IN-DEPTH SURVEY REPORT

THE CONTROL OF METHYLENE CHLORIDE IN FURNITURE STRIPPING

at

Association for Retarded Citizens
Washington County Chapter, Inc
Meadow Lands, Pennsylvania

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DISCLAIMER

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INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal organization engaged in occupational safety and health research Located in the Department of Health and Human Services (DHHS), NIOSH was established by the Occupational Safety and Health Act of 1970 This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA), which is located in the Department of Labor (DOL) An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards The Engineering Control Technology Branch (ECTB) of the Division of Physical Sciences and Engineering (DPSE) has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control

Since 1976, the Engineering Control Technology Branch has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need or availability of an effective system of hazard control measures

These studies involve a number of steps or phases Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concepts or techniques Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury

This study is part of a NIOSH initiative directed toward reducing the incidence of work-related diseases among workers employed by small businesses, particularly occupational lung disease, occupational cancer, occupationally related cardiovascular diseases, diseases due to neurotoxic agents, skin disease, hearing loss, and work-related injuries Since many owners of small businesses lack basic knowledge regarding potential health effects and safe handling procedures, and at the same time are, for the most part, not subject to regular OSHA inspections, a concentrated effort on the part of NIOSH is necessary to implement these strategies in the small business sector ECTB is in part responsible for developing recommendations for cost-effective engineering, administrative, and personal protective controls for small businesses

This particular research effort was prompted by the growing concern of the hazards of methylene chloride (CH_2Cl_2, Dichloromethane, or DCM) and the need for technical advice for furniture strippers Furniture is stripped using a solution containing mostly methylene chloride (DCM) and methanol (MAL) NIOSH has recommended that methylene chloride be considered a potential human carcinogen in the workplace NIOSH further recommended that methylene chloride be controlled to the lowest feasible limit [1] The objective of this study is to evaluate local ventilation hoods for the furniture stripping process which use solution recycling-type furniture stripping tanks The results and recommendations of this study apply specifically to this facility, however, this information may be transferred to other furniture stripping facilities The local ventilation system was designed and implemented by ECTB This report will explain the stripping facility, ventilation systems, sampling techniques, results, and recommendations

FACILITY DESCRIPTION

The Association for Retarded Citizens (ARC) is a sheltered workshop where furniture is stripped, in addition to a variety of other tasks being accomplished The retarded citizens (clients) are assigned tasks tailored to their capabilities Jobs performed by the clients include repairing, sanding, and/or painting the stripped furniture, envelope stuffing, and assembling and boxing caps for compressed gas cylinders The actual furniture stripping is performed by a nonclient

In March 1988, the ARC was cited by the Occupational Safety and Health Administration (OSHA) for exceeding the short-term exposure limit to methylene chloride during furniture stripping OSHA allotted the ARC an abatement period for engineering controls to be implemented At this time, a private consultant made general recommendations for improvements Based on these recommendations, a contractor built a ventilation system for the furniture stripping area The ARC requested assistance from NIOSH's Hazard Evaluations and Technical Assistance Branch (HETAB) to determine if the controls were adequate The HETAB investigator's sampling results indicated that the engineering controls installed did not guarantee that the worker's methylene chloride exposure would be below the OSHA established Short-Term Exposure Limit (STEL) of 1000 ppm ceiling for 5 minutes in any 2-hour period NIOSH regards methylene chloride as a potential occupational carcinogen and recommends exposures be kept to a minimum For these reasons, HETAB investigators determined lower exposures must be attained In order to remedy the problem, NIOSH's Engineering Control Technology Branch (ECTB) was asked to recommend functional engineering controls

Upon initial inspection, members of ECTB determined that the ventilation system could be improved An area of the ARC is strictly reserved for the furniture stripping process and is divided into three smaller areas the stripping area, the rinsing area, and the stripping solution room where a 55-gallon drum of solution is kept The floor plans of the stripping area are presented in Figure 1 The doors to this area were kept closed from the rest of the building to keep clients out of the stripping area The three doors shown opening on the bottom side of Figure 1 lead to the furniture storage area which is the work area for most clients The door shown opening on the top of the layout shown in Figure 1 leads to the outside, and is sometimes left propped open

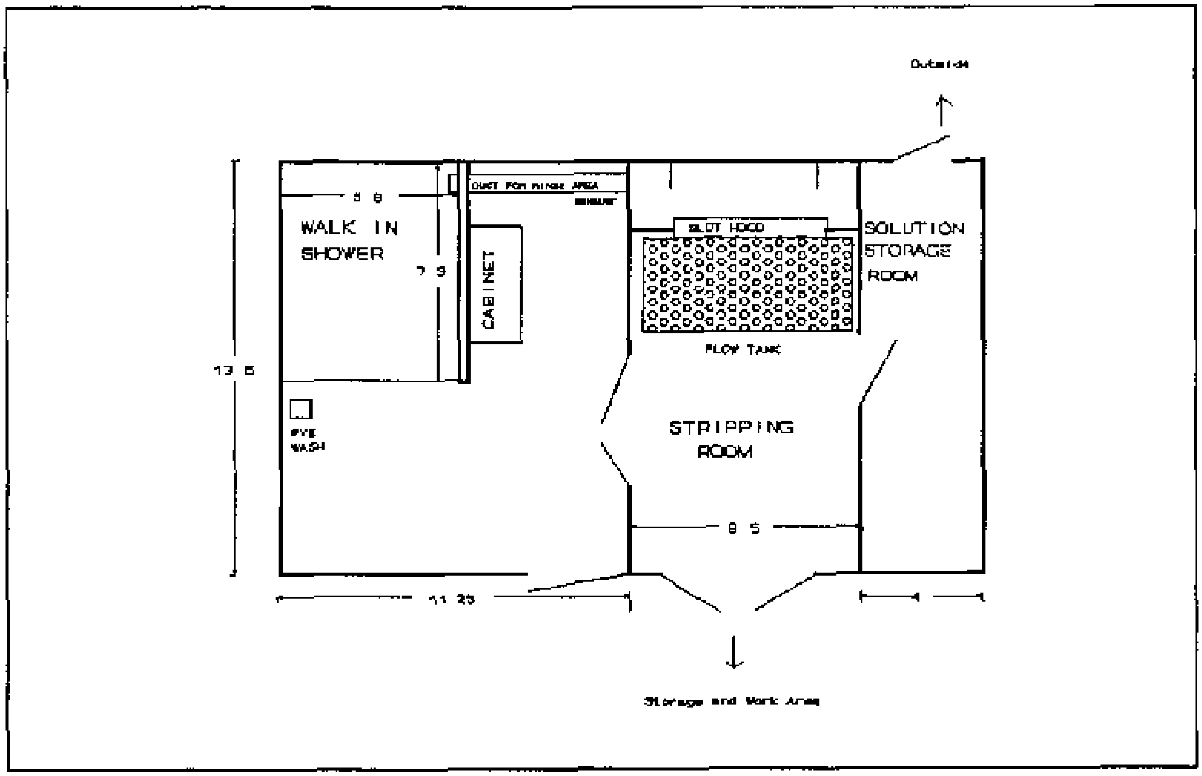

Figure 1 Layout of the ARC Stripping Facility

PROCESS DESCRIPTION

Furniture stripping facilities remove the existing finish and leave a bare wood (or metal) substrate for refinishing Furniture must be stripped carefully so that all the finish is removed from every crack, and the wood is not damaged in any way The furniture may come from institutions, businesses, or individuals, and it may vary from antique to modern The finish may also vary from a variety of paint coverings to stains or varnishes Size and shape may range from large cabinets to small stools Furniture stripping must, therefore, be flexible to accommodate these different sizes, shapes, types, qualities, and finishes of furniture while still protecting the wood substrate

