INDUSTRIAL HYGIENE REPORT
IN-DEPTH SURVEY

Solvent Vapor Survey of Screen Printing Operations

Manuscreens
58-38 Page Place
Maspeth, New York 11378

SURVEY CONDUCTED BY:
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Industrial Hygiene Section
Industry-wide Studies Branch
Division of Surveillance, Hazard Evaluations and Field Studies
National Institute for Occupational Safety and Health
Cincinnati, Ohio

PURPOSE OF SURVEY:	To conduct an in-depth industrial hygiene survey for the purpose of characterizing the screen printing industry.
EMPLOYER REPRESENTATIVES CONTACTED:	Mr. Stanley Martin, Plant Manager (212) 456-9200
EMPLOYEE REPRESENTATIVES CONTACTED:	Mr. C. Meral Local 918 Teamster 2137 Utica Avenue Brooklyn, New York 11234
STANDARD INDUSTRIAL CLASSIFICATION OF PLANT:	2751 Commercial Printing, Letter-press and Screen

INTRODUCTION

The National Institute for Occupational Safety and Health is curently conducting an industrial hygiene study of the screen printing industry to characterize and assess worker exposure to chemical and physical agents which may present a potential health risk.

Two to three day surveys were conducted at the firm to characterize the work place exposures. Screen printing shops were classified according to their degree of automation (hand printing, semi-automatic operation, automatic operation, or combinations) and the type of product produced (point-of-purchase, textile, industrial and container). Personal air samples were taken to characterize each job description, (printer, helper, screen washer, etc.).

DESCRIPTION OF FACILITY

Manuscreens was established about six years ago. Since 1975, the firm has been owned by J. Josephson Ink Division. The plant is located at 58-38 Page Place, Maspeth, New York. The occupied industrial building has 92,000 square feet of floor space with high ceilings. The ventilation system consists of six five-horsepower exhaust fans, evenly spaced near the ceiling. Local fans are above the long printing tables. The makeup air unit is located at one side of the building (packaging area).

The printing shop has a photographic and screen making area, screen printing area, ink storage and cleaning area and a large area for storage and packaging.

Wallpaper screen printing is the main line of work for the firm. Work is done by hand operation on several long tables, semi-automatic operation (two Lyllo type and six Fil-Bar type) and a flatbed automatic printing operation. Printed work is dried by five gas driers, one electric drier, and hand printed work is left to air dry.

DESCRIPTION OF WORKFORCE

The present list of employees on the payroll include 45 males in the production area, and two males and eight females in administrative work. Employees belong to Local 918 of the Teamster Union, 2137 Utica Avenue, Brooklyn, New York 11234. The skilled printers have a low turnover rate. The printing shop often operates on tow shifts per day: first shift 7:00 a.m. to 3:30 p.m.; second shift 3:30 p.m. to 11:00 p.m. The workforce can be defined as follows:

First Shift	Employees
Flatbed, automatic printing operators	3
Lyllo Printers (SemiAutomatic printers)	3
Hand Printers	3 + 1 supervisor
Fil-Bar printers (Semi-Automatic printers0	5
Receivers and Inspectors	5
Color Matchers	2 + 2 supervisors
Screen Washer	1
Screen making	2 + 1 supervisor
Maintenance Personnel	3
Screen Inventory Personnel	1

Second Shift	Employees
Flatbed, automatic printing operators	2 + 1 supervisor
Fil-Bar printers (Semi-Automatic printers)	3
Color Matchers	1
Screen Washer	1
Helper, packaging area	1

During the time of the survey, the printing shop only operated on the first shifts.

DESCRIPTION OF PROCESS

Screen printing techniques can best be described as forcing ink through a screen mesh onto the surface to be printed. The non-printing area of the screen is protected by a cutout stencil or blocking of the mesh. The screen is usually made of fine silk gauze. It can also be made of synthetic material.

Various mesh sizes are used to obtain the desired end product.

