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Control of Methylene Chloride—Furniture Stripping Dip Tank

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The furniture stripping industry has an estimated 21,000 workers who are employed by approximately 4000 small businesses averaging slightly over five employees each. Previous worker exposure studies have documented time-weighted average exposures to methylene chloride in the furniture stripping industry ranging from 300 parts of methylene chloride per million parts of air (ppm) to over 2100 ppm. This article describes an evaluation of a local exhaust ventilation system designed by researchers from the National Institute for Occupational Safety and Health (NIOSH) for furniture stripping dip tanks that can be used to control methylene chloride exposures to workers. The dip tank process makes up approximately 10 percent of the furniture stripping industry. (Ventilation systems for the major process, the solution recycle method, have been previously evaluated by NIOSH researchers and the information has been published elsewhere.) The ventilation system described herein is a two-sided slot hood with an exhaust flow of 2900 ft³/min. After installation of this system at a small commercial furniture stripping and refinishing shop, air samples for methylene chloride were collected during furniture stripping operations. The geometric mean of personal exposures to methylene chloride was 13 ppm (during stripping only processes with no rinsing being done in the shop), which is less than the Occupational Safety and Health Administration (OSHA) proposed permissible exposure limit (PEL) of 25 ppm. In previous worker exposure evaluations at this shop, methylene chloride levels were approximately 2200 ppm with no ventilation system, and 230 ppm with an owner-designed ventilation system. With the slot hood in place, air samples for methanol, toluene, 1,1,1-trichloroethane, and perchloroethylene were all well below the NIOSH recommended exposure limit and OSHA PEL. The estimated cost of the system was \$3500. Other furniture stripping facilities that utilize dip tanks could apply this type of ventilation system to reduce worker exposure to methylene chloride. HALL, R.M.; MARTINEZ, K.F.; JENSEN, P.A.: CONTROL OF METHYLENE CHLORIDE—FURNITURE STRIPPING DIP TANK. *APPL. OCCUP. ENVIRON. HYG.* 10(3):188-195; 1995.

The furniture stripping industry consists of approximately 4000 small businesses averaging slightly over five employees each, with a total of approximately 21,000 workers.⁽¹⁾ Methylene chloride is the primary constituent of most stripping solutions. Methylene chloride exposures have been found to range from 300 parts of methylene chloride per million parts of air (ppm) to over 2100 ppm.⁽²⁻⁴⁾ Stripping solutions can

contain up to 90 percent methylene chloride, with methanol being the second most common constituent; other possible ingredients may include toluene, xylene, sodium hydroxide, acetone, and other organic compounds. Control technology information is needed in the furniture stripping industry because methylene chloride is a potential occupational carcinogen and there are a large number of workers potentially exposed.^(5,6) In addition, furniture stripping shops generally do not have the financial or technical resources to develop engineering control solutions on their own.

The two major types of stripping methods used in the industry are the solution-recycling stripping method and the dip tank stripping method. Previous engineering control studies by researchers at the National Institute for Occupational Safety and Health (NIOSH) have documented worker exposures and control measures during the solution-recycling stripping method.^(7,8) This technique is used by approximately 85 to 90 percent of the furniture stripping industry.⁽⁹⁻¹¹⁾ The dip tank stripping process discussed herein is used by approximately 10 to 15 percent of the furniture stripping industry.⁽⁹⁻¹¹⁾

In this article, a control technology demonstration at a facility that strips furniture using a dip tank is presented. This facility is a furniture stripping and refinishing shop that has six full-time employees, including co-owners. Two persons regularly stripped furniture on a daily basis and the other four performed refinishing operations. The furniture stripping area occupied 300 ft² of the 1500-ft² work area. The purpose of this case study was to evaluate the extent to which a local exhaust ventilation system may reduce workers' exposures to methylene chloride. Although the results of this case study apply specifically to this facility, the findings should be relevant to other dip tank stripping operations since processes in general are similar.

Furniture stripping must be flexible to accommodate different sizes, types, and finishes of furniture while still protecting the wood for refinishing. The dip tank method is relatively simple. Furniture is dipped in an open tank containing stripping solution, which softens and dissolves the finish that is on the furniture. Brushes and scraping tools are utilized to remove the remaining finish. The furniture is then moved to a rinse table, where the stripping solution is rinsed from the furniture with water. After the rinsing is completed, the furniture is set aside to dry before a new finish is applied.

