In-Depth Survey Report

Control of Methylene Chloride during Furniture Stripping

at

Tri-County Furniture Stripping
Cincinnati, Ohio

REPORT WRITTEN BY:
Cheryl Fairfield Estill
Daniel S. Watkins
Stanley A. Shulman
Robert W. Kurimo
Ronald J. Kovein

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
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4676 Columbia Parkway
Cincinnati, Ohio 45226-1998

FACILITY SURVEYED	Tri-County Furniture Stripping and Refinishing 1101 Springfield Pike Cincinnati, Ohio 45246
SIC CODE:	7641
SURVEY DATES:	August 28 & 29, October 17, November 25,1997, March 20, April 2&3, June 2, 13 &15, July 8&9, 1998, May 25-27, June 21 & 22,1999.
SURVEY CONDUCTED BY:	Jon Cleary Cheryl Fairfield Estill Ronald M. Hall Stephen D Hudock Ronald Kovein Robert W Kurimo David Marlow Daniel S. Watkins
DATA ASSISTANCE:	James H. Jones
EMPLOYER REPRESENTATIVE:	Jerry Ash, Owner
ANALYTICAL SERVICES:	DataChem Laboratories Salt Lake City, Utah Ardith Grote Analytical Research and Development Branch Division of Applied Research & Technology National Institute for Occupational Safety & Health (NIOSH), Cincinnati, OH
MANUSCRIPT PREPARATION:	Diana R Flaherty

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SUMMARY

The National Institute for Occupational Safety and Health (NIOSH) has been conducting research on ventilation controls to reduce furniture stripping exposures to methylene chloride The goal of this study was to reduce exposures to methylene chloride below the current (issued January 1997) OSHA PEL of 25 ppm at Tri-County Furniture Stripping in Cincinnati, Ohio Five surveys were completed at this facility The second survey showed the highest exposures with a geometric mean of 334 ppm Since the second survey, the ventilation system at the stripping tank was upgraded and cleaned for a final exhaust volume of 2720 cfm Since the third survey, a local exhaust ventilation system for the rinsing area was installed with a total exhaust volume of 2140

Additional controls instituted during the fifth and final survey included upgrading the stripping ventilation, adding paraffin wax to the stripping solution, and discussing good work practices with the employee The methylene chloride concentrations during the fifth survey were reduced to a geometric mean of 9 ppm with an 95% upper confidence limit of 13 ppm This final survey showed that the methylene chloride levels have been reduced to below the new OSHA PEL of 25 ppm The important engineering and administrative controls that led to reducing exposures were the following

- increasing the stripping tank local exhaust ventilation to 2700 cfm,
- increasing the rinsing area local exhaust ventilation to 2100 cfm,
- opening all doors to the facility to allow for plentiful make-up air,
- adding paraffin wax to the stripping solution and bringing up the level of the solution in the stripping tank, and
- training the employee in good work practices

The cost of the ventilation system and the make-up air system is projected to be $15,720, with a yearly operating cost of $1000 For the facility in this study, an additional $5200 would need to be spent to upgrade their gas line for installation of the make-up air unit

INTRODUCTION

In January 1997, the Occupational Safety and Health Administration reduced the methylene chloride standard from 500 ppm to 25 ppm over an eight-hour time-weighted average (TWA) As a follow-up from that reduction, researchers from the National Institute for Occupational Safety and Health (NIOSH) determined that a demonstration site was needed to show that employees' exposures to methylene chloride while furniture stripping can be reduced to meet the new OSHA standard Previous work had already been conducted at Tri-County Furniture Stripping in September 1991 (Hall, Martinez and Jensen, 1995) Therefore, the goal was to reevaluate the methylene chloride exposure levels at that facility and to determine what other upgraded or new ventilation should be installed at the facility to meet the new OSHA standard

PLANT AND PROCESS DESCRIPTION

Tri-County Furniture Stripping and Refinishing currently employs four full-time men, including the owner One person strips furniture full-time and the others perform repairing and finishing of the furniture The furniture stripping area occupies 266 square feet of the 2055 square feet building The rest of the building includes a paint spray booth (operated intermittently exhausting about 5000 cfm), a storage room, offices, restrooms, and a work area for applying finishes (Figure 1) There is also an adjacent building where sanding and repair work are performed

Paint, varnishes, and stains are stripped by dipping the furniture in an open stripping tank containing the stripping solution After the item has sat in the stripping tank for a while, the employee leans over the stripping tank and scrubs the furniture to remove the finish from the crevices The employee then transports the furniture to a rinse area where a high pressure water system is used to spray the solution off the furniture If there is still finish on the furniture, the employee uses a scraper to remove it An oxalic acid solution is then lightly sprayed on most pieces of furniture to lighten and neutralize the wood The furniture is then moved to an adjacent area to dry

Tri-County Furniture Stripping and Refinishing mixes their own stripping solution The facility purchases 55 gallon drums of the following muriatic acid (hydrochloric acid), 1,1,1-trichloroethane, methylene chloride, methanol, sodium hydroxide, xylene, acetone, and TCF blend (Tri-County Furniture blend which according to the material safety data sheet has the following ingredients methylene chloride (10 - 40%), trichloroethane (5 - 20%), trichloroethylene (5 - 20%), toluene (5 - 20%), acetone (5 - 20%), and hexane (5 - 20%) The employee who strips the furniture also mixes the stripping solution He does not have an exact schedule, e g., when he feels the solution is not working well he adds ingredients. Paraffin wax was also added to the stripping solution sometimes

The furniture stripping ventilation in this facility was originally installed in August 1991 during a previous NIOSH research study (Hall et al, 1995) The ventilation system was evaluated for air velocity, total air volume exhaust rate, and worker's methylene chloride exposures The ventilation system consisted of front and back exhaust slots on the stripping tank There was no local ventilation at the rinsing area The average slot velocity at the stripping tank was 3200 fpm and the exhaust volume was 2900 cfm At that time, breathing zone methylene chloride samples ranged from 6 to 93 ppm with a geometric mean of 59 ppm

HEALTH HAZARDS AND OCCUPATIONAL EXPOSURE CRITERIA

Methylene Chloride

Potential chemical hazards in the furniture stripping industry are found primarily during the actual handling, stripping, and rinsing of the furniture Other exposure sources may include the mixing or transferring of the stripping solution, the evaporation of solution from the stripping tank, or the evaporation of the solution off the furniture The major routes of entry of methylene chloride and other solvents into the body include inhalation of vapors and absorption of the liquids through the skin The severity of the hazard depends on ventilation, general workstation design, work practices, duration of exposure, the formulation of the stripping solution, type of operation, and temperature

Health effects studies of methylene chloride exposure have been focused on three primary areas 1) effects on the central nervous system, 2) effects on cardiovascular morbidity and mortality, and 3) induction of cancer in exposed workers (NIOSH, 1977) Research has shown methylene chloride as a possible reproductive toxicant (Kelley, 1988) In addition, solvents are known to affect liver function, some studies suggest that this effect occurs secondary to methylene chloride exposure Repeated skin contact with methylene chloride may cause dry, scaly, and cracked skin At high airborne concentrations (greater than 500 ppm), vapors are irritating to the eyes and upper respiratory tract Direct contact with the liquid can cause skin burns Methylene chloride is a mild narcotic Effects from intoxication include headache, giddiness, stupor, irritability, numbness, and tingling in the arms and legs The reports of odor threshold range from 25 to 250 ppm (NIOSH, 1977)

A death from using methylene chloride to strip furniture was reported in the summer of 1999 An 18-year old man was stripping furniture at a small facility in Chattanooga, Tennessee where it was assumed that he was overcome by vapors and collapsed into the stripping tank This facility had no local ventilation system to remove the methylene chloride vapors Also the solution in the dip tank was at a low level causing the employee to lean into the tank to scrub the furniture thus putting his head (and breathing zone) inside the tank A local exhaust ventilation system for the dip tank in conjunction with maintaining a higher level of stripping solution in the tank were recommended to the facility owner to prevent another tragedy (Hall and Estill, 1999)

The current Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) for methylene chloride (62 Federal Register 1494, 1997) is an 8-hour time-weighted average (TWA) concentration of 25 parts per million (ppm), with a short-term exposure limit (STEL) concentration of 125 ppm for a 15 minute period This standard was adopted on January 10, 1997 The previous standard was a PEL of 500 ppm with a STEL of 1000 ppm The 1997 standard will go into effect over a three-year period depending on the size of the company For employers with 20 or fewer employees (which is the case with this and most other furniture stripping shops), engineering controls will be required to meet the standard on April 10, 2000 An amendment to the final rule was issued in 1998 which changed the requirements effective before April 10, 2000 This amendment removed the requirement of using a supplied air respirator to achieve the 25 ppm level for furniture stripping (63 Federal Regulation 50712, 1998)