The design to be printed is transferred to the screen by direct or indirect photomechanical processes. In the direct photomechanical processing, the screen is bonded with a photosensitive layer and then exposed under a photographic illustration. In the indirect photomechanical processing, the printing (pervious) and the non-printing (impervious areas of the screen are similarly prepared. However, the photosensitive film is first exposed by itself before bonding to the screen. Both processes are finished by washing out the non-exposed resist on the photosensitive film with water. The screen is dried and ready to be used.

Screen printing is still done largely by hand. Semi-automated and fully-automated machines can also perform the basic operations. Generally, the process consists of positioning the object to be printed under the frame, lowering the frame onto the material to be printed, and inking and spreading the ink with a squeegee. The frame is lifted up after each application and the printed material removed. The printed object is usually either air dried or speed dried in an exhausted gas heated dryer. Inks can be applied to a wide variety of surfaces such as paper, cardboard, glass, wood, plastic, bottles, electric circuit boards, etc. If printing has to be done on unusual shapes, the squeegee is held stationary while the screen passes under the squeegee at the same time as the object to be printed.

The screen is required to be cleaned at the end of each day and before a long break to prevent ink from permanently clogging up the screen. Ink thinner and screen wash (aromatic hydrocarbon solvents, mineral spirits) are poured over the screen, then wiped and cleaned with cloth or paper towels.

The screen printing inks are extremely varied in consistency depending on the surface to which they are to be applied, but there is little difference from industrial paints except that the composition of the inks must not be such that rapid drying would clog the mesh of the screen.

DESCRIPTION OF EXPOSURES

Health hazards are inherent in the properties of the solvents families (aliphatic and aromatic hydrocarbons, alcohols, ketones, esters, and glycol ethers) used most often by screen printers. Because solvents are flammable liquids with highly combustible vapors, they are potential fire and explosion hazards.

Depending upon the degree of exposure and the solvent involved, the organic solvents affect the central nervous system to some extent as a depressant or an anesthetic. Excessive vapor inhalation causes a lack of coordination and drowsiness, often a leading factor in accidents. Solvents in screen printing also are potential threat for creating effects, (e.g. neuropathy).

Other effects of the misuse of solvents can lead to acute or chronic dermatitis or inflammation of the skin which ranges in severity from simple irritation to systemic damage to the skin.

SAMPLING AND ANALYTICAL METHODS

Standard 150 mg charcoal tubes (100 mg front and 50 mg back-up section), purchased from SKC, Inc., Lot #107, were used with MDA Accuhaler, Model 808 personal sample pumps. All personal samples were taken in the breathing zone of the worker. Pumps were precalibrated to a specific air flow rate for:

1. Time-weighted-average personal samples at 20 cc per minute a full period single sample from workers in the screen printing shops.

2. Threshold Limit Value - Short Term Exposure Limit personal samples at 150 cc per minute for 15 minutes. Workers were randomly selected from the job descriptions throughout the work shift.

3. Area samples at 50 cc per minute for full period single samples, full period consecutive samples, and some partial consecutive samples. Samples were taken near the emmission sources and among the work areas.

Charcoal tube samples were individually desorbed in 1 ml of carbon disulfide containing benzene as an internal standard and analyzed by gas chromatography according to NIOSH P & CAM method #127. Hewlett-Packard 5711 A and 5731 A gas chromatographs with flame ionization detectors were used. The detection limits were calculated to be 0.01 to 0.05 mg for each analyte per tube. Standards and blanks were run on each chromatograph. All samples were analyzed by a NIOSH contract laboratory.

RESULTS

Quantitative analysis of the charcoal tubes samples for organic solvents collected during the three days of the industrial hygiene survey found the following major contaminates:

1. For the time-weighted-average personal samples - toluene, xylene, MIBK, MEK, ethyl acetate, butyl acetate, cyclohexanone, 1,3,5-trimethyl benzene, 1,2,3-trimethyl benzene, and 1,2,4-trimethyl benzene.

2. For the full period single samples, full period consecutive samples and the Short Term Exposure Limit personal samples - toluene, xylene, 1,3,5-trimethyl benzene, 1,2,3-trimethyl benzene, MEK, MIBK and cyclohexanone.

The average time-weighted-average exposure of the personal samples listed by solvent for the individual job descriptions are given in Table I.

