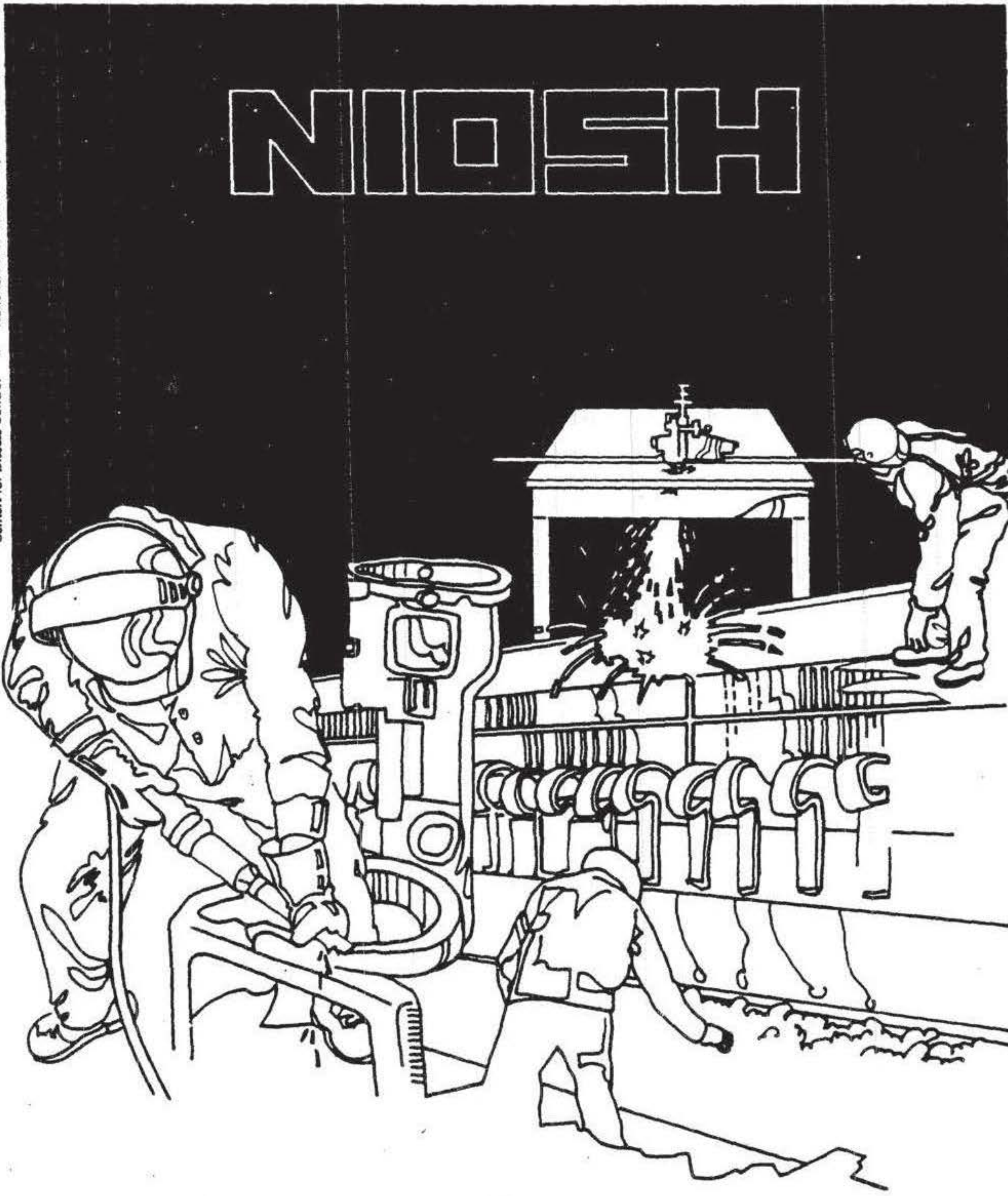
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
Centers for Disease Control ■ National Institute for Occupational Safety and Health



Health Hazard Evaluation Report

HETA 82-212-1553
SCREEN PRINTING SHOPS

PREFACE

The Hazard Evaluations and Technical Assistance Branch of 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 technical and consultative 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.

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SCREEN PRINTING SHOPS

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I. SUMMARY

In March 1982, the National Institute for Occupational Safety and Health (NIOSH) received a request to evaluate mixed solvent exposures for silk screen printing workers at five small printing shops in the Boston, Massachusetts and Denton, Maryland areas. Workers in these facilities had reported headache, nausea, vomiting, dizziness, and other symptoms.

Medical and industrial hygiene investigators conducted site visits to these facilities to evaluate exposures to solvents and associated health effects. Personal and area air samples were collected to characterize exposures to ethyl acetate, n-butyl acetate, 2-butoxyethanol, isophorone, hexane, heptane, toluene and xylene. Direct reading instruments were used to characterize brief, peak exposures to some of these solvents. Work diary reports were also collected in order to estimate solvent exposure. Urine samples were collected to evaluate exposures to xylene and toluene by measuring concentrations of their urinary metabolites, methyl hippuric and hippuric acid. Questionaires were administered to obtain information on neurological symptoms, and a battery of neurobehavioral tests were conducted to evaluate possible neurological effects from solvent exposure. These tests included continuous performance testing and a Profile of Mood States.

On screening workers at the facilities were found to have average toluene exposures of 14.2 ppm; xylene 3.4 ppm; and 2-butoxyethanol 6.8 ppm. All were below the evaluation criteria of 100 ppm, 100 ppm, and 25 ppm, respectively. Spray painters had slightly lower exposures, averaging 13.9 ppm for toluene, 1.1 ppm for xylene, and 0.3 ppm for 2-butoxyethanol. However, exposure of two of the nine personal samples for spray painters exceeded the evaluation criteria for the work day taking into account that the workers were exposed to a mixture of solvents. In addition, one screen cleaning and one blasting operation short-term mixed solvent exposure exceeded the short-term exposure criteria. Urinary metabolite testing results showed increasing absorption of toluene and xylene with increasing air concentrations of these solvents, even in the relatively low exposure ranges found in these evaluations. The work-diaries combined with task-specific environmental sampling proved to be a useful and reliable measure of daily exposure.

The 19 workers included in the medical study reported a prevalence of some neurological symptoms, notably headache and trouble remembering (36.8%). However, the number of employees in the unexposed group was small (4), and no symptom was reported significantly more often by the exposed group than by the unexposed group. Continuous performance testing results did not differ significantly over the workday in exposed and unexposed groups.

Based on the environmental monitoring conducted for these evaluations, a potential health hazard was found due to occasionally elevated exposures to solvents in screen printing operations. However, no major health problems were identified. Recommendations to assist in controlling exposures are included in the report.

SIC: 2751 (Screen Printing), Toluene, Xylene, 2-Butoxyethanol, neurobehavioral tests, continuous performance testing.

III. INTRODUCTION

On March 31, 1982, the General President of the International Brotherhood of Painters and Allied Trades requested a health hazard evaluation of workplace hazards associated with mixed solvent exposure in silk screen printing. The union received written permission from the owners of five silk screen print shops for members of the Health Hazard Evaluation (HHE) Program at the Harvard School of Public Health, in cooperation with NIOSH, to carry out a medical and environmental evaluation of their workplaces. Ownership of one shop changed shortly after we performed our walk through evaluation; further medical and environmental evaluations of this workplace were not performed.

This investigation was conducted to: 1) characterize the nature and extent of the airborne solvent exposure in silk screening operations; 2) estimate biologic dose for solvents whose urinary metabolites could be accurately and reliably measured; and 3) examine the relationship of solvent exposure, and uptake to neurologic symptoms, performance on neurobehavioral tests and urinary metabolite levels.

IV. A. Background Description of General Process

The silk screen printing process is a form of printing used primarily to print posters, signs, and other graphic materials. The operations included in this investigation involved five basic steps:

1. A positive image of the work to be printed is made (either by photographic process or hand cut).

2. This positive image is transferred to a special film material (either by arc or hand cut).

3. The film material is adhered to the screen and areas where no printing occurs are blocked out.

4. The base material is printed using various inks.

5. The screen is cleaned for reuse (removal of paint film and blocker), using various solvents.

The silk screen operations included in this investigation print primarily on plastic, vinyl, and poster-board, and to a lesser extent on metal. Each of these substrates uses its own ink/thinner/cleaner system. Each operation involves a set-up time which is often longer than actual printing and clean-up time.

B. Background: Description of Specific Work Sites
(Listed in chronological order of performance of evaluations)

Sam Johnson & Company (#82-215)

Employees and Work Process

There are seven workers in this plant; four in the shop and three in the office. In the printing process, the positive of the image and silk screen film are placed into a device which burns the image into the film with an arc-like light. A developer is added to develop the film and fixer 2is used to fix the image. The film is placed in the sink and washed.

The completed film is covered with either silk, nylon, or polyester and dried. The mylar backing is removed and the film remains on the screen. The silk screen printer aligns the screen on the press and paint is applied to the screen. The print is placed in a dryer to evaporate the solvent in the inks, leaving the pigment on the substrate. The dryers are vented into the room air. The plant has one semi-automatic and three automatic presses and two dryers. After the print comes out of the dryer, it is placed in a rack for further drying.

At the end of the day, a screen must be cleaned so that the paint doesn't set overnight. To accomplish this task, two cardboard squares 6"x3" (one in each hand) are used to scoop up the excess paint and return it to the paint can. The paint spreader is removed and scraped. The screen is cleaned with xylene (or lacquer thinner, depending on the paint) which is applied with clean rags. Rags are stored in drums and cleaned weekly. Rubber gloves are worn during this operation. The printer stands directly over or very close to the work piece while applying the solvents during screen cleaning.

During the final stages of cleaning, the screen is brushed with a heavy detergent and blasted with water to remove the blockout material. Lacquer thinner is applied with rags and the screen is rinsed again.

Materials

Materials used in the photographic process are Dupont* and Fuji A & B Developer and Fixer. General Formulations Blockout #11-195 is used in preparing the screen, which is thinned with methanol or methylene chloride.

The following Nazdar inks are used: #70000 Plasti-Vac gloss ink for plexiglass printing; #1100 Sty-Ra-Lac gloss ink for styrene printing; GV Gloss Vinyl ink for vinyl printing; Industrial Lacquer for printing on lacquer coated surfaces; #7500 Gloss posters and #5500 Flat poster for printing on paper and cardboard. Varsol is used only to thin particular paints- 7500 or 5500 paints. It is used by the printer and is not used for cleaning. Xylene is used for clean-up of these paints.