An action level of 12 5 ppm was also put into place by the new methylene chloride standard Once it has been determined that employees have exposures over the 12 5 ppm action level, the employer must begin compliance activities including exposure monitoring and medical surveillance If the employee's exposure is above the action level, exposure monitoring is required at least every six months (if the exposure is also above the PEL, exposure monitoring is required every three months) If an employee's exposure is above the action level, these employees should see a health care provider at the expense of the employer if exposed to methylene chloride more than 30 days per year (OSHA, 1997)

The NIOSH regards methylene chloride as a "potential occupational carcinogen" and recommends that methylene chloride be reduced to the lowest feasible limit (NIOSH, 1992) This recommendation was based on the observation of cancers and tumors in both rats and mice exposed to methylene chloride in air (NIOSH, 1986)

Methanol, Toluene, and Acetone

Methanol has very similar central nervous system effects to methylene chloride (NIOSH, 1977) The NIOSH REL for methanol is 200 ppm as a TWA for up to 10 hours per day, 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 (29 USC[1] 1910, 1973)

Health effects for exposures to toluene which are above 200 ppm 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 (NIOSH, 1973) The NIOSH REL for toluene is 100 ppm as a TWA for up to 10 hours per day, with a ceiling of 150 ppm averaged over a 15-minute period The current OSHA PEL for toluene is an 8-hour TWA concentration of 100 ppm

Acetone is one of the least toxic of the industrial solvents as far as health is concerned In cases of repeated exposure to low concentrations, complaints were received of headache, drowsiness, vertigo, irritation of the throat, and coughing (Inoue, 1983) The NIOSH REL for acetone is 250 ppm, as a TWA for up to 10 hours per day The current OSHA PEL for acetone is an 8-hour TWA concentration of 750 ppm with a STEL of 1000 ppm However, acetone is extremely flammable with a flash point of 0°F (-13°C) and is rated a class IB flammable liquid For comparison Gasoline also is a class IB flammable liquid

Previous NIOSH studies of furniture stripping found no exposures over the OSHA PEL or NIOSH REL for methanol, toluene, or acetone (Hall et al, 1995, Estill and Spencer, 1996, Fairfield and Jensen, 1991) Therefore, no attempt was made in this study to quantify exposures to these solvents

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[1]United States Code

ENGINEERING CONTROLS AND SAMPLING METHODS

Quantitative air sampling was conducted for methylene chloride on five different occasions over a two year period

1 August 28 & 29, 1997
2 March 20, 1998
3 June 2, 1998
4 July 8 & 9, 1998, and
5 June 21 & 22, 1999

The facility was visited on other dates for measuring the exhaust system (October 17, November 25, 1997, and January 29, 1999) and for installing or modifying the ventilation systems (April 2-3, 1998, June 13-15, 1998, and May 25-27, 1999)

The same employee performed furniture stripping for all five sampling surveys This employee alternated about equally between the two workstations, stripping tank and rinsing area, to perform the furniture stripping Additionally, minimal time was spent by the employee transferring items from the storage area and to the drying area Infrequently, this employee also helped customers or answered the phone

First Sampling Survey

On August 28 and 29, 1997, personal air samples were collected in the breathing zone of the employee during stripping and rinsing. Area samples were collected in the following locations

1 Near the stripping tank, 12 inches to the left and 9 inches behind the rear left corner of the stripping tank, at a height of 54 inches above the floor
2 Near the rinsing area, 2 feet behind the right rear corner of the water holding tank at a height of 54 inches above the floor

Air samples for methylene chloride were collected on two 50/100 mg charcoal tubes (SKC 226-01, SKC, Inc , Eighty-Four, PA) in series Sampling was conducted at a nominal flow rate of 0 02 liters per minute (LPM) using a personal sampling pump (Gilian LFS113, Gilian Instrument Corporation, West Caldwell, NJ) Samples were sent to DataChem Laboratory (Salt City, UT) for analysis using NIOSH method 1005 from the NIOSH Manual of Analytical Methods (NIOSH, 1994) No bulk samples of the stripping solution were collected

The ventilation system was tested in October 1997 and believed to be in the same condition as it was during the August 1997 sampling The average slot velocity was recorded by measuring air velocity with a Velocicalc (T S I , Model 8386A, St Paul, MN) velometer at eight evenly spaced locations across each slot The total exhaust volume was measured at eight feet above the fan in the duct It was measured using the pitot traverse method with a digital micromanometer (Air Neotronics, Model MP20SR, Oxford, England) The employee was videotaped to determine the task that the worker was doing during data collection

Second Sampling Survey
On March 29, 1998, a second sampling survey was conducted to determine the exposures in the shop during the winter months when the building was closed and to compare two different sampling media Personal air samples were collected side-by-side on the lapel in the breathing zone of the employee using three different methods

1 Two 50/100 mg charcoal sorbent sample tubes (SKC 120) in series with a flow rate of 0 02 LPM using NIOSH Method 1005
2 One 50/100 mg charcoal sorbent sample tube (SKC 120) with a flow rate of 0 02 LPM using NIOSH Method 1005
3 One ORBO 91 (Lot 3611) sorbent sampling tube (Supelco, Inc , Bellefonte, PA) with a flow rate of 0 05 LPM using OSHA Method 80

Area samples were collected using the three methods near the rinsing area, 4 inches behind and 48 inches to the right of the right front corner of the rinsing table at a height of 87 inches from the floor Personal sampling pumps (Gilian LFS 113) were used for all samples collected Samples were sent to DataChem Laboratories for analysis No bulk samples, video recordings, real-time sampling, or ventilation measurements were collected

Third Sampling Survey
It was determined that the stripping tank ventilation system had to be improved (renovated) to reduce exposures In April 1998, the following improvements were made to the ventilation system

1 Hinges were added to the exhaust plenums at the slots so that they could opened for cleaning (Figure 2)
2 Two 10-inch diameter access holes were made toward the bottom of each plenum for cleaning (Figure 3)
3 A new exhaust stack head was added for rain protection and the old stack head was removed (Figures 4 and 5)
4 The T-duct located immediately after the fan was replaced by a 90° wide-sweep duct Because the 90° duct was a wider turn than the T-duct, two 45° angle ducts had to be installed to align the exhaust with the existing mounting on the side of the building (Figure 5)
5 The stripping tank and ventilation system were thoroughly cleaned and fresh stripping solution was added

At the time of the renovation (April, 1998) and during the sampling survey (June, 1998) air velocity and air volume measurements were made of the stripping tank local exhaust system The average slot velocity was recorded by measuring air velocity with a Velocicalc velometer at eight evenly spaced locations across each slot The total exhaust volume was measured at eight feet above the fan in the duct It was measured using the pitot traverse method with a digital micromanometer (Air Neotronics, Model MP20SR)

On June 2, 1998, personal air samples were collected side-by-side on the lapel in the breathing zone of the employee using two different methods

1 Two 100/50 mg charcoal sorbent tubes (SKC 120) in series with a flow rate of

0 02 LPM using NIOSH Method 1005
2 One ORBO 91 (Lot 3611) sorbent sampling tube with a flow rate of 0 05 LPM using OSHA Method 80

Area samples were collected using the same two methods in the following locations
1 Near the stripping tank, 12 inches to the left and 12 inches behind the left rear corner of the stripping tank, at a height of 70 inches above the floor
2 Near the rinsing area, 4 inches behind and 48 inches to the right of the right front corner of the rinsing table at a height of 70 inches from the floor
3 In the drying area, at a height of 48 inches from the floor

Personal sampling pumps were used for both sampling media The samples were sent to DataChem Laboratories for analysis One bulk sample of the stripping solution from the stripping tank was collected and submitted to the Analytical Research and Development Branch, NIOSH for determination of percent weight methylene chloride (wt%/wt) Notes were taken during the survey to quantify the amount of time the worker spent at the stripping tank versus the rinsing area

Fourth Sampling Survey

Previously there had been no local exhaust ventilation for the rinsing operation at this facility In June 1998, a rinse area local ventilation system was installed This ventilation system was an enclosed booth for the furniture to be rinsed in while the employee stood outside the booth The system had a 16" tubeaxial fan (Dayton Model 4C660, Niles, IL) which was ½ HP, 1800 rpm, 110 volt, single phase, rated at 2565 cfm for 1/8 inch static pressure Metal louvers were attached to the outside of the fan to keep animals out when the fan was not in use The booth was mounted in a corner against one existing cinder block wall and was built of 22 gauge sheet metal or welding curtain (Frommelt, Weld-Tex M-1053, Dubuque, Iowa) on the other three sides There was an opening in the front for access of the employee to rinse the furniture The curtain was used in place of sheet metal at certain locations to allow its removal for stripping larger objects such as church pews Figure 6 shows a diagram of the rinse booth The booth was designed so that the opening for employee access would be 3 feet by 7 feet with a face velocity of 120 fpm

