

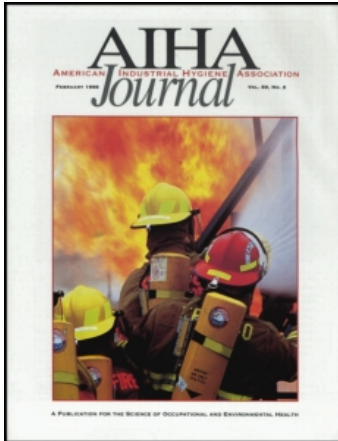
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Case Study: Control of Methylene Chloride Exposures During Furniture Stripping

Methylene chloride, a potential occupational carcinogen, is one of the principal solvents used for furniture stripping. Methylene chloride exposures among workers in furniture stripping operations have been found to be high. This article describes a furniture stripping operation at a sheltered workshop before and after the ventilation system was modified. Previous to ventilation system modifications, workers who were stripping furniture had exposures to methylene chloride ranging from 600 to 1150 ppm. These high exposures and an evaluation of the ventilation system prompted the design and installation of a modified ventilation system. Primary modifications included installing a local ventilation hood, decreasing the velocity of makeup air entering the stripping area, removing a contaminated charcoal adsorption bed, and improving work practices. The modified system was arranged into three configurations that included a slot hood, a downdraft hood, and a combination slot and downdraft hood. The three configurations were evaluated over a three-day period, and it was found that they controlled the worker's personal exposures to methylene chloride while stripping to 28 ppm for the combination configuration, 30 ppm for the downdraft configuration, and 34 ppm for the slot configuration. Although the exposures are above the proposed Occupational Safety and Health Administration permissible exposure level of 25 ppm, these results show a substantial improvement over the existing ventilation system. The ventilation system described is applicable to other furniture stripping facilities if rinse area local ventilation is improved.

Furniture is typically stripped using a non-flammable, methylene chloride-based stripping solution, which contains 55 to 85% methylene chloride.⁽¹⁾ High methylene chloride exposures have been reported among furniture strippers in the literature. Table I shows methylene chloride exposures among furniture strippers from four studies.⁽²⁻⁵⁾ Measurement of personal methylene chloride exposures up to 2160 ppm demonstrate that furniture strippers may be exposed to methylene chloride levels above the current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) of 500 ppm. Additionally,

OSHA has published a Notice of Proposed Rule-making to lower the PEL to 25 ppm with an action limit at 12.5 ppm and a short-term exposure limit (STEL) of 125 ppm.⁽⁶⁾

The National Institute for Occupational Safety and Health (NIOSH) has recommended that methylene chloride be considered a potential occupational carcinogen and that it be controlled to the lowest feasible limit.⁽⁷⁾ The threshold limit value (TLV[®]) for methylene chloride established by the American Conference of Governmental Industrial Hygienists (ACGIH) is 50 ppm.⁽⁸⁾

The research effort described in this article was prompted by the growing concerns associated with methylene chloride and the need for control measures for furniture strippers. The furniture stripping industry includes an estimated 22,000 workers who are employed by approximately 4,000 small businesses, averaging 5 employees each.⁽⁹⁾ Furniture stripping operations, in general, do not have an occupational safety and health program as an integral part of their

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Mention of company names or products does not constitute endorsement by the Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH).

TABLE 1. Methylene Chloride Exposures Among Furniture Strippers⁽²⁻⁵⁾

Reference	Shop	Methylene Chloride Personal Exposures	
		Time-Weighted Average (ppm)	Range (ppm)
2	A	854	297-2160
	A	124	
	B	277	
	B	122	
	C	366	
	C	303	
	D	88	
3	A	57	325-1250
	B	350	
	C		
4	A	69	30-1080
5	A		21-73

business. Additionally, owners of small businesses often lack the resources and expertise to determine basic health effects and safe handling procedures. This article presents a case study of a furniture stripping operation at a sheltered workshop. The objectives of this study were two-fold: first, to compare the worker's methylene chloride exposures when using a modified ventilation system to using the existing ventilation system; and second, to determine which hood configuration of the modified ventilation system controlled methylene chloride exposures best.