In order to accommodate the variety of furniture to be stripped, the ARC facility uses a flow-over tank with a solution recycling system, which is the most commonly used process for removing finish from furniture The furniture is initially set in the tank and covered with the stripping solution Once the piece is covered, the operator waits (time depends on the finish and substrate) for the solution to begin penetrating the finish The operator decides whether to begin brushing or to cover the piece with more solution The operator can wait for the solution to do most of the work, however, the operator will sometimes begin scrubbing as soon as the solution is put on the piece Once scrubbing has begun, the operator alternates between brushing the finish off the piece and covering the piece with more solution until the finish is completely removed This process can take anywhere from a few minutes to an hour After the finish is removed, the furniture is carried into the rinsing area and set on the floor where the operator rinses it with water from a high-pressure hose After an initial rinse, the piece is brushed and rinsed intermittently until all solution is rinsed from the furniture The piece is then moved to an open area to dry and later to be sanded and refinished

The tank is made of galvanized steel which is 4 feet wide by 8 feet long The lip of the tank stands 3 feet from the floor and the depth in the tank slopes from 9 to 12 inches with a drain at the low end The process includes a 5-gallon pail, a pump, and a brush with plastic tubing connecting the three The pail is located under the drain in order to catch the used solution Solution is pumped from the pail out through the brush and into the tank which returns the solution back to the pail through the drain The solution is recycled until it loses its stripping ability or until it was lost through evaporation

Kwick Kleen No 2105 was the solution used at this facility This stripping solution is made of methylene chloride, methanol, toluene, and sodium hydroxide Wax or paraffin is also added to the solution to provide a vapor barrier When the solution is spread over a piece of furniture, the wax migrates to the surface and forms a film barrier to reduce the evaporation rate of the stripping solvents Kwick Kleen, which manufacturers this solution, recommends the solution's temperature be approximately 70°F (343K) When used at this temperature, the wax is allowed to form a vapor barrier on the surface of the liquid while some wax is suspended in the stripping solution

After the furniture is stripped, it is rinsed with water The furniture is set on the floor and a handheld nozzle is used to spray water on the finished piece of furniture There is a small exhaust duct in the corner of the stripping area The exhaust opening is about 15 inches wide and 30 inches high from the floor

POTENTIAL HAZARDS

Exposures to stripping solvents in the furniture stripping industry are found primarily during the actual handling and stripping of the furniture Other exposure sources may include the mixing or transferring of stripping solution, and vapor buildup in the room air The solution used at the Association for Retarded Citizens contained a mixture of methylene chloride, methanol, toluene and sodium hydroxide (60, 30, 8, and 2% by volume, respectively) [2] This solvent may enter the worker's body through inhalation or dermal absorption Of these three components, methylene chloride may cause the greatest potential hazard to the worker, both because of its greater concentration in the liquid and because of concern over chronic health effects discussed in the subsequent text

HEALTH EFFECTS - METHYLENE CHLORIDE

Methylene chloride has a narcotic effect on the central nervous system, as well as the cardiovascular and respiratory systems Historically, it was used as an anesthetic Exposure may result in symptoms of dizziness, headache, tingling or numbness of the extremities, and impairment of mental alertness and physical coordination The intentional or accidental inhalation of volatile organic solvent vapors in high concentrations is a well recognized cause of morbidity and mortality [3]

Inhalation of methylene chloride causes the endogenous formation of carbon monoxide (CO) which attaches to the hemoglobin, which changes to carboxyhemoglobin The CO has an affinity to hemoglobin 200 times that of oxygen, therefore limiting the oxygen transporting capability of the body causing oxygen deprivation This can lead to heart, brain, and other tissue damage Cardiovascular stress can cause myocardial infarction in susceptible individuals This could also occur in a fetus, methylene chloride has the ability to cross the placental barrier

The National Toxicology Program (NTP) performed a 2-year methylene chloride inhalation study on rats and mice F344/N rats were grouped with methylene chloride exposures of 0, 1000, 2000, or 4000 ppm The B6C3F$_1$ mice were grouped with methylene chloride exposures of 0, 2000, or 4000 ppm Increased incidence of testicular atrophy in the male rats and mice were detected Increased ovarian and uterine atrophy were present in female mice exposed to methylene chloride All groups of male rats and the mid- and high-dose female rats experienced unusually high incidence of mononuclear cell leukemia Body weights of the exposed rats were comparable to those rats receiving no exposure to the methylene chloride (the control group) High incidence of liver and lung neoplasia reduced the survival rate of dosed mice Final body weights of the dosed mice were lower than those of the control group Incidence of mammary gland tumors were increased in the dosed rats

The researchers of the NTP concluded that the benign neoplasms occurring in the female rat showed clear evidence of carcinogenicity in animals, whereas the occurrence in male rats gave some evidence of carcinogenicity In all mice, increased incidence of alveolar/bronchiolar neoplasms produce clear evidence of carcinogenicity [4]

The Greater Cincinnati Occupational Health Clinic reported four cases of workers exposed to methylene chloride who had excessive serum levels of carboxyhemoglobin and low sperm counts [5] Based on this information, NIOSH conducted a field study, it was determined that a much more extensive study is necessary to statistically validate the finding of methylene chloride as a reproductive toxicant [6]

Although epidemiologic data derived from workers exposed to methylene chloride are inconclusive about its carcinogenicity, animal inhalation studies reveal the occurrence of tumors and cancers in rodents exposed to methylene chloride These results meet the criteria established by the Occupational Safety and Health Administration (OSHA) cancer policy to consider methylene chloride a potential occupational carcinogen Based upon these data, NIOSH regards methylene chloride as a potential occupational carcinogen, and recommends that workers exposure to methylene chloride be controlled to the lowest feasible limit [1] In addition, the U S Environmental Protection Agency (EPA) regards methylene chloride as a probable human carcinogen based on sufficient animal testing

HEALTH EFFECTS - OTHER SOLVENTS

Methanol has very similar central nervous system effects to methylene chloride Breathing very high concentrations may produce headache, weakness, drowsiness, lightheadedness, nausea, vomiting, drunkenness, irritation of the eyes, blurred vision, blindness, and even death Methanol may also cause liver and kidney damage [7]