A smaller water holding tank for the rinsing water was needed to alleviate the space constraint caused by adding the new rinsing booth The previous water holding tank held 450 gallons, which was larger than necessary A 250 gallon, 18 gauge metal, 2 by 2 by 8 foot animal trough was purchased (Quality Farm and Fleet Supply), and a lid was made from 18 gauge sheet metal Two hazardous location light fixtures (Appleton) were installed inside the rinse booth In addition to the ventilation for the new rinsing booth, the stripping tank ventilation (as described in survey 3) also operated during the fourth sampling survey

On July 8 & 9, 1998, personal breathing zone air samples were collected side-by-side on the left lapel of the employee using three different methods
1 Two 100/50 mg charcoal sorbent tubes (SKC 120) in series with a flow rate of

0 02 LPM using NIOSH Method 1005
2 One ORBO 91 (Lot 3611) sampling sorbent tube with a flow rate of 0 05 LPM using OSHA Method 80
3 Passive monitors (SKC 575-001)

Personal sampling pumps were used for the first two methods Area samples were also collected using the same three methods in the following locations

1 Near the stripping tank, at the left rear corner of the stripping tank at a height of 67 inches above floor
2 Near the rinsing area, 54 inches in front of the right front corner of the rinsing booth at a height of 32 inches above the floor
3 In the drying area, 2 feet in front of the right front corner of the storage rack at a height of 51 inches from the floor

Bulk samples of the stripping solution in the stripping tank and the water in the rinse water holding tank were collected for analysis to determine the methylene chloride percentages (wt%/wt). All of the sorbent tubes and bulk liquid samples were sent to DataChem Laboratories to be analyzed Doors to the facility were opened during all sampling

The ventilation system was tested in conjunction with the fourth survey The total exhaust volume for the stripping tank was measured at eight feet above the fan in the duct It was measured using the pitot traverse method with a digital micromanometer The average air velocity of the rinsing booth was measured with a Velocicalc velometer at 12 evenly spaced locations across the opening of the rinsing booth The dimensions of the opening were measured to compute the total exhaust volume of the rinsing booth

Real-time exposure to total solvents present in the breathing zone of the worker was measured using a MiniRae photo ionization monitor (Model PGM-7600, Rae Systems, Inc , Sunnyvale, CA) with a 10 6 eV ultraviolet lamp The MiniRae responds to the mixture of both the methylene chloride and methanol vapors The analog output signal from the MiniRae was recorded on a Metrosonics data logger (Model 3200, Rochester, NY) The data from the data logger were later downloaded to a portable computer for further analysis

Fifth Sampling Survey

The following physical changes were made to the stripping local exhaust system between the fourth and fifth surveys

1 A square 60 degree transition piece was connected from the stripping tank plenums to the duct to reduce static pressure losses between the plenum and the duct (figure 7)
2 Twelve inch duct work was replaced with 16 inch diameter duct before and after the fan
3 A new 16⅛ inch centrifugal fan was installed (Dayton Model 3C495) which was 2 HP, 1890 rpm, 220 volt, single phase, rated at 3905 cfm for 1½ inch static pressure (the new fan was the same size as the old fan, the old fan was rusting and deteriorating)

4 An 18 inch duct was installed on the stack to protect the fan against rain
5 The combination of the new fan and the new ducting eliminated the need for any elbows in the revised system (figure 8)
6 The curtain at the top front of the rinse booth was lowered by 7 inches
7 A 36" square table (2½ feet high) that swivels was added inside the rinsing area for the worker to set the smaller pieces of furniture enabling the worker to turn the table to rinse the other sides of the furniture (Figure 9)

Early on the day of the sampling survey before any sampling or stripping, the employee mixed the stripping solution The stripping solution level in the tank before adding any solution was about 12 inches high (about 200 gallons) The employee added 176 gallons of the following to the stripping tank 85 gal methylene chloride,(48 3%), 30 gal methanol(17 1%), 20 gal xylene (11 4%), 20 gal toluene (11 4%), 20 gal acetone (11 4%), ½ gal caustic soda flake (<1%), and 10 lbs paraffin wax (about 0 4 gal, <1%) After adding the solution, the height of the solution in the tank was 22 inches from the bottom with a freeboard height of 14 inches The employee noted that this was the first time that the solution had been so high or that paraffin wax had been added in years The investigators suggested that he fill the tank to 10 inches below freeboard height and add paraffin wax on a permanent basis

The week before the fifth sampling survey, the worker watched an hour-long video cassette with a bar graph of the real-time solvent concentration overlaid from the fourth sampling survey The tape showed this same employee stripping and rinsing furniture with a bar graph on the left side of the screen showing the employee's solvent concentration The bar graph moved as the employee worked The video cassette was explained to the employee He was asked to watch the tape and then to think of ways that he might be able to reduce his exposures He said that the company had changed one of their methods for stripping large pieces of furniture since the previous survey They now remove the plywood or cardboard backing from large furniture They found that those materials retain the solution and often warp Removing this backing meant that large pieces of furniture are now open for the exhaust air to blow through rather than being a barrier Previously the employee spent a lot of time rinsing behind large pieces of furniture where he was unprotected from the rinse booth The employee had no other ideas to reduce his exposure

On June 21 & 22, 1999, personal breathing zone air samples were collected side-by-side on the left lapel of the employee using one method--one ORBO 91 (Lot 3611) sampling sorbent tube with a flow rate of 0 05 LPM using OSHA Method 80 Personal sampling pumps were used Area samples were collected in the following locations (same as survey 4)

1 Near the stripping tank, at the left rear corner of the stripping tank at a height of 67 inches above floor
2 Near the rinsing area, 54 inches in front of the right front corner of the rinsing booth at a height of 32 inches above the floor
3 In the drying area, 2 feet in front of the right front corner of the storage rack at a height of 51 inches from the floor

Bulk samples of the solutions in the stripping tank and the rinse water holding tank were collected during each run to determine the methylene chloride percentages (wt%/wt) Also, the height of the stripping solution was recorded before every run and after the last run All of the sorbent tubes and bulk liquid samples were sent to DataChem Laboratories for analysis Doors to the facility were opened during all sampling

The ventilation system was measured during the fifth survey The total exhaust volume for the stripping tank was measured at 13 feet above the fan in the duct It was measured using the pitot traverse method with a Velocicalc velometer with a pitot tube The average slot velocity was recorded by measuring air velocity with a Velocicalc velometer at eight evenly spaced locations across each slot The average air velocity of the rinsing booth was measured with a Velocicalc velometer at 12 evenly spaced locations across the opening of the rinsing booth The dimensions of the opening were measured to compute the total exhaust volume of the rinsing booth

Real-time sampling was not collected, but the employee was videotaped during the entire survey The amount of time that the employee conducted each task and the furniture stripped was collected from the video cassettes

DATA RESULTS AND ANALYSIS

First Sampling Survey

Methylene chloride personal breathing zone and area samples results are shown in Table 1 During this sampling survey, all doors to the facility were opened to allow for personal comfort because it was warm outside

Table 1. Results from First Sampling Survey, August 28, 29, 1997

Sample Location	Number of Samples	Sampling Time (min)	Methylene Chloride Concentration (ppm)
Breathing Zone	3	130	74
Area - Strip	3	182	8
Area - Rinse	1	57	3

Since the 1991 evaluation, a different, smaller fan had been installed on the stripping tank ventilation system, and the system had deteriorated significantly The fan was a 2 HP, single phase, 230 volt, 16-1/8" diameter centrifugal fan (Dayton, Model 3C495). The slots on the stripping tank were visibly clogged with used stripping solution (Figure 10) There was no access for employees to clean out the slots The duct immediately following the fan was T-shaped and only one direction was used resulting in unnecessary turbulence and static pressure loss The lower portion of the T had a hole from rust (Figure 11) A rain cap which resulted in an extreme pressure loss had been installed (Figure 4) Subsequent to this visit, it was found that the front and back plenums for the stripping tank exhaust had as much as 9 inches of paint chips, sawdust, and other debris in the bottom of the plenum (Figure 3) As with the slots, there were no means for the employees to clean the plenums The average slot velocity at the stripping tank was 880 fpm, and the exhaust volume of the stripping tank ventilation system was 1060 cfm There was no local ventilation at the rinsing area. The task analysis for the first survey is shown in Table 2 As shown, the employee's time was divided almost evenly between stripping and rinsing with slightly more time to rinsing

Table 2 Task Analysis from Video Cassettes from First Survey

Run No	Strip Time (Min)	Rinse Time (Min)	Transport Time* (Min)	Furniture Stripped
1	17	23	3	Headboard, footboard, 2'x2' cabinet door
2	6	9	4	4 - 1'x2' cabinet doors
3	25	23	8	2 - bed rails, 3 - small 1'x1' cabinet doors, 2'x2' door, 1'x4' door, wall unit top (8'x1'x1')
	48 (41%)	55 (47%)	15 (13%)	

* Transport time was time spent transporting the furniture and other tasks including washing the floor, answering the phone, or being outside the camera's view

Second Sampling Survey

Methylene chloride personal breathing zone and area samples results are shown in Table 3

Table 3 Results from the Second Sampling Survey, March 20, 1998

Sample Location	Number of Samples	Sampling Time (min)	Methylene Chloride TWA Concentration (ppm)			
			Charcoal Media		ORBO 91 media	Average of 3 methods
			2 tubes in Series	1 tube		
Breathing Zone	3	169	347	312	346†	335
Area - Rinse	3	168	58	59	71†	63

† Sampling time was 115 minutes and the number of samples was two for this time-weighted average

During this survey, all doors to the facility were closed because of the cold weather outside. The facility had no method for make-up air to enter the building. No exhaust volume or air velocity measurements were taken during this survey to quantify the ventilation system. Even without air measurements it was obvious to the researchers that the building was under negative pressure as evident from feeling the air blowing under windows and through cracks and the difficulty of shutting the customer entrance door.