GENERAL PROCESS DESCRIPTION

At this facility furniture was stripped using a solution-recycling furniture stripping tank; the stripping solution is collected in the tank and reused. The stripping process is relatively simple. Furniture is set in the tank, covered with stripping solution that dissolves its finish, brushed to remove finish that did not dissolve, moved to a rinse area, sprayed with water, and set aside to dry.

Facility Description

The sheltered workshop's furniture stripping area consisted of three rooms that were partitioned from the rest of the facility: a stripping room, a rinsing room, and a solution storage room. Figure 1 shows the layout of this facility. The stripping room contained a galvanized steel, solution-recycling tank with a sloped bottom to permit draining. A bucket was positioned under the tank's drain to capture the stripping solution. To recycle the solution, a pump circulated the stripping solution from the bucket to a nozzle attached to a brush. The stripping solution (Number 2105, Kwik Kleen Industrial Solvents, Inc., Vincennes, Ind.) used at this facility contained a mixture of methylene chloride, methanol, toluene, and sodium hydroxide (60, 30, 8, 2% by volume, respectively).⁽¹⁰⁾ The furniture was rinsed in a walk-in shower located in the rinsing room. The stripping solution room contained a 210-L (55-gallon) drum of stripping solution and several empty 20-L (5-gallon) stripping solution containers.

Description of the Existing Ventilation System

Existing ventilation at the sheltered workshop included local exhaust ventilation in the stripping room and dilution ventilation in

the rinsing room. In the stripping room the existing ventilation system exhausted approximately 79 m³/min through a 1.8- by 1.2-m charcoal adsorption bed located at the north end of the room (Figure 1). This exhaust volume was determined by using the average of six measurements taken with a velometer at the face of the charcoal adsorption bed. Air entered the stripping room through four 46- by 46-cm air filters located in the double doors at the south end of the room. Air moved through the filters at a velocity of 91 m/min.

The existing local exhaust ventilation in the rinsing room consisted of a 20- by 61-cm open duct located on the floor in the walk-in shower (Figure 1). An average velocity of 280 m/min was measured at the face of the duct by taking three measurements with a velometer, yielding an exhaust volume of 34 m³/min. The exhaust duct was connected to the same fan as the local exhaust in the stripping room. There was no local ventilation in the stripping solution room. A makeup air unit was located in a nonstripping portion of the facility. This unit brought fresh, tempered air into the facility.

Evaluation of the Existing Ventilation System

The existing ventilation system was previously evaluated during a NIOSH Health Hazard Evaluation (HHE).⁽¹¹⁾ The NIOSH HHE researcher visited the sheltered workshop on three different days to monitor the worker's exposure to methylene chloride. Personal breathing zone samples for methylene chloride attached to the worker's right lapel were collected using charcoal tubes in conjunction with calibrated sampling pumps as recommended in NIOSH Method 1005.⁽¹²⁾ The ventilation system was the same during all three visits. During the first evaluation the stripping tank was located in the middle of the stripping room, and all doors were kept closed as shown in Figure 2. At that time, the worker spent approximately four hours stripping furniture. The type and quantity of furniture was not documented. During 260 minutes of stripping, the worker was exposed to a time-weighted average (TWA) airborne concentration of 600 ppm of methylene chloride in the breathing zone.

The second evaluation took place about one month later. The stripping table was turned 90° and positioned beside the charcoal adsorption bed as shown in Figure 3. For this evaluation one of the double doors in the south end of the room was opened. The worker stripped furniture for 195 minutes and had a TWA exposure to methylene chloride in the breathing zone of 960 ppm.