Exposures to toluene of 200 ppm or greater have been found to cause changes in muscular coordination, reaction time, and production of mental confusion and irritation of mucous membranes These adverse effects have not been reported for toluene exposures of 100 ppm or less in industrial workers or experimental subjects [8]

ENVIRONMENTAL CRITERIA

As a guide to the evaluation of the hazards resulting in workplace exposures, NIOSH field staff employ environmental evaluation criteria for assessment of a number of chemical and physical agents These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects It is, however, important to note that not all workers will be protected from adverse health effects if their exposures are maintained below these levels A small percentage may experience adverse health effects because of individual susceptibility, preexisting medical conditions, and/or hypersensitivity (allergy) In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medication or personal habits of the workers to produce adverse health effects, even if the occupational exposures are controlled at the level set by the evaluation criterion These combined effects are often not considered in the evaluation criteria Also, some substances are absorbed by direct contact with the skin and mucous membranes, and these multiple routes of entry potentially increase the overall dose

The primary sources of environmental evaluation criteria for the workplace are (1) NIOSH recommended exposure limits (RELs), (2) the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs®), and (3) the U S Department of Labor (OSHA) permissible exposure limits (PELs) Often, the NIOSH RELs and ACGIH TLVs are lower than the corresponding OSHA PELs Both NIOSH RELs and ACGIH TLVs usually are based on more recent information than are the OSHA PELs because they are easier to update The OSHA PELs are required to take into account the feasibility of controlling exposures in various industries where the agents are used, the NIOSH RELs, by contrast, are based primarily on concerns relating to preventing any occupational health effects In evaluating the exposure levels and the recommendations for reducing these levels found in this report, it should be noted that industry is legally required to meet the levels that are specified by the OSHA PELs

A time-weighted average (TWA) exposure refers to the average permissible airborne concentration of a substance during a normal 8- to 10-hour workday In addition, some substances have recommended short-term exposure limits or ceiling values which are intended to supplement the TWA where there also are recognized toxic effects from high-level, short-term exposures

In 1986, NIOSH recommended that methylene chloride be regarded as a "potential occupational carcinogen " NIOSH further recommended that occupational exposure to methylene chloride be controlled to the lowest feasible limit This recommendation was based on the observation of cancers and tumors in both rats and mice exposed to methylene chloride in air [1]

The current OSHA PEL for methylene chloride is an 8-hour TWA concentration of 500 parts per million (ppm), with a ceiling concentration of 1000 ppm, and maximum peak concentration of 2000 ppm for no more than 5 minutes within any 2 hours This PEL was derived from a standard recommended by the American Standards Institute (ANSI) and adopted in 1971 without rulemaking [9] In 1986, OSHA published an Advanced Notice of Proposed Rulemaking for methylene chloride OSHA is considering revising the present occupational health standard because of scientific studies (discussed previously) which have reported that inhalation of methylene chloride has caused cancer in two animal species [10]

The 8-hour TLV established by the ACGIH is 50 ppm, and ACGIH has classified methylene chloride as a suspected human carcinogen This TLV was lowered from 100 ppm in order to provide a wider margin of safety in preventing liver injury This level is recommended only in the absence of occupational exposure to carbon monoxide The old TLV of 100 ppm is based on experimental data obtained from male, nonsmoking subjects at rest The ACGIH stated that the blood of workers who were exposed at 100 ppm of methylene chloride would have carboxyhemoglobin levels below 5% in their blood Normal carboxyhemoglobin saturation ranges from 0 4-0 7% for nonsmokers and 4-20% for smokers The ACGIH further cautioned that "concurrent exposures to other sources of carbon monoxide or physical activity will require assessment of the overall exposure and adjustment for the combined effect "[11]

The NIOSH REL for methanol is 200 ppm, as a TWA for up to 10 hours per day, 40 hours per week, with a ceiling of 800 ppm averaged over a 15-minute period The current OSHA PEL for methanol is an 8-hour TWA concentration of 200 ppm [9] The 8-hour TWA-TLV established by ACGIH is 200 ppm, with a 250 ppm STEL [11]

The NIOSH REL for toluene is 100 ppm, as a TWA for up to 10 hours per day, 40 hours per week, with a ceiling of 200 ppm averaged over a 15-minute period The current OSHA PEL for toluene is an 8-hour TWA concentration of 100 ppm The 8-hour TWA-TLV established by ACGIH is 100 ppm, with a 150 ppm STEL

STUDY METHODS

The following steps were accomplished to administer the study (1) evaluation of the existing ventilation system, (2) modification of the ventilation system, (3) testing of the new local exhaust system with smoke to determine the best configurations, and (4) using the best configurations identified in (3), sampling with sorbent samples, and real-time methods to determine the level of exposure control achieved by each configuration This study was conducted on two different occasions firstly, the installation and testing of the ventilation systems was performed on January 29-February 1, 1990, secondly, the testing during actual furniture stripping was accomplished on March 12-15, 1990

DESCRIPTION OF EXISTING VENTILATION SYSTEM

The existing local ventilation system (that was found to be inadequate) exhausted approximately 2800 cfm of air through a 6-foot by 4-foot bank of carbon filters These filters, located on the back wall above the edge of the tank, had been installed by the ARC in an attempt to reduce methylene chloride levels exhausting to the atmosphere The carbon filters saturated quickly and the stripping solution often had been accidently sprayed directly on the lower filters further compounding the problem The carbon filters also caused a high static pressure resistance in the exhaust system, thereby reducing the efficiency In addition to the problem of the carbon filters, the ARC had stripped furniture with all the doors adjoining the stripping room closed to keep clients from entering the room Although there were filters in two of the doors, there was not enough open space for make-up air to enter the room This caused the room to be under negative pressure with very high air velocities through filters, cracks in the doors, under the doors, etc A previous NIOSH researcher found that personal exposures during furniture stripping with this ventilation system ranged from 613 to 1152 ppm,[12] as shown in Table A Sorbent tube samples were taken on three different occasions Table A shows the time-weighted average (TWA) exposure while stripping using these controls These results confirmed that modifications to the existing ventilation system were necessary

Table A Exposure to Methylene Chloride Using the Existing Ventilation System[12]

Date	Exposure Time (min)	Time-Weighted Average (ppm)
October 1989	260	613
November 1989	195	959
January 1990	177	1152

MODIFICATION OF VENTILATION SYSTEM

Several modifications were made to the existing ventilation system Following removal of the carbon filters, a slot hood was put in its place on the back wall of the tank In addition, a perforated plate was put in the tank about 9 inches from the bottom to create a downdraft ventilation system across the bottom of the tank, as shown in Figures 2 and 3 These modifications to the ventilation system allowed for many possible configurations for testing, including a slot hood with up to four slots opened from 0 to 4 inches, a downdraft system, or a combination of any of these ventilation systems Another modification was that openings were made in the stripping room ceiling above the stripping tank to allow fresh make-up air to enter the room directly above the worker This modification was to alleviate the lack of make-up air that had been noted