Potential chemical hazards are found primarily during the actual handling and stripping of the furniture. Other potential chemical hazards are found during the following processes: rinsing of furniture after stripping; mixing or transferring of

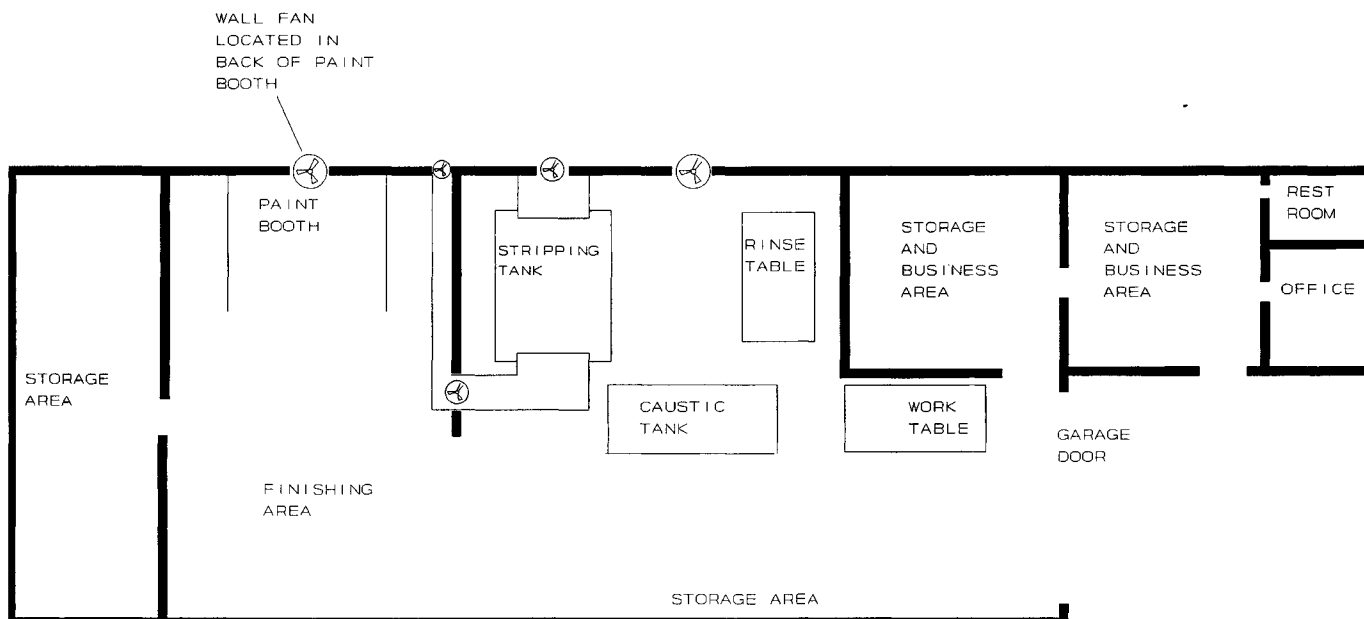


FIGURE 1. Shop diagram with owners' control on dip tank.

stripping solution; evaporation of solution from the dip tank; or evaporation of solution off furniture after stripping. The major routes of entry of methylene chloride and other solvents into the body include inhalation of vapors and absorption of the liquid through the skin.⁽¹²⁾ The severity of the hazard depends on the formulation of the stripping solution, type of stripping process, work practices, personal protective equipment, duration of exposure, temperature, ventilation (i.e., type of system, location relative to worker position, air patterns, and flow rates), and general workstation design.

The facility in this case study consisted of four areas: stripping, rinsing, finishing, and storage. Stripping solutions were prepared by shop personnel to contain approximately 60 to 80 percent methylene chloride and 20 to 30 percent methanol. During this case study the facility used a commercial product, "liquid C," which contains methylene chloride, perchloroethylene, 1,1,1-trichloroethane, and toluene. Liquid C made up 10 to 20 percent of the stripping solution in the dip tank, and was added when the solution in the tank was low.

In some instances a heated caustic soda solution dip tank was used to remove finishes for which methylene chloride was marginally effective, such as enamel-painted doors, windows, and shutters. However, caustic stripping was not performed or evaluated during this study.

The owners at the facility designed and installed a single slot hood at each end of the 8-ft long by 3.5-ft wide by 3.1-ft deep dip tank (located against a wall). This hood was installed after sampling determined that methylene chloride levels were 2160 ppm without any control.⁽²⁾ Figure 1 is a schematic of the facility with the owners' control in place.