The third evaluation took place two months later. The stripping table was positioned as it was during the previous visit. Again, one of the front double doors was left open during stripping. The

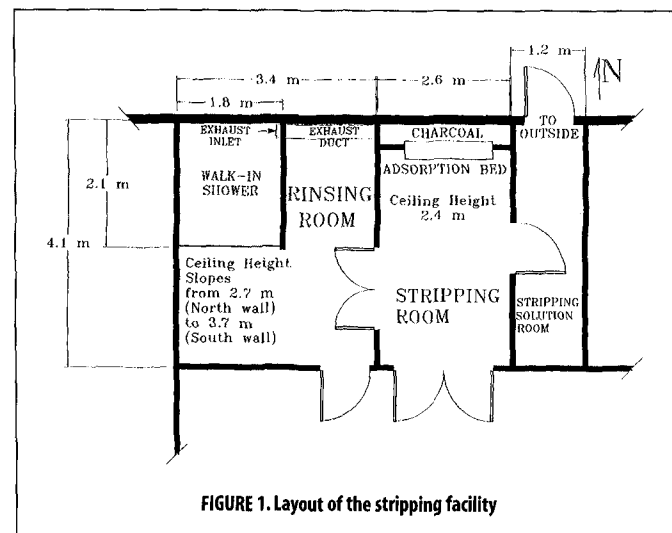


FIGURE 1. Layout of the stripping facility

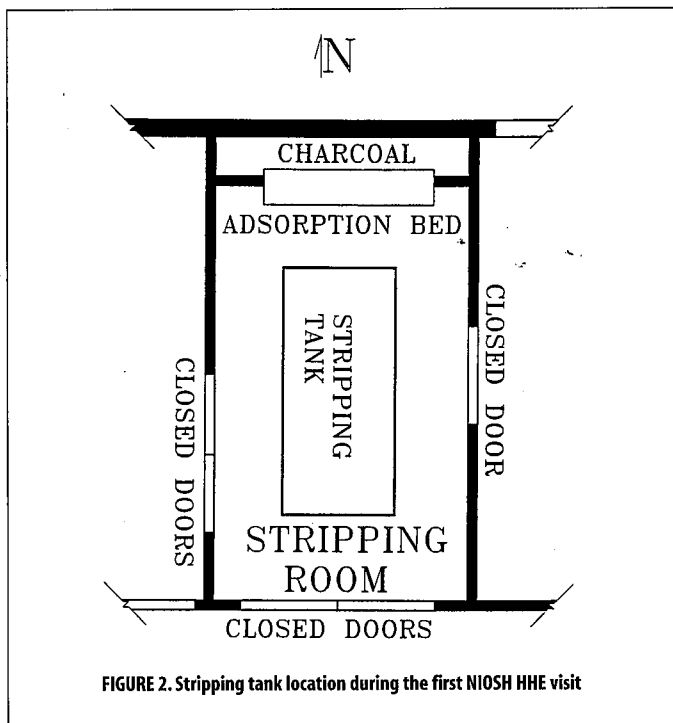


FIGURE 2. Stripping tank location during the first NIOSH HHE visit

worker stripped furniture for 177 minutes and had a TWA exposure to methylene chloride in the breathing zone of 1152 ppm.

Rationale for Ventilation System Modifications

The NIOSH HHE researcher did not comment on the possible cause of the high exposures found using the existing ventilation system. There were limitations to the modifications that could be performed at this facility. The sheltered workshop had just finished installing the existing fan and walls; hence, they were frustrated that the exposures were still high. They did not want to make large