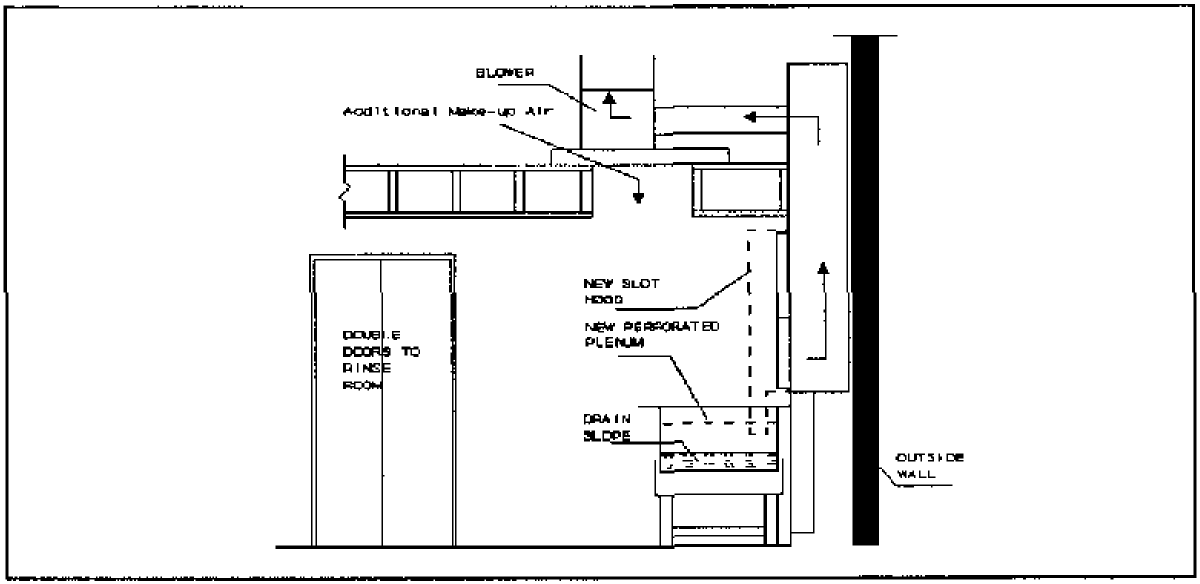

Figure 2 Modifications to Existing Controls - End View of Tank

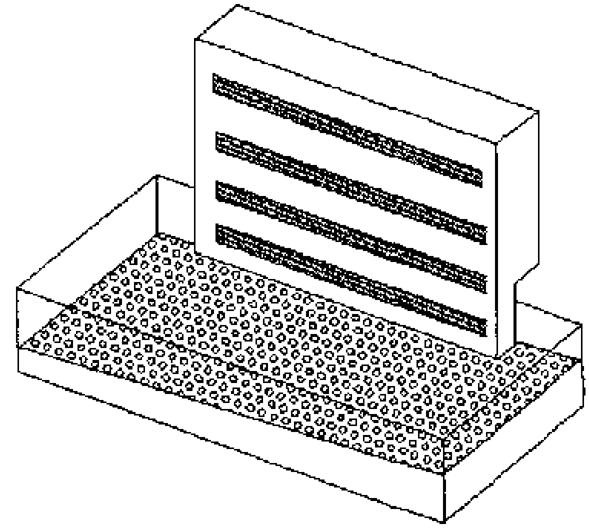

Figure 3 Local Exhaust System Installed - Isometric View

TESTING OF MODIFIED VENTILATION SYSTEM

Since there were a number of possible configurations for the modified ventilation system, each configuration was tested with a smoke generator prior to measuring the worker's breathing zone exposure levels with sorbent samples Many configurations were tested A box was used to simulate the furniture, the smoke generator simulated the air flow, and a video camera recorded the resulting flow pattern Also, the smoke was used to see the airflow patterns with all connecting doors opened or closed Nine different configurations were tested, as shown in Table B The configurations with the asterisks in this table were judged to be best based on the videotaped smoke test, and were therefore, chosen for further testing with sorbent sampling

TABLE B Configurations Tested

Configuration number	Number of slots opened	Slot Opening (inches)	Doors	Total exhaust (cfm)	Rinse exhaust (cfm)	Strip area exhaust (cfm)
1	4	2	Closed	2780	320	2460
2	bottom 2	2	Closed	3315	625	2690
3	bottom 2	1	Closed	3246	750	2496
4	4	1	Closed	3114	625	2489
5*	4	1	Open	3320	600	2720
6*	0	0	Open	3067	800	2267
7	0	0	Closed	-	-	-
8	middle 2	1	Open	3341	700	2641
9*	second 1 (from bottom)	2 25	Open	4217	650	3567

* configurations chosen for testing

The openings in the ceiling used to provide make-up air could only be placed on the sides, not in the center This caused air above the tank, to flow downward into the room very quickly on the right and left sides, while the air in the middle moved upward Therefore, the air from the ceiling was moving in circles over the tank The airflow diagram with the doors closed is shown in Figure 4 Because of the lack of make-up air, closing the doors was determined to be disadvantageous to the worker

The three best configurations were determined based on the observed airflow patterns of the smoke from the smoke generator They were as follows (1) slot opening ventilation only, with an approximate exhaust rate of 3300 cfm, (2) downdraft ventilation only, with an approximate exhaust rate of 3050 cfm, and (3) and a combination of the two (consisting of the downdraft ventilation and opening the second slot from the bottom of the slot hood), which had an approximate exhaust rate of 4200 cfm The stripping area exhaust for each ventilation system was the product of the average velocity [determined by an ALNOR® Velometer (Model 6077A, Alnor Instrument Co , Skokie, Illinois)] at the top edge of the tank and through the slots times and the total cross-sectional area There was also a small exhaust duct in the rinse area which was characterized by placing an ALNOR® Balometer® (Alnor Instrument Company, Niles, Illinois) over the opening The total exhaust rate for each configuration consisted of adding the total flow for the rinsing and stripping areas