The velocity at the slots averaged 500 ft/min and the flow through each slot averaged 700 ft³/min.⁽¹³⁾ The system exhausted at a rate of 50 ft³/min per ft² of tank surface area. [The American Conference of Governmental Industrial Hygienists (ACGIH) recommends 125 ft³/min per ft² for open surface

tanks located against a wall (see Table 10.5-4 in Reference 14).⁽¹⁴⁾] A wall fan between the dip tank and the rinse area exhausted at a rate of approximately 3000 ft³/min.⁽¹³⁾ This control system reduced worker exposures to methylene chloride to 230 ppm.⁽¹³⁾

Methodology

Hood Design

After evaluating the owners' control system,^(2,13) NIOSH researchers decided that a new ventilation system was needed to control methylene chloride exposures to lower levels. This decision was made because methylene chloride is considered a potential occupational carcinogen by NIOSH and because the Occupational Safety and Health Administration (OSHA) has a proposed permissible exposure limit (PEL) of 25 ppm. With the cooperation of the owners, a slotted hood ventilation system was designed and installed based on criteria established by ACGIH for open surface tanks (see VS-503.1 in Reference 14). The ventilation system was constructed of galvanized sheet metal (22 gauge) with reinforcement steel used on stress points to maintain physical integrity. A plenum was attached to the front end of the tank and to the slot hoods on each side of the tank to obtain even air flow distribution throughout the system. A 12-inch-diameter duct from the center of the front plenum passed through the wall of the building into a fan located outside. For evaluation of this system, a portable, gasoline-powered, 2900-ft³/min fan was used.

The total cost of the system including the purchase of a similar sized electric fan, fabrication of the system (40 hours of labor at \$50/hour), and materials was estimated at \$3500. The annual cost of heating the replacement air is estimated at \$560. The following equation was used to calculate the estimated cost of the replacement air:⁽¹⁴⁾

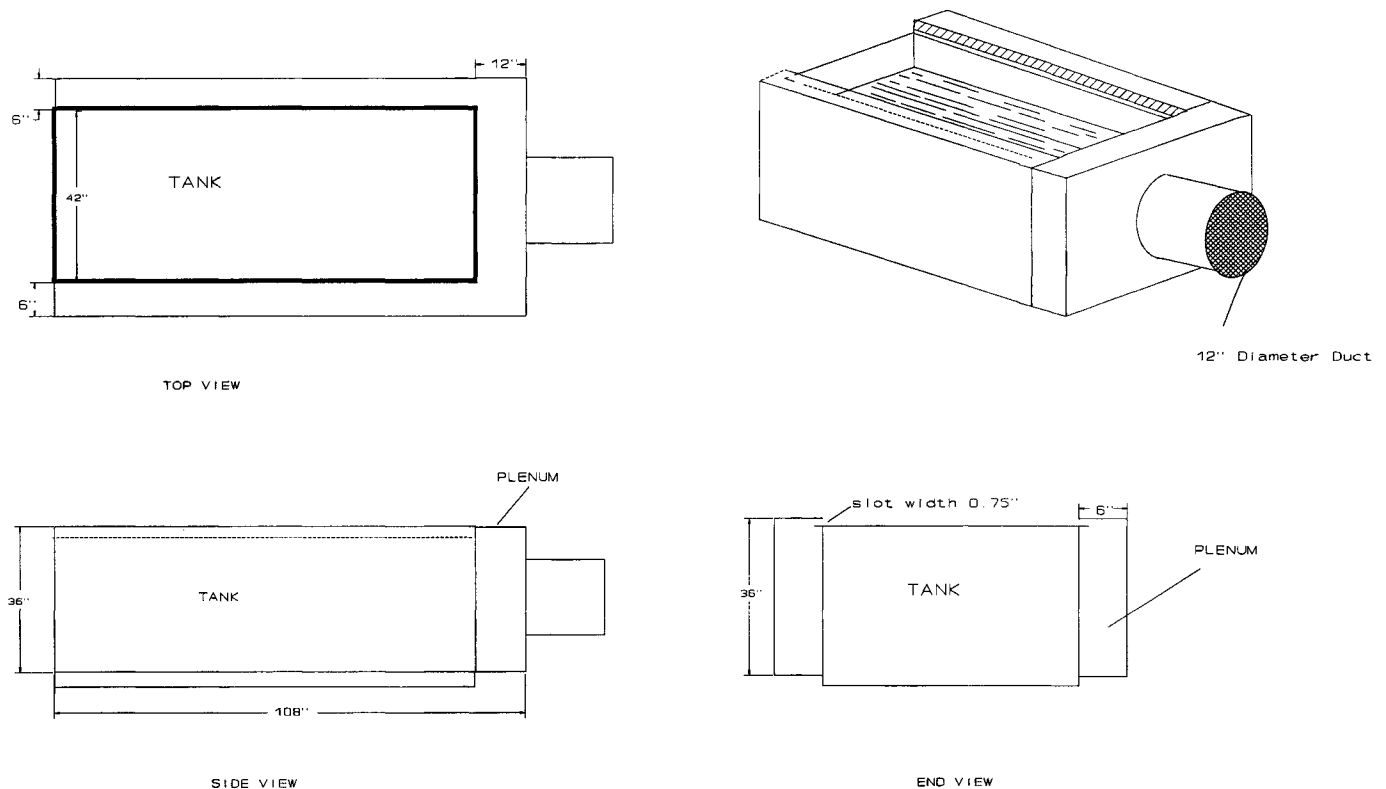


FIGURE 2. New exhaust hood attached to furniture stripping dip tank.