Since the reported solvents have the similar narcosis effects, the Threshold Limit Values for mixtures are calculated by using the standard formula:

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \frac{C_3}{T_3} + \qquad = 1$$

C = concentration of a somponent and T = TLV for that component. Table II shows the TLV mixtures for the individual job descriptions.

The concentration levels of the solvents reported could vary from day to day, or even within the same day depending on the type of printing job and the kind of ink and solvent used. Table III shows the solvent concentrations in the printing areas: Automatic Printing area, semi-automatic printing area and hand-printing area. For the other areas in the printing shop, Table IV shows the major solvent concentrations found from the full period single samples taken in the paint storage room and the screen washing area.

There were limited Threshold Limit Value - Short Term Exposure personal sample collected due to the nature of the workers' activities. Table V shows the solvent exposure of automatic printers, semi-automatic printers, hand-printers, screen-washer, and paintman.

DISCUSSION AND RECOMMENDATIONS

Although the solvent concentration levels of the personal and area samples were well below the present Federal OSHA Standards and the NIOSH recommended levels, general recommendations are made in view of the fact that the toxic effect of the concentrations will improve conditions of safety, efficiency, and comfort of the worker. The suggested improvements do not involve expense of engineering changes, or reorganization of present work procedures. They do require more tutored habits of work and general awarness of the influential factors:

1. Maintaining self closing capacity of the bins, leaving open to a minimum.

2. Inks and solvent containers should be habitually closed when they are not being used. Materials that are often used (thus opening the containers frequently) should be used and stored in a well ventilated area, e.g. an exhausted solvent cabinet.

3. Since certain solvents can be absorbed through the skin, solvent resistant gloves should be provided in a convenient spot. When large quantities of solvents are used, as in the cleaning of the screens, gloves should be worn as a matter of practice.

4. Storage bins should be routinely emptied after the workers have cleaned their screens or working surfaces at the end of the day, to avoid additional evaporation that takes place overnight in the work shop.

5. Spillage should be absolutely avoided, and promptly cleaned up when they occur, especially when the work shops have wood floors as gradual evaporation will accumulate with time.

6. In the working habits of different workers, it was observed that workers doing the same task used greatly different quantities of solvent. For example, in cleaning, one worker might use as much as double the quantity of solvent as the other. Workers should be instructed as to the judicial use of solvents.

7. The relation of workers' height and the level of the work bench, the worker should be encouraged to adjust the level to the best height.

   Working habits should be observed and brought to the attention of worker not only for safety but for efficiency and comfort.

8. If a respirator is used, either during printing or washing, the workers should be instructed as to the proper use and maintenance of the respirator. It should be remembered that the use of respirators is no substitute for proper engineering controls of solvent vapors.

9. Eating and smoking should be prohibited in or near the working area.

10. The information provided by most chemical supplies is not adequate to identify the hazards associated with a particular product. Seek and obtain help from trade associations, insurance carriers, or from a professional organization for the formulation and implementation of a safety and health program for the workplace.

11. Workers should be properly educated about the hazards of solvents and ink exposure, the proper and judicious use of solvents, and, if necessary, the proper use and care of respirators.

CONCLUSIONS

It appears that workers in all job descriptions were exposed to low concentrations of many solvents. Never-the-less, recommendations are made to improve conditions of safety, efficiency, and comfort of the workers.

