WALK-THROUGH SURVEY REPORT:

CONTROL OF METHYLENE CHLORIDE IN FURNITURE STRIPPING

AT

Ronald Alsip Furniture Refinishing
Cincinnati, Ohio

REPORT WRITTEN BY:
Paul A. Jensen
William F. Todd
Thomas J. Fischbach

REPORT DATE:
June 1990

REPORT NO.:
ECTB 170-12a

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health
Division of Physical Sciences and Engineering
Engineering Control Technology Branch
4676 Columbia Parkway, R-5
Cincinnati, Ohio 45226

PLANT SURVEYED:	Ronald Alsip Furniture Refinishing 3700 Burch Avenue Cincinnati, Ohio 45208
SIC CODE:	7641
SURVEY DATE:	August 23, 1988
SURVEY CONDUCTED BY:	Paul A. Jensen, P.E. William F. Todd, P.E. Eugene M. White
EMPLOYER REPRESENTATIVES CONTACTED:	Ronald Alsip, Owner
EMPLOYEE REPRESENTATIVES CONTACTED:	None (nonunion)
ANALYTICAL WORK PERFORMED BY:	DataChem, Salt Lake City, Utah

Disclaimer

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health.

I. INTRODUCTION

Under the authority of the Occupational Safety and Health Act of 1970 (Public Law 91-596), the National Institute for Occupational Safety and Health (NIOSH), located in the Department of Health and Human Services (formerly DHEW), conducts research to prevent occupational safety and health problems. 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) in the Department of Labor. 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 has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, ECTB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of these completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; biotechnology processes; and the recirculation of exhaust air. 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 for 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 professional who are responsible for preventing occupational illness and injury.

This particular research effort (the subject of this walk-through survey) was prompted by the growing concern of the hazards of methylene chloride (dichloromethane) and the need for technical advice to furniture strippers. For years, methylene chloride and methanol have been the primary constituents in paint stripping solutions. Methylene chloride provides the furniture stripper with an effective and efficient paint remover. This project will evaluate the technology available for the control of hazardous substances in furniture stripping applications, particularly methylene chloride vapors.

Ronald Alsip Furniture Refinishing was chosen as a site to conduct a walk-through survey because of the existing ventilation system on its Flow-Over system and because Mr. Alsip uses methylene chloride-based paint stripper. This report contains results of the walk-through survey, conclusions, and recommendations relevant to the operations at Ronald Alsip Furniture Refinishing. The recommendations, if followed, will help lower the worker's exposure to methylene chloride vapors.

II. PLANT AND PROCESS DESCRIPTION

PLANT DESCRIPTION

Ronald Alsip Furniture Refinishing was founded in 1970 by Ronald Alsip and moved to its current location approximately six months ago. Mr. Alsip is the sole employee, and normally strips furniture one day a week or less.

Presently, the furniture stripping end of the business occupies approximately 230 square feet of a building owned and operated by a lumber company. See Figure 1 for diagram of the painting and work area, the stripping area, and the wood shop.

PROCESS DESCRIPTION

Many strippers purchase pre-formulated solutions that are merely transferred to their process equipment by pouring or pumping. Some strippers bulk purchase the raw materials and mix stripping solutions both for their own use and for consumer and franchise sales.

Paint is stripped by dipping the object in an open tank containing the stripper, by spraying or brushing recycled stripper on the surface of the furniture in a large open tank (Flow-Over® system), by a combination of these two methods, or by manual application of the stripper to the furniture.

There is little standardization in the industry due to the diversity in size, construction, and finish of items to be stripped and the type of stripping solution.

In this facility, varnish and lacquer finishes are normally stripped using Kwick Kleen® Paint Remover 125 (Kwick Kleen, Vincennes, IN) in a Flow-Over system. On occasion, pieces will be hand stripped in order to prevent damage to veneers and glued laminates. Large pieces are sent elsewhere for stripping. Paint Remover 125 contains approximately 70% methylene chloride, 25% methanol, 1% sodium hydroxide, and 4% unspecified materials (see Appendix A which contains a copy of the Material Safety Data Sheet provided by the manufacturer).

POTENTIAL HAZARDS

Potential chemical hazards 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, the evaporation of solution, or the evaporation of solution off furniture after stripping. The major routes of entry of methylene chloride and other solvents into one's body include inhalation of vapors into the lungs and absorption of the liquid through the skin. The severity of the hazard depends on the formulation of the stripping solution, type of operation (i.e., dip tank, flow-over system, hand stripping), work practices, duration of exposure, temperature, ventilation (i.e., type of system, location relative to worker, air patterns, and flow rates), and general work station design.