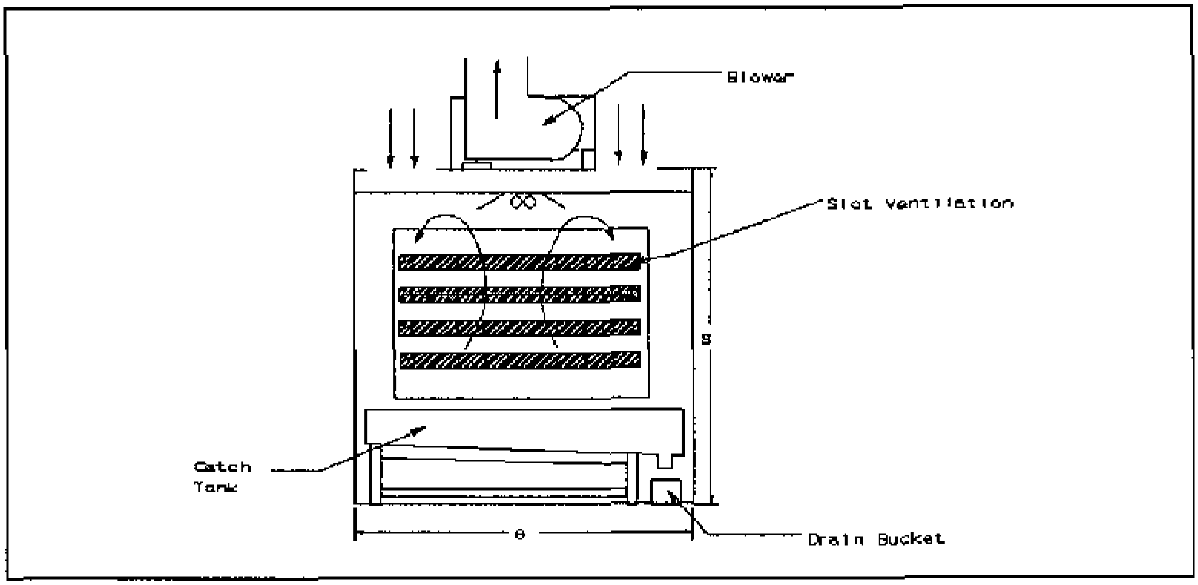

Figure 4 Airflow Diagram With All Doors Closed

SAMPLING STRATEGY

After installing the new ventilation system, the operator was given time (2 to 3 weeks) to adjust to it Good work practices were discussed with the operator before he began stripping the furniture Each configuration was tested once per day during each of the three testing days, for a total of nine tests during the survey Between each test, both downdraft and slot ventilation were opened to clear the area of any residual solvents in the air Chairs of similar size and style were stripped during the three days, one day a desk was also stripped during each configuration The same person stripped the furniture during the entire study However, the furniture had different finishes and required different amounts of time to strip The number of pieces of furniture stripped during each test varied from one to four pieces, as shown in Table C Also in Table C, the check marks refer to the frequency of samples taken

The area and personal air samples for methylene chloride and methanol were taken side by side Samples were taken on the floor of the stripping room, over the stripping tank and rinse tank, and in the room where the barrel of

TABLE C Sampling Strategy

DATE	VENTILATION SYSTEM	FURNITURE	PERSONAL		AREA		PLENUM
			DCM	MAL	DCM	MAL	DCM
3/13	Slot vent	Chair 1	✓	✓	✓	✓	✓
		Chair 2	✓	✓			
		Chair 3	✓	✓			
3/13	Downdraft	Chair 1	✓	✓	✓	✓	✓
		Chair 2	✓	✓			
		Chair 3	✓	✓			
3/13	Combination	Chair 1	✓	✓	✓	✓	✓
		Chair 2	✓	✓			
		Chair 3	✓	✓			
		Chair 4	✓	✓			
3/14	Slot vent	Chair 1	✓	✓	✓	✓	✓
		Chair 2	✓	✓			
		Chair 3	✓	✓			
		Desk 1	✓	✓			
3/14	Downdraft	Chair 1	✓	✓	✓	✓	✓
		Chair 2	✓	✓			
		Chair 3	✓	✓			
		Desk 1	✓	✓			
3/14	Combination	Chair 1	✓	✓	✓	✓	✓
		Chair 2	✓	✓			
		Desk 1	✓	✓			
3/15	Slot vent	Chair 1	✓	✓	✓	✓	✓
3/15	Downdraft	Chair 1	✓	✓	✓	✓	✓
3/15	Combination	Chair 1	✓	✓	✓	✓	✓
		Chair 2	✓	✓			

fresh solution was kept Additional area samples were taken in the rinse plenum, and on the roof in the plenum near the exhaust

All sorbent tubes were sent to DataChem, Inc (Salt Lake City, Utah) for analysis using NIOSH Method 1005 (gas chromatography, FID) for methylene chloride, NIOSH Method 2000 (gas chromatography, FID) for methanol, and NIOSH Method 1501 (gas chromatography, FID) for toluene Sampling for methylene chloride and toluene was collected on two 50/100 mg charcoal coconut sorbent sample tubes (SKC 226-01, SKC, Inc , Eighty-four, Pennsylvania) in series Samples for methanol were collected on one 75/150 mg silica gel sorbent tube (SKC 226-10, SKC, Inc , Eighty-four, Pennsylvania) Methylene chloride and toluene area and personal samples were collected at a flow rate of 60 cc/min, methanol personal and area samples were collected at a flow rate of 80 cc/min The plenum samples were collected at a flow rate of 15 cc/min All samples were taken with a personal sampling pump (P200A, E I DuPont deNemours and Co , Inc , Wilmington, Delaware)

Real-time monitoring was used to determine which tasks contributed to the worker's overall exposure In this case, the instrument used to collect the real-time data (Tip II®, Photovac Inc , Thornhill, Ontario, Canada) recorded the total ionizable solvents present in volts (the term "ionizables" means gases which can be photoionized by a miniature lamp inside the instrument) The instrument, therefore, gives a combined reading (in volts) for the organic solvents present The Photovac Tip II® was mounted on the frame of a backpack and put on the worker's back with the sampling intake tubing clasped on the worker's collar for a breathing zone measurement The output of the Photovac Tip (in volts) went directly to a Rustrak® Ranger Data Logger (Gulton Industries, Inc , E Greenwich, Rhode Island) which also was mounted on the backpack frame The furniture stripping operation was also videotaped during all sampling periods The internal clock of the video camera was synchronized with the data logger so that changes in solvent concentrations (in volts) could be correlated with stripping activities The data were downloaded to a Lotus 1-2-3 spreadsheet (Lotus Development Corp , Cambridge, Massachusetts) for further analysis The data were averaged over 6-second intervals Significant tasks were identified for each 6-second interval and coded into the Lotus spreadsheet containing elapsed time and concentration data The voltage reading from the Photovac TIP II® was converted to parts per million using the corresponding sorbent tube value of methylene chloride for that sampling period using the following formula [13]

$$C(t)=IR(t)*ST*[\frac{n}{\Sigma IR(t)}]$$

Where

C(t) - Concentration of vapor at time t (ppm)
IR(t) - Instrument response at time t (volts)
ST   - TWA concentration of contaminant as collected on sorbent tubes for the time period (ppm)
n   - Number of time intervals during the period
ΣIR(t)- Sum of the instrument response at every time interval (volts)

The major assumption in this estimation is that dilution of the evaporated solvent occurs instantaneously with no change in the relative composition of solvents in the air In addition, it is assumed that there is linear variation in instrument response with respect to changes in concentration of all contaminants in the air By the use of real-time data combined with the video camera, an approximation of exposure to methylene chloride is available for each task Conversion of the data to parts per million puts the results into more useful and understandable units

RESULTS

The results are for personal and area sorbent tube samples and real-time data Personal samples were taken while stripping each piece of furniture during this study From these data, a time-weighted average was computed for each test configuration as shown in Table D