TABLE I

THE AVERAGE TWA EXPOSURE OF THE PERSONAL SAMPLES LISTED BY SOLVENT

Job Description	Number of days	Toluene (ppm)	Xylene (ppm)	MIBK (ppm)	MEK (ppm)	Ethyl Acetate (ppm)	Butyl Acetate (ppm)	Cyclohexanone (ppm)	1,3,5 Trimethyl Benzene (ppm)	1,2,3 Trimethyl Benzene (ppm)	1,2,4 Trimethyl Benzene (ppm)
Hand Printer 65	3	0.98	1.5	9.1	3.9	0.91	0.13	3.2	1.7	4.0	1.6
Hand Printer 70	3	1.3	1.7	4.7	3.4	2.6	0.39	2.8	2.1	2.8	1.5
Hand Printer 73	3	0.16	0.28	1.6	0.73	1.1	0.17	0.46	0.37	0.88	0.25
Semi-Automatic Printer 60	3	1.8	0.74	1.3	9.9	7.6	1.2	1.8	0.93	1.5	0.84
Semi-Automatic Printer 61	3	0.62	0.52	1.6	1.0	0.75	0.11	1.1	0.71	1.5	0.47
Semi-Automatic Printer 62	1	2.7	1.9	0.24	2.8	1.4	0.21	6.6	2.9	7.0	2.1
Semi-Automatic Printer 63	3	2.3	1.5	1.7	2.0	1.0	0.15	5.2	1.5	1.7	1.2
Semi-Automatic Printer 64	3	1.1	1.9	2.4	2.0	0.75	0.11	3.8	1.9	4.6	1.3
Semi-Automatic Printer 69	2	2.0	0.97	1.5	2.0	1.0	0.15	6.1	2.1	2.4	1.3
Semi-Automatic Printer 72	2	0.60	0.91	1.6	1.6	0.82	1.3	1.8	0.92	1.7	0.69
Semi-Automatic Printer 75	2	0.48	0.56	1.2	0.70	0.72	0.11	1.2	0.49	0.74	0.37
Semi-Automatic Printer 178	1	0.01	0.01	0.01	--	--	--	--	0.01	0.02	0.01
Semi-Automatic Printer 179	1	0.01	--	0.01	--	--	--	--	0.01	0.01	--
Semi-Automatic Printer 180	1	0.01	0.01	0.02	--	--	--	--	0.01	0.02	--
Automatic Printer 57	3	0.21	0.18	0.60	0.49	0.73	0.11	0.68	0.40	1.0	0.32
Automatic Printer 58	3	0.37	0.45	1.3	2.0	0.88	0.13	1.3	0.41	1.7	0.63
Automatic Printer 59	3	0.48	0.59	1.3	3.1	0.85	0.13	1.1	0.64	1.5	0.75
Hand Washer 68	3	0.02	2.1	4.5	6.3	9.5	0.20	1.9	3.9	8.0	2.7
Screenmaker 202	1	0.01	--	--	0.34	--	--	--	--	--	--
Paint Man 66	3	0.44	0.19	0.77	2.2	3.3	0.50	1.6	0.33	1.0	0.33
Paint Man 67	3	0.82	0.08	1.3	2.2	1.7	0.25	1.1	0.89	1.5	0.54
General Laborer 71	3	0.09	0.19	3.2	0.60	0.92	0.14	0.26	0.15	0.36	0.14
General Laborer 74	2	0.33	0.28	0.64	2.0	0.72	0.11	0.46	0.37	0.88	0.25
General Laborer 181	1	--	--	--	--	--	--	--	--	0.01	--
General Laborer 182	1	0.01	--	--	--	--	--	--	--	0.01	--
Federal Standard (ppm)		100	100	100	200	400	150	50	25	25	25

TABLE II

THRESHOLD LIMIT VALUES FOR MIXTURES BY INDIVIDUAL JOB DESCRIPTIONS

Job Description	Days Sampled	TLV for Mixtures
Hand Printer 65	3	0.44
Hand Printer 70	3	0.42
Hand Printer 73	3	0.10
Semi-Automatic Printer 60	3	0.25
Semi-Automatic Printer 61	3	0.18
Semi-Automatic Printer 62	1	0.65
Semi-Automatic Printer 63	3	0.35
Semi-Automatic Printer 64	3	0.45
Semi-Automatic Printer 69	2	0.41
Semi-Automatic Printer 72	2	0.24
Semi-Automatic Printer 75	2	0.13
Semi-Automatic Printer 178	1	—
Semi-Automatic Printer 179	1	—
Semi-Automatic Printer 180	1	—
Automatic Printer 57	3	0.09
Automatic Printer 58	3	0.12
Automatic Printer 59	3	0.17
Hand Washer 68	3	0.63
Screen Maker 202	1	—
Paint Man 66	3	0.11
Paint Man 67	3	0.17
General Laborer 71	3	0.09
General Laborer 74	2	0.08
General Laborer 181	1	—
General Laborer 182	1	—
Federal Standard		1.00