For lacquer, styrene or vinyl paints, a special thinner is used to thin each paint. Lacquer thinner is used for clean-up.

* A trade name-generic component summary table derived from material safety data sheets and other manufacturer-supplied information is provided elsewhere (Table 1).

Richard Screen Printing (#82-212)

Employees and Work Process

There are four employees. The owner does all the layout and oversees the running of the operation. One worker mixes the paints and supervises the printing, but does no printing. Another worker does all the printing, and the fourth person in the shop takes the finished silk screen prints off the press and places them on the dryer conveyor belt.

This plant is very small, consisting of one room with a large closet in one corner for the darkroom. Upstairs, there is a very small area in the attic where screens are washed with water.

The paints are mixed at the press in use. The press has local exhaust ventilation - a hood and two wall fans. The hood is vented through the back wall. A fan in the duct system helps pull the vapors and mist out. The dryer has a duct leading from the heater (which heats to 180 F) to the outside, but the inside of the dryer itself is not vented. All cardboard, paper, and vinyl prints are dried in the dryer; prints on metal (which is rarely done in this shop) are dried on the drying racks.

After printing, the screens are first cleaned with the appropriate solvent (see below) while still on the press. The screens are taken upstairs to the attic where they are washed with water and degreaser. This area is locted under the eaves in the attic (with exposed fiberglass insulation) and there is no ventilation.

Materials

The developer used is 3M Negative Color Key & Transfer Key Hand Developer 77-9800-7992-3. The area between the print area and the screen frame is filled in with blue filler: General Formulations. Blox #11-1965.

For cardboard and paper, the paints used are Poster Rich 526, and Serascreen 2323; thinner used is 590 reducing varnish; cleaning solvent is

Lamsol. For vinyl, the paints used are Nazdar plasti-Vac #70-159 Blue and other Nazdar Plastic-Vac; thinner used is Nazdar Thinner #5500; cleaning solvent is Master Chemical Lacquer Thinner 300. The degreaser used in clean-up is Lynch Products Ultra-Solu Degreaser.

Simard Litho (#82-213)

Employees and Work Process

Simard is a small print shop with six employees, and only two of whom work in silk screening operations. The other employees are involved in the artwork, word processing, or finish work.

The main floor is used for printing, artwork, and finish work. The printing operation is in the rear. There is a small, ventilated drying booth where prints are put after screening. The ventilation system is also connected to a nearby screen washing rack, which has overhead hood ventilation. The outlet for the ventilation was directly outside the rear door.

Downstairs is an unventilated darkroom, screen stretching table, arc set-up, and an unventilated screen washing booth where final screen clean-up is done.

Materials

The image for the screen is made by putting Autosol #2000, which is a photocoat, on the screen. Ulano #60 is a water-soluble screen filler and is placed around the edges of the screen to make the seal between the screen and the frame, thereby blocking out the areas where ink is not wanted. When printing on plastic, Nazdar #44000, Plastic-Vac #70000, or Tibbets Western Paint is used. For vinyl printing, Nazdar #44000 is used.

To obtain the proper consistency for printing, each paint has its own thinner. Plasti-Vac #70000 thinner is used for all plastic inks. Nazdar #44000 thinner is used for the vinyl inks. Nazdar #5500 and PPI #10000 poster series inks are used to print on poster paper; these are thinned with regular paint thinner (100% mineral spirits).

The screens are washed out with master Chemical #300 lacquer thinner to remove paint. To prepare each screen for reuse, the screens are washed with Seristrip and a mixture of Seripaste and Supersol. Each screen is then degreased with Screen Degreaser Liquid #3 Ulano; this is a water-soluble substance.

E. Wisewell, Jr., Inc. (#82-214)

Employees and Work Process

Wisewell is a small print shop with four employees, two of whom do the screen printing, a third assists in screen cleaning and other tasks and the fourth person does the artwork.

The operations take place on one floor. The only ventilation consists of two small window fans; one near the printing operation, the other near the screen cleaning area. Neither the photographic darkroom nor the screen printing booth are ventilated.

Workers in this plant complained of symptoms of acute solvent toxicity. Workers were provided with gloves for clean-up, but no other protective equipment such as aprons or masks.

The solvents used in the process are absorbed with cloth towels and stored in large cans. The rags are removed once a month for cleaning, and replaced. There is no particular area for drying the screens. They are left open on a large table in the center of the room to dry.

The main chemicals used are Nazdar block and the Ulano block, which is also water-soluble. For paper, the inks used are Nazdar #5500 series and the Serascreen Corp. #150. Vinyl plastic inks are the Nazdar #4400 or the Plasti-Vac #70000. The hard plastic inks are used with Plasti-vac

#70000. Plasti-vac #70000 inks must be cleaned with lacquer thinner. Paper and cardboard inks were the Nazdar #5500 series. Most of the work at Wisewell is cardboard work. Metal inks are the Nazdar #5900 and Serascreen. Screenwash is used to clean the metal inks.

Pine oil thinner is sometimes used to thin some of the inks. Xylene is used to thin all the inks and to clean the screen. Glacial acetic acid, Masterchemical screen wash #230, and #300 Masterchemical lacquer thinner are used to clean the screens.

Mulholland Harper Company (#82-216)

Employees and Work Process

Mulholland is a large sign manufacturing plant with 75 employees in six departments, which include the painting, electrical, machining, packing, welding, plastic forming, administrative, and finish work areas. There are maximum of 20 employees in the paint area.

The plant is a large, single-story building. The paint department is located in a separate room of the plant. The welding area is in a separate building.

When screening is done with KC ink, the film is put on with lacquer thinner. The others, including reprographic film, are put on when wet with water.

About 25% of the work is on metal (steel or aluminum) while about 75% is on plastic (polycarbonate or acrylic). The number of pieces and the number of hours it takes to make them are recorded for each job. Each worker records the number of hours they work on various tasks in the plant.

The plastic is generally screened and then formed into a desired shape on a vacuum table. Occasionally, if a small number of pieces are being made, the plastic is formed and sprayed rather than screened. Prior to spray painting the preformed plastic is sprayed with a film of mask. The parts to be painted are cut out and removed. Typically, eight employees perform screen printing full time although this number may range from two to twenty.

For the metal cleaning process, the metal is cleaned with alkali dip and etched with acid dip. The pieces are sprayed with one of a number of paints and put in an oven to bake. After removal from the oven, the pieces are machined. The paint is applied by spray in a booth. The booth is vented but the pieces are often large, so correct positioning is difficult. Two to four people work on this operation. Metal is also painted by roller coater in an unvented area. Cleaning of the silkscreens takes 10-15 minutes.

Materials

In preparation, the part of the screen not printed is covered with either Ulano #60 screen filler or Serascreen screen filler. In printing on plastic, methylene chloride is used to weld small pieces onto the plastic. Sometimes glue is used when the pieces to be attached are large.

Screening on plastic surfaces utilizes Spraylat-Lacryl paint or Wyandotte-Gripflex. Screening on metal surfaces utilizes KC Enamel Plus, Dupont Dulux, or Pittsburgh Duracron. For the metal applications, the amount of each type of paint was estimated:

50% Dupont Dulux (75 gal/mo)

20% KC Enamel Plus (30 gal/mo)

10% Pittsburgh Duracron (15 gal/mo)

Clean-up is initially done with xylene to remove the paint. Silkscreen cleaner is applied (40% acetone, 50% toluene, 10% secondary butyl alcohol) at the end of the job. Each paint has its own thinner.

V. METHODS

A. GENERAL METHODS - MEDICAL

Medical Testing

Continuous Performance Test

This test measures sustained visual attention by having the field study participant press a button upon seeing the letter "S" appear in a series of letters projected onto a video display terminal (Rosvold et al, 1956). The response time for each stimulus is recorded. Serial display of response times allows for computation of mean reaction time, learning effects noted during the early stage of the task and variability in attention which occurs during the latter part of the test. The proportions or omission and commission of errors are also recorded. Previous research in the areas of solvent toxicity (Baker and Smith, 1984) has used reaction time testing extensively as a measure of psychomotor function. The CPT uses the standard features of reaction time testing in a more demanding task which also evaluates sustained attention. The CPT was chosed for this Hazard Evaluation because previous studies of solvents used for screen printing suggest that they may have neurotoxic effects which alter visuomotor function such as hand-eye coordination, speed, and the ability to concentrate.

Profile of Mood States

The Profile of Mood States (POMS) has been widely used in the evaluation of the efficacy of psychotherapeutic drugs and, as such, the reproducibility of this self-administered questionnaire has been assessed and found to be acceptable (McNair, et al, 1978). Factor analysis of the 65 responses to the questionnaire has yielded six affective dimensions (tension, anger, depression, fatigue, confusion, and vigor) that receive scores by summing the responses to individual questions.

Medical Questionnaire

The Questionnaire (Appendix 2) is a work health history focusing on central and peripheral nervous system symptoms and confounding factors such as caffeine, alcohol and drug use. It has been developed over a period of several years for a series of neurotoxin evaluations.

Urinary Metabolites

Urine samples were collected for analyses of hippuric and methylhippuric acids, the metabolites of toluene and xylene respectively. These analyses were chosen because toluene and xylene are two of the most common solvent exposures in this population of silk screeners and the methods for their metabolite analyses has been previously established.

The high efficiency of metabolism of toluene and xylene has led to the formulation of methods which correlate urinary metabolites with solvent exposure. Because it is possible to collect the end-product of metabolism over several hours, urine analysis is often preferable to measurement of exhaled air or blood, which yield exposure data at a single point in time.

Exposure to toluene and xylene in the workplace can be estimated by determination of hippuric and methyl hippuric acids in urine samples from the last four hours of the work shift. Lauwerys (1983) has summarized the rationale for using mg metabolite/mg creatinine as the parameter which corresponds best with exposure. At low exposures, estimates of toluene exposure may be inaccurate because hippuric acid occurs naturally in the urine as a metabolite of certain foods. Dietary consitutents interfere with test analyses due to the presence of benzoic acid which is metabolized by a common pathway. It is desirable to obtain a dietary and drug history and a baseline "pre-exposure" urine sample from participants in the Hazard Evaluation. Methylhippuric acid is not a physiologic constituent of urine in nonsolvent exposed individuals, so dietary factors do not decrease the correlation of urinary methylhippurate with xylene absorption. Separation of methylhippuric acid into its M, P, and O isomers is usually unnecessary.