Third Sampling Survey

Methylene chloride personal breathing zone and area samples are shown in Table 4. The time-weighted average of all the breathing zone samples for this survey was 84 ppm.

Table 4. Results from Third Sampling Survey, June 2, 1998

Run no	Sample Location	Facility Doors	Sample Time (min)	Methylene Chloride TWA Concentration (ppm)		
				Charcoal Tubes 2 in Series	ORBO 91 tubes	Average
1	Breathing Zone	Closed	61	150	149	150
2, 3, 4	Breathing Zone	Open	183	67.8	57.5	62.6
1	Area - Strip	Closed	61	10.4	9.68	10.0
2, 3, 4	Area - Strip	Open	183	12.0	10.9	11.5
1	Area - Rinse	Closed	61	82.6	81.3	82.0
2, 3, 4	Area - Rinse	Open	183	18.7	17.1	17.9
1	Area - Dry	Closed	61	9.89	8.41	9.15
2, 3, 4	Area - Dry	Open	183	9.42	8.06	8.72

With all doors to the facility *closed*, immediately after the renovation (April 1998) to the stripping tank and ventilation system, the average slot velocity was 1384 fpm and the average exhaust volume was 1873 cfm. With all doors to the facility *opened*, at the time of the sampling survey (June 1998) the average slot velocity was 1695 fpm and the average exhaust volume was 2076 cfm. The bulk sample showed 49% of methylene chloride in the stripping solution.

The time that the employee spent at the stripping and rinsing tasks are shown in Table 5 along with the area sampling results. As can be seen from the table, only about 38% of the worker's time was spent working at the ventilated stripping area and the stripping area concentration was one-third the rinsing area concentration.

Table 5 Task Analysis and Area Methylene Chloride Concentration for the Third Survey

Run No	Tasks Time (min)		Methylene Chloride TWA Concentrations (ppm)	
	Stripping	Rinsing	Area - Strip	Area - Rinse
1	0	62	10 0	82 0
2	23	39	4 53	32 6
3	59	3	19 1	8 79
4	10	49	10 7	12 1
	92 (38%)	153 (62%)	11 1	34 1

Fourth Sampling Survey

Methylene chloride personal breathing zone and area samples are shown in Table 6 Actual measurement of the finished design of the rinse booth showed a face velocity of 117 fpm with an opening of 32 inches by 88 inches for a total exhaust volume of 2284 cfm (Figure 12) The stripping tank average exhaust volume was found to be 1978 cfm (slot velocity was not measured) The bulk sample showed there was 18% methylene chloride found in the stripping solution and a non-detectable percentage found in the rinse water

Table 6 Results from Fourth Sampling Survey, July 21, 22, 1998

Sample Location	Number of Samples †	Methylene Chloride Concentrations (ppm) and Sampling Time (min)			
		Charcoal Media	ORBO 91 Media	Passive Monitors*	Average
Breathing Zone	6	50 4 (397)	44 0 (395)	74 5 (336)	56 3
Area - Strip	6	11 8 (381)	10 6 (381)	10 3 (329)	10 9
Area - Rinse	6	22 1 (380)	14 8 (385)	13 3 (328)	16 7
Area- Dry	6	13 5 (385)	12 8 (385)	11 6 (332)	12 6

* Passive Monitor averages include only five samples

† Run 5 was removed because the charcoal sample was much larger than the ORBO sample for the breathing zone

The real-time sampling data were analyzed by task The video cassettes were watched to determine which task the worker was doing during every second The output of the real-time monitor was then averaged by task to determine an approximate breathing concentration of the worker during each task The results are shown in Table 7 The results show that no one task was the sole contributor to the solvent concentrations for the worker It appears that the task of stripping is controlled better than any of the other tasks because the concentration was the lowest However, it was still not below the 25 ppm PEL Some drawbacks to this analysis are that 1) another worker was using other solvents in the same room that could have contributed to the concentrations, and 2) overall averages do not show the task that was being done during very high peaks About one hour of the real-time data was overlaid onto a corresponding video cassette of the employee working The video cassette and the data were matched by time The result was a video cassette that could be used for training purposes to show an employee certain tasks that may contribute to high exposures

Table 7 Real-time Breathing Zone Concentration and Time by Task from the Fourth Survey

Run No	Strip Tank		Rinse Area		Transport*		Other†	
	Conc (ppm)	Time (min)	Conc (ppm)	Time (min)	Conc (ppm)	Time (min)	Conc (ppm)	Time (min)
2	44 9	24	74 4	30	52 7	2	47 8	10
3	30 9	41	13 7	12	23 4	1	24 3	4
4	18 6	20	34 2	20	49 0	1	39 8	19
Avg	31 9	85, 46%	49 3	62, 34%	46 1	4, 4%	40 2	33, 18%

* Transport is time spent moving a piece of furniture from one location to anther
† Other usually includes answering the phone and helping customers, but also includes any time that the camera could not capture the worker's location

Fifth Sampling Survey

The results from the fifth sampling survey are shown in Table 8

Table 8 Time Weighted Average Results from Fifth Sampling Survey, June 21, 22, 1999

Sample Location	Number of Samples*	Sampling Time (min) in Parentheses	Methylene Chloride TWA Concentrations (ppm) ORBO 91 Media
Breathing Zone	8	456	8 85
Area - Strip	7†	417	4 72
Area - Rinse	8	462	8 46
Area- Dry	8	468	6 08

* The concentration of two samples for the breathing zone were non-detectable, runs 5 and 10 were removed from analyses

† A sample was lost before analyses

Bulk samples of the stripping solution and the rinsing solution were collected before each run of the survey and after the final run Results showed that the average percent weight of methylene chloride in the stripping tank was 50 2% (n=10, one sample was broken) and the range was 45 to 52% For the rinsing tank the average percent weight of methylene chloride was 0 03% (n=11) The height of the solution in the dip tank started at 24 inches at the beginning of the first day and finished at the end of the second day at 22-½ inches For a 8 by 3½ foot tank, there was a use of approximately 26 gallons of stripping solution during two days The amount of furniture stripped during the two-day survey is shown in Table 9 along with the time the worker spent on each task The task analysis is a little different than survey four because transport time has been moved into the category called Other

The stripping tank average exhaust volume was found to be 2720 cfm The average slot velocity of the two stripping tank slots was 2570 fpm The face velocity of the rinse booth was 121 fpm with an opening of 34 inches by 75 inches for a total exhaust volume of 2140 cfm

Table 9 Task Time for Fifth Survey

Run	Strip Time (min)	Rinse Time (min)	Other Time* (min)	Furniture or Task Completed
1	21	23	14	3 Drawers, Night Table, 2 Shelves, 2 Chairs, 1 Board
2	17	24	16	2 Boards, 1 Chair, 1 Large Desk
3	15	11	34	1 Large Desk, 3 Long Boards
4	9	16	26	3 Drawers, 3 Boards, loaded oxalic acid
5	20	27	17	4 Chairs, 1 Rocking Chair, 1 Shelf (Overnight Soak)
6	24	24	8	1 Large Dresser, 3 Drawers
7	19	19	21	5 Drawers, 1 Large Desk
8	21	27	12	1 Large Desk, 2 Mirrors
9	26	9	23	2 Bed Posts
10	29	15	19	2 Bed Posts
	201 (34%)	195 (33%)	190 (32%)	

* Other time consisted of the worker transporting furniture to the stripping area, washing the floor, answering the phone, and all other areas of his job (excluding stripping and rinsing)

Data Analysis
The data from the five surveys were combined into one data set Analyses of this data determined that it was lognormally distributed, the natural log of the concentration was used for all analyses The following data was excluded from the analyses as explained below

1 Three 100 to 200-minute breathing zone charcoal samples from the fourth survey were removed because they were collected concurrently with the one-hour breathing zone samples
2 Run five (breathing zone and area samples) from survey four was removed because the charcoal breathing zone result was twice the concentration of the ORBO breathing zone result or the breathing zone results for other runs
3 Runs 5 and 10 (breathing zone and area samples) from survey five were removed because the results showed that the breathing zone concentrations were non-detectable It does seem plausible that these results were correct, however, these samples were much lower than the other runs, causing them to appear to be outliers The conservative approach was to remove them