$$\text{annual cost} = \frac{0.154(Q)(dg)(T)(c)}{q}$$

where:

- Q = air flow rate (cubic feet/minute)
- dg = annual degree days
- T = operating time (hours/week)
- c = cost of fuel (\$/unit)
- q = available heat per unit of fuel

The annual cost of heating replacement air was based on several assumptions. The operating time of the ventilation system was estimated at 40 hours/week. The annual degree days for the location of the shop were not readily available; data for St. Louis, Missouri, 4822, were used. The temperature was assumed to be maintained at 65°F with a natural gas heat exchanger system operating at 80 percent efficiency (available heat of gas is 800 btu/ft³). The gas was estimated to cost \$0.0052/ft³.⁽¹⁵⁾

Figure 2 shows a diagram of this newly designed local exhaust ventilation system. Figure 3 shows the shop layout with the new ventilation system attached to the dip tank.

The hood entry coefficient is not given since design constraints (space available in the shop) did not allow for optimum plenum design. The slots that extended the length of the tank had a width of 0.75 inches and an average velocity of 3200 ft/min. The average exhaust flow through the system was 2900 ft³/min (evaluated using a standard pitot traverse with an inclined tube manometer), an average of 104 ft³/min per ft² of tank surface area. If more space were available in the shop,

modifications could be made to reduce static losses and increase the efficiency of this system.

Study Methods

During the evaluation of the local exhaust ventilation system, the facility operated under normal conditions, with worker A performing stripping operations and worker B performing both stripping and rinsing operations. Various types of furniture including chairs, doors, bookshelves, and tables were stripped during the evaluation.

Quantitative air sampling was conducted for methylene chloride, methanol, toluene, perchloroethylene, and 1,1,1-trichloroethane. All personal air samples were collected side by side in the breathing zone of the workers for the duration of the sampling periods. Samples for all solvents other than methylene chloride were well below the NIOSH recommended exposure limit and the OSHA PEL.

The rinse area was located near the furniture stripping dip tank (see Figure 3). During the evaluation of the local exhaust ventilation system, stripping and rinsing operations were generally performed at the same time when worker A was present. Air flow patterns through the shop indicated that the air flowed through the rinse area into the stripping area (see Figure 3). Therefore, when these operations were performed at the same time, emissions from the rinse station could increase the exposure concentrations of the operator at the stripping tank.

The charcoal and silica gel sorbent tubes were used in combination with Dupont P200a (Dupont, Wilmington, Del-