B. GENERAL METHODS - ENVIRONMENTAL SAMPLING AND EXPOSURE CHARACTERIZATION

To evaluate exposure levels over the work day, three types of conventional environmental samples were collected using sampling pumps and collection media of two types: area sampling, personal eight-hour sampling to obtain a time-weighted average exposure estimate, and task-specific sampling. In addition, continuous sampling using three direct reading instruments was performed to evaluate peak exposure levels associated with various operations. To supplement direct exposure measurements, work diaries were compiled by each worker specifying time spent in each task over the work day. Diaries were prepared by each worker for the day of personal and task-specific sampling as well as all previous days in the work week. Diary-derived data were combined with the results of task-specific environmental sampling to estimate workday exposures. Diary data from other days in the work week were used to estimate cumulative exposure over the work week and to determine the representativeness of exposure on the day of sampling. Further details on the exposure estimation process appear below under specific site descriptions and under the results section of this report.

C. GENERAL ANALYTIC METHODOLOGY (COMMON TO ALL SITES)

Based on material safety data sheets obtained during walk-through visits, a list of silk screening materials was developed for printing on each type of surface. A partial list of solvents found in the inks, washes and other products was developed (Table 1). It was decided, based on vapor pressure, toxicity and previous study results that exposures to six solvents should be directly quantified: ethyl acetate, toluene, N-butyl acetate, xylene, n-butoxyethanol and isophorone. A preliminary analytical scheme to separate these solvents was developed. However, desorption of butyl cellosolve (2-butoxyethanol) was poor using carbon disulfide so a mixed desorption solvent that would not interfere with the separation of the other solvents was needed. After several attempts, a solution of 45% carbon disulfide, 45% methylene chloride and 10% acetonitrile was used.

Desorption efficiencies were run for all six solvents combined at each of three concentrations for each sorbent type. The concentrations injected directly onto the sorbent were approximately 1.5 x TLV, 1.0 x TLV, 0.5 x TLV. The sorbents used were XAD-2 resin (8 x 110 mm 150 mg/75 mg, SKC #226-30-05) and charcoal (8 x 110 mm 400 mg/200 mg, SKC # 226-09).

D. SPECIFIC WORK SITES
(Listed in the order of performance of evaluations; summarized in Table 2)

Sam Johnsons and Co. (#82-215)

Subjects: Four employees working in this shop were evaluted. One person worked in the screening area but did not print. One employee cleaned screens and printed approximately 50% of the time. Two employees were full-time screeners (this work includes set-up and clean-up).

Environmental

Work Diaries

At the start of each work shift an investigator brought the work diary cards (Appendix 1) to the shop and distributed them to the employees with instructions for filling them out. The following morning the investigator returned to the work site, reviewed the cards from the previous day and distributed new cards for that day. This was done for the three days prior to medical testing. Each person was asked to record the job performed over the work day at 30-minute intervals.

Air Sampling

Twenty-four area samples were taken at Sam Johnson's and Co. These represent 12 side-by-side samples using and XAD-2 sorbent (8x110 mm, 150 mg/75 mg) and charcoal sorbent (400 mg/200 mg, 8 x 110 mm) set in an Acculator replicate sampler. Air was drawn through the tubes at approximately 2 cc/stroke.

Personal samples were taken on four workers in the morning and afternoon. Time weighted average samples were taken for the tasks of printing, blasting and cleaning. Each represents several individuals doing a single task at different times of the day.

Samples were analyzed for ethyl acetate, toluene, n-butyl acetate, xylene, 2-butoxyethanol, and isophorone concentration.

Direct reading instruments with chart recorders were used to identify peak exposures for various job tasks. The instruments used included the Miran infrared spectrophotometer, HNu photoionization detector and century OVA hydrocarbon analyzer.

<u>Medical</u>

<u>Urine collection</u>. Urine was collected in the morning (7:00 a.m.) before the start of the work shift and at the end of the work shift (4:00 p.m.), and refrigerated immediately after collection, and transferred to the laboratory for analysis within 24 hours.

<u>Questionnaires</u>. A health history questionnaire and a work history questionnaire (Appendix 2) were administered on the day of personal environmental sampling.

<u>Neurobehavioral testing</u>. The Continuous Performance Test (CPT) (Rosvold et al, 1956) was administered using personal computers at the worksite. The test was given to each person for five minutes, four times throughout the work shift and once again on the following Monday morning to obtain results after a period of no exposure. The Profile of Mood States (McNair et al, 1978) was also administered on the day of environmental testing.

Richard Screen Printing (#82-212)

A walk-through evaluation only was conducted at this location. This shop changed management after the first site visit and no further evaluation was possible.

Simard Litho(#82-213)

Subject. One full-time screener was included in the evaluation.

Environmental

Area Sample. One sample was collected on XAD-2 and charcoal simultaneously. This sample was analyzed for toluene and xylene.

Questionnaire. A health history questionnaire, work history questionnaire and the POMS test were administered on the day the area environmental sample was taken.

E.Wisewell Jr., Inc. (#82-214)

Subjects. Three employees in this shop who were screeners were included in this evaluation.

Environmental

Personal samples were taken for three workers in the morning and afternoon. Task samples were taken on the tasks of cleaning and screening.

Samples were analyzed for toluene and xylene. No direct reading instruments were used.

Medical

Urine collection. Urine from the three employees was collected, stored, and analyzed, as described above.

Questionnaires and Neurobehavioral Evaluation These phases were identical to those described above under Sam Johnsons and Co. with the exception that no CPT testing was performed on Monday morning.

Mulholland Harper & Co. (#82-216)

Subjects. Seventeen employees involved in the silk-screening operations were included in this evaluation. Thirteen "exposed" employees worked directly with solvents in the screening area of the plant. Four "nonexposed" employees worked full-time in the art room, located in a separate area of the plant. All subjects worked a 10-hour day (7:00 a.m. - 5:00 p.m.), 4-day work week.

Medical. Medical testing was conducted for each employee on the same day personal environmental samples were collected for that individual. The testing was conducted over a 3-day period.

Urine collection. Urine was collected in the morning before the start of the work shift for all individuals. Six individuals had urine samples collected at mid-day. All individuals had urine samples collected at the end of the work shift.

Questionnaire. A health history questionnaire, work history questionnaire and POMS test were administered on the same day as the personal environmental sampling.

Neurobehavioral Testing. The CPT test was administered using personal computers in a quiet room at the work site. The test was given to each person for five minutes, three times furing the work shift beginning, mid-shift and end of the shift.

Environmental

Work Diaries. Employees at this shop are required to keep daily time cards accounting for the length of time spent performing a specific task for each job being done in the shop. All of the employees' time must be accounted for on these cards. These time cards were obtained for each employee for all four days of the work week during which medical and environmental testing was conducted for this evaluation.

Work diaries were developed from cards given out to workers each day. Investigators checked time and tasks reported and added the type of paint or solvent used.

Sampling

Personal samples were taken for 18 workers. Task samples were taken on 9 tasks including spray painting, screening, cleaning and blasting. These task samples represented several individuals doing this type of task at different times of the day. Samples were analyzed for hexane, heptane, toluene, xylene and butyl cellosolve. The HNu photoionization detector with data logger was used to measure the concentration profiles of several tasks.

Job histories were developed from time cards which used a coding for time spent in each type of work. In the paint department there were 18 possible task codes. These were further broken down by type of paint used and time spent hand cleaning screens. This information was obtained by interviews. Eleven tasks were assigned exposures either by direct measurement or by grouping with similar tasks.

VI. RESULTS

Medical Questionnaire

Exposed employees (those working in the screening operations of the four plants where medical testing occurred) reported experiencing more health symptoms known to be associated with solvent exposure than did unexposed employees (Table 3). The numbers in both groups were small, particularly for the non-exposed group and these differences are not statistically significant at the $p = .05$ level. Moderately increased reports of headache were reported by the screeners as compared to the unexposed employees. The nonexposed group gave increased reports of skin rashes and dry, cracked skin.

Continuous Performance Testing

Continuous performance testing (CPT) did not show significant slowing in reaction time over the work day when comparing those with more exposure with those having less. Urinary methyl hippuric acid concentrations correlated for creatinine concentrations were calculated and compared with end of day reaction time and changes in reaction time over the work day. Regression of urinary methyl hippuric acid concentration against reaction time showed no significant decrement in performance (figure 3).

Profile of Mood States (POMS)

No significant differences were noted between the reports of mood of the 19 exposed and 4 unexposed workers. In view of the small numbers evaluated and the variability of mood reporting, further analysis to compare exposure estimates with POMS scores was not performed. Since no baseline scores were available for the POMS (of the type collected for the CPT), statistical analyses would be less powerful than those performed for CPT testing which showed no exposure effect.

Urinary Metabolities

Although the health history questionnaire and Continuous Performance Time test did not detect a significant increase in health problems in the silk screeners, the metabolites of toluene and xylene were increased in their urine. In most cases the levels of urinary metabolite increased over the work day (table 4). The levels of methyl hippuric acid increased with increasing air concentration levels of xylene exposure (fig. 1). Within job category in one of the Boston area shops, the screeners had the highest and layout artist the lowest excretion rates (fig. 2).

Conventional Environmental Sampling

All personal samples taken were below the ACGIH threshold limit value (TLV) for all substances. Table 5 shows the average concentration in three job categories of the compounds measured at all work sites; toluene, xylene and 2 butoxyethanol. The job means were well below the TLV though the screeners and spray painters did have higher exposures than controls.

Task samples were below the TLV for most substances. However, blasting the screens clean led to exposures over both the TLV and short-term exposure limit (STEL) for toluene. Also one of the samples taken during the screen cleaning by hand process resulted in exposures over the TLV for toluene and xylene, and over the STEL for toluene. The average concentration for most tasks was below both the TLV and STEL with the exception of blasting (Table 6).

Table 7 shows the results of calculating an exposure measure for the combined effect of the mixture of solvents. The exposure measure for the personal samples was defined as the sum of the ratios of the measured concentrations of each substance over its TLV. If the sum was greater than 100% then the "mixture TLV" was exceeded. Likewise, for task samples the exposure measure was defined as the sum of the ratios of the measured concentration of a substance over its STEL (an STEL has not been set for all of the solvents). If the sum was greater than 100% the mixture-STEL was exceeded.

Only two of the personal samples were over the mixture-TLV, both of these were spray painters (133% and 123%). One screen cleaning and one blasting operation task sample exceeded the mixture-STEL.