Table D Personal Sampling Results by Test Configuration

Ventilation System	Day	Total Time (Min)	Methylene Chloride Concentration (ppm)	Methanol Concentration (ppm)
Combination	1	129	26	17
Combination	2	141	43	129
Combination	3	78	7	10
Downdraft	1	99	28	50
Downdraft	2	116	28	16
Downdraft	3	147	33	2
Slot hood	1	49	19	21
Slot hood	2	76	59	13
Slot hood	3	59	16	15

The time-weighted averages while stripping and the averages over the whole day are shown in Table E These results show a significant decrease from the methylene chloride levels (shown in Table A) using the existing ventilation system, which ranged from 613 ppm to 1152 ppm on a Time-Weighted Average while stripping

Sorbent sampling tube results for area and exhaust system are shown in Appendix A

The objective of the real-time data was to determine which task was responsible for exposing the worker to the highest concentration of methylene chloride Thereby, the worker's overall exposure could be reduced most

Table E Personal Sampling Results by Day					
Day	Actual Stripping Time (hours)	Concentration during Actual Stripping (ppm)		8-hour Time Weighted Average (ppm)	
		DCM	MAL	DCM	MAL
1	4.5	25	30	14	17
2	6.25	35	63	27	44
3	4.75	22	7	13	4

substantially by determining which specific tasks to change. The job was divided into specific tasks by the room in which they occurred: stripping area, rinsing area, or drum room, where the 55-gallon drum of stripping solution was kept. The job was broken down into 6-second intervals, and it was determined which task occurred during each interval by observing the videotapes of the three days of the survey. The stripping area is the room in which the local ventilation system was redesigned and, therefore, it was expected to cause only a small amount of the worker's overall exposure. The rinse area had very limited local ventilation and, therefore, was expected to account for as much or more of the worker's exposure than the modified stripping area. The room where the stripping solution was kept was not initially considered to be a problem, although upon observing the worker, it became apparent that the worker was often exposed to the drum. There was also a category for tasks that did not occur in any of these rooms or it could not be determined exactly where the worker was by viewing the tapes, in these situations, the "other" task was marked.

During the three days, the worker stripped furniture during nine runs. However, real-time data was successful in only seven of the nine runs due to video or data problems. Table F shows the seven runs broken down into average concentration of methylene chloride in part per million during each task and the percent of the worker's entire exposure during that run.

The real-time data comparisons for the stripping and rinsing areas were not conclusive. None of the tasks were consistently higher. However, if local ventilation had not been installed in the stripping area, the worker's exposure while in that area would probably have been consistently the highest. It is felt that exposures in the stripping area cannot be substantially further reduced. Since exposures while in the rinsing area are existent and in some cases relatively high, those exposures could be reduced through changes to work practices and engineering controls. The exposures which occurred in the drum room are relatively high, but account for a low percentage of the overall exposures because of the relatively small amount of time the worker spent in this room. However, the exposures the worker encountered while in this room were higher than expected because empty solution containers were stored there causing a higher overall level. Also, the solution pump malfunctioned often causing the worker to use the full

Table F Average Concentration of Methylene Chloride by Task (ppm) Percentages - Relative to Exposures and Time of Activity

Ventilation System	Day	Stripping Area (ppm)	Rinsing Area (ppm)	Soln 55 Gal Drum Area (ppm)	Other Areas or Out of Camera Site (ppm)
Slot Hood	1	14 (26%)	26 (51%)	14 (2%)	17 (22%)
Slot Hood	2	25 (14%)	94 (46%)	293 (9%)	49 (31%)
Slot Hood	3	17 (72%)	12 (12%)	24 (14%)	8 (2%)
Downdraft	1	22 (20%)	38 (29%)	2 (0%)	89 (51%)
Downdraft	2	31 (35%)	26 (41%)	36 (1%)	25 (23%)
Downdraft	3	23 (30%)	10 (25%)	284 (22%)	27 (23%)
Combination	3	8 (73%)	5 (13%)	0 (0%)	5 (14%)

55-gallon drum to prime the pump to make it work again This information shows that although the real-time data is not always conclusive it can give clues on outcomes of existing problems or tasks which can be altered to reduce exposures

The breathing zone, area, and plenum samples for methylene chloride were taken using a modified NIOSH Method 1005 As the NIOSH Analytical method suggests, two 100/50 mg charcoal sorbent tubes were used in series For each sample taken, the second of these sorbent tubes was reported as "nondetectable" (ND) by the analytical laboratory, hence, was disregarded

Personal samples were taken for each piece of furniture stripped There was no significant difference between the three ventilation configurations for breathing zone samples for methylene chloride or methanol data The time-weighted average of the personal samples for each piece of furniture stripped consecutively was used to give a personal sample value for each period The geometric mean for personal sample exposures for each ventilation system was Combination - 20 ppm, Slot - 26 ppm, and Downdraft - 29 ppm Since these differences were not statistically significant, the mean and confidence intervals for all personal sample data is shown in Table G

Table G Personal Methylene Chloride Samples

Number of Samples	Lower Confidence Limit (ppm)	Geometric Mean (ppm)	Upper Confidence Limit (ppm)
9	11	25	58

The area locations at the stripping tank, the floor, and the rinse area were used to compare the ventilation system's ability to dilute the amount of methylene chloride in the room in addition to the personal samples There was no statistically significant difference among the ventilation systems The confidence limits for the area samples are shown in Table H

Table H Area Methylene Chloride Samples

Sample Location	Number of Samples	Simultaneous Lower Confidence Limit (ppm)	Geometric Mean (ppm)	Simultaneous Upper Confidence Limit (ppm)
Stripping Area	9	1	3	7
Rinsing Area	9	3	6	13
Floor of Stripping Area	7	21	55	143

Samples for methylene chloride were also taken at the exhaust of the fan for the ventilation system These exhaust samples were used to compare the capture potential of the different ventilation systems There was a difference among the ventilation systems which is statistically significant ($p<0\ 0069$) The combination ventilation hood is statistically significant from the downdraft and slot ventilation hoods Table I shows the exhaust concentration differences among the ventilation systems

Table I Ventilation Exhaust Concentration (ppm) and Difference Among Exhaust Systems

Geometric Mean	Number of Observations	Ventilation System
337	3	Combination
250	3	Downdraft
217	3	Slot

DISCUSSION

This study tested a modified ventilation system, designed and installed by NIOSH researchers, for its ability to control exposures to methylene chloride This modified ventilation system greatly reduced methylene chloride exposures to the worker (geometric mean - 25 ppm) compared to the existing ventilation system (600 to 1150 ppm) The four modifications which were responsible for this extreme reduction in exposures included (1) opening the connecting doors to the stripping area to provide adequate make-up air to exhaust, (2) removing the panel of charcoal filters, (3) modifying work practices, and (4) installing an improved local exhaust hood

While stripping, the two sources of the worker's exposure to methylene chloride were the furniture being stripped and the bottom of the furniture stripping tank Therefore, three different hood configurations were tested to determine which could control these two exposure sources most efficiently The three configurations were slot, downdraft, and a combination of the two The following is a discussion of each of these configurations and how they worked in this particular facility and the possibilities of using each configuration in other facilities

