used except the Summit Brand K-24567 Engineering Grade Black Ink.

On both days xylene or Stoddard solvent-soaked rags were used to dissolve and absorb ink from the screens during cleanup. The workers switched from the thin nitrile N-DEX gloves to a mid-forearm length nitrile rubber glove when handling solvent-soaked rags.

On March 28, 1996, two screen printers reported the same feelings of lethargy and inebriation that all four of the screen printers reported during the September 6 and 7, 1995, NIOSH surveys. The workers associate the feelings of lethargy and inebriation with exposures to high-intensity inks.

The screen printers and an ODOT manager stated that workers decide when to replace respirator OVCs. There is no written schedule to help workers decide when to replace the OVCs.

Work practice and respiratory program recommendations that were listed in the recommendations section of the November 20, 1995, report were instituted by the time of the March 1996 visit. However, polyvinyl alcohol (PVA) gloves were not in use when handling screen cleaning solvents, and work clothing was not sealed in a container or plastic bag to prevent exposures to solvent vapors when returning the work clothing to worker residences.

RESULTS

Results of the environmental air sampling are listed in Tables 3 through 8. Unless otherwise noted, concentrations are based on full-shift TWA exposures (in parts analyte per million parts air [ppm]). Minimum quantifiable concentrations (MQC) are noted in the tables in ppm with the exception of Stoddard solvent. Stoddard solvent concentrations are expressed in milligrams solvent per cubic meter of air (mg/m^3) in order to compare exposures to Stoddard solvent exposure limits expressed in mg/m^3. The MQC is based on the limit of quantification (LOQ), which is the smallest quantity of analyte that can be quantified with an acceptable level of precision. The MQCs are calculated by dividing each LOQ by the sampling volume of each sample.

Three chemicals were not detected (ND) during the course of all area and personal air sampling: n-pentane, 1,2-dichloroethylene, and toluene. Four chemicals were present below the sample MQC. The range of sample MQCs (in ppm) for these chemicals are: acetone; 0.10 to 0.28 ppm, 1,1,1-trichloroethane; 0.05 to 0.19 ppm, n-propyl acetate; 0.03 to 0.14 ppm, and methyl isobutyl ketone; 0.03 ppm.

Full-shift Area Samples

Among five full-shift area samples collected on March 27, 2-ethoxyethyl acetate (2EGEEA), isophorone, and Stoddard solvent were detected above their respective MQCs (see Table 3). Concentrations of these chemicals did not exceed full-shift TWA exposure limits. The concentrations of 2EGEEA ranged from below the MQCs to 0.31 ppm; MQCs were 0.05 ppm. All five samples analyzed for isophorone and Stoddard solvent found concentrations above respective MQCs. Isophorone concentrations ranged from 0.23 to 0.38 ppm. Stoddard solvent concentrations ranged from 8.9 to 13 mg/m^3.

Among five full-shift area samples collected on March 28, 2EGEEA, isophorone, and Stoddard solvent were detected above the MQCs (see Table 4). The 2EGEEA sample concentrations ranged from ND to 0.11 ppm. Four of five samples contained isophorone, and five contained Stoddard solvent. No concentrations exceed full-shift TWA exposure limits. Isophorone concentrations ranged from ND to 0.26 ppm. Stoddard solvent concentrations ranged from 2.3 to 8.6 mg/m^3.

Full-shift Personal Samples

Among four full-shift personal samples collected on March 27, 2EGEEA, isophorone, and Stoddard solvent were detected above trace concentrations (see Table 5). Three of the four 2EGEEA concentrations (0.52, 0.78, and 0.87 ppm) exceeded the full-shift TWA NIOSH REL for 2EGEEA. All four samples contained isophorone and Stoddard solvent; no concentrations exceeded full-shift TWA exposure limits. Isophorone concentrations ranged from 0.53 to 0.66 ppm. Stoddard solvent concentrations ranged from 13 to 31 mg/m^3.

One full-shift personal sample was collected on March 28. The sample contained 2EGEEA, isophorone, and Stoddard solvent above the MQCs (see Table 6). The 2EGEEA concentration (0.74 ppm) exceeded the full-shift TWA NIOSH REL for 2EGEEA. The isophorone concentration was 0.35 ppm. The Stoddard solvent concentration was 27 mg/m^3.