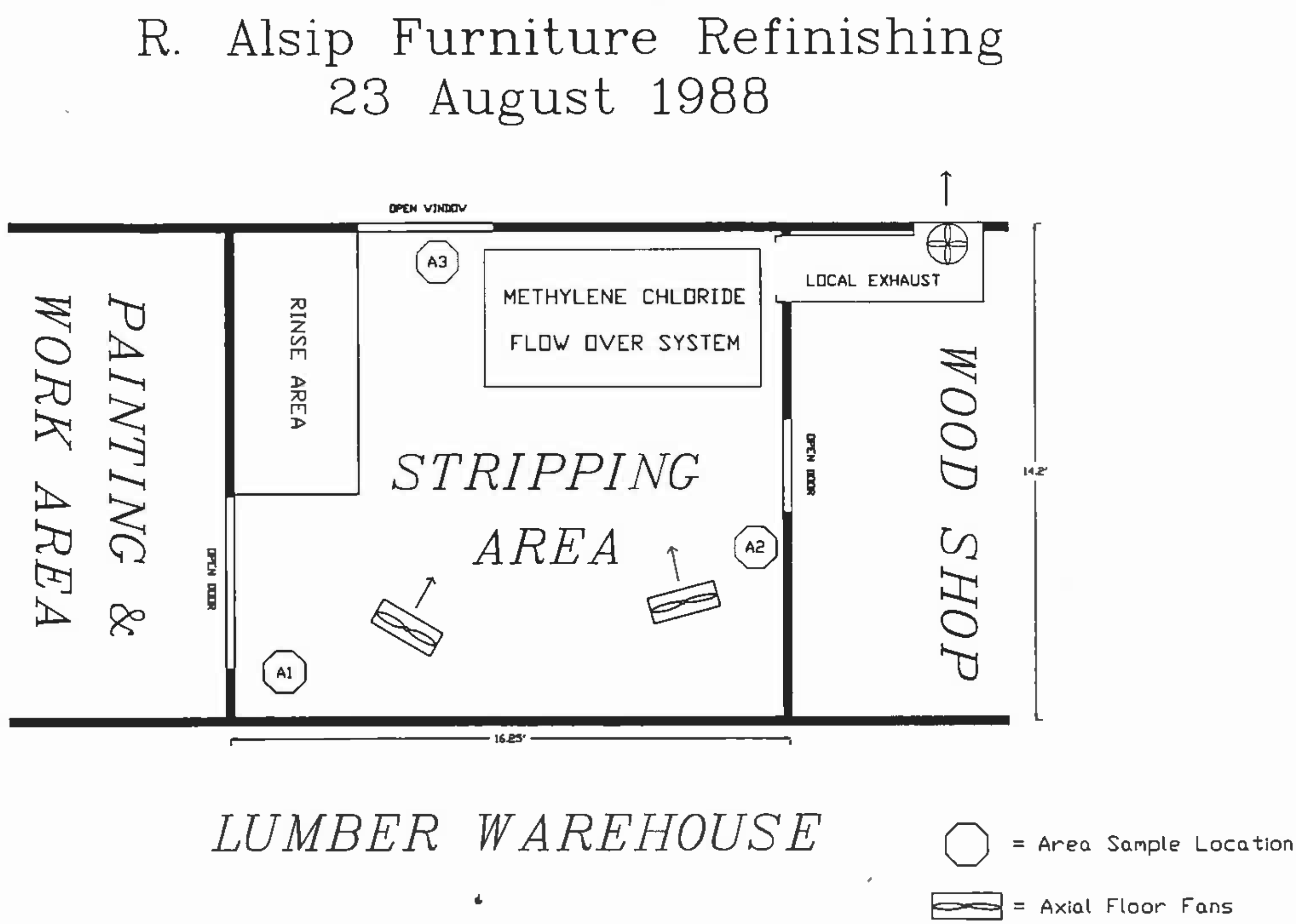

Figure 1. Shop Floor Plan

Health effects studies of methylene chloride exposure have been focused on three primary areas: effects on the central nervous system, effects on cardiovascular morbidity and mortality, and induction of cancer in exposed workers.[1] Most recently, research has shown methylene chloride as a possible reproductive toxicant.[2] In addition, solvents are known to affect liver function, and 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 25-350 ppm.[1]

Methanol has very similar central nervous system effects to methylene chloride. Breathing very high concentrations may produce headache, weakness, drowsiness, light-headedness, nausea, vomiting, drunkenness, and irritation of the eyes, blurred vision, blindness, and even death. Methanol may also cause liver and kidney damage.[1]

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, a preexisting medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the evaluation criteria. 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 thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

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. The OSHA PELs also may be 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 the prevention of occupational disease. 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 only those levels specified by the OSHA PELs.

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

The current OSHA PEL for methylene chloride (29 CFR 1910.1000 Table Z-2) is an 8-hour TWA concentration of 500 parts per million (ppm), with a ceiling concentration of 1,000 ppm, and a maximum peak concentration of 2,000 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.[3] In 1986, OSHA published an Advanced Notice of Proposed Rulemaking and did not include methylene chloride in their recent PEL update. OSHA is expected to publish the Notice of Proposed Rulemaking to reduce the PEL in 1990.[4]

In 1976, the NIOSH REL for methylene chloride was 75 ppm, as a TWA for up to 10 hours per day, 40 hours per week, with a 500 ppm peak exposure as determined over any 15-minute sampling period during the workday. This REL was based on the need to prevent significant reduction in the oxygen carrying capacity of the blood which affects the central nervous system.[5] Then 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 new recommendation was based on the observation of cancers and tumors in both rats and mice exposed to methylene chloride in air.[6]

The 8-hour TWA TLV established by the ACGIH is 50 ppm with no STEL, and is classified as a Suspected Human Carcinogen. This TLV is based on liver toxicity studies. The previous TLV of 100 ppm was 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 to 0.7% for nonsmokers and 4 to 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."[7]

The current OSHA PEL for methanol (29 CFR 1910.1000 Table Z-1-A) is an 8-hour TWA concentration of 200 ppm, with a STEL of 250 ppm. 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 8-hour TWA-TLV established by ACGIH is 200 ppm, with a 500 ppm STEL.[7]

The current OSHA PEL for acetone (29 CFR 1910.1000 Table Z-1-A) is an 8-hour TWA concentration of 750 ppm with a STEL of 1,000 ppm. The NIOSH REL for acetone is 250 ppm, as a TWA for up to 10 hours per day, 40 hours per week. The 8-hour TWA-TLV established by ACGIH is 750 ppm, with a 1,000 ppm STEL.

The current OSHA PEL for toluene (29 CFR 1910.1000 Table Z-1-A) is an 8-hour TWA concentration of 100 ppm with a STEL of 150 ppm. 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 8-hour TWA-TLV established by ACGIH is 100 ppm, with a 150 ppm STEL.

The current OSHA PEL for xylene (29 CFR 1910.1000 Table Z-1-A) is an 8-hour TWA concentration of 100 ppm with a STEL of 150 ppm. The NIOSH REL for xylene 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 8-hour TWA-TLV established by ACGIH is 100 ppm, with a 150 ppm STEL.

III. CONTROLS

PRINCIPLES OF CONTROL

Occupational exposure can be controlled by the application of a number of well-known principles, including engineering measures, work practices, personal protection, and monitoring. These principles may be applied at or near the hazard source, to the general workplace environment, or at the point of occupational exposure to individuals. Controls applied at the source of the hazard, including engineering measures (material substitution, process or equipment modification, isolation or automation, local ventilation) and work practices are generally the preferred and most effective means of control both in terms of occupational and environmental concerns. Controls which may be applied to hazards that have escaped into the workplace environment include dilution ventilation, dust suppression, and housekeeping. Control measures may also be applied near individual workers, including the use of remote control rooms, isolation booths, supplied-air cabs, work practices, and personal protective equipment.

In general, a system comprised of the above control measures is required to provide worker protection under normal operating conditions as well as under conditions of process upset, failure, and/or maintenance. Process and workplace monitoring devices, personal exposure monitoring, and medical monitoring are important mechanisms for providing feedback concerning effectiveness of the controls in use. Ongoing monitoring and maintenance of controls to insure proper use and operating conditions, and the education and commitment of both workers and management to occupational health are also important ingredients of a complete, effective, and durable control system. These principles of control apply to all situations, but their optimum application varies from case to case. The application of these principles are discussed below.