4 Passive samples from survey four were not used in the full model They were only used for the specific analysis to compare the passive samples to the charcoal and ORBO samples
5 Only breathing zone, rinsing, and stripping samples were used

Survey 1 used only charcoal samples, and survey 5 used only ORBO samples The three other surveys used both The comparison involving surveys 1 and 2 was done with charcoal results The comparison involving surveys 4 and 5 was done with ORBO results Other comparisons used the average of both sample types There were some differences between the media by survey, probably a difference by loading An alternative analysis was carried out, ignoring such differences, and the period comparisons had similar results

Of the five surveys, there was a difference in the methylene chloride concentrations among the surveys (F=44 15, df=4 and 5 81, p=0 0002). Each consecutive survey was compared to the preceding survey to determine if methylene chloride concentrations between the consecutive surveys had been reduced Percent reductions for the consecutive surveys in which exposures were reduced are shown in Table 10 The consecutive surveys that showed a statistically significant reduction from surveys 2 to 3 and surveys 4 to 5 Survey 3 showed an estimated reduction of 78 % (95% CI 20, 94) from survey 2 (p=0 0038) Since survey 2 is entirely with doors closed, and survey 3 with doors open, except for one run, this is an estimate of the reduction due to opening the doors If that run were eliminated from survey 3, the estimated reduction would be 82% Survey 5 compared to survey 4 showed an estimated reduction of 78 % (95% CI 44, 91) (p=0 0001)

Table 10 Reduction of Survey Relative to Preceding Survey - Breathing Zone Data, Estimates and Simultaneous 95% Confidence Limits (chance that any interval does not contain true value is no more than 5%)

Survey Pair	Geometric Mean for Each Survey Pair (ppm)	Percent Reduction Estimate	Simultaneous 95% Confidence Limits	
			Lower	Upper
1 vs 2	63 vs 334	†	†	-110
2 vs 3	334 vs 73	77 8‡	20	94
3 vs 4	73 vs 39	46 4	-108	86
4 vs 5	39 vs 8	78 0‡	44	91

† For 1 versus 2, only upper limit shown since there was no reduction
‡ These consecutive surveys showed a statistically significant reduction

There was an interaction between survey number and sample location, e g , breathing zone, stripping area, rinsing area (F=14 79, df= 7 and 7 5, p=0 0007) For each survey the sample locations were compared (Figure 13) The stripping and rinsing area samples were not statistically different from each other except in survey five (p=0 0018) corresponding to an estimated percent reduction from the rinsing area to the stripping area of 44% The geometric means for each sampling location by survey are shown in Table 11 and figure 14

Table 11 Geometric Means for All Surveys

Survey Number and Sample Location	Number of samples	Methylene Chloride Concentration (ppm) & 95% Confidence Levels		
		Geometric Mean	Lower	Upper
Survey 1, BZ†	3	63	18	215
Survey 1, Strip†	3	8	2	28
Survey 2, BZ	5	334	96	1141
Survey 2, Rinse	5	59	17	205
Survey 3, BZ	8	73	17	324
Survey 3, Strip	8	10	2	43
Survey 3, Rinse	8	23	5	101
Survey 4, BZ	12	39	16	99
Survey 4, Strip	12	10	4	25
Survey 4, Rinse	12	16	6	40
Survey 5, BZ*†	8	8	4	16
Survey 5, Strip†	7‡	4	2	9
Survey 5, Rinse†	8	8	4	16

† Survey one only used charcoal media and Survey 5 only used ORBO media Other survey use both methods

* After a conversion from ORBO media to equivalent charcoal units, the estimated geometric mean for breathing zone for survey 5 is 9 ppm with an upper individual 95% confidence limit of 13 ppm The corresponding values for the arithmetic mean are an estimate of 10 ppm and an upper confidence limit of 15 ppm

‡ In survey 5, run 4 had no stripping sample

Media Comparison

During surveys 2, 3, and 4, charcoal and ORBO sampling media were used A comparison of these media was made Table 12 gives the geometric means for the two sampling methods

Table 12 T-Test Comparison of Charcoal and ORBO Sampling Media

Location	Number of Samples	Methylene Chloride Concentration Geometric Mean (ppm)		Average Difference ORBO minus Charcoal (ppm)	P Value
		ORBO	Charcoal		
All	48	19 9	22 8	-1 15	0 0001
BZ only	13	69 8	81 4	-1 17	0 0240
Area only	35	12.5	14 2	-1 14	0 0001

For all samples, the two methods were statistically different, however, the two values were highly correlated (R^2=0 98) The ratio of charcoal to ORBO was found to be 1 15 1, charcoal samples were 15% higher than ORBO samples

Because there was a difference between the two sampling methods and because the lower of the two methods (ORBO) was used for the fifth survey, a conversion of ORBO samples to charcoal samples was created The stripping area samples from surveys 3 and 4 were used because they were of similar magnitude to the breathing zone samples of survey 5 The geometric mean of ORBO breathing zone samples in survey 5 was 8 ppm, that of stripping samples in surveys three and four was about 9 2 ppm Figure 15 shows a linear equation to predict the charcoal values given the ORBO values This equation was used to convert breathing zone (ORBO) samples in the fifth survey to their equivalent charcoal values Had the 15% inflation factor presented above been used instead of the linear equation graphed in Figure 15, the results would have been similar The converted mean and upper confidence limit for the breathing zone samples for the fifth survey as shown in the footnote of table 11

For survey 4, the passive samples were compared to both the charcoal and ORBO samples No statistically significant difference was found when comparing the passive samples to the charcoal samples (t-test, df = 23, p = 0 4758) or to the ORBO samples (t-test, df =23, p=0 1488)

DISCUSSION

First Survey

The first survey showed that the exposures of the employee performing the furniture stripping were above the new OSHA PEL of 25 ppm The geometric mean for the breathing zone samples was 63 ppm The task analysis showed that more than half of the worker's time was spent away from the ventilated stripping tank (either rinsing or transporting the furniture). Therefore, there was a need to add local ventilation to the rinsing area to further reduce this employee's exposure. The results from the area samples located at the stripping tank and the rinsing area showed that the exposures of other employees working in the vicinity of the stripping area were below the new OSHA PEL of 25 ppm and the action level of 12.5 ppm.

Evaluation of the stripping tank ventilation system showed that it had deteriorated since the 1991 visit, exhaust volume was reduced from 2900 cfm to 1060 cfm. Although the new fan should have been large enough for the job, the deterioration of the fan, the plenums, and ductwork significantly reduced the exhaust volume.

Second Survey

The second survey gave a methylene chloride geometric mean for the breathing zone of 334 ppm. The second survey methylene chloride concentrations were five times higher than those of the first survey. The reason for the higher concentrations was most likely that the doors to the facility were closed. This facility had no mechanical system to bring air into the building. Before the winter, the owner installed two additional heaters, but the heaters only recirculated air already in the building. The heater's air intake pipes were for combustion air only. All air which was supplied to the stripping tank ventilation system was brought into the building through cracks near windows and doors. Other less significant reasons for the higher concentrations could have included the slots in the stripping tank which appeared to be more clogged and, according to the employee, the paint and varnish sludge buildup in the bottom of the stripping tank was greater than during the previous survey.

Third Survey

The third survey showed a methylene chloride geometric mean for the breathing zone of 73 ppm. Before the third survey, the stripping ventilation system was cleaned and upgraded essentially doubling the exhaust volume. Unfortunately, increasing the stripping tank exhaust volume did little to reduce the employee's overall exposures because almost 2/3 of his time was spent at the unventilated rinse table. This survey showed that although the controls at the stripping area were working very well, local exhaust ventilation was still needed at the rinsing area. The employee spent only 1/3 of his time at the upgraded stripping tank, it is believed that the largest reason for the decreased exposures compared with survey two was the opening of the facility's doors. Giving the exhaust system adequate make-up air can play a significant role in employee exposures.