Partial-shift Personal Samples

Two partial-shift personal samples were collected on March 28. Methyl ethyl ketone (MEK), 2EGEEA, isophorone, and Stoddard solvent were detected above the MQCs (see Table 6). No concentrations exceeded full-shift TWA exposure limits. The MEK concentration above the MQC was 0.09 ppm. The 2EGEEA concentrations were 0.19 and 0.27 ppm. Isophorone concentrations were 0.51 and 0.77 ppm. Stoddard solvent concentrations were 22 and 23 mg/m^3.

Seven partial-shift personal samples were collected on March 27. The duration of these samples was limited to approximately 15 minutes for comparison of concentrations to 15-minute STELs or 15-minute TWA C exposure limits. Isophorone and Stoddard solvent were detected above MQCs; neither exceeded TWA STEL or C exposure limits (see Table 7). Isophorone concentrations ranged from ND to 1.2 ppm. Stoddard solvent concentrations ranged from below the MQCs to 26 mg/m^3.

Two partial-shift, task-length samples were collected on March 28. Only isophorone was detected (0.64 and 0.90 ppm) above the MQCs; full-shift TWA exposure limits were not exceeded (see Table 8).

Mixture Calculations

As mentioned in the Evaluation Criteria section, the TLV® for the mixture of chemical concentrations above the MQCs was calculated (see Tables 3 through 8).

Three full-shift personal samples collected on March 27 detected mixture concentrations that exceeded the limit of 1.0 (1.2, 1.8, and 2.0) (Table 5). One full-shift personal sample collected on March 28 indicated a mixture TLV® of 1.7 (Table 6).

DISCUSSION

The chemical 2EGEEA (a glycol ether) was present in occupationally significant concentrations. Four of five personal samples measured 2EGEEA concentrations which exceed the 2EGEEA full-shift TWA NIOSH REL of 0.5 ppm (see sample #'s 1, 4, and 3 in Table 5 and sample # 18 in Table 6).

Historically, ACGIH TLVs® for 2EGEEA have been reduced from 100 ppm to 5 ppm as a result of toxicity studies in the 1980's that linked 2-ethoxyethanol (2EE) and 2-methoxyethanol (2ME) to reproductive effects. These reproductive effects were also associated with 2EGEEA since the acetate of 2EGEEA is hydrolyzed in the body, yielding 2EE. The OSHA PEL for 2EGEEA, 100 ppm, has not changed, nor was change proposed during the 1989 OSHA rulemaking on air contaminant PELs.[6]

In 1983, NIOSH urged employers to reduce exposures to 2ME and 2EE to the lowest extent feasible, and extended this reduction to structurally related glycol ethers such as 2EGEEA.[7] Later toxicity studies of 2ME, 2EE, and structurally related glycol ethers resulted in NIOSH RELs of 0.5 ppm for both 2EGEEA and 2EE.[7]

The subchronic inhalation of 600 ppm of 2EGEEA by dogs after 120 seven hour exposures resulted in a small increase in sulfobromophthalein retention, which suggests liver injury. In addition, the dogs experienced eye and nasal passage irritation. Liquid 2EGEEA can be absorbed through the skin; however, the lethal dose in the rabbit was found to be relatively large. Approximately equal degrees of testicular atrophy have been reported by oral administration of 2EE and its acetate ester, 2EGEEA.[6] Since the acetate of 2EGEEA is hydrolyzed in the body to 2EE, reproductive effects associated with 2EE may occur from 2EGEEA exposure. Effects of 2EE exposure include embryonic deaths and fetal abnormalities in females, and testicular atrophy in males. However, these effects were elicited in animals after administration of 2EE by mouth or injected under the skin.[7]

Human reproductive effects from inhalation of 2EE include significant increases in the rate of birth defects among female enamelers compared with controls at an enameling plant. The concentrations of 2EE were characterized as "low." There was no difference in the incidence of gynecological disorders between enamelers and administrative workers, but these disorders were 2.6 to 9.4 times the incidence rate found in other comparison groups.[7] The ACGIH reports no records of adverse worker health effects from 2EGEEA exposure; likely because its "vapors are objectionable at concentrations necessary to cause adverse effects."[6]

Concentrations of 2EGEEA that are close to the REL, as measured in the silk screening department, are not likely to be associated with overt central nervous system effects.