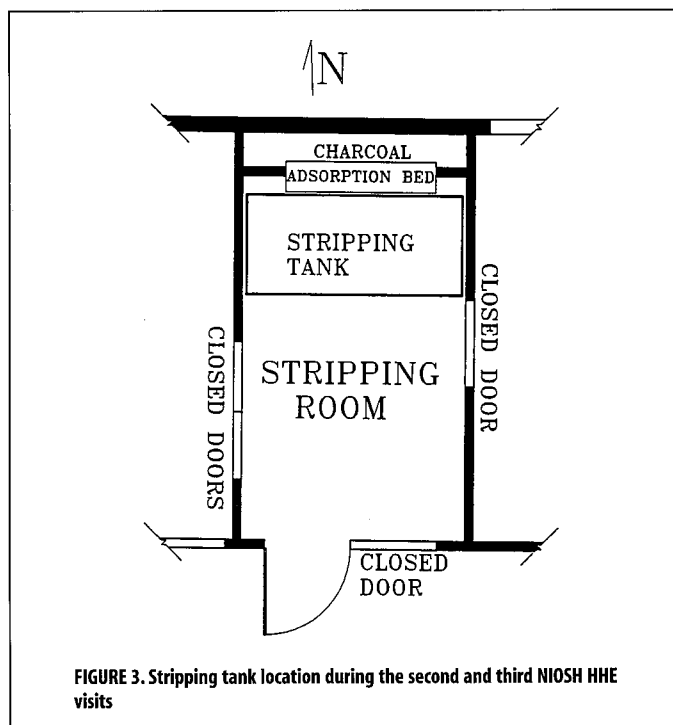


FIGURE 3. Stripping tank location during the second and third NIOSH HHE visits

changes to the ventilation system or facility design. The authors of this paper used smoke tubes to better understand the air movement in the room. The smoke tubes showed that the capture efficiency of the ventilation system was limited and the air around the tank traveled in circles rather than in a straight path to the exhaust. Based on these observations the following modifications were recommended: remove the charcoal adsorption bed, open all doors to the stripping area, and install a modified local exhaust system.

Charcoal Adsorption Bed

The charcoal adsorption bed had been installed by the sheltered workshop in an attempt to avoid neighbors' complaints of odors exhausting from the facility. However, because of its proximity to the stripping tank, the charcoal adsorption bed had been repeatedly sprayed and splattered with stripping solution; hence, it had become saturated. Its saturation made it a potential methylene chloride exposure source when the ventilation system was not in use. Also, charcoal is a poor adsorber of methylene chloride. For example, breakthrough will occur in a charcoal air-purifying respirator in 40 minutes when exposed to a concentration of 15 ppm.⁽¹³⁾ Therefore, the charcoal adsorption bed may have become saturated during the first week it was installed. The facility also did not change or rejuvenate the charcoal adsorption bed. Additionally, it is highly unlikely that the charcoal adsorption bed as installed at this facility controlled methylene chloride ambient air pollution emissions.

Stripping Area Doors

Previously, management had required all doors to the stripping room to be kept closed to prevent unauthorized workers from entering the stripping room. Hence, the only place for air to enter the stripping room was through the four air filters in the double doors at the south end of the room. Air entered through these filters at an average velocity of 91-m/min. At that high velocity the four filters acted as free air jets. The free air jets induced additional air flow as a result of air entrainment. This entrained air flow was 50% greater than the amount exhausted through the local exhaust system. The amount of air that an air jet produces can be deduced using the air entrainment ratio:⁽¹⁴⁾

$$\frac{Q_x}{Q_0} = \frac{0.45X}{\sqrt{A_0}}$$

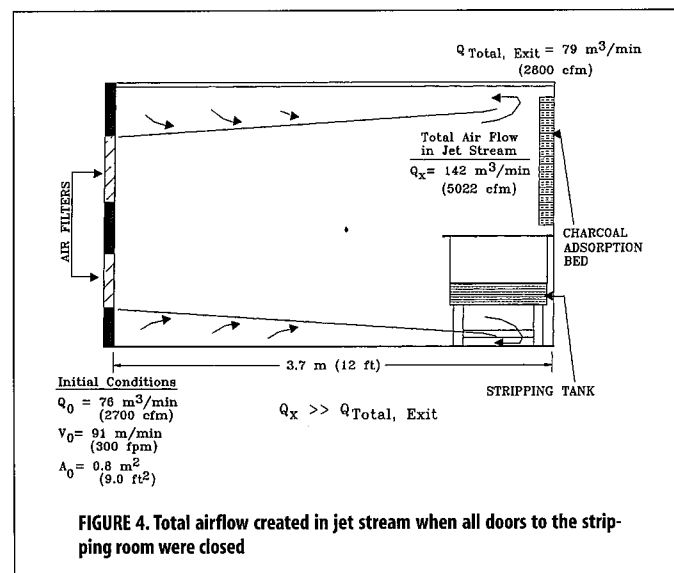


FIGURE 4. Total airflow created in jet stream when all doors to the stripping room were closed

where: Q_x = amount of air at a distance x from the air jet,
 Q_0 = amount of air at the air jet, $76.4\text{-m}^3/\text{min}$ ($2700\text{-ft}^3/\text{min}$),
 A_0 = area of the air jet opening, 0.8-m^2 (9.0-ft^2), and
 X = distance from the air jet, 3.7-m (12-ft).