ENGINEERING CONTROLS

Mr. Alsip was told by his supplier of stripping solution that methylene chloride vapors are heavier than air. The supplier recommended that Mr. Alsip install a 24 inch diameter wall fan (exhausting to the outside) on the floor under the flow-over system. This quasi-local exhaust ventilation system had a flow rate of approximately 860 cubic feet per minute as determined by an ALNOR® Balometer® (ALNOR Instrument Company, Niles, IL). Two propeller fans were used to direct room air towards the exhaust vent. The window in the stripping room was open as well as the door from the wood shop to the outdoors. No other fresh air was supplied to the stripping area. This open window, and to some extent the effect of the wall fan comprised the general ventilation at this facility.

The benefit of locating an exhaust air inlet below and behind the flow-over system will be realized only if the air velocity induced across the liquid surface is significantly higher than ambient room air currents. This becomes a difficult problem when comfort fans produce high air velocities and unpredictable eddy currents and the open window produces unpredictable air velocity and direction.

The use of propeller-type floor fans aids in mixing the vapors with room air but the exhaust of contaminants from the room was not consistent or well designed. In addition, the flow-over system's exhaust may be overwhelmed by the propeller-type floor fans.

WORK PRACTICES

In principle, Mr. Alsip was using good judgement in that he was standing in the draft of the two axial floor fans while at the paint stripping station. All materials are manually handled and limited personal protective equipment (described later) was normally worn by the worker.

ENVIRONMENTAL MONITORING

During our survey, limited quantitative sampling was conducted. No environmental monitoring had previously been conducted. A chair and a roll-top desk were stripped of lacquer during the one-hour sampling period. Personal air samples for methylene chloride and methanol were collected side by side in the breathing zone of the worker for the duration of the stripping. Samples for methylene chloride were collected on two 50/100 mg charcoal coconut sorbent sample tubes (SKC 226-01, SKC, Inc., Eighty-four, PA) in series, and samples for methanol were collected on two 75/150 silica gel sorbent sample tubes (SKC 226-10, SKC, Inc., Eighty-four, PA) in series. Sampling was carried out at a nominal flow rate of 0.02 liters per minute (lpm) using a personal sampling pump (P200A, E.I. DuPont deNemours & Co., Inc., Wilmington, DE). In addition, real time exposure to total ionizable compounds present in the breathing zone of the worker was measured using a TIP II® (PHOTOVAC, Inc., Thornhill, Ontario, Canada) with a 10.6 eV ultraviolet lamp. The output signal was collected on a Rustrak® Ranger data logger (Gulton Industries, Inc., E. Greenwich, RI). The data logger was later downloaded to a COMPAQ Portable III® (Compaq Computer Corp., Houston, TX) for further data analysis.

Area samples for methylene chloride, acetone, toluene, styrene and xylenes, were collected using the same method as described above for personal samples for methylene chloride. Area samples for methanol were collected using the same method described above for personal samples for methanol. Three sets of area samples were collected; one between the flow-over system and the rinse area, one at the doorway leading to the back of the building, and one at the doorway leading to the front of the building.

The furniture stripping operation was video taped. The internal clock of the video camera was synchronized with the data logger so that changes in solvent concentrations could be correlated with stripping activities. Significant activities (e.g., stripping, rinsing, and other) were identified and coded into a computer spread sheet containing elapsed time and concentration data. Statistical analysis of the solvent concentrations were modeled as a function of the change in concentration, worker activity, and type of furniture being stripped.

A TIP II was also used to verify the exhausting of hydrocarbons through the ventilation system and the window.

All sorbent tubes were sent to DataChem (Salt Lake City, UT) for analysis using the appropriate NIOSH Method:

Chemical Name	CHRIS Code	NIOSH Method No.
Methylene Chloride	DCM	1005
Methanol	MAL	2000
Acetone	ACT	1300
Toluene	TOL	1501
Xylenes	XYL	1501

The results of the sorbent tubes are as follows:

		CHEMICAL SAMPLED (ppm 1-hour TWA)				
		DCM	MAL	ACT	TOL	XYL
LOCATION SAMPLED	BZ	618	85	NA	NA	NA
	A1	ND	ND	ND	ND	ND
	A2	158	17	ND	ND	ND
	A3	409	23	ND	ND	ND

BZ = Breathing zone of the worker.
A# = Area sample, see Figure 1 for location.
NA = Parameter not collected for analysis.
ND = Parameter not detected.

The real time data are shown graphically in Figure 2. The ordinate on the left is the scale for methylene chloride concentrations and the ordinate on the right is the scale for the methanol. At no time during this sampling period did the exposure exceed the 2,000 ppm maximum acceptable peak set forth in the OSHA Regulations. The TWA exposure during this time period was 618 ppm for methylene chloride and 85 ppm for methanol. The exposure to methylene chloride exceeded the ACGIH recommended STEL of 500 ppm. Since this was the only time period that Mr. Alsip stripped furniture that day, his 8-hour TWA was approximately 86 ppm and 12 ppm, respectively. The 8-hour TWA exposures are below the OSHA PELs and ACGIH TLVs.

Statistical analyses were performed on the real time data to see how well the data fit a material balance model and to generate hypotheses for investigation in future analyses. Figure 3 shows the model in graphical form.

The factors that were statistically significant, thus effecting exposure, included the following:

a. the item being processed (chair, desk, roll-top, or nothing); and
b. the task being performed (stripping, rinsing, or other tasks).

Generally speaking, the exposure while stripping was greater than while rinsing or performing any other task. In addition, the exposure while stripping the chair was higher than while stripping the desk or roll-top.

PERSONAL PROTECTIVE EQUIPMENT

While using the flow-over system, we observed Mr. Alsip wearing an apron, neoprene gloves, splash goggles, and a disposable dust filter. Mr. Alsip had several pairs of gloves, and he would use a different pair each week. The apron and goggles were used every time he stripped furniture.

OTHER OBSERVATIONS

This workplace was maintained in a neat condition. The workplace was divided into three areas, the furniture stripping area, the painting and work area, and the wood shop area. Paint stripping was performed only on pieces of furniture that Mr. Alsip was going to refinish and could easily handle. This limited the amount of paint stripping performed.