The combination hood design, which consisted of both the slot and downdraft hoods, showed the most promise for lowering methylene chloride exposures at this facility The combination hood controls both of the exposure sources, the furniture and the tank bottom For this facility, the combination hood is recommended because the combination hood was able to control exposures to methylene chloride far better than that of the existing ventilation system (20 ppm - combination, 600 to 1150 ppm - existing), had the lowest personal exposure to methylene chloride compared to the other hood designs (geometric means combination - 20 ppm, slot - 26 ppm, and downdraft - 29 ppm), and controlled vapors at the two sources of solvent emission (the furniture and the tank) A drawback to the combination was that it exhausted slightly more air than the other two hoods (4200 cfm versus 3300 and 3100 cfm, respectively) and, therefore, may cause the facility added operating expenses from conditioning make-up air and possibly increased evaporation of the solution

Although not quite as low as the combination hood, the slot and downdraft hood designs did control personal exposures to methylene chloride much better than the existing ventilation system Because the slot hood design for this stripping tank was a retrofit, it did not include a means to eliminate the downdraft exhaust Therefore, the slothood was actually a combination hood with most of the air exhausting from the slots However, the downdraft hood exhausted totally from the downdraft portion of the hood

In order to further reduce exposures to methylene chloride, this facility must apply control techniques to the rinse area, it is felt that exposures in the stripping area cannot be substantially further reduced The real-time sampling and the sorbent tube samples suggested that the tasks completed in the rinse area are responsible for a large portion of the worker's exposure to methylene chloride The rinse area, which was not altered with the implementation of the new exhaust system, could be improved by further enclosing the area to take advantage of the existing exhaust which was already in place in the area and adding a steel table for the worker to set the furniture upon while rinsing This table would prevent the worker from bending over the solution-covered furniture and enable him to stand comfortably while working Other facilities should consider adding engineering controls to the stripping and rinsing areas simultaneously

Another area in which the real-time data showed a need for improvement was those tasks associated with the solution storage room There were two problems which caused exposure to the worker while in this area the solution recycling pump which kept malfunctioning and the empty 5-gallon solution cartons which were stored in this room The pump malfunction caused the worker to continually take the hose out of the solution pail and put it into the 55-gallon drum to re-prime the pump   A properly working pump should only need to be primed once a day or less and, therefore, should not be a consistent exposure source   The empty solution cartons were open to the air and caused additional unnecessary exposure

Solution temperatures observed at this facility were lower than those recommended by the manufacturer   The manufacturer of the stripping solution (Kwick Kleen Industrial Solvents, Inc) recommended this solution be used at 70°F (ARC solution temperature was <50°F)   The 70°F temperature is required to form a vapor barrier on top of the solution to keep the solution from evaporating too quickly   If the solution is too warm, the wax liquifies so there is no barrier, if the solution is too cool, as in this case, the wax thickens throughout the solution instead of on the top

Other facilities considering retrofit local ventilation designs for a solution recycling type furniture stripping tank may wish to consider the hood designs used at this facility   A combination hood design would be the best hood to install, because it was shown to control personal exposures to methylene chloride to the lowest level   Nevertheless, all three designs would be adequate local exhaust systems   For facilities where a retrofit of the current tank is not necessary, the designs shown here could be improved by redesigning the stripping tank to exhaust a lower volume of air, thereby decreasing the operating cost of the ventilation system

Inadequate make-up air was a problem at this facility and could be a problem at many other facilities which have substantially increased the volume of their exhaust system   The solution to this problem was a simple one   open the doors to the stripping area   Other facilities may have to install a make-up air unit to make sure there is adequate replacement air which is properly conditioned

RECOMMENDATIONS

It is recommended that this facility continue to use the ventilation system installed for this study   The modified ventilation system significantly reduced the worker's exposure to methylene chloride   Additionally, it is recommended that this facility use the installed ventilation system as a combination configuration since the worker had the lowest exposure to methylene chloride while using this hood

A heating belt should be wrapped around the stripping solution bucket in order to maintain a temperature in the range of 70°F   This addition will eliminate some solution evaporation and also make the stripping solution work better, thereby decreasing the stripping time

The design of the rinse area was not changed during this study   This is the area of this facility which could be improved in order to reduce exposures to methylene chloride   The facility could take advantage of the existing 500 cfm exhaust in the rinse area by further enclosing the area   A plastic tarp could cover the rinse area and reduce the opening to half the existing size

The furniture stripper at this facility wore chemical splash goggles, shoulder length electrical linesman gloves, an apron, and work boots This facility should continue providing this personal protective equipment to the furniture stripper In addition, a face shield will prevent chemical splash or spray onto the worker's face Shoulder length gloves, as used at this facility, are much better than elbow length gloves because they protect the upper arm However, a cuff at the top of the glove would be an improvement because it would prohibit the solution from running off the end of the glove onto the worker's arm when it is raised This facility used reject electrical linesman gloves of two thicknesses, 2 mm and 1 4 mm Both of these gloves were tested with furniture stripping solution for breakthrough times of methylene chloride and methanol by NIOSH's Division of Safety Research for their study entitled "Evaluate Field CPC Permeation Method for Furniture Stripping Industry," as described in Appendix B The following are recommendations for care and use of furniture stripping gloves replace (or change) the glove before chemical breakthrough occurs, rinse and dry gloves in a warm, well ventilated area, and inspect the gloves prior to use for pin holes, cracks, thin spots, stiffer than normal or sticky surfaces, and other abnormalities Chemical breakthrough time should be tested for each glove Electrical linesman gloves can be reused with the proper decontamination and inspection There should be a rotation program which incudes many pairs of gloves, rotating in new gloves often [14]

Another study conducted by NIOSH researchers demonstrated that full shift use of organic vapor respirators are not adequate for removing methylene chloride, since cartridge breakthrough time is approximately 40 minutes for a methylene chloride challenge of 15 parts per million [15] Because the odor threshold of methylene chloride is near the PEL, the worker will not smell methylene chloride until significant breakthrough has already occurred Therefore, it is not recommended that the ARC continue to use organic vapor respirators

When engineering controls have been exhausted, the only respirators which may be used are a self-contained breathing apparatus (SCBA) with a full facepiece operated in pressure demand or other positive pressure mode, or a supplied-air respirator (SAR) with a full facepiece operated in pressure demand or other positive pressure mode in combination with an auxiliary SCBA operated in pressure demand or other positive pressure mode The auxiliary SCBA must be of sufficient duration to permit escape to safety if the air supply is interrupted Where employees must wear respirators, an appropriate respiratory protection program in accordance with 29 CFR 1910 134 must be instituted [9]