Solving for Q_x , the result is $142\text{-m}^3/\text{min}$ ($5022\text{-ft}^3/\text{min}$) for the total air flow. This volume is the amount of air that was in motion as a result of air entrainment. This situation is depicted in Figure 4. Since the amount of air in motion was greater than that which could exit the room, a backflow of air was created in the room. To solve the problem of air jets inducing a backflow of air, all doors to the stripping room were opened to allow makeup air to enter the room at low velocity.

Modified Local Exhaust System

A modified local exhaust ventilation system was installed at this facility. It was designed to control two sources of methylene chloride exposure: (1) the solution-covered furniture that extended well above the edge of the tank, and (2) the bottom of the tank where the stripping solution collected. To ensure that both of these sources were controlled, the local exhaust system included a slot hood to directly control the solution-covered furniture and a downdraft hood to control the bottom of the tank. The design was based on criteria established by ACGIH's *Industrial Ventilation Manual* for open surface tanks (VS-503.1 D).⁽¹⁵⁾

The slot hood was located where the charcoal adsorption bed had been. There were four 1.8-m (5.9-ft) long slots. The slot width could be adjusted from a closed position to a maximum of 7.6-cm (3.0-in) wide. Slot velocity was determined by averaging six measurements along the opening of the slot. For downdraft ventilation a perforated plate with 40% open area was placed inside the stripping tank. Downdraft exhaust volume was determined from the average air velocity at the opening of the tank. The average air velocity was determined by taking 12 measurements across the top of the tank with a velometer. The perforated plate created a 23-cm (9.0-in) deep plenum in the stripping tank