Environmental Sampling with Direct Reading Instruments

Three direct reading instruments were used with chart recorders to evaluate short-term exposures: the Century OVA Portable Gas Chromatograph, HNu photoionization detector, and the Miran infrared unit. Century OVA Portable Gas Chromatograph was used as a direct reading continuous monitor by using the flame ionization detector without the column attached. In this mode the response was slow and peaks not clearly defiend. The HNU photo-ionization detector was used to analyze the peak exposures. Major peaks during screening lasted from 10-40 seconds with high peaks appearing in a cyclic fashion. Within these major peaks subpeaks appeared lasting less than 1 to 3 seconds. During a screen cleaning operation, an ambient air scan was run using the Miran 1A infrared spectophotometer. The goal was to use this ambient air scan to assess which of the target solvents, suspected to be present, actually could be measured in the workplace. This information was to be used so that further direct reading continuous monitoring could be targeted to specific solvents and the solid sorbent analysis protocol could be simplified.

The result of the scan showed peaks at the approximate wavelengths of: 3.2-3.5; 7.2-7.4; 8.0-8.4; and 9.0-10.2 microns. The problem with this scan was that because of the low concentrations involved, for a given solvent not every wavelength associated with that solvents showed a peak, in most cases only one or two of the expected wavelengths showed any peaks. Thus it was impossible to exclude any of the solvents suspected to be present in the workplace air. This also meant no wavelength could be picked to exclusively monitor a particular solvent. Rather, continuous monitoring to profile the exposure was chosen for the wavelength of 3.4 microns since it represented all solvents.

<u>Exposure estimates using Work Diaries and Environmental Measurements</u>

By combining information from the work diaries about time spent working at a task with the exposure measurements for that task, we were able to construct an estimate of that worker's TWA exposure to specific solvents (figures 4 and 5). We felt this approach was useful because the silk screeners' solvent exposure varied greatly from day to day as their tasks changed and because of the many types of screening being done. Figure 6 shows the daily toluene exposure calculated for three silk screeners using the task measurement and job history method. The numbered shapes show the actual time weighted average (TWA) air sample results taken on that worker on the day of their health testing. By using these daily estimates for unsampled days, an accurate cumulative weekly exposure up until the end of the day of neurological testing could be calculated. Table 8 shows the results of paired T-tests on silk screener exposures measured and calculated using the job task method. There was no difference in the calculated or measured TWA exposures for this small test group (n=7).

This method of using job task measurements and work histories can be expanded to include mixed solvents by using a total solvent exposure index. As described above for individual solvents, the time each worker spent on specific job tasks was determined from the work diaries. For each job task, airborne levels of hexane, heptane, toluene, xylene, and 2-butoxyethanol were determined and expressed as millimoles/m . The total exposure index was calculated in mmoles/m to obtain a biologically based measure of total solvent exposure. The common biological effect of all organic solvents is their anesthetic action, which is directly related to their blood concentration. It is the number of molecules altering the neurological cell wall that accounts for the anesthetic effect, hence the blood concentration necessary to reach clinical anesthesia is quite similar when expressed in molar concentration. Thus it may be preferable to simply add the TWA molar exposure of a mixed solvent matrix together and report this summary measure as the total solvent exposure. Table 9 shows this approach using the TWA exposures of a worker. The use of the total solvent measure in millimoles/m was also applied to the estimation of the cumulative exposure based on the task exposures and the worker's job history. Table 10 shows an example of the result of using this approach, a cumulative total solvent measure in mmole-min/m . This measure was then added across days, resulting in a cumulative exposure for the work week up until the end of the day of neurological testing.

VII. EVALUATION CRITERIA

General Toxicity

In general, the solvents used in screen printing vaporize easily at room temperature and atmospheric pressure. Heating the solvents or mechanically drying solvent-containing inks or paints will liberate higher quantities of vapor. It is generally thought that the most significnat solvent exposures occur from inhalation of vapors given off by the non-enclosed use of liquid solvents in processing and cleaning. Ventilation rate is an important determinant of solvent uptake by inhalation and increased levels of physical exercise have been associated with increasing uptake by a factor of two to three times the baseline level (Monster et al, 1971).

Because of their high solubility in lipid, the solvents used in screen printer are also absorbed through the skin. Dermatitis from the solvents' drying effect has been well-documented. In most situations it is thought that solvents absorbed through the skin are less likely to produce high systemic levels of the compounds, but relatively little is known about skin absorption as a route of exposure.

Skin absorption is influenced by various skin characteristics such as skin thickness, skin integrity, degree of dehydration of the skin surface, and skin temperature. Skin absorption may be increased when solvents are trapped between clothing and the skin. Two recent reports of the evaluation of barrier cremes in humans (Lauwerys et al, 1978) and in animals (Bowman et al, 1982) indicate little evidence of efficacy of barrier cremes in preventing sking absorption of xylene and toluene.

Specific Compounds

The current OSHA standard (the permissable exposure limit, PEL) for n-butyl acetate is 150 ppm averaged over an 8-hour work shift. The American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) is also 150 ppm. The principal effect of overexposure to n-butyl acetate is irritation of the eyes and nose, which generally occurs at 200-300 ppm. Butyl acetate splashed in the eye causes marked irritation, but recovery is rapid. Prolonged overexposure may produce irritation of the skin.

The current OSHA standard for 2-butoxyethanol, "Butyl cellosolve", is 50 ppm. The American Conference of Governmental Industrial Hygienists' TLV for 2-butoxyethanol is 25 ppm. Overexposure to 2-butoxyethanol may cause irritation of the eyes, nose and throat. Through its irritant effects, 2-butoxyethanol can be detected at concentrations only a few times the OSHA permissable exposure limit (PEL). Percutaneous absorption may account for more absorption than does inhalation in some cases. The liquid is damaging to the eye, producing pain, conjunctival irritation, and transitory injury to the cornea. Long-term health effects are not known. A 1983 NIOSH Current Intelligence Bulletin on glcol ethers reported 2=methoxy ethanol and 2-ethoxyethanol as potential reproductive hazards.

The current OSHA Standard for heptane is 500 ppm averaged over an eight-hour workshift. NIOSH has recommended that the PEL limit be reduced to 85 ppm averaged over a workshift of up to 10 hours per day, 40 hours per week. The TLV for heptane is 400 ppm. Overexposure to heptane may cause a slight irritation of the eyes, nose and throat. It may also cause loss of appetite and nausea. Since heptane is a skin defatting agent, prolonged exposure may cause skin irritation.

The current OSHA Standard for n-hexane is 500 ppm averaged over an eight-hour shift. NIOSH has recommended that the PEL be reduced to 100 ppm averaged over a work shift of up to 10 hours per day, 40 hours per week. The TLV for n-hexane is 50 ppm. Overexposure to hexane may cause light-headedness, giddiness, nausea and headache. It may also cause irritation of the eyes and nose. Prolonged exposure may cause skin irritation and possibly nervous system damage.

The current OSHA standard for ethyl acetate is 400 ppm. The TLV is also 400 ppm. Overexposure to ethyl acetate may cause irritation of the eyes, nose and throat. Since ethyl acetate is a defatting agent, it may cause skin irritation with prolonged exposure.

The current OSHA standard for toluene is 200 ppm. NIOSH has recommended that this PEL be reduced to 100 ppm toluene averaged over an eight-hour work shift. THE TLV for toluene is 100 ppm. Toluene can enter the body by inhalation or through the skin. Toluene may cause irritation of the eyes, respiratory tract and skin. Exposure to 200 ppm for eight hours produce mild fatigue, weakness, confusion, tearing, and a "pins and needles" skin sensation or numbness and other nervous system symptoms. Higher concentrations may cause headache, nausea, dizziness, and dilated pupils and insomnia. The liquid splashed in the eyes of two workers caused transient corneal damage and conjuctival irritation; complete recovery occurred within forty-eight hours. Repeated or prolonged skin contacat with liquid toluene has a degatting action, causing drying, fissuring, and dermatitis.

The current OSHA standard for xylene is 100 ppm averaged over an eight-hour work shift. NIOSH has recommended that the PEL be changed to 100 ppm averaged over a work shift of up to ten hours per day, forty hours per week. THe TLV for Xylene is 100 ppm. Xylene can affect the body if it is inhaled, if it comes in contact with the eyes or skin, or if it is swallowed. Xylene irritates the eyes, mucous membranes and skin. At higher concentrations it may cause neurobehavioral symptoms and narcotic effects. Three painters working in a confined space of a fuel tank were overcome by xylene vapors estimated to be 10,000 ppm; they were not found for 18.5 hours after entering the tank. One died from pulmonary edema shortly thereafter; the other two recovered completely in two days; both had temporary liver damage and one had temporary kidney damage. Workers exposed to concentrations above 200 ppm complain of loss of appetite, nausea, vomiting and abdominal pain. There are reports of reversible corneal damage in the eye. The liquid is a skin irritant and causes redness, dryness and defatting.

VIII. DISCUSSION

This investigation of several relatively small silk screen printing shops has shown that exposure to organic solvent vapors in various processes in this operation are at levels that usually did not exceed the current NIOSH recommended standard or OSHA permissible exposure limits. Despite the relatively low levels of exposure, increased absorption of toluene and xylene was noted in these workers as reflected in increased urinary concentrations of metabolites of these substances. The principal routes of absorption appear to be both percutaneous and through inhalation. Although some increases in absorption of these solvents were noted, the levels of absorption were relatively low and therefore no health effects directly attributable to acute exposure to solvents was noted. Some workers did report symptoms consistent with chronic solvent toxicity, but the rate of symptoms in the exposed group did not differ significantly from the small unexposed population tested. In view of the nature of the work, the environmental levels measured, and the known toxicity of the solvents being used, it is reasonable to conclude that some individuals have in the past experienced transient acute symptoms of central nervous system dysfunction attributable to peak exposures to solvent vapors. Since our evaluations took place at only one point in time, our ability to evaluate the effects of such repeated high exposures was quite limited.

This set of investigations was undertaken in response to a general concern about excessive exposure to solvents in the workplace expressed by the International Union which represents these employees. This investigation has clearly demonstrated the utility of simultaneous exposure, absorption, and health monitoring to evaluate the transient health impact of exposure to solvents in the workplace. Specifically, the measurement of morning and afternoon urinary methylhippuric acid levels as an index of exposure to xylene over the workday was quite successful. Furthermore, this investigation demonstrated the feasibility of measuring reaction time using the continuous performance test over a workday to compare changes in reaction time with measures of exposure to and absorption of organic solvents in the workplace.