Chemical Mixtures

Environmental sampling performed during March 27 and 28 indicates that concentrations of 2EGEEA in particular, as well as MEK, isophorone and Stoddard solvent contributed to mixture TLV® values which exceeded the limit (1.0) for a mixture of these chemicals.

The mixture TLV® is based on combined or additive effects. The common health effect of MEK, 2EGEEA, isophorone, and Stoddard solvent of interest in contributing to feeling of inebriation is the additive or combined nervous system effect.

Concentrations of MEK, isophorone, and Stoddard solvent, when combined in the mixture TLV® equation, do not come close to exceeding the mixture TLV®. The mixtures exceed the 1.0 TLV ® only when 2EGEEA concentrations are added to the mixture equations. *Based on the large contribution of the 2EGEEA concentrations to the mixture TLVs®, and toxicological data that indicates 2EGEEA does not produce central nervous system effects at the 2EGEEA concentrations measured,* the mixture TLV® values that exceed the limit of 1.0 are not likely to produce a feeling of inebriation or lethargy. This conclusion is based on the assumption that the sampled components act additively in eliciting health effects, rather than synergistically, or by some other mechanism.

This environmental assessment only indicates that there was no obvious explanation for the feeling of inebriation and lethargy, based on sampling a few chemicals with exposure limits. A majority of the chemicals to which silk screeners are exposed do not have exposure limits, therefore the effects of exposures to the mixture of chemical vapors as a whole are virtually impossible to completely assess.

Worker Lethargy

Silk screening does not appear to be physically demanding. However, it is perceptually demanding in that screen printers must maintain care and concentration to properly prepare and align the sign blanks, print signs, and remove and stack printed signs. A lack of concentration and care in any of these repetitive activities can result in poor ink adhesion, poor image transfer, or damage to a freshly printed image.

Silk screening tasks require repetitive, monotonous motions which require a constant state of alertness. Setup, printing, and cleaning activities do not deviate a great deal from day to day. Silk screening requires hundreds of repetitions of the same movements throughout the course of a work shift. The monotony of these activities are complimented by isolation of the worker by respirator use that interferes with speech, and background noise from the ventilation system which interferes with hearing.
Studies have demonstrated that prolonged repetitive work that is not very difficult, yet does not allow the operator to think about other things may give rise to boredom. Some industrial conditions make boredom more likely: brief cycles of operations, few bodily movements, dimly lit or warm work rooms, and solitary work without contacts with other workers. Boredom may contribute to stress, weariness, lethargy, and diminished alertness in light effort and perceptually demanding work.[8,9]

Personal factors have a role in the ability of individuals to withstand boredom. Boredom is more likely to affect:[8,9]

- Workers in a state of fatigue
- Not adapted night workers
- Workers with low motivation and little interest
- Workers with a high level of ability, knowledge, or education
- Keen workers, who are eager for a demanding job

Boredom is less likely for:[8,9]

- Workers who are fresh and alert
- Workers who are still learning
- Workers who are content with a job because it suits their abilities

CONCLUSIONS

Based on air sampling data, the maximum TWA concentration of 2EGEEA measured in the breathing zones of screen printers was 0.87 ppm (see Table 5), roughly 1.7 times the NIOSH REL of 0.5 ppm. This exposure level can plausibly result in reproductive health effects, but is not likely to produce nervous system effects resulting in feelings of inebriation and lethargy. If properly maintained, the full-facepiece PAPRs worn by the screen printers provide adequate protection for up to 50 times the NIOSH REL for 2EGEEA.

According to the NIOSH respirator decision logic, respirators are the least desired means of controlling workplace exposures to chemicals because they can be unreliable, require worker cooperation, and can result in adverse physiological effects.[10] Screen printers expressed dissatisfaction with respirators due to the effect of environmental heat on respirator comfort.

Currently, no ODOT silk screening department guidelines address the storage and maintenance of respirator masks and OVCs. Currently no program is in place to monitor worker exposure and exposure controls.