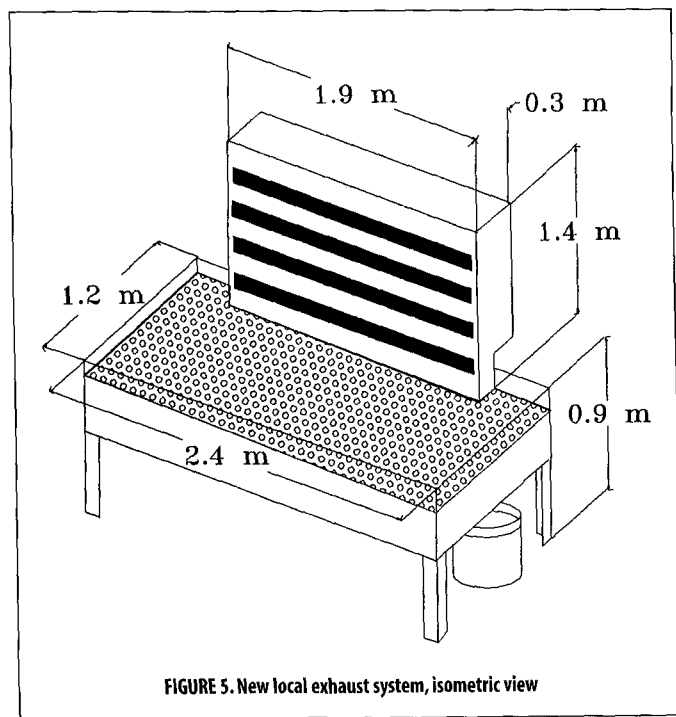


FIGURE 5. New local exhaust system, isometric view

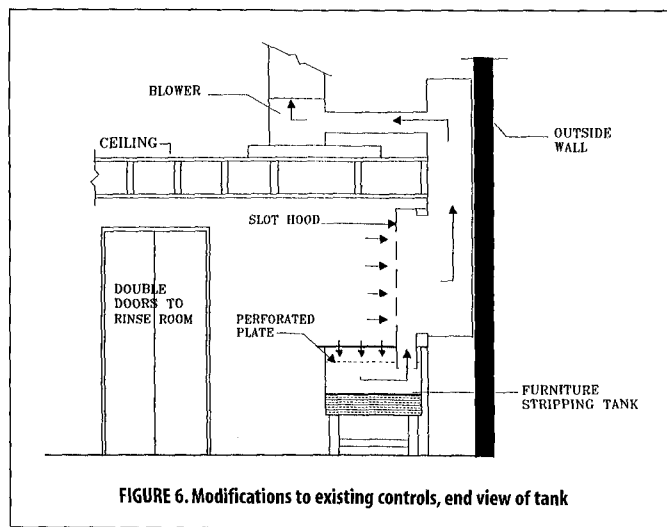


FIGURE 6. Modifications to existing controls, end view of tank

and consisted of four sections that rested on metal supports. Each section could be easily removed for cleaning. Freeboard height of the tank was reduced to a range from 2.5- to 13-cm (1.0- to 5.0-in). Air exhausted through the perforated plate and traveled through the bottom of the slot hood to reach the exhaust duct. There was no mechanism to disconnect the downdraft ventilation from the rest of the ventilation system. This ventilation design is shown in Figures 5 and 6. No changes were made to the exhaust in the rinsing room.

STUDY METHODS

Modified Ventilation System Parameters

Nine configurations of the hoods were evaluated initially. The configurations included different combinations of doors opened or closed and slots opened or closed. A smoke generator was set in the stripping tank, and a researcher stood in front of the tank posing as a worker. This method allowed the authors to judge the local ventilation system's apparent capture efficiency for each configuration. Using this method the authors determined that all doors to the stripping room had to be opened to avoid eddy currents. The following three hood configurations were chosen for further testing: a slot hood, a downdraft hood, and a combination slot and downdraft hood.

The slot hood configuration consisted of four slots opened to 2.5-cm (1.0-in). This configuration also included downdraft ventilation, because that portion of the local ventilation could not be disconnected. The exhaust volumes were determined by measuring the air velocity with a velometer at the face of each opening. Six measurements were averaged for each slot and twelve measurements were made across the opening of the tank. The downdraft configuration consisted of only downdraft ventilation with all slots completely closed. The combination slot and downdraft configuration consisted of one open slot with downdraft ventilation. The second slot from the bottom was opened 5.7-cm (2.3-in). Hood entry coefficients were not measured for any of the configurations because of space constraints. Exhaust volumes, slot and downdraft velocities, and air exchange rates are shown in Table II.

Sampling Strategy

Each of the three hood configurations was tested once a day during three testing days, for a total of nine testing periods. The or-

TABLE II. Exhaust Volumes, Slot and Downdraft Velocities, and Air Exchange Rates^A

Hood Configuration	Velocity (m/min)		Exhaust Volume (m ³ /min)		Air Flow Per Area Tank Surface ^B (m ³ /min Per m ²)	Total Exhaust Volume (m ³ /min)		Air Exchange Time (min)	
	Slot	Downdraft	Slot	Downdraft		Stripping Room	Rinsing Room	Stripping Room	Rinsing Room
Existing ventilation system	N/A ^C	N/A	N/A	N/A	32	79	34	0.3	0.5
Slot hood	200-300	67	45	37	29	82	26	0.3	0.6
Downdraft		107		59	21	59	23	0.4	0.7
Combination	290	110	40	62	35	102	18	0.2	0.9

^AAll hood configurations used a centrifugal fan rated at 140 m³/min with a 7.6 cm wg fan static pressure.

^BACGIH *Ventilation Manual* recommends 38 m³/min per m².

^CN/A - Not applicable because the existing ventilation system did not have slots or downdraft ventilation. These features were created in the modified ventilation system.

der of the configurations was selected randomly each day. All slots were completely opened between testing periods to remove residual concentrations. In five minutes, with no contaminant generation, the concentration in the stripping room was expected to drop by 99% based on dilution ventilation theory and using a mixing factor of 2.5. From one to four pieces of furniture were stripped during each testing period. Chairs of similar size and style were stripped during the three days; on one day desks also were stripped during each testing period. All furniture was made of wood and finished with stains or varnishes. The chairs and desks were of similar sizes. Because the furniture had different finishes, it required different amounts of time to strip.