Paint sludge is collected in a 5 gallon bucket. Saw dust is added and the owner pays for the pickup and disposal of the sludge.

Several 5 gallon plastic buckets with lids were used to store the stripping solution in the stripping area.

IV. CONCLUSION AND RECOMMENDATIONS

In general, furniture strippers are exposed to high levels of methylene chloride. Worker exposure to methylene chloride and methanol during stripping was 618 ppm and 85 ppm, respectively. Since this was the only stripping for this day, the 8-hour TWA for methylene chloride and methanol was approximately 86 ppm and 12 ppm, respectively, which are below the OHSA PELs and ACGIH TLVs.

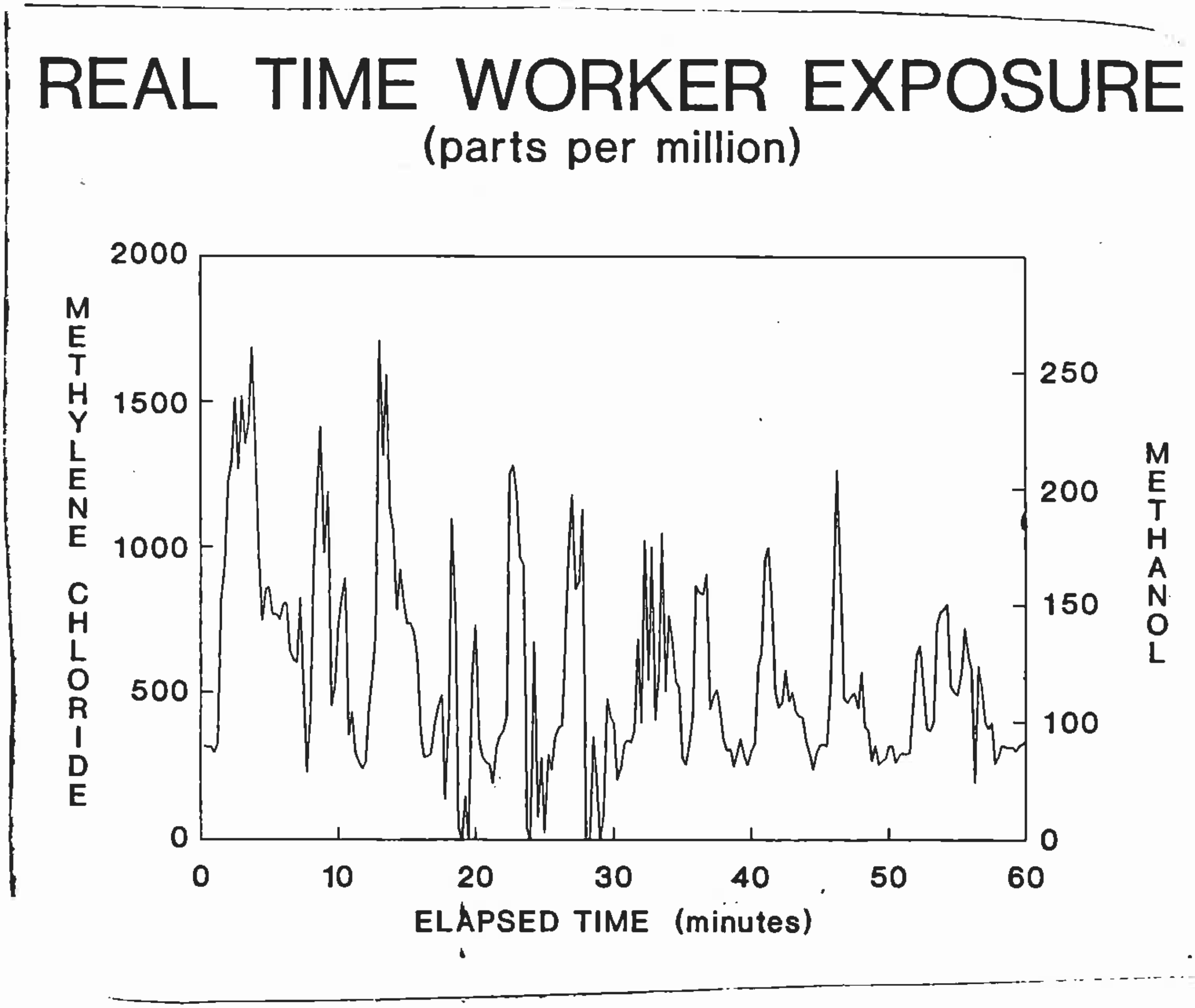

Figure 2. Real Time Worker Exposure

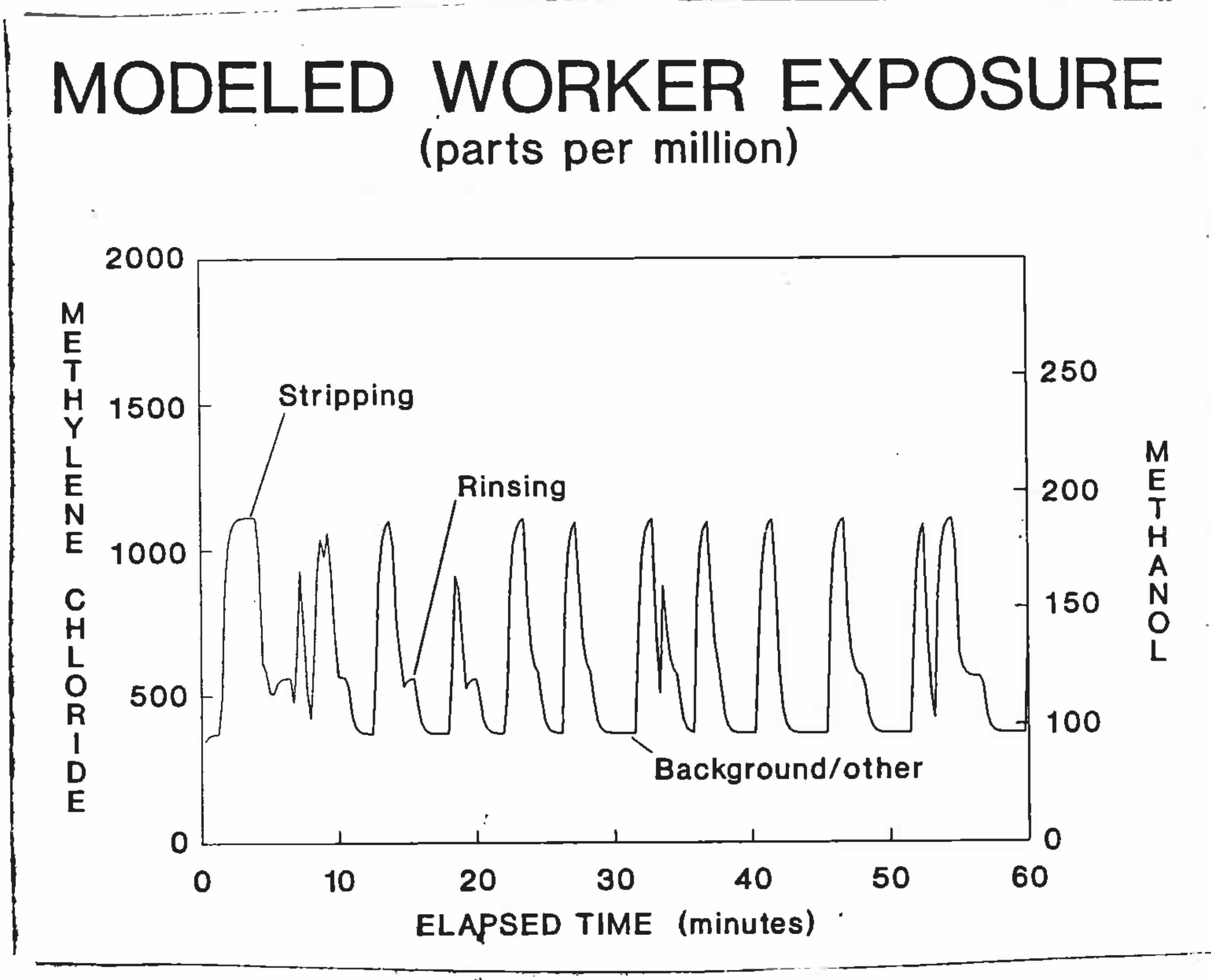

Figure 3. Modeled Worker Exposure

The exposure to methylene chloride exceeded the ACGIH recommended STEL of 500 ppm. Also, NIOSH recommended that methylene chloride be controlled to the lowest feasible level based on methylene chloride's classification as a potential occupational carcinogen. Considerable improvements in the controls, with an accompanying reduction in exposure, are possible, and the lowest feasible level would therefore be considerably lower than that seen in this study.

In operations where splashing, spilling, spraying or skin and eye contact with methylene chloride may occur, employees should wear protective solvent-impermeable gloves (long enough to cover the forearms), aprons, shoe coverings, and chemical splash goggles. Neoprene (currently used), butyl rubber, nitrile rubber or polyvinyl chloride (PVC) provide limited protection against methylene chloride and should be used with caution for short-term contact with this solvent. No material has been found which provides long-term protection from methylene chloride and is durable enough for the furniture stripping environment. Whenever swelling or softening of the gloves or seepage of methylene chloride into the glove is observed, dispose of the gloves immediately and replace with new ones.[8]

A study conducted by NIOSH researchers demonstrated that full shift use of chemical cartridges 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.[9] Because the odor threshold of methylene chloride is near the PEL, the worker will not smell methylene chloride until significant breakthrough has already occurred. Though not generally recommended, respirators with organic vapor cartridges may be used for short-term exposure to low levels of methylene chloride provided the cartridges are changed prior to breakthrough (every 15-30 minutes, depending on room concentrations). Because NIOSH has identified methylene chloride as a potential human carcinogen in the workplace, two types of respirators are recommended: 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 and 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.[8]