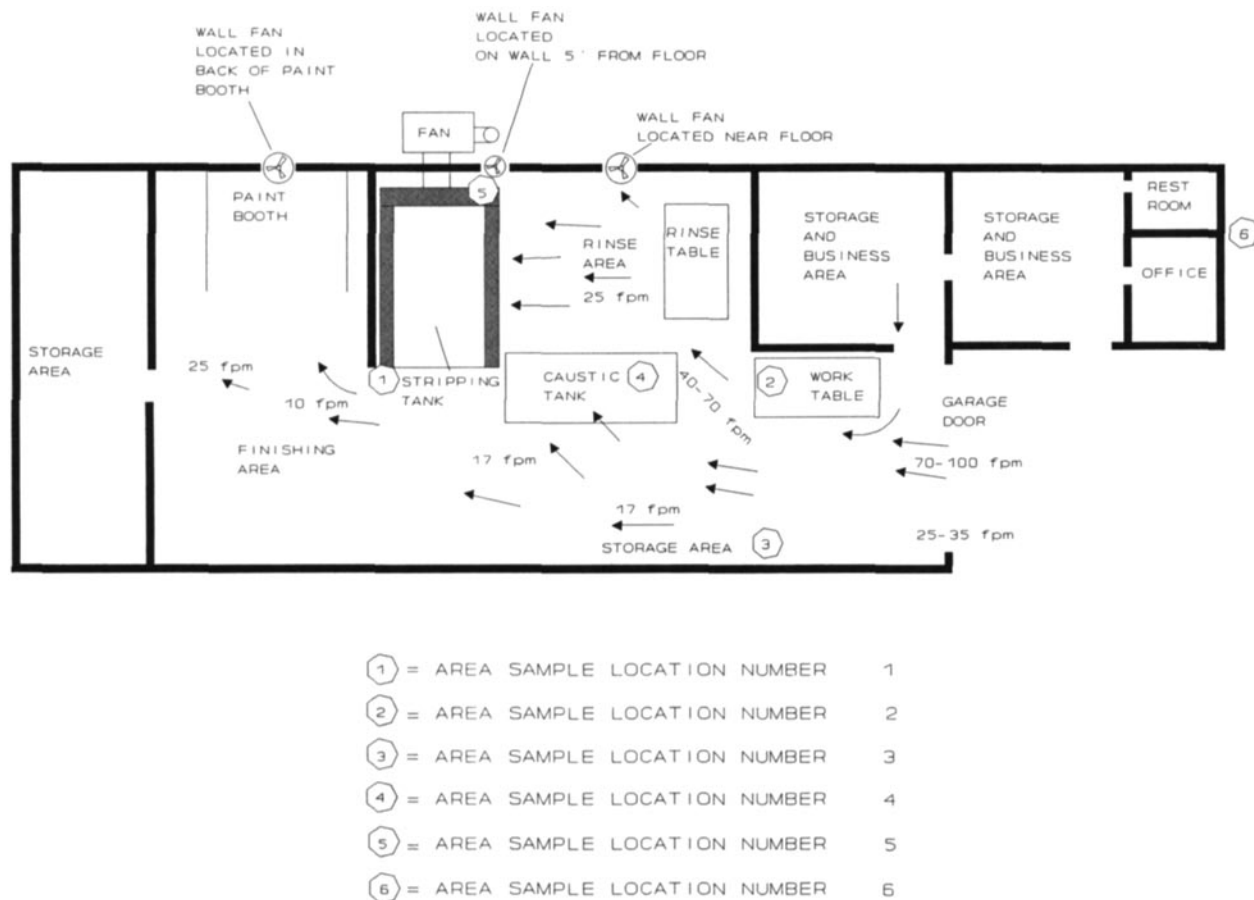


FIGURE 3. Shop layout with new ventilation system attached to dip tank with air currents plotted.

aware) personal sampling pumps. Sorbent tube sampling was conducted at a nominal flow rate of 0.02 L/min, in accordance with NIOSH Methods 1005 (methylene chloride), 1500 (toluene), 1003 (perchloroethylene and 1,1,1-trichloroethane), and 2000 (methanol).⁽¹⁶⁾ Methylene chloride, toluene, perchloroethylene, and 1,1,1-trichloroethane were absorbed onto two 100/50-mg activated charcoal tubes (model 226-01; SKC, Inc., Eighty-four, Pennsylvania) in series, and methanol was absorbed onto a 150/75-mg silica gel sorbent tube (model 226-10; SKC, Inc.). The sorbent tubes were sent to a contract analytical laboratory for analysis. The methanol was desorbed from the silica gel using 1.0 ml of deionized water (4 hours). Samples were analyzed by gas chromatography/flame ionization detector (GC/FID) on a 30 m × 0.53 mm fused silica capillary coated internally with 1.0 μm of DB-WAX. The oven temperature was maintained at 50°C. The other solvents were desorbed from the charcoal tubes using 1.0 ml of carbon disulfide containing 0.5 μL/ml of *n*-hexane as an internal standard (30 minutes). Samples were analyzed by GC/FID on a 30 m × 0.32 mm fused silica capillary column coated internally with 0.50 μm of DB-WAX. The oven temperature was programmed from 40° to 75°C at a rate of 10°C/min.

On the first day of the evaluation, four personal air samples were collected during stripping only operations, and 12 during stripping operations while rinsing operations also were being accomplished. On the second day, eight personal air samples

were collected during stripping only operations, and ten during stripping operations while rinsing operations also were being accomplished. On the third day, eight personal air samples were collected during stripping only operations, and seven during stripping operations while rinsing operations also were being accomplished.

Area samples for solvent vapors were also collected. As shown in Figure 3, six sets of area samples were collected: (1) behind the dip tank near the rinse area; (2) on a table near the rinse area; (3) along the wall in the storage area; (4) on the caustic tank near the rinse area; (5) above the dip tank on the plenum near the fan; and (6) outside the building near the office as a background sample.