A particularly important aspect of this investigation was the attempt to assess exposure levels to solvent mixtures. Typically, in the view of the complexity of exposures, most health hazard evaluations find difficulty in characterizing exposure intensity in a way that relates directly to health effects in exposed individuals. Since our investigations occupied only one or two days out of a prolonged work experience, we felt that we should attempt to evaluate the representativeness of environmental sampling performed by our team. Therefore, task-specific job diaries were completed by all individuals which yielded daily estimates of solvent exposure for each individual. These day-specific exposure estimates utilized task-specific exposure estimates derived from direct sampling of the important tasks performed by silk screen workers. This task sampling was performed independent of individual time weighted average exposure sampling which was executed in the traditional manner.

This extensive environmental assessment was successful in demonstrating that there was a close correspondence between measured levels of exposure using full work day traditional TWA sampling and estimated exposure levels based on job diaries and task-specific exposure methods. The method of work diaries could have been extended over a longer period of time to evaluate the variability of exposure profiles. In situations where the exposure profiles appear to be extremely variable over time, environmental sampling may need to be extended beyond one day of testing.

Since there were some reports of transient symptoms potentially related to over exposure to solvents, and since these agents have all recognized toxicity, we have developed a number of work practice recommendations designed to reduce potential for over exposure. Work practice modifications are particularly important in this type of work since each individual works independently and controls his work to a significant degree. In this context, the use of personal protective equipment during certain specified processes appears to be appropriate.

We have not made recommendations of any specific ongoing medical surveillance since the tests that we performed show essentially no evidence of chronic health impairment. In our view, monitoring of these populations over time should be restricted to the assessment of adherence to specified work practices and to periodic environmental measurements. Medical monitoring in this context would only serve to distract attention from more important issues in environmental control.

RECOMMENDATIONS

1. Solvents absorbed through the skin can be a significant source of exposure. Since much of the solvent exposure in screeners occurs during short peaks of high solvent concentrations, it is recommended that long-sleeved gloves be used during the peak periods (i.e., the jobs when the most solvents are being used such as screen cleaning and blasting). Gloves should be removed when solvents are not in use so that any solvent trapped in the glove will not be held next to the skin. Gloves should be chosen that are resistant to the specific solvents in use.

2. All solvent-soaked rags should be stored in fireproof containers with lids. The rags should be cleaned or disposed of regularly.

3. All solvent containers should be covered when not in direct use.

4. Solvent storage containers (such as 55-gallon drums) should be grounded and stored in a ventilated area.

5. The environmental and medical monitoring conducted for this evaluation tested a specific set of screening products under specific conditions. As new screening products or materials are introduced into an operation (such as the use of a new cleaning solution) or as workplace conditions change chemical exposures change. It is recommended that the shops in this evaluation continue to use the products currently being used. No substitutions are recommended. When it is necessary to change products or use a new material it is recommended that the regional office of NIOSH, the State Department of Occupational Hygiene, or the State Right-to-Know Clearing House be called for information on the specific new product.

6. Although the individual solvent exposures measured in these operations were well below the current legal standards and TLV's, it was shown that increasing air levels of xylene were associated with increasing levels of its urinary metabolite, methylhippuric acid. At this time, no health

risk is known to be associated with these higher levels of urinary metabolites; however it would be desirable to perform routine air level monitoring to detect any changes in levels or types of airborne solvents. Two screeners and one task sample were found to be over the mixture TLV or mixture STEL. Although this is not a legal limit, it suggests that solvent exposures may periodically reach potentially hazardous levels on certain jobs.

7. It was noted that several workers had developed individual work practices to limit their personal exposures, especially on jobs where there were short, high doses solvents (such as screen cleaning and printing). Some employees moved as far away from the solvent-coated work piece as possible to perform further tasks. Other employees did not use any special technique. Health and safety training for proper solvent work practices should be given to each employee. The International Brotherhood of Painters and Allied Trades Occupational Safety and Health (IBPAT/OSH) project has developed training manuals outlining specific work practices for workers using solvents. These materials should be made available to workers in these screen printing operations.

8. Chemical cartridge, half-face respirators suitable for work with organic solvent vapors would be desirable for screen cleaning, blasting and spray painting, the highest solvent exposure jobs in these work places. IBPAT/OSH project has information on the respirator use and maintenance. Proper maintenance is essential for the respirators to be of any use. Several employees included in this evaluation had difficulty with proper respirator fit. There are self-adjusting disposable charcoal masks made by the 3M Company and American Optical Company suitable for screening work.

9. "Non-exposed" employees working in the art departments as well as screeners reported problems with skin irritation. There are many artists'

materials known to cause skin irritations ranging from dryness and cracking to rashes and open lesions. An evaluation of the art materials used, proper handling and personal protection is recommended.

10. Two of the shops in this evaluation had gas drying ovens with open pilots. It is recommended that fire protection experts be consulted to assess the fire and explosion hazard presented by the open pilot light in a solvent containing environment.

Silkscreen/Quinn

JMF

Table 1: Constituents of products used in silk screen printing

INKS AND PAINTS

Product	Constituents	Percent Composition
Nazdar Plastivac Gloss #70-111	Diacetone alcohol	19.5
	Isophorone	5
	Ethylene Glycol Mono Butyl Ether	22
	Chempro 150 (aromatic petroleum solvent)	7.5
	Ethylene Glycol Mono Butyl Ether Acetate	9
Nazdar Styralac Gloss #11-11	Ethylene Glycol Mono Butyl Ether	55
	Diacetone alcohol	6.25
	Chempro 150 (aromatic petroleum solvent)	0.7
Nazdar GV Gloss Vinyl #GV-170	Isophorone	45
	SC-150 Solvent (aromatic petroleum solvent)	15
	Ethylene Glycol Mono Butyl Ether Acetate	8
Nazdar Nitrocellulose Lacquer #IL-111	Ethylene Glycol Mono Butyl Ether	40
	SC-150 Solvent (aromatic petroleum solvent)	12
	Isopropenol	9
Wyandotte Grip-Flex #OFR-1-900S	2-Butoxyethanol	45
	2-Nitropropane	<1
Wyandotte Grip-Mask #GM-2-210P	2 ((Hydroxymethyl) amino) ethanol	0.29
Spraylat Lacryl #800	High Boiling Aliphatic Petroleum Distillates	25
	Glycol Ethers	75
KC Enamel Plus	Mineral Spirits	2-3
	Petroleum Hydrocarbon Fraction	1-10
Dupont Dulux	Aliphatic Petroleum Distillates	30
	Aromatic Petroleum Distillates	18
	Xylene	3
Scothcal #39000	Cyclohexane	<50
	Isophorone	<30
	Aromatic Hydro	<5
	Di-sec-octylphthalate	<10

THINNERS AND CLEANERS

Product	Constituents	Percent Composition
Spraylat Lacryl Thinner #205-T	Glycol Ether	5
	Lower Alcohols	50
	Aromatic Napthas	10
	Aliphatic Napthas	35
KC Enamel Plus Thinner	Mineral Spirits	100
Dupont Thinner #3812-S	Toluene	48
	Aliphatic Petroleum Distillates	52
Dupont Thinner #3819-S	Aliphatic Petroleum Distillates	29
	Aromatic Petroleum Distillates	71
Wyandotte Thinner for Polycarbonate #T-4000	Ethanol	95
	Isopropyl Alcohol	5
Wyandotte Fast PC and Ecology Spray Thinner #T-2004	Ethanol	55
	Butanol	25
	Toluol	16
	Xylol	4
Wyandotte Spray Thinner and Remover #T-2002	SC-100 Aromatic Hydrocarbons	95
	Toluene	5
Exxon Varsol 1, 3, 18	Complex mixture petroleum hydrocarbon solvents	100
Silk Screen Cleaner (Mulholland Blend)	Acetone	40
	Toluol	50
	Secondary Butyl Alcohol	10

Table 2: EVALUATION METHODS

Plant	Walk-Through	Environmental Testing (N = No. of Employees Sampled) Area Sampling	Personal Sampling	Job Sampling	Direct Readout Sampling	Daily Work Diaries	Medical Evaluations (N = No. of Employees Sampled) Health Work History Quest.	Urinalysis	POMS	CPT
Sam Johnsons	X	X	4	3	X	4	4	4	4	4
Wisewell	X	X	3	0	X	0	2	2	2	2
Simard	X	X	0	0	0	0	1	0	1	0
Richards	X	0	0	0	0	0	0	0	0	0
Mulholland-Harper	X	X	17	9	X	17	17	17	17	17
TOTAL			24	12		21	24	23	24	23

Table 3: Percentage of Employees Reporting Symptoms

Symptoms	Exposed N = 19	Unexposed N = 4
Fatigue	31.6%	50%
Dizziness	31.6	0
Difficulty Concentrating	26.3	25
Confused, Disoriented	21.0	50
Trouble Remembering	36.8	50
Difficulty Reading	26.3	0
Irritability	26.3	0
Depression	21.0	50
Loss of muscle strength in arms or hands	10.5	0
Numbness or tingling in fingers lasting more than 1 day	0	0
Headache at work more than once per week	36.8	0
Headache outside of work more than once per week	36.8	0
Skin Rashes	21.0	25
Dry, Cracked Skin	63.2	75
Difficulty driving home after work	5.3	0
Nausea	21.0	0

Table 4: Urinary metabolite testing results over workday

Subject Number	Urine Hippuric Acid Concentration (gm/gm creatinine) Time of Sample Collection (mg/mg) 8 AM	Noon	4 PM	Urine Methylhippuric Acid Concentration (gm/gm creatinine) Time of Sample Collection (mg/mg) 8 AM	Noon	4 PM	Morning-Afternoon Hippuric Acid Level	Morning-Afternoon Methylhippuric Acid Level
1	1.10	---	.562	.050	---	.018	-.538*	-.035**
4	.144	.208	---	.016	.072	---	---	---
7	.327	.359	.243	.080	.134	.341	-.084	.291
10	.122	.139	---	.023	.096	---	---	---
13	.113	.350	.544	.014	.049	.194	.432	.180
16	.100	---	.174	.012	---	.137	.074	.125
19	.218	.243	---	.034	.032	---	---	---
22	.189	.647	.544	.052	.247	.431	.355	.379
25	.280	---	.435	.060	---	.265	.155	.205
28	.388	---	.520	.058	---	.093	.132	.036
31	.916	1.345	---	.017	.010	---	---	---
34	.110	.632	.459	.045	.268	.547	.348	.502
37	.550	.256	---	.037	.055	---	---	---
40	.470	.409	.395	.007	.048	.060	.076	.053
43	.404	---	.386	.034	---	.119	-.017	.085
45	.156	---	.200	.021	---	.207	.044	.186
46	.406	.206	.857	.006	.032	.013	.451	.007
49	.092	---	.460	.038	---	.120	.368	.082
50	.342	---	.304	.012	---	.057	-.039	.046
60	.283	---	1.308	.033	---	.012	1.024	-.022
70	.071	---	.105	.008	---	.132	.034	.123
80	.291	---	.219	.038	---	.043	-.072	.005
90	.253	---	.363	.055	---	.104	.110	.049

* A negative value indicates presence of probable dietary sources of hippuric acid (e.g., coffee) (see text)

** Since dietary sources of methylhippuric acid are uncommon, a negative value may reflect high exposure to xylene on the day prior to sampling causing a relatively high morning value.