To ensure consistency in procedure, the same worker stripped the furniture during the entire study. The following work practices were discussed with the worker prior to the study: turn the solution recycling system off except as needed, and minimize the time that the breathing zone is between the solution-covered furniture and the exhaust hood.

Sorbent tube samples for methylene chloride, methanol, and toluene were collected during the study. One personal breathing zone sample was collected for each piece of furniture stripped. All personal breathing zone samples were taken by attaching the sample air in-take to the worker's right lapel, which was the worker's dominant side because he was right-handed. Area sample locations are shown in Figure 7. Area samples were collected

at each location during each of the nine testing periods except for the stripping room floor sample and the solution room floor sample.

The sorbent tubes were analyzed using NIOSH Method 1005 for methylene chloride,⁽¹²⁾ NIOSH Method 2000 for methanol,⁽¹⁶⁾ and NIOSH Method 1501 for aromatic hydrocarbons (toluene).⁽¹⁷⁾ Two 100/50 mg charcoal coconut sorbent tubes (SKC 226-01, SKC, Inc., Eighty-Four, Pa.) were used in series at a flow rate of 60 cm³/min with a Dupont P10-200 pump to determine concentrations of methylene chloride and toluene. To determine concentrations of methanol, 150/75 mg silica gel sorbent tubes (SKC 226-10, SKC, Inc.) were used at a flow rate of 80 cm³/min with a Dupont P10-200 pump. The samples were sent to Data Chem Laboratories (Salt Lake City, Utah), the NIOSH contract laboratory (American Industrial Hygiene Association [AIHA] accredited) for analysis. Also, standard NIOSH quality control procedures were followed.

RESULTS

Testing periods varied from 49 to 147 minutes depending on the number of furniture items stripped. The time between testing periods ranged from 5 to 60 minutes. The methylene chloride concentrations during stripping for consecutive days during the study were 25, 41, and 22 ppm as shown in Table III. The methylene chloride exposures during stripping for the slot, downdraft, and combination slot and downdraft hood configurations were 34, 30, and 28 ppm, respectively, as shown in Table IV. Concentrations for methanol and toluene were below the NIOSH recommended exposure limits (Table III). Analysis of variance was performed using sample concentration as the dependent variable and hood configuration and sample location as the independent variables.

Personal samples were not statistically different among the three hood configurations. However, the personal exposures for the combination slot and downdraft configuration were the lowest. Area samples located at the ceiling and floor levels in the stripping room and at the ceiling level in the rinsing room showed no significant differences among the three hood configurations. The geometric means for the area samples were 3 ppm for the ceiling of the stripping area, 55 ppm for the floor of the stripping area, 6 ppm for the ceiling of the rinsing area, and 16 ppm for the floor of the solution room, as shown in Table V.

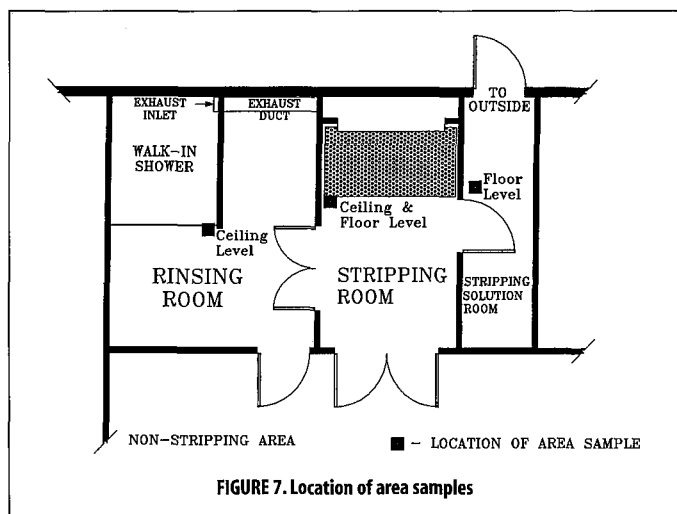


FIGURE 7. Location of area samples

TABLE III. Personal Sampling Results for the Modified Ventilation System (All Three Hood Configurations)

Day	Strip Time (hours)	Number of Samples	Breathing Zone Methylene Chloride (ppm)			Breathing Zone (ppm)	
			Range	Conc.	8-hr. TWA ^A	Methanol Conc.	Toluene Conc.
1	4.62	10	13-64	25	15	30	3
2	5.55	11	17-106	41	29	63	4
3	4.73	4	6-32	22	13	7	2

^A8-hour TWAs were computed using a value of zero during the time the worker was not stripping.