Mr. Alsip may wish to consider substitute stripping products. Research is currently being conducted to develop non-methylene chloride based strippers, which include N-Methyl-2-Pyrrolidone (NMP) blends and DiBasic Esters (DBE) blends. The active ingredient in NMP-based paint removers is 1-methyl-2-pyrrolidinone. Research conducted by GAF indicates that NMP has low potential for skin irritation, and NMP is a severe eye irritant, but permanent damage is not expected. The mutagenicity potential of NMP, as measured using the AMES test, was negative. Several other animal studies were performed, and they all showed no significant toxicological effects.[10] DiBasic esters such as dimethyl adipate, dimethyl glutarate, and dimethyl succinate are the active components of DBE based paint remover. Research conducted by DuPont and 3M indicates that DBEs caused moderate and temporary eye irritation, exhibited no reproductive or developmental toxicity, and caused no organ damage other than mild nasal effects indicative of irritation in 90-day tests. In addition, DBE was negative in several highly sensitive bacterial mutation assays, including the AMES test and in a whole animal chromosome damage study.[11,12] Thus far, data indicate that these blends require two to three times more stripping time than methylene chloride and cost approximately 50 percent more. Another substitute that has been on the market for many years is a blend of flammable solvents including acetone, methanol, toluene and xylene.[13] In addition, two manufacturers of methylene chloride are developing an additive for paint stripping solutions to reduce the emissions of methylene chloride vapors.

Local exhaust ventilation at the source of methylene chloride is the best primary control of vapors short of using a non-methylene chloride product. The appropriate form of local exhaust will depend on the application method. The floor level exhaust in the flow-over system may not be performing as efficiently as expected by the owner and he would benefit from further research in evaluating its efficiency. Industrial Ventilation (VS-502) recommends the use of a slotted exhaust hood for the removal of vapors from dip tanks (see Figure 4).[14] This type of local ventilation can also be applied to the flow-over system. The slots would be located on the back side of the flow-over system and exhausted through the existing duct work. A larger fan (approximately 4,000 cfm) would need to be purchased. The figure also lists data necessary for fan sizing. The Industrial Commission of Ohio could also help in the design of a local ventilation system. General room ventilation must also be considered as a necessary secondary control method. Vapors in the building will build up if there is not adequate air movement or exchange. Figure 5 illustrates the principles of dilution ventilation.

Good work practices can significantly reduce worker exposure. Keeping the worker's head as far as possible from the stripping solution and the furniture will lower the exposure. Keep all soiled cloths, brushes or tools in a ventilated area or in an airtight container. Paint scrapings contain substantial amounts of methylene chloride and other organics and should be stored in airtight containers until properly disposed. Any clothing that becomes soaked with stripping solution should be immediately removed and the exposure area thoroughly washed. Soiled clothing should not be taken home and washed with other clothes.