At the beginning and end of each sampling day, a 20-ml sample of the stripping solution was collected. These samples were analyzed by NIOSH researchers. An aliquot of each bulk sample of furniture stripping solution (70 to 200 mg) was weighed into a 10-ml volumetric flask. Carbon disulfide was added immediately to dissolve the liquid and reduce the loss by evaporation. The samples were then diluted to volume and injected into a gas chromatograph equipped with a 50 m × 0.3 mm fused silica capillary column coated internally with 0.5 μm of HP-1. A flame ionization detector was used to detect compounds eluting from the column, and quantitation was accomplished by comparing analyte chromatographic peak areas of the samples with those of prepared standards. The

TABLE 1. Personal Concentrations of Methylene Chloride (ppm) During Both Stripping and Rinsing Operations and Stripping Only Operations with 95 Percent Confidence Levels Calculated

	Number of Samples	Geometric Mean	Geometric Standard Deviation	Upper 95 Percent Confidence Limit	Lower 95 Percent Confidence Limit
During stripping operations while worker B performed rinsing					
Worker A	8	26	2.6	38	18
During both stripping and rinsing operations					
Worker B	10	59	1.4	63	56
During stripping only operations					
Worker A	4	13	2	19	9
Worker B	5	13	1.4	14	12

results of the analyses were reported on a mass fraction basis (mass of analyte \cdot 100 percent/mass of solution).

In addition, real-time measurements of exposure to solvents was measured using a photoionization detector (PID) with a 10.6-eV ultraviolet lamp. The PID responds to the mixture of methylene chloride and methanol vapors as well as all other volatile organic compounds. The analog output signal from the PID was recorded on a data logger. The data logger was later downloaded to a portable computer for further data analysis. Grab samples of air from the exhaust of the PID were analyzed using a portable, computer-operated gas chromatograph with an argon ionization detector to provide a near real-time indication of the exposure of the workers to organic solvent vapors. Results indicated that the ratio of methylene chloride concentration to the methanol concentration was relatively constant. Thus, it was assumed that the PID should respond proportionally the same, regardless of absolute concentration. Since the ratio of the two concentrations was relatively constant, back-calibration of the real-time PID exposure data was performed using the sorbent tube data. The following formula was used to convert the output of the PID (volts) to concentration of contaminant (ppm):

$$C(t) = IR(t) * ST * / SIR(t)$$

where:

- $C(t)$ = concentration of vapor at time t (ppm)
 $IR(t)$ = instrument response at time t (volts)
 ST = time-weighted average (TWA) concentration of contaminant as collected on sorbent tubes for the sampling time (ppm)
 $SIR(t)$ = TWA of the instrument response over the sampling time (volts)

The major assumption in this estimation was that dilution is instantaneous and occurs with no change in the relative vapor ratios. In addition, it was assumed that there is linear variation in instrument response with respect to changes in concentration of all contaminants in the air.

Analysis of the real-time data allowed a 15-minute average concentration to be calculated for any time interval during the work shift. The 15-minute averages for methylene chloride were compared to the OSHA proposed short-term exposure limit (STEL) of 125 ppm.⁽¹⁷⁾ Analysis of real-time data also allowed specific operations to be identified that were causing elevated exposures.

Temperature and humidity were monitored continuously using a data logger with a special probe (POD 29/03). The temperature ranged from 19° to 33°C and the relative humidity ranged from 60 to 100 percent.

Results and Discussion

Sorbent Tube Data

Perchloroethylene was not detected on any of the sorbent tubes. 1,1,1-Trichloroethane was not detected on 65 percent of the samples with a maximum concentration of 5 ppm detected in the other tubes. Average concentrations for toluene during the study ranged from 3 to 4 ppm. Breathing zone samples for methanol ranged from 11 to 25 ppm, with a geometric mean of 17 ppm. Because of the high humidity experienced during this study, a majority of the samples contained methanol in the back-up section of the silica gel tubes. Thus, the actual exposures to methanol may be higher than those reported. A detailed analysis of methylene chloride exposures follows.

PERSONAL SAMPLES. The results of the personal air sampling data for methylene chloride are summarized in Table 1. Table 2 presents TWA worker exposure to methylene chloride for the duration of work activities (ranging from 227 to 549 minutes) by day. Table 2 also includes sample concentration ranges (the concentrations varied throughout the day because sampling periods included both stripping only operations and

TABLE 2. Time-Weighted Average (for the Duration of Work Activities) of Methylene Chloride (ppm) of Workers by Day

	Number of Samples	Concentration Range (ppm)	Total Time Sampled (min)	TWA (ppm)
Worker A				
Day 1	5	(10-79)	407	36
Day 2	4	(6-33)	224	14
Day 3	3	(26-69)	227	46
Worker B				
Day 1	5	(13-80)	461	70
Day 2	6	(13-93)	549	46
Day 3	4	(8-69)	287	48