TABLE III

THE MAJOR SOLVENT CONCENTRATIONS IN THE SCREEN PRINTING AREAS

Solvent	Federal Standard (ppm)	Automatic Printing			Semi-Automatic Printing			Hand Printing
		Day 1	Day 2	Day 3	Day 1	Day 2	Day 3	Day 3
Toluene (ppm)	100	10.8	0.57	1.0	44.3	0.66	0.42	0.11
Xylene (ppm)	100	2.4	0.75	0.44	9.6	1.2	1.4	1.1
MIBK (ppm)	100	2.5	0.80	0.47	10.2	0.96	1.3	1.3
1,3,5-Trimethyl Benzene (ppm)	25	2.1	0.44	0.39	8.5	0.76	0.85	0.70
1,2,3-Trimethyl Benzene (ppm)	25	2.1	1.6	1.0	8.5	2.3	2.0	1.74
1,2,4-Trimethyl Benzene (ppm)	25	2.1	0.11	0.20	8.5	0.51	0.64	0.52
Cyclohexanone (ppm)	50	2.5	0.54	0.12	10.4	0.94	0.91	0.74
MEK (ppm)	200	6.9	0.37	0.66	28.3	0.42	0.88	0.14

TABLE IV

THE MAJOR SOLVENT CONCENTRATIONS IN THE PAINT ROOM AND THE SCREEN-WASH AREA

Solvent	Federal Standard (ppm)	Paint Room			Screen-Wash Area		
		Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
Toluene (ppm)	100	0.29	3.9	--	5.9	2.3	0.12
Xylene (ppm)	100	0.37	0.85	1.7	5.9	2.1	0.05
MIBK (ppm)	100	1.8	0.91	0.94	4.9	1.0	0.05
1,3,5-Trimethyl Benzene (ppm)	25	0.87	0.75	0.59	15.7	6.6	0.05
1,2,3-Trimethyl Benzene (ppm)	25	2.4	1.5	1.6	27.4	7.4	0.05
1,2,4-Trimethyl Benzene (ppm)	25	0.66	0.75	0.49	7.8	2.7	0.05
Cyclohexanone (ppm)	50	0.80	0.92	0.72	3.9	1.3	0.05
MEK (ppm)	200	0.91	2.5	1.8	2.6	0.80	0.16

TABLE V

THE AVERAGE SHORT TERM EXPOSURE OF THE MAJOR JOB DESCRIPTIONS

SOLVENT	FEDERAL STANDARD (ppm)	AUTOMATIC PRINTER		SEMI-AUTOMATIC PRINTER		HAND PRINTER		SCREEN WASHER		PAINT MAN
		Day 2	Day 3	Day 2	Day 3	Day 2	Day 3	Day 2	Day 3	DAY 3
Toluene (ppm)	100	2.7	0.89	3.1	1.5	1.8	3.5	9.7	4.9	1.1
Xylene (ppm)	100	5.0	1.1	0.76	2.6	0.90	0.77	4.0	2.9	1.1
MIBK (ppm)	100	0.82	0.61	1.8	1.6	3.9	4.1	3.8	2.7	1.6
1,3,5-Trimethyl Benzene (ppm)	25	0.80	0.34	1.5	0.84	1.5	0.68	8.4	4.9	0.67
1,2,3-Trimethyl Benzene (ppm)	25	2.7	1.0	4.6	2.7	4.5	3.4	16.1	9.7	2.3
1,2,4-Trimethyl Benzene (ppm)	25	0.52	0.34	1.0	0.42	0.52	0.34	3.1	2.4	0.50
Cyclohexanone (ppm)	50	0.41	0.42	1.5	1.2	1.1	0.42	2.0	1.0	0.51
MEK (ppm)	200	3.9	1.3	1.1	2.3	1.1	1.1	6.5	1.7	4.5
NUMBER OF SAMPLES		2	2	4	4	2	1	2	4	2