Table 5: Personal Samples for All Companies
(Arithmetic Mean (ppm)*

Job	n	Toluene	Xylene	2-butoxyethanol
Screeners	16	14.2	3.4	6.8
Spray painters	5	13.9	1.1	2.6
Controls	6	3.4	0.7	0.3
TLV		100	100	25

---

* Limit of detection value used for exposure below limit of detection.

Table 6: Task Samples for All Companies
(Arithmetic Mean (ppm)*

Job	n	Toluene	Xylene	2-butoxyethanol
Screen	5	17.9	3.3	9.1
Spray paint	2	11.6	2.3	3.1
Hand clean	4	17.8	15.2	1.8
Metal coat	1	18.6	2.9	0.1
Blast clean	2	602.9	123.6	115.2
TLV		100	100	25
STEL		150	150	75

* Limit of detection value used for exposure below limit of detection.

Table 7: Exposure Measure for Solvent Mixtures

Company	N	Percent of TLV-mixture or STEL-mixture <20%	21-50%	51-75%	76-100%	>100%
Mullholland						
personal TWA samples (a)	16		7	6	1	2
task samples (b)	9	4	4		1	
Wisewell						
personal TWA samples (a)	4	2	1		1	
task samples (b)	2	1				1
Simard						
personal TWA samples (a)	1	1				
Sam Johnson						
personal TWA samples (a)	5		2	3		
task samples (b)	3	1	1			1

(a) TLV-mixture measure $= \frac{\text{concentration}}{\text{TLV}} + \frac{c_2}{t_2} + \frac{c_3}{t_3}$

(b) STEL-mixture measure $= \frac{\text{concentration}}{\text{STEL}} + \frac{c_2}{\text{STEL}_2} + \frac{c_3}{\text{STEL}_3}$

TABLE 8

MEASURED VS. CALCULATED TWA

PAIRED T-TEST
SCREENERS ONLY

	HEXANE	HEPTANE	TOLUENE	XYLENE	2BUTOXY ETHANOL
MEAN DIFF	-6.0	-1.6	-1.4	-0.8	-2.2
STD. ERROR	7.0	3.9	1.7	0.5	1.8
T-VALUE	-0.9	-0.4	-0.8	-1.6	1.2

For measured vs. calculated TWA to be significantly different (P=0.05) the T-value must be $\geq$ 2.4

TABLE 9

WORKER #3's PERSONAL TWA SOLVENT EXPOSURE

SOLVENT	MMOLES/M^3	%TLV
2BUTOXYETHANOL	235	23.2
HEXANE	621	30.4
HEPTANE	639	3.9
TOLUENE	516	12.6
XYLENE	151	3.7
TOTAL SOLVENT EXPOSURE FOR DAY	162	73.8%

TABLE 10

EXAMPLE OF JOB HISTORY (WORKER #3 DAY 1)

JOB	TIME (min)	TOTAL SOLVENT	mmole-min/m^3
Screen ink A	120	2.57	308
Clean screen	30	3.86	116
Blast screen	60	10.6	636
Art room	30	0.58	51
Screen ink B	180	1.98	356
Total m ole - min/m^3			1467

$$\text{Cumulative Total Solvent Exposure (moles-min/m}^3) = \sum_{task=1}^{n} \left[\text{task exposure (mmole/m}^3) \times \text{task time (min)} \right]_{(task)}$$

FIGURE 1 - COMPARISON OF METHYL HIPPURIC ACID (MHA) EXCRETION WITH XYLENE EXPOSURE

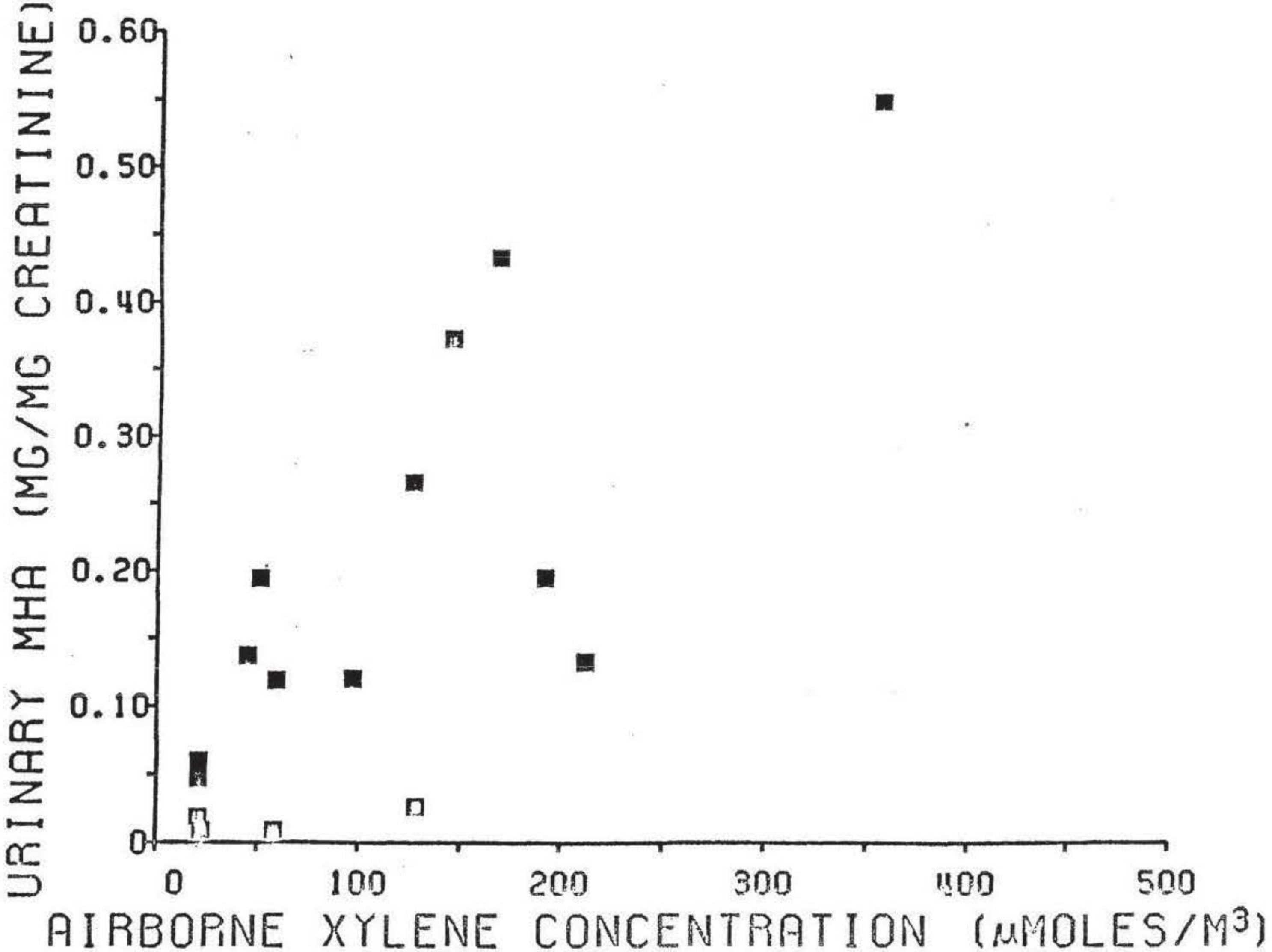


Figure 2 :Methylhippuric Acid Excretion Rates for Printers - Sam Johnson & Co.