An effective owner/employee education and training program can also reduce potential exposure to methylene chloride, and may be required under OSHA's hazard communication standard (29 CFR 1910.1200) for any additional employees. The program should contain the following elements:

The hazards of methylene chloride exposure and methods which can be used to prevent respiratory, skin or eye contact;

Use, care, and limitations of respirators and other personal protective equipment;

Safe handling of methylene chloride and other relevant work practices;

Effective housekeeping procedures;

DESIGN CRITERIA

Q	-	3000	4000	5000	cfm
FSP	-	0.4	0.7	1.1	in. w.g.
U_{slot}	-	1500	2000	2500	fpm
U_{duct}	-	1000	1300	1600	fpm
$U_{tank\ edge}$	-	60	80	100	fpm

Tank dimensions: 4 ft. x 8 ft.

Slot dimensions: 8 ft. x 1 in.

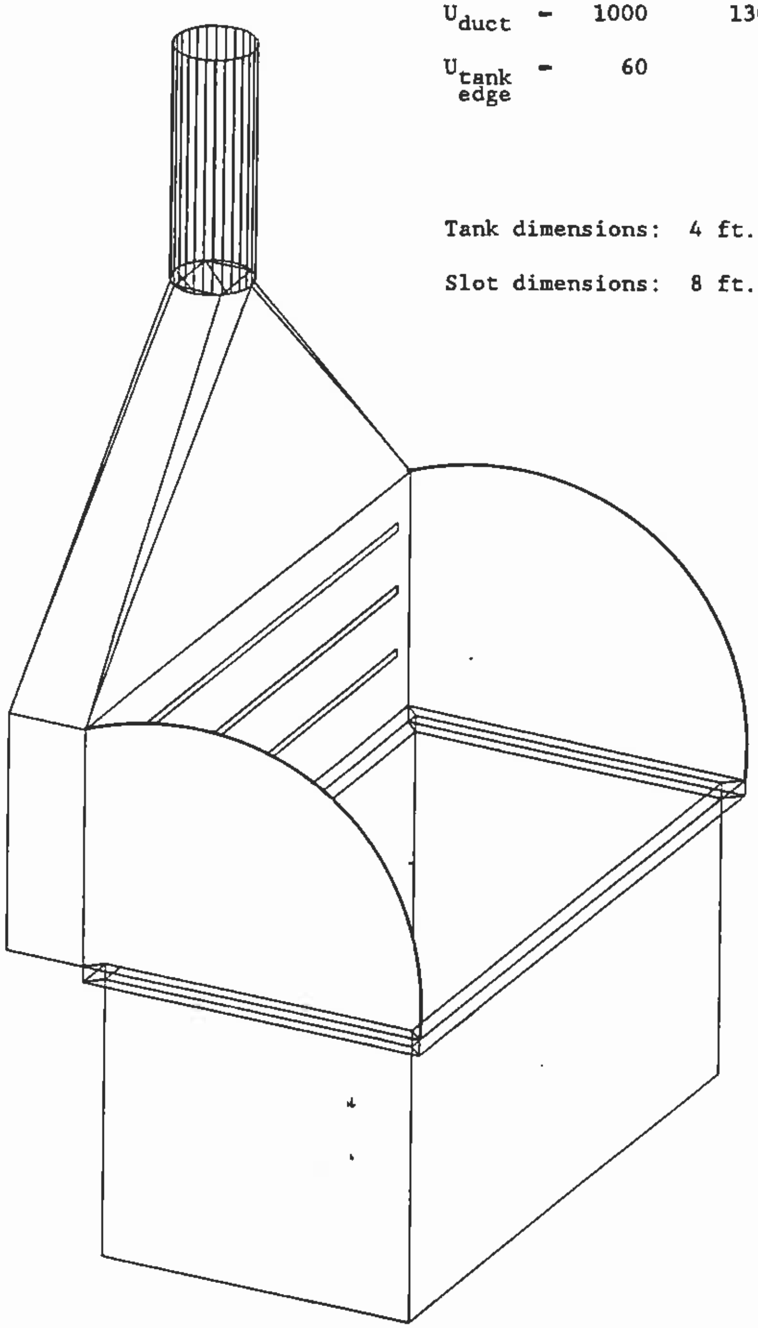

Figure 4. Recommended Ventilation System[8]