Fourth Survey

The fourth survey showed a methylene chloride geometric mean for the breathing zone of 39 ppm. The results of the fourth survey were a reduction from the third survey but not enough to be statistically significant. During this survey local exhaust ventilation was added to the rinsing area. It was projected that the addition of the rinse area exhaust system would reduce breathing zone exposures to below the OSHA PEL. The rinsing area exhaust system performed as projected but was not able to reduce exposures to below the new standard. Eighty percent of the employee's time was spent at the ventilated stripping tank or the ventilated rinsing booth. The reason that the exposures did not meet the standard could have been the following 1) the total exhaust volume at the stripping tank was not as high as the 1991 ventilation system (2900 cfm versus 1980 cfm), 2) no paraffin wax had been added to the stripping solution, 3) the level of the stripping solution caused the worker to lean into the stripping tank, and 4) there were many times when the employee was not protected by the local exhaust system (for instance, very large pieces of furniture would cover almost the entire opening of the rinse booth)

Fifth Survey

The fifth survey showed a methylene chloride geometric mean for the breathing zone of 8 ppm Because only ORBO samples were collected and found to result in a lower concentrations, the survey five concentrations were adjusted The breathing zone concentrations when adjusted for sampling media were found to be 9 ppm with an individual 95% upper confidence interval (one sided) of 13 ppm Therefore, these data were statistically less than the OSHA PEL of 25 ppm The OSHA action level is 12 5 ppm Although the upper confidence interval was above the action level, the TWA methylene chloride exposure for this employee during the two day survey was 8 9 ppm Hence, for this facility the employee's TWA concentration was below the action level for purposes of the OSHA standard As was pointed out above, the upper confidence limit on the geometric mean exceeds 12 5 ppm Another indicator for comparison to the Action Level value would be an upper 95% confidence limit for a future value from the same distribution of breathing zone samples actually obtained in survey 5 This limit, which for compliance purposes is based only on analytical and sampling variability as estimated from the data, is also about 13 ppm Thus, there is some chance greater than 5% that another sample of the employee's exposure from the same distribution as survey 5 would exceed 12.5 ppm

Employees at this facility mixed the stripping solution themselves rather than buying commercial stripping solution The percentage of methylene chloride that this facility used in their stripping solution was at best 52, commercial strippers normally contain 75 to 80 percent methylene chloride This difference may have contributed to the low methylene chloride exposures

There were four reasons that may have contributed to reducing exposures to below the OSHA standard 1) paraffin wax was added to the stripping solution, 2) the level of the stripping solution in the dip tank was higher, 3) changes were made to the ventilation system, and 4) the employee was trained to think about work habits Because all of these changes were made between the fourth and fifth survey, it is not possible to determine which change was most significant in reducing the employee's exposure All of these changes are important and are considered to be necessary in meeting the OSHA standard

It is believed that paraffin wax should always be added to the stripping solution The paraffin wax acts as a barrier to reduce evaporation of methylene chloride The addition of paraffin wax not only reduces employee exposures but also reduces loss of solvent through evaporation Methylene chloride has a solvent drying time relation of 1 0 (ACGIH, 1995), a vapor pressure of 349 mm Hg (at 68°F), and a boiling point of 104°F (NIOSH, 1994) The evaporation rate for this chemical is very fast and any kind of barrier which can slow evaporation would be helpful in reducing methylene chloride exposures. Most commercial strippers already have paraffin wax

The level of stripping solution in the stripping tank was not measured during any of the first four surveys However, there were numerous photos of the worker during the first four surveys which showed that the low level of stripping solution in the tank caused the worker to bend into the tank Bending into the tank caused the worker's head and therefore his breathing zone to be below the level of the slots for local exhaust ventilation Also, the worker partially covered the slots when leaning over the tank Hence, the methylene chloride-laden air was traveling past the worker's breathing zone before being exhausted through the local ventilation system Figures 16 and 17 show the worker stripping furniture with a low level and a high level of solution in the stripping tank

The engineering changes that were made to the ventilation system improved the exhaust volume of the stripping tank from 1980 cfm during survey four to 2720 cfm during survey five This increase helped to reduce the employee's exposures while working at the stripping tank The rinsing area was exhausting 2140 cfm as compared to surveys 1, 2, and 3, where there was no local exhaust system in the rinsing area

The final change between the fourth and fifth survey that may have been a factor at reducing the employees exposure was employee training The worker mentioned that the practice of removing the backs from the large pieces of furniture is now common practice compared to the fourth and previous surveys The training may have encouraged the employee to keep his face out of the stripping tank as much as possible If the employee did change his work habits, the change did not appear to reduce the amount of furniture stripped It appears to be similar to the amount stripped during the first survey

Media Comparison

During the second, third, and fourth surveys both the charcoal sampling media and the ORBO sampling media were used side-by-side Sampling results using the charcoal media were found to be approximately 15 percent greater than when using the ORBO media for the three surveys Since during the fifth and final survey only the ORBO media was used, a conservative approach was used to estimate the charcoal media breathing zone exposures The passive samples were not found to be significantly different from the charcoal or ORBO samples Although this was a very small study, it is an important finding because furniture stripping owners are most likely to use the passive sampling method

Cost of the System

The cost of the original stripping tank local exhaust ventilation that was installed at this facility was given by Hall et al (1995) The authors determined that the stripping tank ventilation cost approximately $3500 including the fan and fabrication of the system The authors also estimated that heating replacement air would cost about $650 per year Subsequently, the following changes were made to the stripping ventilation

1 Piano hinges were added to the plenums to make the slots easier to clean
2 Openings with covers were made in the plenum for cleaning
3 The rain cap was changed
4 The T-duct was changed to a 90 degree turn.

5 Ductwork was upgraded to 16 inch diameter

6 A gradual transition piece from the plenum to the ductwork was added

Taking these changes into account, a new estimate of the cost of building a new stripping tank ventilation system is $4540 as shown in Table 13

The costs for building the rinse booth were approximately $4340 as shown in Table 13 These are the costs accrued in the spring of 1998 It is believed that a sheet metal contractor can purchase materials and perform the installation for less than the costs shown here. Technicians who perform this kind of work daily can probably build and install the fan and other components in a much shorter time

Table 13 Cost* for Building and Installing the Stripping Tank and the Rinse Booth

Item	Stripping Tank Cost	Rinse Booth Cost	Make-up Unit Cost
Material			$4640
Fan	$980	$560	
Curtain		$170	
Sheet metal and fasteners	$720	$470	
Gradual Transition Piece (labor included)	$345		
Hazardous location lights		$340	
Labor @ $50 / hour			
Building fan components	2 hours	8 hours	
Building hood	16 hours	16 hours	
Installation	32 hours	32 hours	$2200*
Total	$4545	$4340	$6840

* This is the typical cost of installation This facility would need to spend an additional $5177 to have their natural gas line upgraded

An additional cost associated with these ventilation systems is the cost of providing and heating make-up air It is believed that this facility will need a system to provide and heat make-up air during the colder months when the doors to the facility cannot be opened. The ventilation systems will not work correctly if no air is brought in from the outside One make-up air system that met the needs of this facility cost $4640 The make-up air system (Cambridge Engineering, Model C390-LTR, Chesterfield, MO) was designed for outdoor vertical mounting and has the following specifications 400,000 Btus, 2 HP supply motor, 115 v, single phase, natural gas, and 4000 cfm This cost does not include installation Typical installation cost for this unit is about $2200 (Morgan, 1999) However, at this facility the existing natural gas line that serves the building is 3/4" in diameter which is barely enough to support the three existing furnaces The outside gas line would have to be replaced with a 2" line Furthermore, only one line is permitted by the gas company per building, so the inside gas lines would need to be reworked to continue to feed the three furnaces This gas line upgrade would cost the facility an additional $5,177 (Morgan, 1999) Most furniture stripping shops, especially those located in industrial parks, will not have to upgrade their gas lines This facility is located in a building originally designed as a storage facility Once installed, operating cost of this unit would be about $1000 per year (see Appendix A)

Maintenance of Ventilation Systems

It is apparent that maintenance of the ventilation system will be an important consideration for furniture stripping shop operators The original ventilation system was installed in this facility in September 1991 By 1998, some extreme deterioration had occurred in the exhaust system Because there was a change to the fan and exhaust stack from the 1991 survey, it is impossible to determine the reduction in exhaust flow rate due only to deterioration of the system. However, it was easy to see that the exhaust slots were clogged with stripping solution and finishes The employee indicated that he was unable to clean inside the slots As a result, the system progressively became less efficient In addition, a large amount of debris had accumulated in the plenum The owner stated that from 1991 to about 1996 sanding of furniture had also been done in this building and that much of the debris resembled the sawdust from the sanding Also, paint chips and other dried particles from the finishes and the stripping solution had accumulated At that time, there had been no method for the employee to clean the plenum Now, the employee has access to the plenum to determine whether there is a need for cleaning and to perform the cleaning

The ventilation system installed at this facility must be maintained to enable it to continue to operate correctly Periodic maintenance should be performed as follows

1 Monthly, open and clean the slots in the stripping tank
2 Every two months, assure that the curtain of the rinse booth is held tight to the edges
3 Every six months, open the access holes on the plenum of the stripping tank and clean out any debris
4 Open the access hole in the transition piece located between the stripping tank and duct and clean out any debris every six months
5 Open the motor housing of each fan and check the belt to make sure that it is tight and not slipping If it is not tight, move the pulleys to tighten Also grease the motor bearings and fan shaft Perform these tasks every six months
6 Make sure that the blades are free from debris, wipe clean if necessary For the stripping fan, open the fan housing to look at the fan blades Perform this task yearly
7 Look at the fan for the stripping tank and make sure that it is free from rust and that connections with the inlet and exhaust ducts are still good Perform this task yearly