The ODOT plans to install a local exhaust ventilation system which will likely result in lowered concentrations of chemicals such that the need for respiratory protection will be greatly reduced or eliminated. This practice is in accordance with 29 CFR 1910.1000, which states that compliance with air contaminants exposure standards should be achieved first by administrative or engineering controls whenever feasible.

Based on air sampling data, mixed concentrations of 2EGEEA, isophorone, Stoddard solvent, and MEK can combine to exceed an effective exposure limit for the mixture. However, the additive effect of exposures to the sampled mixture of individual chemicals, each with nervous system and other health effects, cannot explain the feelings of lethargy and inebriation experienced by screen printers. However, the air sampling data cannot rule out the possibility that the mixture of sampled and unsampled chemicals could have contributed to feelings of inebriation and lethargy.

Repetitive, monotonous tasks associated with silk screening could also be the primary contributing cause of lethargy.[8,9]

RECOMMENDATIONS

The ODOT should install a newly designed local exhaust ventilation system which will control worker exposures to vapors emitted from processes associated with manufacturing silkscreened signs.

The ODOT should institute methods to identify materials (chemical ingredients of inks and thinners, for example) and physical agents (heat, for example) that may result in adverse health effects. These methods can include a combined approach of employee exposure assessment and monitoring and hazard identification by examining the use of new, existing, and modified materials or processes.

The ODOT should perform facility inspections and develop maintenance programs to assess methods used to control employee exposures (for example, ventilation systems and respirators).

Until local exhaust ventilation is installed, the use of respirators should continue. As a general rule, a PAPR equipped with a full-facepiece and OVCs provides protection from concentrations of 2EGEEA up to 50 times the NIOSH REL. Other practical options for respiratory protection include: an OVC equipped PAPR with a loose-fitting hood or helmet (protection up to 25 times the 2EGEEA REL); an OVC equipped full-facepiece respirator (protection up to 50 times the 2EGEEA REL); and an OVC equipped half-mask respirator (protection up to 10 times the 2EGEEA REL). If eye irritation results from exposures to solvent vapors, a full-facepiece respirator is recommended.[10]
The ODOT should devise a written respirator maintenance program based on recommendations in the NIOSH Guide to Industrial Respiratory Protection and the NIOSH Guide to the Selection and Use of Particulate Respirators Certified under 42 CFR 84.

Workers and management at ODOT must maintain adequate protection from vapors and gases by replacing air-purifying OVCs on a regular basis. The NIOSH Respirator Decision Logic contained in the NIOSH Guide to Industrial Respiratory Protection encourages employers to use caution when relying on air-purifying sorbent respirator cartridges. Currently, no general service life information is available for air-purifying OVCs used for protection against essentially all gases and vapors. Employers should possess valid and reliable estimates of service lives for all OVCs used in the respiratory protection program. Service life test data should be representative of all conditions of intended use that can be reasonably anticipated. Factors known to affect the service lives of OVCs include, but are not limited to, the make and model of OVC, air concentrations of contaminants, and relative humidity. When appropriate service life data are available, any reliance on the data should be undertaken with caution and with recognition of the limitations and uncertainties of the information. It is recommended that ODOT consult with the OVC manufacturer in order to obtain OVC service life data and advice in developing a schedule for replacing the OVCs on a regular basis.[10]

Boredom may contribute to the lethargy experienced by screen printers. The following two principles of job design should be applied to silk screening tasks to determine if the principles have an effect on reducing feelings of lethargy experienced among screen printers. The principles are:

- make tasks easier to do by:[8,9]
  - reducing environmental fatigue enhancers, such as:
    - highly repetitive, monotonous tasks
    - isolation of the worker
    - awkward posture requirements
    - high heat and humidity
    - high noise levels
    - glare
    - nonadjustable workplaces
- vary the tasks by:[8,9]
  - alternating physically demanding tasks with perceptually demanding tasks where possible
  - alternating perceptually demanding tasks with ones having lower demands
  - alternating long-cycle tasks with shorter cycle ones, even for short periods
  - rotating tasks among workers
  - providing a break schedule every half-hour (by rotation or some other means) for people doing continuous tasks

REFERENCES

1. NIOSH [1994]. Eller PM, ed. Draft: NIOSH

manual of analytical methods. 4th ed. supplement. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 94-113.

2. NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

3. ACGIH [1995]. 1995-1996 Threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

4. CFR [1994]. 29 CFR 1910.1000. Washington, DC: U.S. Government Printing Office, Federal Register.

5. ACGIH [1992]. Industrial ventilation; a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists, Inc.

6. ACGIH [1991]. Documentation of the threshold limit values and biological exposure indices. 6th ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

7. NIOSH [1983]. Current Intelligence Bulletin 39: glycol ethers; 2-methoxyethanol and 2-ethoxyethanol. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 83-112.

8. Rogers SH [1986]. Ergonomic design for people at work. Vol. 2. New York, NY: Van Nostrand Reinhold Company, pp. 222 - 227.

9. Grandjean E [1980]. Fitting the task to the man. 4th ed. Bristol, PA: Taylor & Francis Inc., pp. 187 - 194.

10. NIOSH [1987]. NIOSH respirator decision logic. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 87-108.

TABLE 1

Chemicals Selected for Sampling and Health Effects Associated with the Chemicals
March 27 and 28, 1996

Ohio Department of Transportation, Columbus, Ohio HETA 95-0308

Chemical	Health Effect[1]
acetone *Class: ketones*	Narcosis; Central Nervous System (CNS) depression; eye, nose, throat, and skin irritation
1,2- dichloroethylene	Narcotic effects, mucous membrane irritation
ethylene glycol monoethyl ether acetate (2-ethoxyethyl acetate or 2EGEEA) *Class: glycol ethers*	Reproductive and developmental effects; blood, CNS, and hematopoietic system effects
isophorone *Class: ketones*	Irritation; liver, kidney, and nervous system effects
methyl ethyl ketone (2-butanone) *Class: ketones*	Irritation; liver, kidney, and nervous system effects
methyl isobutyl ketone (hexone) *Class: ketones*	Irritation; liver, kidney, and nervous system effects
n-pentane *Class: alkane*	Skin and nervous system effects
n-propyl acetate	Conjunctival and upper respiratory irritation; narcosis in animals
Stoddard solvent *Class: refined petroleum solvents*	Eye, nose, and throat irritation; dermatitis, nervous system effects
toluene	CNS depression
1,1,1- trichloroethane (methyl chloroform) *Class: chloroethanes*	CNS, liver, and cardiovascular effects

1 = NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements.

TABLE 2

Chemicals Sampled and Occupational Exposure Limits
March 27 and 28, 1996

Ohio Department of Transportation, Columbus, Ohio HETA 95-0308

Chemical	Occupational Exposure Limits (ppm unless designated in milligrams per cubic meter, mg/m^3)		
	NIOSH REL[1]	ACGIH TLV®[2]	OSHA PEL[3]
acetone	250-TWA	750-TWA 1000-STEL 500-TWA[4] 750-STEL[4]	1000-TWA
1,2-dichloroethylene	200-TWA	200-TWA	200-TWA
2-ethoxyethyl acetate (2EGEEA)	0.5-TWA[skin]	5-TWA[skin]	100-TWA[skin]
isophorone	4-TWA	5-C	25-TWA
methyl ethyl ketone	200-TWA 300-STEL	200-TWA 300-STEL	200-TWA
methyl isobutyl ketone	50-TWA 75-STEL	50-TWA 75-STEL	100-TWA
n-pentane	120-TWA 610-STEL	600-TWA 750-STEL 600-TWA[4] NO STEL[4]	1000-TWA
n-propyl acetate	200-TWA 250-STEL	200-TWA 250-STEL	200-TWA
Stoddard solvent	350 mg/m^3-TWA 1800 mg/m^3-STEL	525 mg/m^3-TWA	2900 mg/m^3-TWA
toluene	100-TWA 150-STEL	50-TWA[skin]	200-TWA 300-C 500-10 min. STEL ABOVE CEILING
1,1,1-trichloroethane	350-C	350-TWA 450-STEL	350-TWA

1 = NIOSH Recommended Exposure Limit
2 = ACGIH Threshold Limit Value
3 = OSHA Permissible Exposure Limit
4 = Proposed changes to existing TLVs® as noted in the ACGIH Notice of Intended Changes for 1996-1997
skin = significant absorption of the chemical may occur through the skin