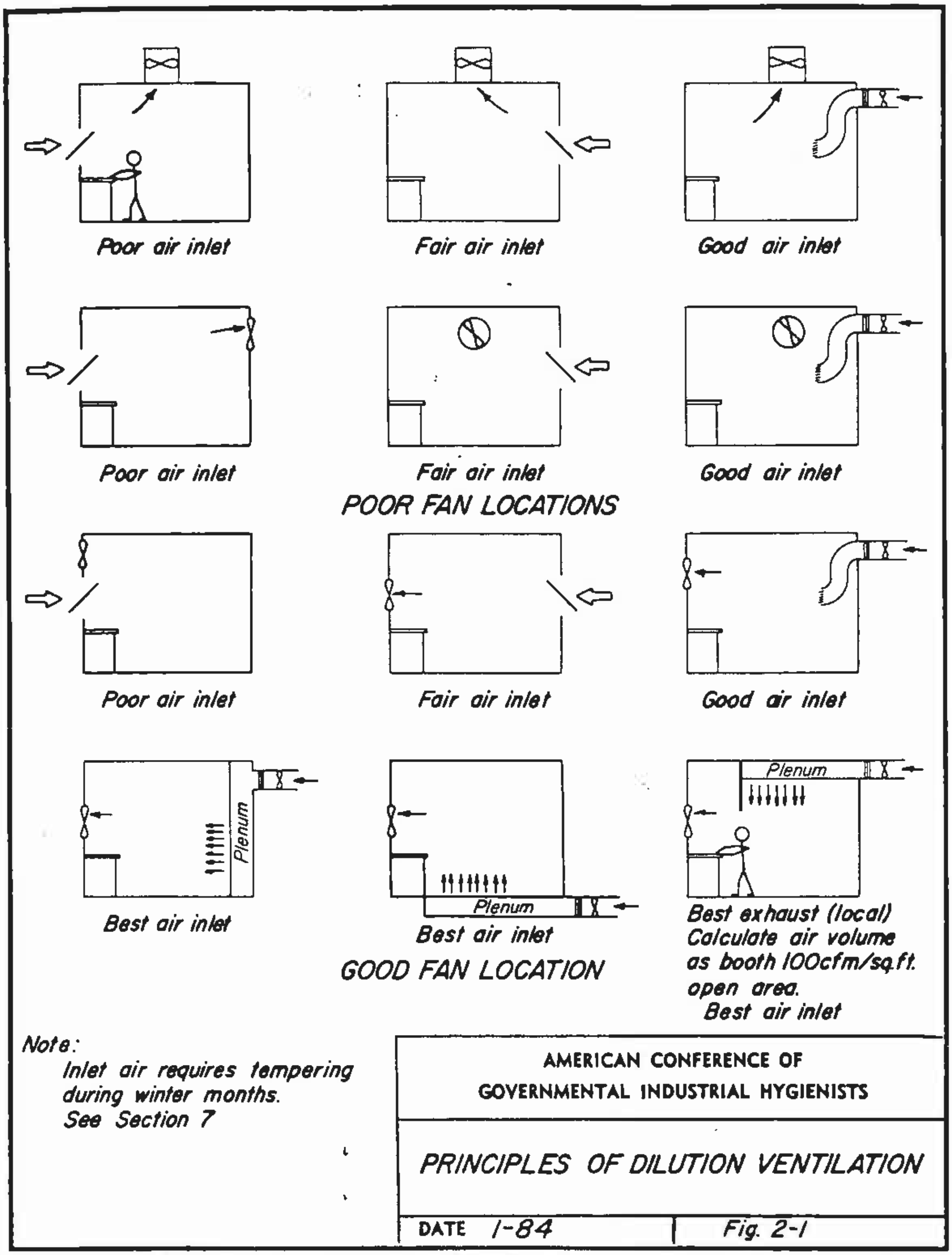

Figure 5. Dilution Ventilation[14]

From Industrial Ventilation: A Manual of Recommended Practice, 19th edition. American Conference of Governmental Industrial Hygienists - Committee on Industrial Ventilation: Edwards Brothers, Inc., Ann Arbor, Michigan, 1986. Adapted with permission of ACGIH.

First aid and emergency procedures; and

Relevant personal hygiene aspects for controlling methylene chloride exposure.[8]

Ronald Alsip Furniture Refinishing would be an excellent facility in which to conduct an in-depth study to test the proposed local ventilation system.

V. REFERENCES

1. Occupational Diseases, A Guide to Their Recognition, Revised Edition, DHEW (NIOSH) Publication No. 77-181, June 1977.

2. Kelley, Michael. Case Reports of Individuals with Oligospermia and Hydrocarbon Exposures, Primarily Methylene Chloride, Society of Occupational and Environmental Health, Washington, DC, April 28, 1986.

3. Code of Federal Regulations. U.S. Department of Labor. Occupational Safety and Health Administration. 29 CFR 1910.1000, Rev. July 1, 1986.

4. Occupational Safety and Health Administration, U.S. Department of Labor. Occupational Exposure to Methylene Chloride, Advance Notice of Proposed Rulemaking. 51 Federal Register 42257, November 24, 1986.

5. Criteria for a Recommended Standard . . . Occupational Exposure to Methylene Chloride. U.S. Department of Health, Education, and Welfare, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, 1976; DHEW (NIOSH) Publication No. 76-138.

6. Current Intelligence Bulletin 46: Methylene Chloride. U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health, Cincinnati, Ohio, 1986; DHHS (NIOSH) Publication No. 86-114.

7. Threshold Limit Values and Biological Exposure Indices for 1987-88. American Conference of Governmental Industrial Hygienists, Inc., Cincinnati, Ohio, 1987.

8. OSHA Instruction PUB 8-1.2A, "Guideline for Controlling Exposure to Methylene Chloride," U.S. Department of Labor, Occupational Safety and Health Administration, Washington, DC, 11 August 1986.

9. Bollinger, Nancy J. and Christopher C. Coffey. Report on OSHA Requested Study, National Institute for Occupational Safety and Health, Division of Safety Research, Morgantown, WV, December 1, 1987.

10. "N-methylpyrrolidone (M-Pyrol.), Summary of Toxicity Information," GAF Corporation Report No. 2302-151 5M-3/85, GAF Corporation, Wayne, NJ, 1985.

11. "DuPont DiBasic Esters: Solvents and Intermediates for Industry," DuPont Publication No. E-96958-01, E.I. DuPont de Nemours & Company (Inc.), Wilmington, DE.

12. Material Safety Data Sheet for Safest Stripper, Paint and Varnish Remover, 3M Document No. 11-1757-1, 3M General Offices, St. Paul, MN, 1988.

13. Dresser, R.C., L. Tlaiye, M. Wagner, and T. Hok. Use and Substitutes Analysis of Chlorinated Solvents in Paint Stripping, ICF Draft Report to U.S. Environmental Protection Agency, April 26, 1988.

14. Industrial Ventilation - A Manual of Recommended Practice, 19th Ed., Committee on Industrial Ventilation American Conference of Governmental Industrial Hygienists, Edwards Brothers, Inc., Ann Arbor, MI, 1986.

VI. APPENDICES

A. Material Safety Data Sheet for Kwick Kleen Paint Remover 125.

B. Statistical Analysis of the Real Time Data.

C. Estimation of Real Time Worker Exposure.

A P P E N D I X   A

MATERIAL SAFETY DATA SHEET

Manufacturer: Kwick Kleen Industrial Solvents
Address: 1202 Barnett PO Box 905
Vincennes, Indiana 47591
Emergency Telephone Number 812-882-3987

HMIS HAZARD RATING:

4=Extreme	Health.......2
3=High	Flammability.1
2=Moderate	Reactivity...1
1=Slight	Personal Protection
0=Very low	goggles,gloves apron

Section I - Product Identity

Product Name (same as on label): KWICK KLEEN PAINT REMOVER 135
Product Class: Halogenated Hydrocarbon, Alcohol blend

Section II - Hazardous Ingredients

Ingredient (CAS No.)	% Vol	Occupational Exposure Limit	Vap Pres.
Methylene Chloride (75-09-2)	70	OSHA 8 hr. TWA 500 ppm ceiling 1000 ppm 2000 ppm peak for 5 min. in avg. 2 hrs. ACGIH 8 hr TLV 100 ppm	350 mm 68° F
Methanol (67-56-1)	25	OSHA 8 hr. TWA/TLV 200 ppm	100 mm 68°
Sodium Hydroxide (1310-73-2)	1	OSHA 8 hr, TWA 2 mg/m^3 ACGIH ceiling 2 mg/m^3	not reported

Section III - Physical Data

Boiling range of solvents: 103-149°F

Vapor Density: __X__ Heavier than air ____ Lighter than air

Evaporation rate: ____ Faster than ether __X__ Slower than ether

% Volatile by weight: 96.6%

Weight per gallon: 10.17

Flash point (PMCCO): none at boiling point

Appearance and odor: light yellow and aromatic, sweet

Specific Gravity: 1.18 at 72°F

Section IV - Fire and Explosion

Flammability classification: OSHA, Nonflammable
DOT, not regulated

Extinguishing media: Dry chemical, CO_2, water fog. Do not use water stream.