Besides the outlined preventive maintenance, the facility also needs to install grates over the rinse and paint booth fans and a eye wash booth

CONCLUSIONS

The data shows that the new OSHA PEL of 25 ppm can be achieved by furniture strippers using engineering controls and work practices with repeated efforts The final survey showed that not only was the worker's exposure below the PEL but that the time-weighted average was also below the action level of 12 5 ppm The variability in the data suggests this configuration will not achieve the action level with 95% confidence The important facts that led to the achievement of reducing exposures to below the PEL were the following 1) the stripping tank had local exhaust ventilation of 2700 cfm, 2) the rinsing area had local exhaust ventilation of 2100 cfm, 3) all doors to the facility were open to allow for plentiful make-up air to feed the local exhaust systems, 4) the stripping solution contained paraffin wax as a barrier against evaporation and was plentiful enough to mostly fill the stripping tank, and 5) the worker was trained in good work practices

Installation of these engineering controls are projected to cost other furniture stripping facilities approximately $15,720 This facility will also have to pay an additional $5200 to upgrade their gas line Southern parts of the US may not need to install a heated make-up air unit which would reduce cost These engineering controls would cost most facilities an additional $1000 in the natural gas costs to operate the heated make-up air unit per year

Besides installation of the engineering controls, furniture stripping shop owners must also perform preventive maintenance on the ventilation systems to keep them running properly Because stripping solution has a tendency to stick to the ventilation systems, it is important that the ventilation systems are cleaned and that the fans are checked

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APPENDIX A

Operating cost of the make-up air unit were determined using the following equations and values Only the cost of the natural gas fuel costs were included

$$Heat\,Load\;(Btu/hr)\;=\;60Q\rho C_p\Delta T$$

$$Yearly\,Fuel\,Consumption\,(Btu)\;=\;\frac{dg\cdot q_s\quad 24\cdot use}{\Delta T\cdot System\,Efficiency}$$

Yearly Fuel Cost ($/yr) = Yearly Fuel Consumption   cost/unit

Where
q_s - heatload = 302,400 Btu/hr
Q - Air Flow Required = 4000 cfm
ρ - air density = 0 081 lb_m/ft^3 at 32 °F
C_p - Specific Heat of Air = 0 24 Btu/lb °F
ΔT - Design Temperature Difference = 70°F
dg - degree days = 6127 °F days (for Chicago)
use - 45 hours/week - 0 268
system efficiency = 0 92 (from manufacturer)
cost/unit = $0 588/100,000 Btu or $0 588/CCF

Therefore, heat load (q_s) equals 326,189 Btu/hr, yearly fuel consumption equals 199,607,732 Btu, and yearly fuel cost equals $1,174/year

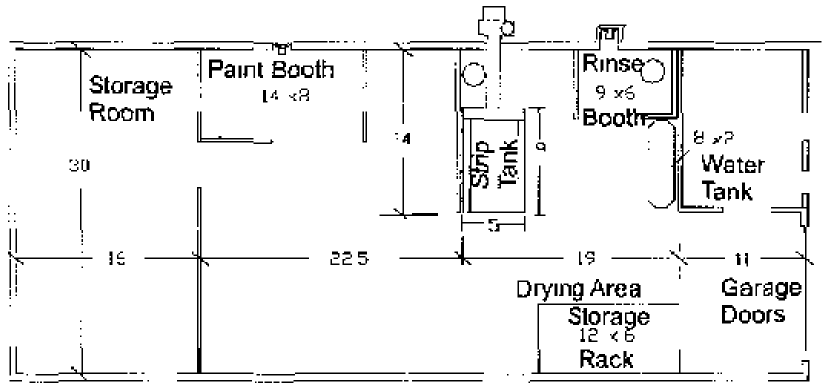

Figure 1 Layout of Tri-County Furniture Stripping facility Furniture stripping took place at the strip tank and rinse booth

Figure 2 Hinges for Slots to Open for Cleaning on stripping tank

Figure 3 10-inch diameter access hole on each plenum for access
Note the paint chips and sawdust inside the plenum prior to survey 3

Figure 4 The old stack head which was previous to survey 3

Figure 5 Exhaust stack head for rain protection added before survey 3

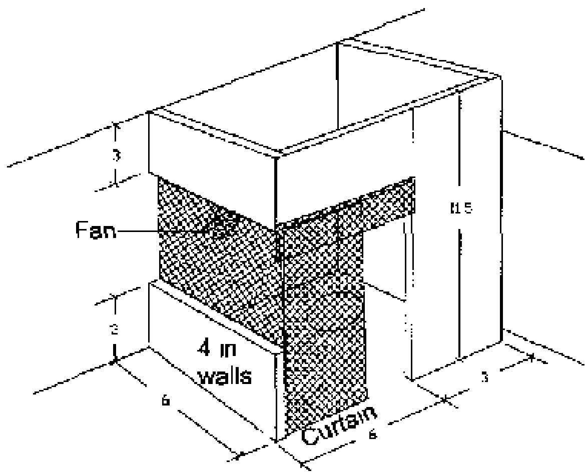

Figure 6 Diagram of the rinse booth installed before survey 4

Figure 7 Square 60 degree transition piece connecting the stripping tank plenums to the duct, installed prior to survey 5

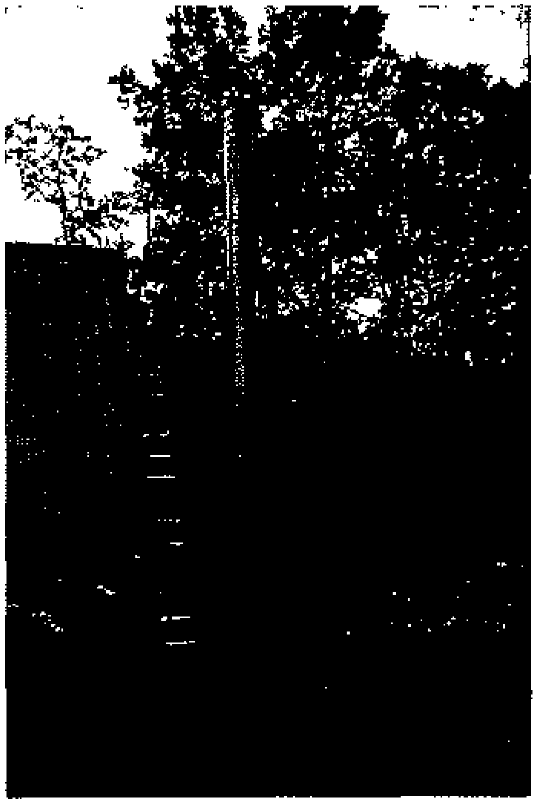

Figure 8 All elbows were eliminated because the new fan was oriented differently prior to survey 5

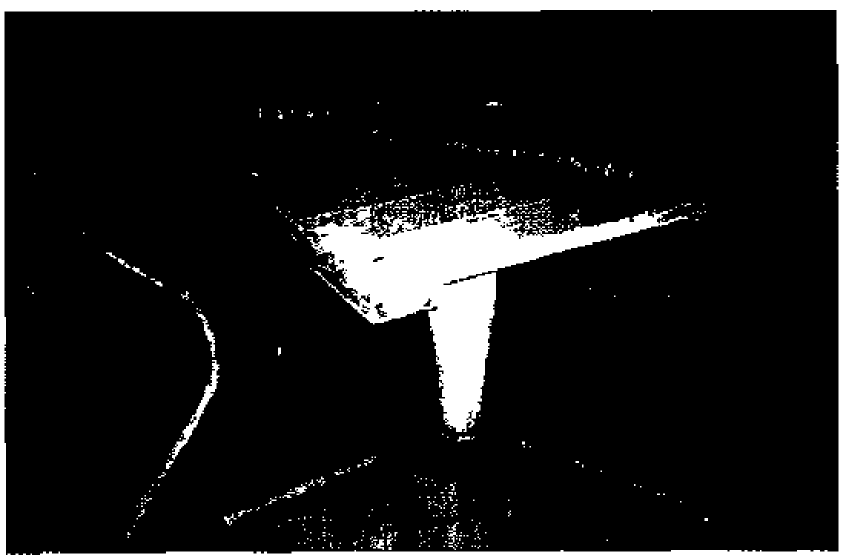

Figure 9 table (36 in square by 2½ feet high) that swivels was added inside the rinsing area prior to survey 5

Figure 10 Rear slot shown is visibly clogged with used stripping solution, prior to survey 3