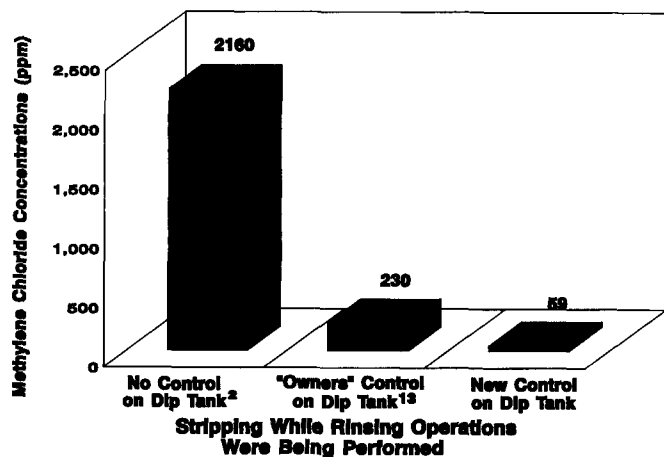


FIGURE 4. Personal sampling data recorded in shop.

stripping operations while rinsing was being performed) and number of samples used in calculating TWA exposures. All sample results were assumed to be lognormally distributed; statistical analyses were performed on the log-transformed data.⁽¹⁸⁾ The differences between stripping only and both rinsing and stripping personal air samples were analyzed by a *t*-test.

Table 1 shows personal air sampling results. When worker A performed stripping operations at the same time worker B performed rinsing operations, worker A had a geometric mean personal exposure of 26 ppm of methylene chloride. Worker B, while doing both rinsing and stripping, had a geometric mean personal exposure of 59 ppm of methylene chloride. When stripping was done while the rinse station was idle (stripping only), both worker A and worker B had a geometric mean exposure of 13 ppm of methylene chloride. Daily TWA exposures (for the duration of work activities) of methylene chloride were calculated for each worker. On the first day, the TWA exposure was 36 ppm for worker A and 70 ppm for worker B. Worker A's TWA exposure was 14 ppm on the second day of the survey and worker B's was 46 ppm. On the third day the TWA exposure was 46 ppm for worker A and 48 ppm for worker B.

It was observed that worker A was in and out of the building performing other duties; therefore, his exposure was less than that of worker B, who performed rinsing and stripping operations throughout the day. Worker A did not perform any rinsing operations. However, he sometimes performed stripping operations at the same time worker B was rinsing. At these times, exposures for worker A were higher than when worker B was not rinsing. Data collected for worker B showed a statistically significant increase in exposure during periods in which he performed both stripping and rinsing operations, as opposed to periods when he performed only stripping operations. This indicated that the rinsing operation contributed to the exposure. The lack of statistical significance between exposures to worker A while stripping only and stripping while worker B performed rinsing operations supports this conclusion.

Figure 4 shows the personal exposure reduction of methylene chloride concentrations (during stripping operations while rinsing operations were being performed) as a result of the

installation of the owners' ventilation system and the new local exhaust ventilation system. Worker exposure to methylene chloride was 2160 ppm with no controls on the dip tank.⁽²⁾ The owners' control lowered worker exposure to 230 ppm.⁽¹³⁾ With the new local exhaust ventilation system installed on the dip tank, worker B had a geometric mean of 59 ppm while doing both stripping and rinsing operations.

AREA SAMPLES. Table 3 summarizes area sampling data. Statistical analyses were performed on log-transformed data⁽¹⁸⁾ and were analyzed by an analysis of variance.⁽¹⁹⁾ A significance level of 0.05 is the basis for the following discussion. There was a significant difference in concentration between area samples 1, 2, 3, 4, and 5 (inside the facility) versus area 6 (outside near the office). There was no significant difference in concentration between areas 2, 4, and 5. Area 1 had a geometric mean concentration (GMC) of 17 ppm and was significantly lower than areas 2 (GMC = 24 ppm), 4 (GMC = 23 ppm), and 5 (GMC = 36 ppm). Area 3 (GMC = 8 ppm) was also significantly lower than areas 2, 4, and 5. Area 1 (located on the back side of the dip tank) and area 3 (located on the wall in the storage area) were away from the rinse area; therefore, they were not influenced as much by rinsing operations as areas 2 (located on the table near rinse area), 4 (located on the caustic tank near rinse area), and 5 (located on the front plenum of the ventilation system with the sorbent tubes located in front of the wall fan). Air currents plotted on the last day of the survey (see Figure 3) showed that the air flowed through the rinse area into the stripping area before being exhausted out the ventilation system on the tank or the wall fan located above the tank.

Bulk Liquid Samples

The liquid C solution contained approximately 60 percent (wt/wt) methanol, 32 percent methylene chloride, 3 percent toluene, 0.053 percent 1,1,1-trichloroethane, and 0.0031 percent perchloroethylene. Liquid C was diluted with methylene chloride in the stripping tank. The average composition (wt/wt) of solvents in the stripping tank during the study was 22 percent methanol, 69 percent methylene chloride, 6 percent toluene, 0.022 percent 1,1,1-trichloroethane, and 0.0013 percent perchloroethylene.