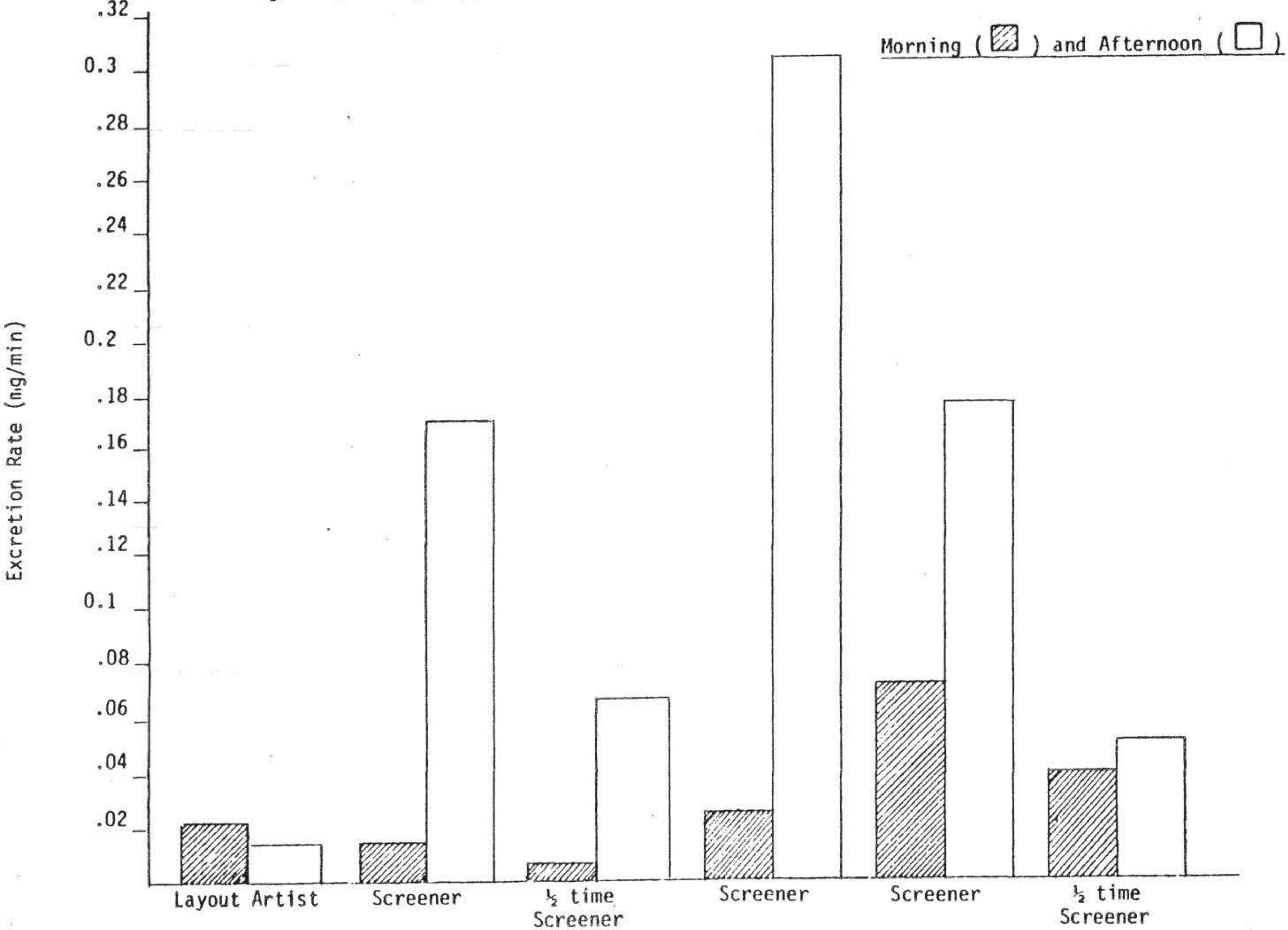


FIGURE 3 - COMPARISON OF METHYL HIPPURIC ACID AND CHANGES IN CPT

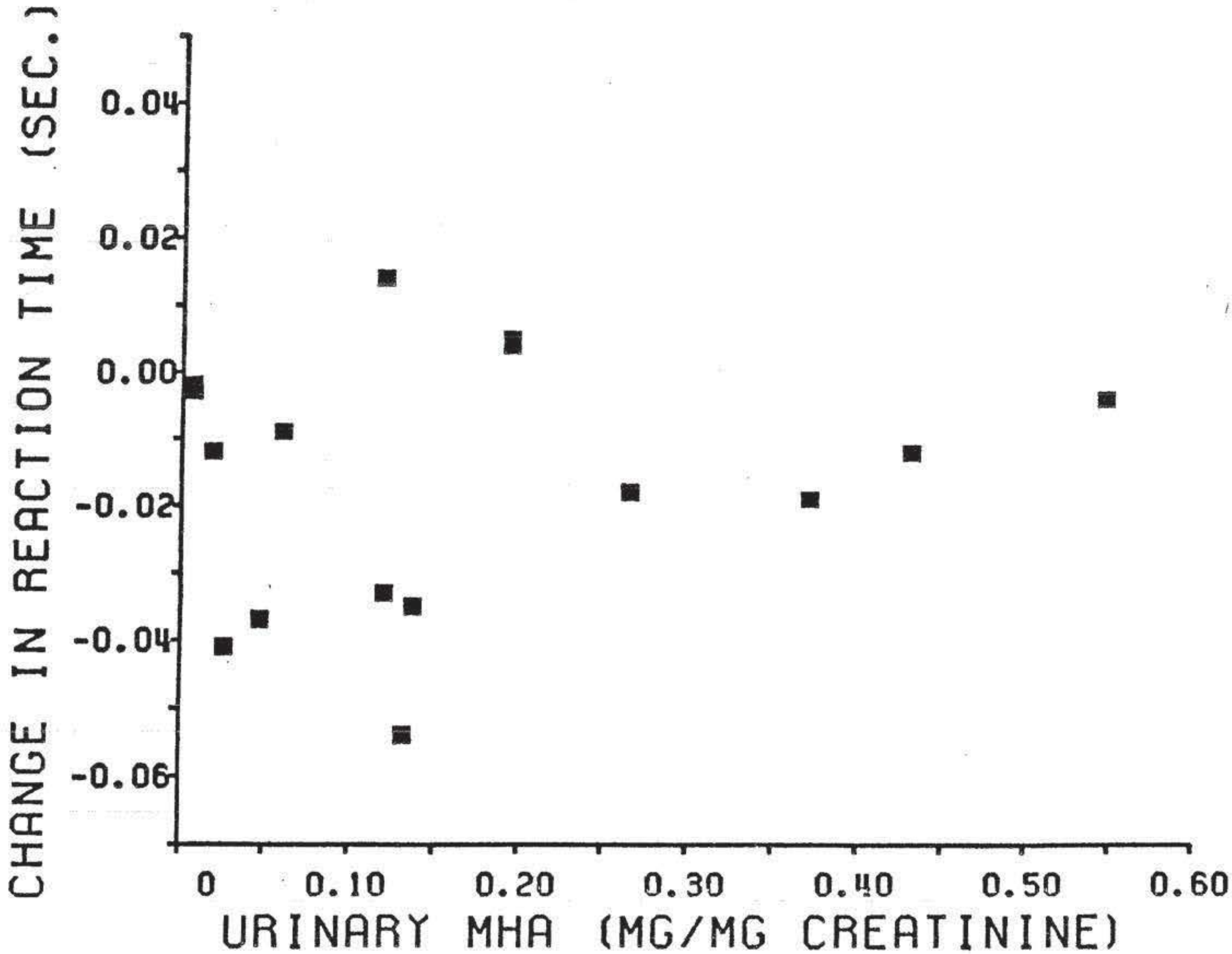


FIGURE 4 - TOLUENE EXPOSURE PROFILE

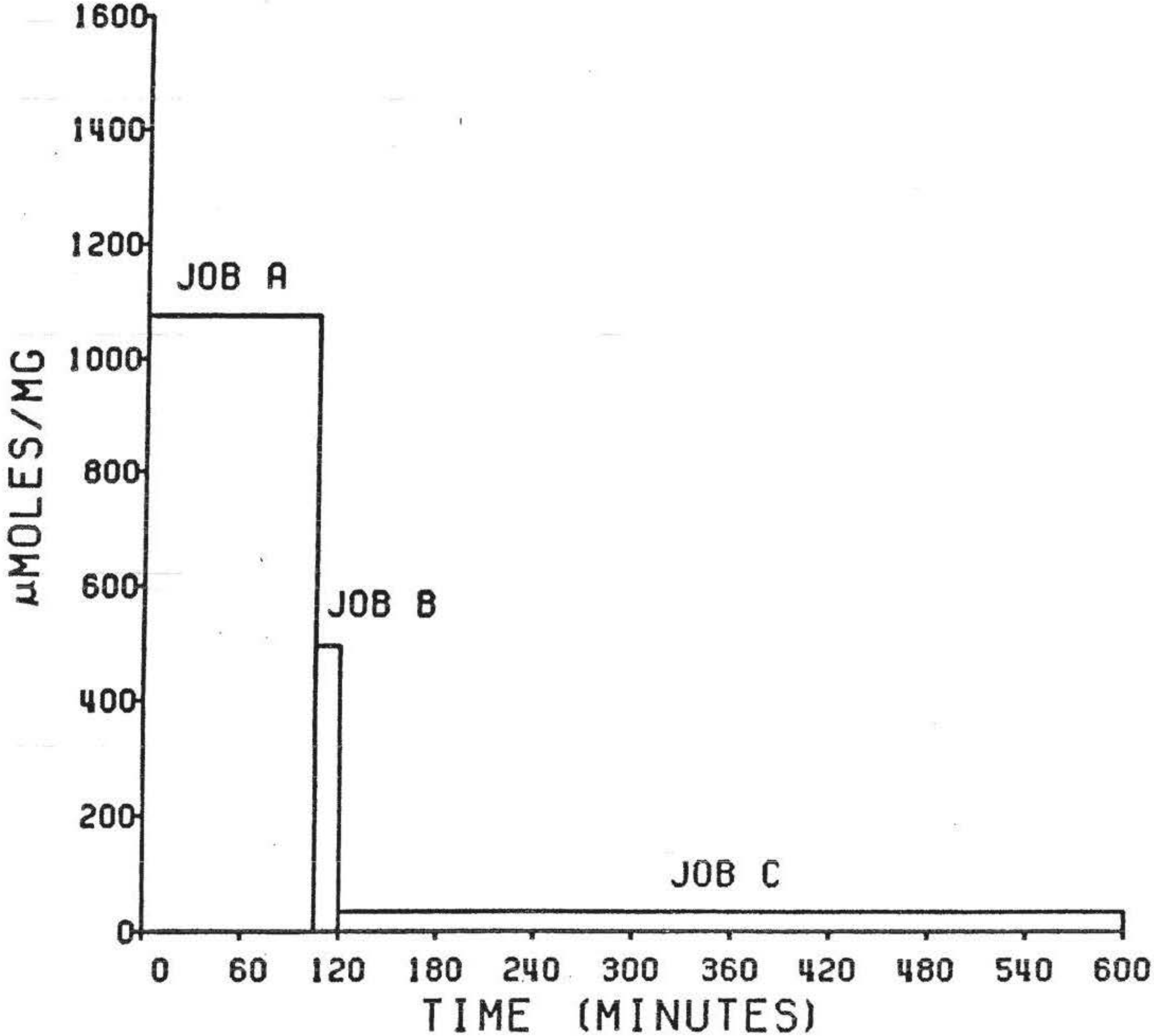


FIGURE 5 - XYLENE EXPOSURE PROFILE

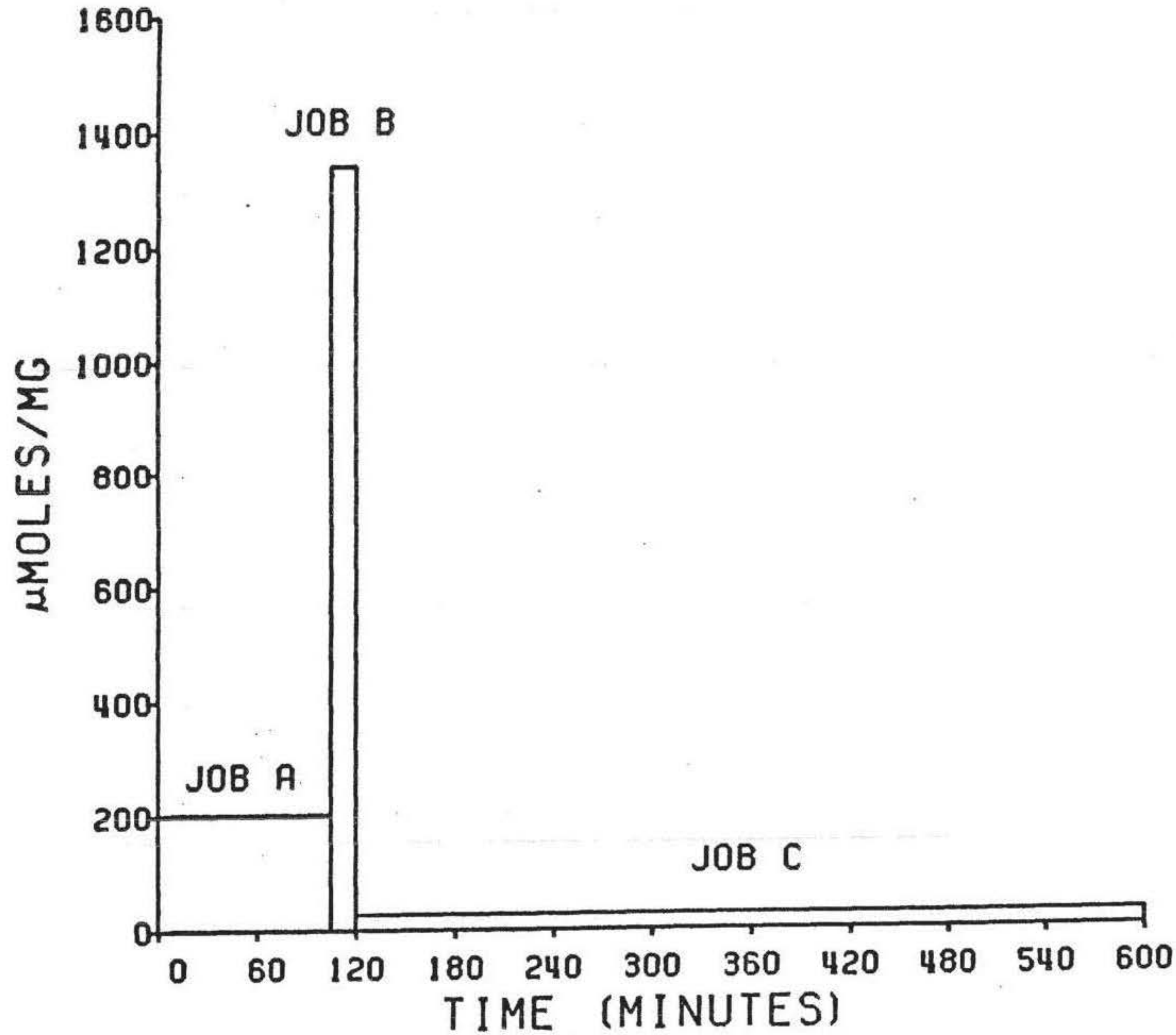