Figure 11 the lower portion of the T had a hole, prior to survey 3

Figure 12 Picture of rinse booth installed prior to survey 4

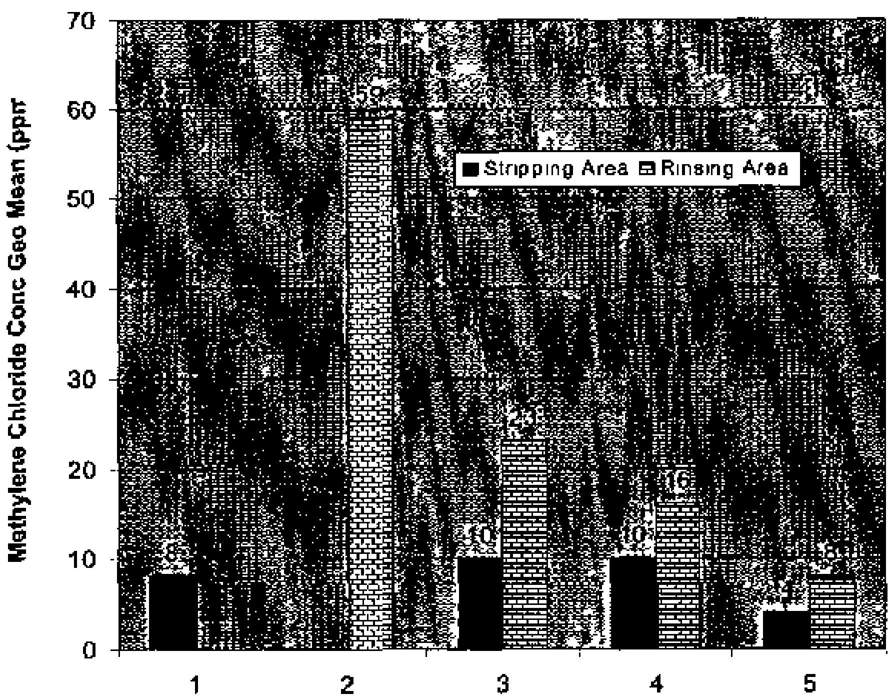

Figure 13 Geometric Mean of the Stripping and Rinsing Area Samples for Each Survey Only survey five showed a statistically significant difference between the stripping and rinsing area Note Not enough rinsing samples were taken during survey one to compute a mean, and no stripping samples were taken during survey two

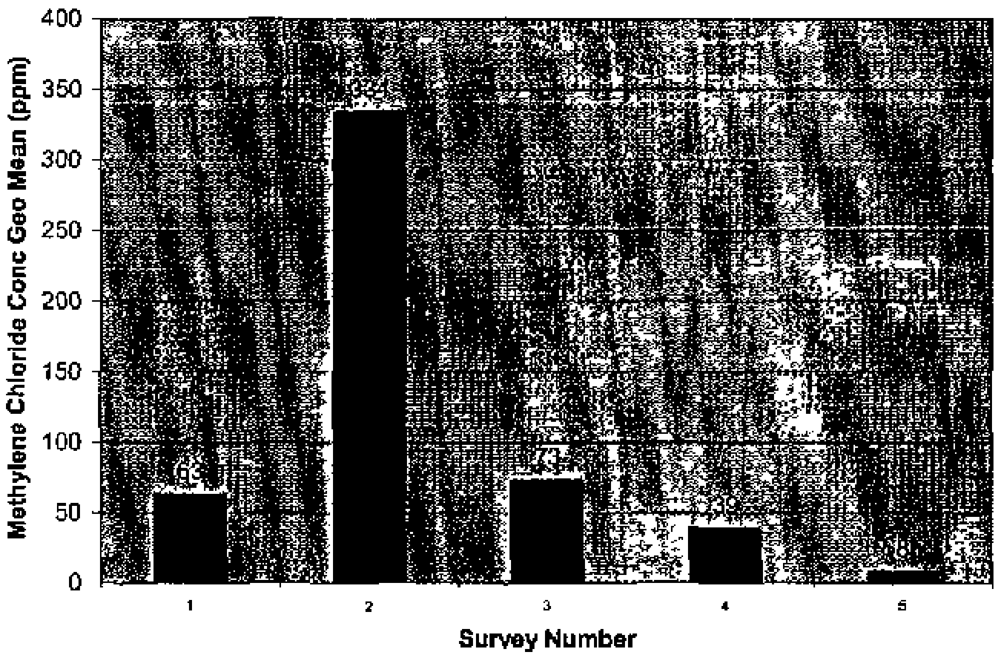

Figure 14 Geometric Mean of the Breathing Zone Samples for Each Survey

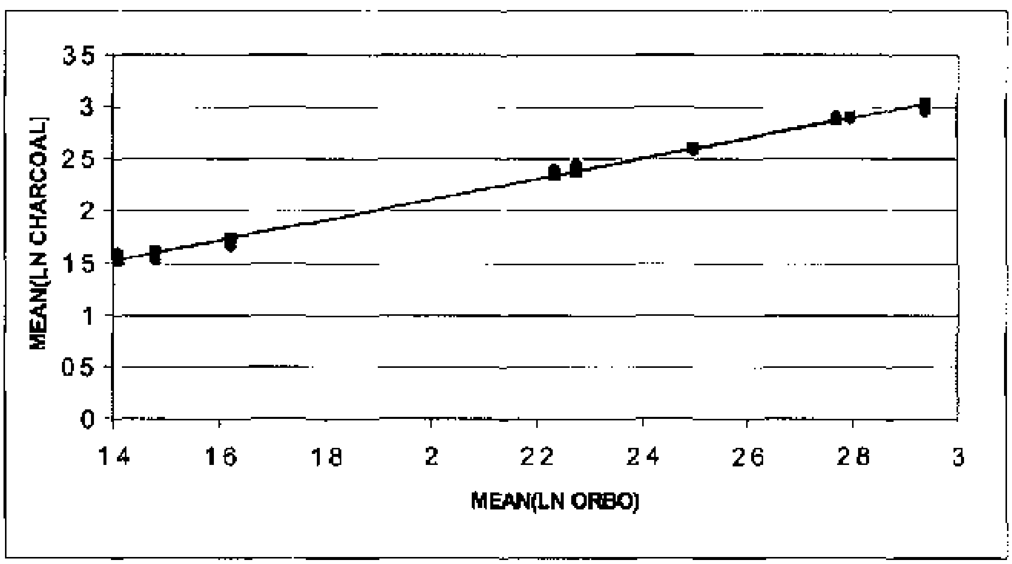

Figure 15 Mean Ln(charcoal) versus Mean Ln(ORBO) for Stripping in Survey 3 & 4 Fitted Equation LN(charcoal)=0 135 + 0 989, R^2=0 987
Note Run 5 in Survey 4 and Run 1 in Survey 3 excluded

Figure 16 shows the employee stripping furniture with a low level of solution in the stripping tank

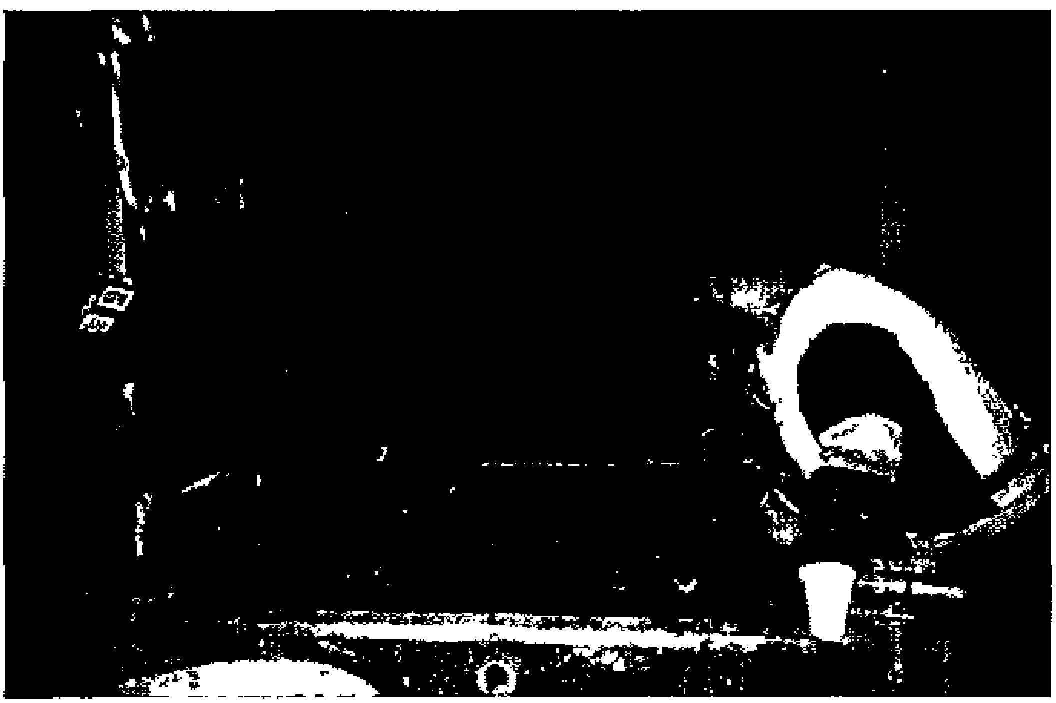

Figure 17 shows the employee stripping furniture with a high level of solution in the stripping tank