Real-Time Data

After business hours the ventilation system was turned off and a cover was placed on top of the furniture stripping dip tank. An air sample, collected and analyzed by the portable gas chromatograph in the morning before the shop opened, showed the methylene chloride concentration to be 1000 ppm.

OSHA has proposed a 125-ppm STEL for methylene chloride.⁽¹⁷⁾ Results of the 15-minute averages calculated over the work shift during the first day of the study for worker B (during both stripping and rinsing operations) are shown graphically in Figure 5. Analysis of the real-time data allows a 15-minute average to be calculated for any time period in the work shift.

A new 15-minute average was calculated every 15 seconds. To do this, an average was calculated for the time period extending 7.5 minutes before and 7.5 minutes after each 15-

TABLE 3. Area Sample Concentrations of Methylene Chloride (ppm)

Area	Number of Samples	Geometric Mean	Geometric Standard Deviation	Upper 95 Percent Confidence Limit	Lower 95 Percent Confidence Limit
1	8	17	2.04	19	14
2	12	24	1.77	29	21
3	7	8	1.61	10	7
4	12	23	1.95	27	20
5	12	36	1.49	42	31
6	5	0.49	1.25	0.57	0.42

second increment. Using this technique, it is possible to calculate 1860 15-minute averages for an 8-hour time period, with each average centered on a different 15-second increment. Between 87 and 100 percent of these averages per day were below 125 ppm of methylene chloride. In cases where the peak exposure was above 125 ppm, the exposure was primarily due to the rinsing operations.

Conclusions and Recommendations

In the furniture stripping industry, stripping operations are generally the major source of methylene chloride exposure. At this facility, worker exposures to methylene chloride were as high as 2160 ppm prior to installation of controls on the dip tank.⁽²⁾ After installation of the owners' control, worker exposures to methylene chloride were reported to be 230 ppm.⁽¹³⁾ The new local exhaust ventilation system (with an estimated cost of \$3500) on the furniture stripping dip tank effectively controlled worker exposures to methylene chloride to 13 ppm when only stripping operations were being performed. When both rinsing and stripping were being performed at the same time, there was an added exposure. The geometric mean for worker A was 26 ppm during stripping operations accomplished when worker B performed rinsing operations. The geometric mean for worker B was 59 ppm during periods when both stripping and rinsing operations were being performed.

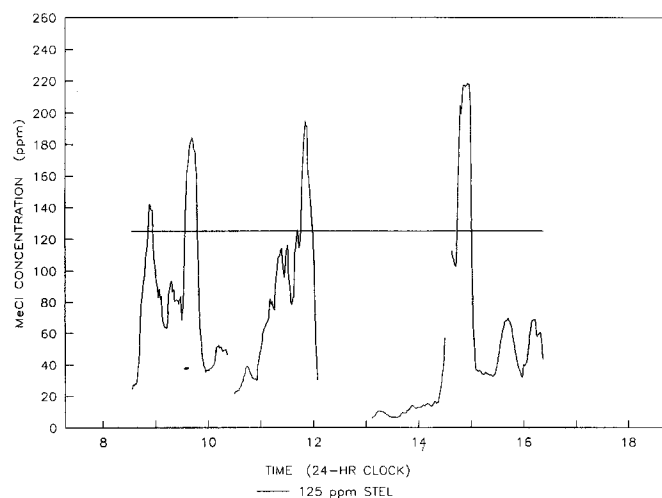


FIGURE 5. STEL 15-minute averages for worker B during both stripping and rinsing operations for day 1.

After installing effective controls on the dip tank, exposures during rinsing operations were greater than stripping or performing any other task. This was mainly due to the fact that the rinse area was not being locally ventilated. A ventilated booth (using design criteria found in Reference 14) was recommended to the shop owners to control rinsing operations. Because of vapor buildup in the shop overnight, it was also recommended that the ventilation systems be started prior to entering the building.

The type of ventilation control described herein for controlling exposures for dip tanks, and the findings regarding ventilating rinse areas, should be applicable in other furniture stripping shops with similar furniture stripping operations. This study shows that such controls are successful in reducing long-term and short-term methylene chloride exposures from the excessive levels that are now found in dip tank processing operations to levels meeting the proposed OSHA PEL of 25 ppm if the rinse area is controlled. Further work in developing control measures for rinsing operations is needed. The efficiency for this system was not optimum because of space limitations. Larger facilities would allow the system to be modified to reduce static pressure losses.

Disclaimer

Mention of company names or products does not constitute endorsement by the Centers for Disease Control and Prevention, NIOSH.

Acknowledgment

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