DISCUSSION AND CONCLUSIONS

Changes made in the stripping area at this facility (i.e., installing a modified ventilation system, reducing the pressure loss in the system, and instructing the worker on proper work practices) lowered the worker's exposure to methylene chloride substantially when compared with the concentrations measured previously (600, 960, and 1150 ppm) using the existing ventilation system. The three hood configurations controlled the worker's personal exposures while stripping to 28 ppm for the combination configuration, 30 ppm for the downdraft configuration, and 34 ppm for the slot configuration. Personal samples while stripping ranged from 6 to 106 ppm. Although the exposures were above the proposed OSHA PEL of 25 ppm, these results show a substantial improvement over the existing ventilation system.

All three hood configurations—slot, downdraft, and combination slot and downdraft—for the modified ventilation system were

found to substantially improve the control of emissions as compared with the existing ventilation system. No significant difference was found among the three hood configurations when comparing personal exposures. The perforated plate used for downdraft ventilation was as easy for the worker to use as the bottom of the tank that had previously been used. The authors saw no evidence that the holes in the perforated plate clogged or collected the stripping solution. Also, the perforated plate was easily cleaned at the end of each day, because it was in movable sections. Adhering to proper work practices seemed to reduce the worker's exposure to methylene chloride. The worker always remembered to turn the solution-recycling system off but often forgot about keeping his breathing zone away from the solution-covered furniture.

Further improvements to control exposures for this operation could be made by improving exhaust ventilation in the rinse room. The walk-in shower in the rinse room could be further enclosed to better utilize the existing exhaust, and a table or other platform could be added to set the furniture on while rinsing. This table would allow the worker to rinse the solution-covered furniture without bending over it. These additional rinse room changes may further lower exposures to methylene chloride at this facility.

Although the stripping solution room samples did not indicate high exposures in that area, it is believed that the open drum added to the worker's exposures. Therefore, the 210-L (55-gallon) drum in the stripping solution room should be closed off when not in use.

Any of the three hood designs described in this case study may be installed at other facilities if additional rinse room ventilation is added and good work practices are followed. For new facilities, the ventilation system should be designed as an integral part of the stripping tank.⁽¹⁸⁾ A new ventilation system design can include features not possible in a retrofit design. Such a design should include a slot hood that extends the entire length of the tank, side baffles, a larger plenum for more even exhaust across the length of the slots, and a larger room to allow makeup air to enter freely. Such an integrated design may control to the same or lower levels using a reduced volume of air; hence, the operating cost and possibly solvent losses of the control system would decrease.

Additional research is needed to quantify the cost of conditioning the makeup air for the modified ventilation system, to determine if the modified ventilation system increased solvent loss, and to examine air pollution control measures.

TABLE IV. Personal Sampling Results by Hood Configuration (All Three Days)

Hood Configuration	Total Time (Hours)	Number of Samples	Breathing Zone Methylene Chloride	
			Range of Samples (ppm)	Concentration While Stripping (ppm)
Combination	5.80	9	6-62	28
Downdraft	6.03	8	14-64	30
Slot hood	3.07	8	13-106	34

TABLE V. Area Sampling Results for the Modified Ventilation System

Hood Configuration	Number of Samples	Methylene Chloride	
		Range of Samples (ppm)	Geometric Mean (ppm)
Stripping room (ceiling level)	9	1-10	3
Stripping room (floor level)	7	4-430	55
Rinse room (ceiling level)	9	2-23	6
Stripping solution room (floor level)	2	13-19	16

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