TABLE 3

Area Sample Full-Shift Time-Weighted Average (TWA) Concentrations
for Comparison to Full-Shift Occupational Exposure Standards
March 27, 1996

Ohio Department of Transportation, Columbus, Ohio HETA 95-0308

Location # (see Figure 1) / Chemicals in use within proximity of sample	Sampling Period	Sample Number	Sample Volume (liters)	TWA Concentration						Effective Exposure for Mixture[1]
				2EGEEA[2] (ppm)	MQC[3]	isophorone (ppm)	MQC	Stoddard solvent (mg/m^3)	MQC	Quantifiable Chemicals[4]
#1 / 3M Scotchlite 845 HI Black Ink, 3M 891 Thinner, xylene	0845 - 1155 1237 - 1426	10	60	0.31	0.05	0.23	0.02	8.9	1.3	0.69
#2 / Summit 700 Black Ink, Summit K-14003 Thinner, Stoddard solvent	0846 -1155 1237 - 1426	9	60	0.27	0.05	0.27	0.02	9.8	1.3	0.64
#3 / 3M Scotchlite 845 HI Black Ink, 3M 891 Thinner, xylene, Summit 41116 HI Black Ink, Summit K-14003 Thinner, Summit 24567 Engineering Grade Black Ink, Summit 700 Black Ink, Stoddard solvent	0848 - 1155 1237 - 1426	8	59	(0.02)[5]	0.05	0.35	0.02	13	1.3	0.12
#4 / No active silk screening in area	0851 - 1155 1237 - 1426	6	59	(0.02)	0.05	0.32	0.02	12	1.3	0.11
#5 / 3M Scotchlite 846 HI Black Ink, 3M 891 Thinner, xylene	0849 - 1155 1237 - 1426	7	59	(0.02)	0.05	0.38	0.02	13	1.3	0.13
Full-Shift TWA Occupational Exposure Standards										
NIOSH REL				0.5 -TWA		4 -TWA		350 -TWA		
ACGIH TLV®				5.0 -TWA		none		525 -TWA		
OSHA PEL				100 -TWA		25 -TWA		2900 - TWA		

1 = See discussion in the Evaluation Criteria section.
2 = 2-ethoxyethyl acetate
3 = Minimum Quantifiable Concentration
4 = Effective exposure based only on chemicals present above the MQC.
5 = ( ) Concentration is below the MQC.

TABLE 4
Area Sample Full-Shift Time-Weighted Average (TWA) Concentrations
for Comparison to Full-Shift Occupational Exposure Standards
March 28, 1996
Ohio Department of Transportation, Columbus, Ohio HETA 95-0308

Location # (see Figure 1) / Chemicals in use within proximity of sample	Sampling Period	Sample Number	Sample Volume (liters)	TWA Concentration						Effective Exposure for Mixture[1]
				2EGEEA[2] (ppm)	MQC[3]	isophorone (ppm)	MQC	Stoddard solvent (mg/m^3)	MQC	Quantifiable Chemicals[4]
#1 / 3M Scotchlite 845 HI Black Ink, 3M 891 Thinner, xylene, Summit 700 Black Ink, Summit K-14003 Thinner, Stoddard solvent	1120 - 1144 1330 - 1517	16	26	ND[5]	0.11	0.26	0.04	7.8	2.9	0.09
#2 / Summit 41116 HI Black Ink, Summit K-14003 Thinner, Stoddard solvent	1121 -1144 1330 - 1516	13	26	ND	0.11	0.15	0.04	5.1	3.0	0.05
#3 / 3M Scotchlite 845 HI Black Ink, 3M 891 Thinner, xylene, Summit 41116 HI Black Ink, Summit K-14003 Thinner, Summit 700 Black Ink, Stoddard solvent	0927 - 1144 1332 - 1451	21	43	0.11	0.06	ND	0.03	2.3	1.8	0.23
#4 / 3M Scotchlite 845 HI Black Ink, 3M 891 Thinner, xylene, Summit K-14003 Thinner, Summit 700 Black Ink, Stoddard solvent	0923 - 1144 1332 - 1451	15	44	0.10	0.06	0.24	0.02	8.6	1.8	0.28
#5 / Summit 41116 HI Black Ink, Summit K-14003 Thinner, Stoddard solvent	0929 - 1144 1331 - 1451	14	43	(0.04)[6]	0.07	0.10	0.03	2.9	1.8	0.03
Full-Shift TWA Occupational Exposure Standards										
NIOSH REL				0.5 -TWA		4 -TWA		350 -TWA		
ACGIH TLV®				5.0 -TWA		none		525 -TWA		
OSHA PEL				100 -TWA		25 -TWA		2900 -TWA		