FIGURE 6:

DAILY EXPOSURE TO TOLUENE CALCULATED FROM WORK HISTORIES OF THREE SILK SCREENERS

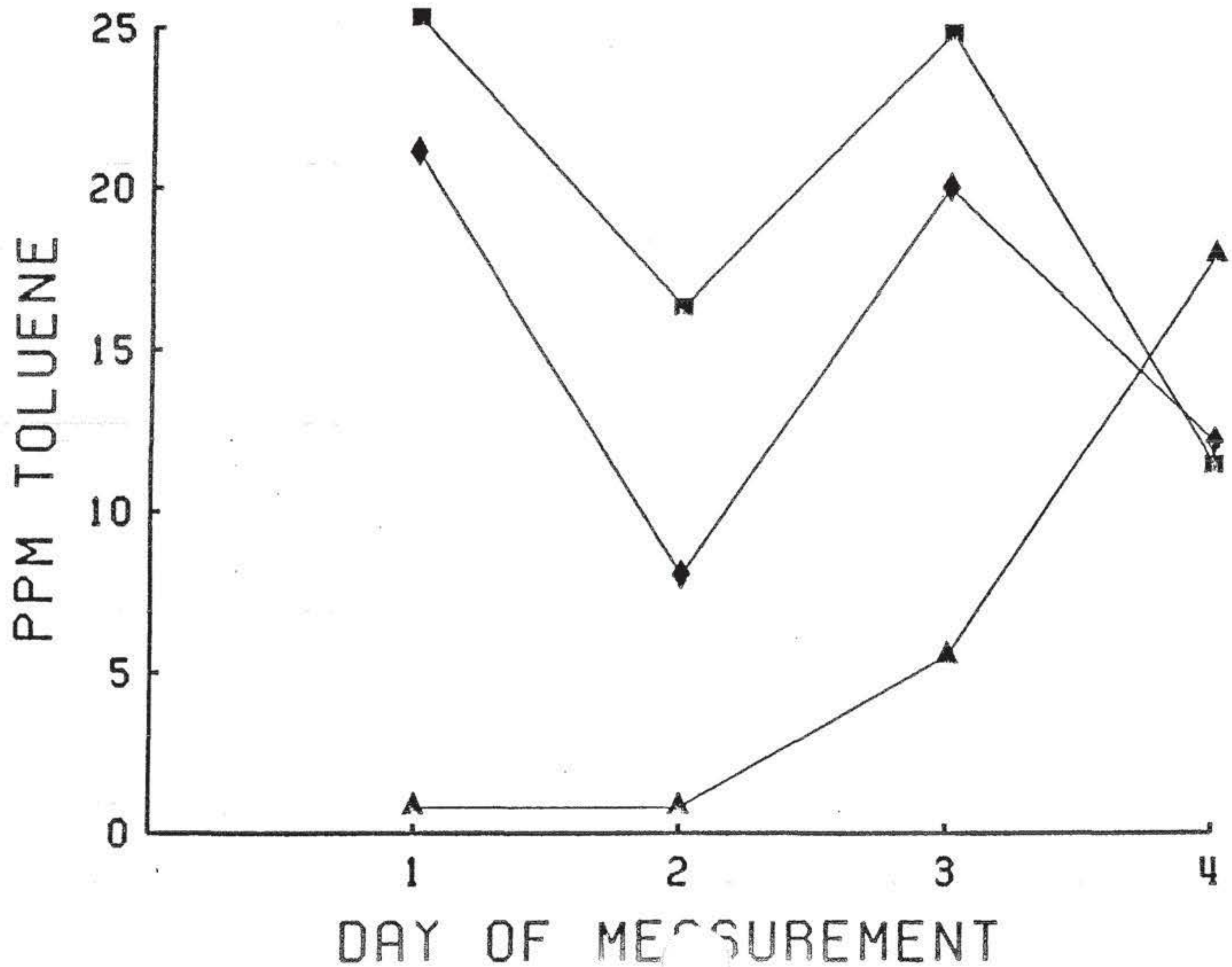
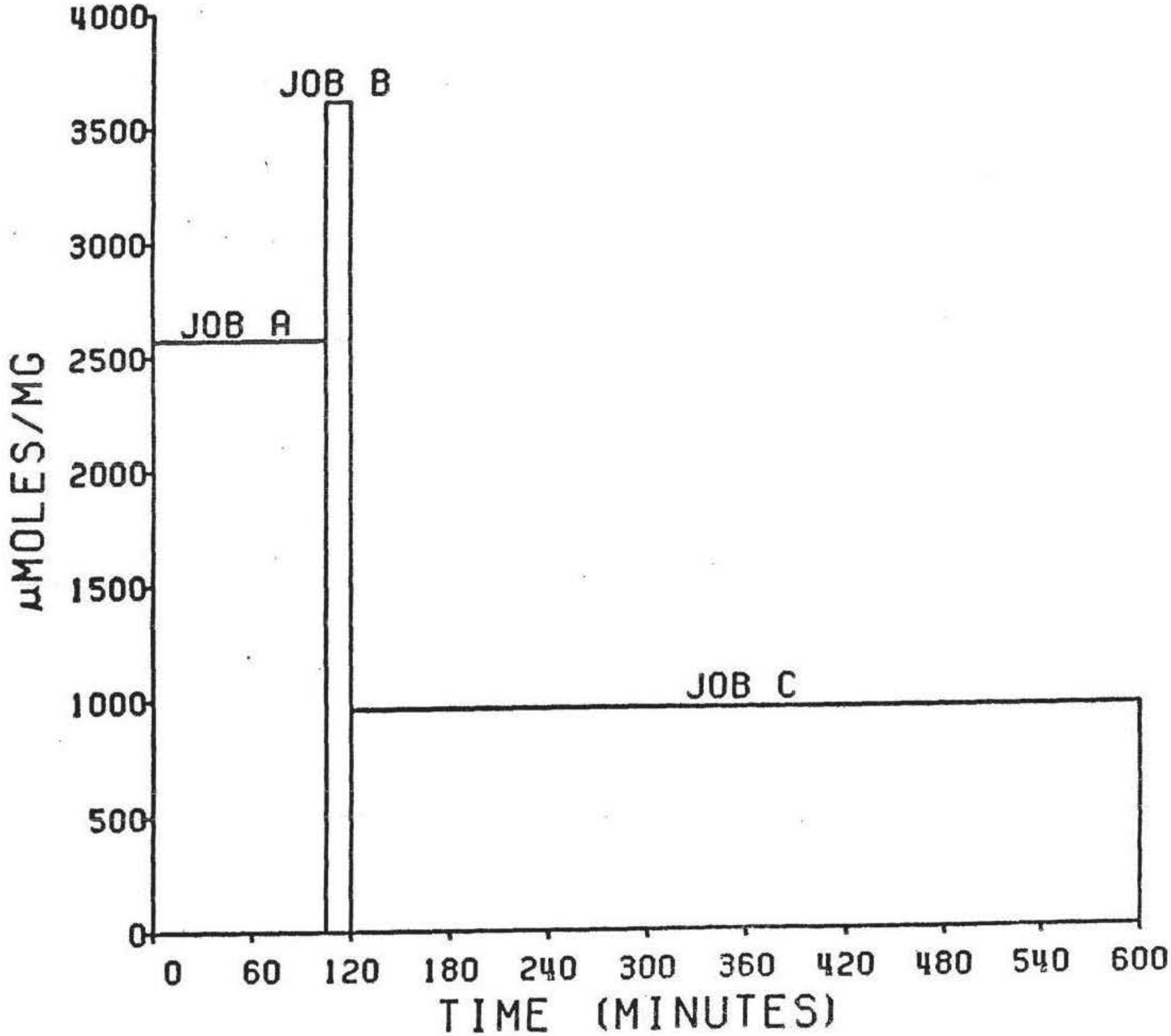


FIGURE 7 - TOTAL SOLVENT EXPOSURE PROFILE



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