Work practices are an important factor in controlling the exposures to methylene chloride among furniture strippers Factors which must be considered at this and other facilities by the workers include the direction in which the air is moving relative to the furniture stripping solution and the placement of their breathing zone relative to exposure sources, the extent to which they leave the stripping solution running, and the physical layout of the facility In the present study, fresh air was entering the room from behind the workers and on both sides, and solvent-laden air was being exhausted from the room at the tank The workers must, therefore, make sure they are in the fresh airstream and never position their breathing zones between the solvent emission source (any part of a solution-covered piece of furniture during either stripping or rinsing) and the location of the exhaust Turning the solution recycling system off when it is not in use should also reduce exposures and conserve solution This may mean having a convenient switch so the workers can easily turn the solution pump on and off Physical environment is also an important factor for the workers' safety the workers must be aware of what they are lifting and avoid lifting very heavy objects by themselves, the shop should be clear of obstacles which the workers might trip over while carrying furniture from the stripping area to the rinsing area, and the rinsing area should have a table on which to set the furniture so that the workers can rinse the piece while standing in a comfortable position

Some further research possibilities may include quantifying the cost to condition the make-up air for this ventilation system and the amount of stripping solution evaporated while using the new ventilation system These factors may influence the feasibility of the new ventilation system for widespread use

CONCLUSIONS

The alterations made to the furniture stripping area at this facility substantially lowered the furniture stripper's exposures to methylene chloride The worker's exposure to methylene chloride using the existing ventilation system ranged from 600 to 1150 ppm The new ventilation systems reduced those exposures to a geometric mean of 25 ppm The installed local ventilation system was designed to be configured and tested using three different hoods slot, downdraft, and a combination of the two In addition to determining if the alterations to the stripping area decreased exposures, the different configurations were also compared The author believes that the combination configuration was the best exhaust hood for this facility for two reasons Firstly, the worker's exposure to methylene chloride was lower, although the levels were not statistically significant between the three configurations Secondly, the combination hood exhausted both at the bottom of the tank and across the solution-covered furniture, which seems to be a preferable control configuration

Regardless of the configuration used, this ventilation system substantially reduced exposures to methylene chloride The important ideas in the design of the improved ventilation system were providing adequate make-up air for the furniture stripping area, removing the charcoal filters, discussing improved work practices with the workers, and redesigning the ventilation system so that it was as close as possible to the exposure sources

The personal exposures to methylene chloride using the new ventilation system was in compliance with the current OSHA PEL of 500 ppm OSHA has proposed to lower this standard in the near future, probably in the range of 50 ppm The levels seen in the present study seem to indicate that control can be achieved in the range of 25 to 50 ppm on an 8-hour time-weighted average basis

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APPENDIX A

Sorbent Sampling Results – DCM and MAL

Dates: March 13, 14, & 15, 1990

Facility: Association For Retarded Citizens

Location of Sample	Ventilation System	Day	Run Time (min)	DCM Conc. (ppm)	MAL Conc. (ppm)
Floor Sample	Combination	1	156	111	
Floor Sample	Combination	2	147	431	28
Floor Sample	Downdraft	3	144	37	1
Floor Sample	Downdraft	1	98	4	28
Floor Sample	Downdraft	2	122	24	11
Floor Sample	Slothood	1	55	21	24
Floor Sample	Slothood	2	82	398	25
Breathing Zone	Combination	1	27	26	17
Breathing Zone	Combination	2	42	43	129
Breathing Zone	Combination	3	54	7	10
Breathing Zone	Downdraft	1	68	28	50
Breathing Zone	Downdraft	2	26	28	16
Breathing Zone	Downdraft	3	147	33	2
Breathing Zone	Slothood	1	13	19	21
Breathing Zone	Slothood	2	20	59	13
Breathing Zone	Slothood	3	59	16	15
Rinse Area	Combination	1	155	8	
Rinse Area	Combination	3	84	2	1
Rinse Area	Combination	2	147	9	3
Rinse Area	Downdraft	2	123	9	2
Rinse Area	Downdraft	3	144	6	0
Rinse Area	Downdraft	1	101	4	2
Rinse Area	Slothood	1	46	6	4
Rinse Area	Slothood	3	63	2	2
Rinse Area	Slothood	2	81	23	7
Stripping Area	Combination	2	145	3	1
Stripping Area	Combination	1	157	5	
Stripping Area	Combination	3	83	1	0
Stripping Area	Downdraft	3	144	3	0
Stripping Area	Downdraft	1	100	2	0
Stripping Area	Downdraft	2	119	5	0
Stripping Area	Slothood	2	80	10	2
Stripping Area	Slothood	1	55	3	0
Stripping Area	Slothood	3	65	1	0
Rinse Plenum	Combination	2	144	15	
Rinse Plenum	Combination	3	99	6	
Rinse Plenum	Combination	1	154	20	
Rinse Plenum	Downdraft	1	101	21	

APPENDIX A (continued)

Sorbent Sampling Results - DCM and MAL

Dates: March 13, 14, & 15, 1990

Facility: Association For Retarded Citizens

Location of Sample	Ventilation System	Day	Run Time (min)	DCM Conc. (ppm)	MAL Conc. (ppm)
Rinse Plenum	Downdraft	2	121	32	
Rinse Plenum	Downdraft	3	143	8	
Rinse Plenum	Slothood	3	58	3	
Rinse Plenum	Slothood	2	79	66	
Rinse Plenum	Slothood	1	61	19	
Roof Exhaust	Combination	1	159	423	
Roof Exhaust	Combination	2	146	421	
Roof Exhaust	Combination	3	84	215	
Roof Exhaust	Downdraft	1	114	270	
Roof Exhaust	Downdraft	2	117	328	
Roof Exhaust	Downdraft	3	186	176	
Roof Exhaust	Slothood	3	70	132	
Roof Exhaust	Slothood	1	69	270	
Roof Exhaust	Slothood	2	107	287	

APPENDIX B

The following are some of the procedures and conclusions from the NIOSH Division of Safety Research's study entitled "Evaluate Field CPC Permeation Method for Furniture Stripping Industry " Two sets of gloves were obtained from the ARC, a 1 4 mm set initially and a 2 0 mm replacement These gloves were reject electrical linesman gloves made of natural rubber, cosmetic rejects are sold for nonelectrical use without an ASTM label Both of these gloves were tested with Kwick Kleen Paint Remover No 125 An ASTM permeation test method was used with an AMK test cell in series and two Miran IRs calibrated for methylene chloride and for methanol The methylene chloride and methanol had similar breakthrough times for all gloves in the study The methylene chloride and methanol broke through the 1 4 mm gloves in 21 minutes and through the 2 0 mm gloves in 48 minutes These gloves were also tested layered over a Silver Shield sheet stock (Siebe North, Charleston, South Carolina) This combination found the breakthrough time to be 85 minutes for the 1 4 mm gloves and 156 minutes for the 2 0 mm gloves These test data indicate that some exposure to methylene chloride and methanol would routinely occur during normal operation The following are recommendations for glove usage replace gloves before chemical breakthrough, breakthrough time should be tested by permeation testing done by the facility or the glove reseller for new and reused gloves, gloves should be dried in a warm, well-ventilated area for reuse, inspect gloves prior to each use for pin holes, cracks, thin spots, and stiffness, and consider layering dissimilar generic material gloves in order to increase breakthrough time