1 = See discussion in the Evaluation Criteria section.
2 = 2-ethoxyethyl acetate
3 = Minimum Quantifiable Concentration
4 = Effective exposure based only on chemicals present above the MQC.
5 = Not Detected
6 = ( ) Concentration is below the MQC

TABLE 5

Personal Sample Full-Shift Time-Weighted Average (TWA) Concentrations
for Comparison to Full-Shift Occupational Exposure Standards
March 27, 1996

Ohio Department of Transportation, Columbus, Ohio HETA 95-0308

Worker # / Chemicals in use	Sampling Period	Sample Number	Sample Volume (liters)	TWA Concentration						Effective Exposure for Mixture[1]
				2EGEEA[2] (ppm)	MQC[3]	isophorone (ppm)	MQC	Stoddard solvent (mg/m^3)	MQC	Quantifiable Chemicals[4]
#1 / 3M Scotchlite 845 HI Black Ink, 3M 891 Thinner, xylene, Summit K-24567 Engineering Grade Black Ink, Summit K-14003 Thinner, Stoddard solvent	0833 - 1137 1304 - 1451	1	12	0.78	0.24	0.66	0.09	31	6.6	1.8
#2 / Same as worker #1	0838 -1137 1306 - 1424	4	10	0.52	0.27	0.56	0.10	20	7.5	1.2
#3 / 3M Scotchlite 845 HI Black Ink, 3M 891 Thinner, xylene, Summit 700 Black Ink, Summit K-14003 Thinner, Stoddard solvent	0838 - 1041 1200 - 1408	3	10	0.87	0.28	0.53	0.11	29	7.7	2.0
#4 / 3M Scotchlite 845 HI Black Ink, 3M 891 Thinner, xylene, Summit 700 Black Ink, Summit K-14003 Thinner, Summit 41116 HI Black Ink, Stoddard solvent	0841 - 1040 1243 - 1349	5	7.4	(0.36)[5]	0.38	0.53	0.14	13	10	0.17
Full-Shift TWA Occupational Exposure Standards										
NIOSH REL				0.5 -TWA		4 -TWA		350 -TWA		
ACGIH TLV®				5.0 -TWA		none		525 -TWA		
OSHA PEL				100 -TWA		25 -TWA		2900 -TWA		

1 = See discussion in the Evaluation Criteria section.
2 = 2-ethoxyethyl acetate
3 = Minimum Quantifiable Concentration
4 = Effective exposure based only on chemicals present above the MQC.
5 = ( ) Concentration is below the MQC.

TABLE 6

Personal Sample Full and Partial-Shift Time-Weighted Average (TWA) Concentrations
for Comparison to Full-Shift Occupational Exposure Standards
March 28, 1996

Ohio Department of Transportation, Columbus, Ohio HETA 95-0308

Worker # / Chemicals in use	Sampling Period	Sample Number	Sample Volume (liters)	TWA Concentration								Effective Exposure for Mixture[1]
				MEK[2] (ppm)	MQC[3]	2EGEEA[4] (ppm)	MQC	isophorone (ppm)	MQC	Stoddard solvent (mg/m^3)	MQC	Quantifiable Chemicals[5]
#1 / Summit 41116 HI Black Ink, Summit K-14003 Thinner, Stoddard solvent	0922 - 1143 (Partial-shift)	20	28	0.09	0.07	0.19	0.10	0.51	0.04	22	2.7	0.57
#3 / 3M Scotchlite 845 HI Black Ink, 3M 891 Thinner, xylene	1003 -1133 1326 - 1520 (Full-shift)	18	41	(0.04)[6]	0.05	0.74	0.07	0.35	0.03	27	1.9	1.7
#4 / Same as Worker #1	0950 - 1143 (Partial-shift)	17	23	(0.06)	0.09	0.27	0.12	0.77	0.05	23	3.4	0.80
Full-Shift TWA Occupational Exposure Standards												
NIOSH REL				200 - TWA		0.5 -TWA		4 -TWA		350 -TWA		
ACGIH TLV®				200 - TWA		5.0 -TWA		none		525 -TWA		
OSHA PEL				200 - TWA		100 - TWA		25 -TWA		2900 - TWA		

1 = See discussion in the Evaluation Criteria section.
2 = methyl ethyl ketone
3 = Minimum Quantifiable Concentration
4 = 2-ethoxyethyl acetate
5 = Effective exposure based only on chemicals present above the MQC.
6 = ( ) Concentration is below the MQC.

TABLE 7

Personal Partial-Shift Time-Weighted Average (TWA) Concentrations for Comparison
to Short-Term 15-minute TWA Occupational Exposure Standards
March 27, 1996

Ohio Department of Transportation, Columbus, Ohio HETA 95-0308

Worker # / Chemicals in use	Sampling Period	Sample Number	Sample Volume (liters)	TWA Concentration				Effective Exposure for Mixture[1]
				isophorone (ppm)	MQC[2]	Stoddard solvent (mg/m^3)	MQC	Quantifiable Chemicals[3]
#1 / 3M Scotchlite 845 HI Black Ink, 3M 891 Thinner, xylene	0950 - 1008	34	3.6	1.2	0.30	26	21	0.37
#1 / Summit K-24567 Engineering Grade Black Ink, Summit K-14003 Thinner, Stoddard solvent	1415 - 1431	32	3.2	0.61	0.33	(19)[4]	24	0.15
#2 / 3M Scotchlite 845 HI Black Ink, 3M 891 Thinner, xylene	0947 - 1003	2	3.2	1.0	0.33	(20)	24	0.25
#3 / 3M Scotchlite 845 HI Black Ink, 3M 891 Thinner, xylene	0937 - 1000	35	4.6	0.86	0.23	(14)	17	0.21
#3 / Summit 700 Black Ink, K-14003 Thinner, Stoddard solvent	1246 - 1302	11	3.2	ND[5]	0.11	ND	24	0.0
#4 / Summit 700 Black Ink, K-14003 Thinner, Stoddard solvent	1309 - 1325	33	3.2	0.37	0.32	ND	24	0.09
#5 / Easiway 201 Screen Remover	1332 - 1346	12	2.8	0.41	0.38	ND	28	0.10
Short-Term Exposure Limit (STEL) or Ceiling (C) TWA Occupational Exposure Standards								
NIOSH REL				none		1800-STEL		
ACGIH TLV®				5 -C[6]		none		
OSHA PEL				none		none		

1 = See discussion in the Evaluation Criteria section.
2 = Minimum Quantifiable Concentration
3 = Effective exposure based only on chemicals present above the MQC.
4 = (   ) Concentration is below the MQC.
5 = Not Detected
6 = STEL and C limits based on 15-minute TWA

TABLE 8

Personal Partial-Shift Time-Weighted Average (TWA) Concentrations for Comparison to Short-Term 15-minute TWA Occupational Exposure Standards
March 28, 1996

Ohio Department of Transportation, Columbus, Ohio HETA 95-0308

Worker # / Chemicals in use	Sampling Period	Sample Number	Sample Volume (liters)	TWA Concentration		Effective Exposure for Mixture[1]
				isophorone (ppm)	MQC[2]	Quantifiable Chemicals[3]
#1 / Summit 41116 HI Black Ink, Summit K-14003 Thinner, Stoddard solvent	0951 - 1010	19	3.8	0.64	0.28	0.16
#3 / Summit 700 Black Ink, Summit K-14003 Thinner, Stoddard solvent	1416 - 1431	22	3.0	0.90	0.35	0.22
Short-Term Exposure Limit (STEL) or Ceiling (C) TWA Occupational Exposure Standards						
NIOSH REL				none		
ACGIH TLV®				5 -C[4]		
OSHA PEL				none		

1 = See discussion in the Evaluation Criteria section.
2 = Minimum Quantifiable Concentration
3 = Effective exposure based only on chemicals present above the MQC.
4 = C limit based on 15-minute TWA

NIOSH

Delivering on the Nation's promise:
Safety and health at work for all people
Through research and prevention