Unusual fire and explosion hazards: Concentrated vapors may burn but will not ignite readily. Decomposition produces hydrogen chloride and phosgene gas.

Special fire fighting procedures: Self contained breathing apparatus should be used. Remove container from fire area if it can be done safely. If not, keep container cool with water.

Section V - Reactivity Data

Stability: __X__ stable ______ unstable
Hazardous polymerization: NO
Hazardous decomposition products: Carbon Monoxide, Hydrogen Chloride, Formic acid
Conditions to avoid: Strong oxidizing materials, heat, sparks, open flame.

Section VI - Health Hazard Data:

Effect of acute overexposure unless noted as chronic.

a. inhalation: Irritation of mucous membrane, dizziness, headache, vertigo, drowsiness, blurred vision, nausea. Severe symptoms may be delayed 12 to 18 hrs. Chronic poisoning may cause visual impairment or blindness. Elevated carboxyhemaglobin.

b. skin: Prolonged exposure my cause burning sensation, scaling and eventual defatting of skin. May be absorbed through skin.

c. ingestion: Vomiting may result. Shock and acidosis may result. Chronic exposure may cause serious damage to CNS, liver and vision.

d. eyes: Painful irritation and possible damage to eye.

Medical conditions generally aggravated by exposure: Persons with known allergies, diabetes, heart or respiratory problems should observe extra care.

Chemical listed as carcinogen:

NTP	____ yes	__X__ No
IARC monographs	____ yes	__X__ no
OSHA	____ yes	__X__ no

First aid and emergency procedures:

a. inhalation: Remove patient to fresh air and assist with respiration if necessary. Obtain medical attention. Careful attention to acidosis and possible ethanol therapy.

APPENDIX A

b. skin: Remove contaminated clothes and flush with water for 15 min. If irritation persists, get medical attention.

c. ingestion: Get medical attention. Do not induce vomiting. If spontaneous vomiting occurs, keep head below hips to avoid aspiration of liquid into lungs. May cause severe burns to mouth, throat and stomach. Physican may use 1-2% sodium bicarbonate lavage. Blood methanol levels over 50 mg/100 ml indicates hemodialysis.

d. eyes: Wash with large amounts of water for 15 minutes lifting lids occasionally for complete washing. Get medical attention. May cause tissue destruction leading to permanent eye damage.

NOTE TO PHYSICIAN: Adrenalin should not be given to persons overexposed to methylene chloride.

CHRONIC TOXICITY

Chronic overexposures to methylene chloride have caused liver and kidney disease in experimental animals.

Carcinogenicity: Methylene chloride has been evaluated for possible concern causing effects in laboratory animals. Inhalation studies at concentrations of 2,000 and 4,000 ppm increased the incidence of malignant liver and lung tumors in mice. Three inhalation studies of rats have shown increased incidence of benign mammary gland rumors in female rats at concentrations of 500 ppm and above and increases in benign mammary gland tumors in males at concentrations of 1,500 ppm and above. Rats exposed to 50 and 200 ppm via inhalation showed no increased incidence of tumors. Mice and rats exposed by ingestion at levels up to 250 mg/kg/day lifetime and hamsters exposed via inhalation to concentrations up to 3,500 ppm lifetime did not show an increased incidence of tumors.

The International Agency for Cancer Research considers liver and lung tumors in mice as limited evidence of animal carcinogenicity. The significance of benign mammary gland tumors is unknown.

Epidemiology studies of 751 humans chronically exposed to methylene chloride in the workplace for a minimum of 20 years did not demonstrate any increase in deaths caused by cancer or cardiac problems. A second study of 2,227 workers confirmed these results.

Methylene chloride has been identified as an an animal carcinogen by NTP, but is not on the IARC or OSHA lists, as of October 31, 1985.

Reproductive Toxicity: Reproductive toxicity tests have been conducted to evaluate the adverse effects methylene chloride may have on reproduction and offspring of laboratory animals. The results indicate that methylene chloride does not cause birth defects in laboratory animals.

Section VII - Special Protection

a. inhalation: None if used in ventilation that keeps vapor concentration less than 100 ppm(TWA). Use is not recommended in lesser ventilation.

b. skin: Rubber gloves, apron and boots should be worn. Wash with soap and water after use.

c. ingestion: Do not eat, drink, or smoke in the work area. Wash thoroughly before eating, or drinking.

d. eyes: Safety goggles should be worn. Contact lenses should not be worn. Eye wash should be available.

Section VIII - Spill or Leak Procedure

Steps to be taken in case material is released or spilled:
Remove all sources of ignition and provide ventilation.
Small spills-take up with absorbent material and place in a non-leaking container. Evacuate and ventilate the area.
Large spills-Evacuate the area. Wear the appropriate respiration equipment. Stop source of leak if possible. Dike and contain. Knock down vapor cloud with water bag. Clean up with vacuum truck. Flush area with water.

Waste disposal method:
Recovered material should be sent to licensed reclaimer or incinerated.

Section IX - Special Precautions

Precautions to be taken in handling and storage: Avoid contact with skin and eyes. Avoid breathing vapors. Wash with soap and water before eating, drinking or smoking. Launder contaminated clothes before reuse.

Other precautions: Keep out of reach of children. Do not transfer contents to bottles or other unlabeled containers for storage. All warranties void if repackaged. Close container after each use. Store in cool, dry place. Do not store in direct sun light. Keep container cool. Open container slowly to allow venting. DO NOT USE NEAR HEAT, FLAME OR SPARKS. VAPORS MAY IGNITE OR EXPLODE. Fumes are heavier than air and will collect near the floor. Air movement can cause fumes to travel among rooms and fall to lower levels. Use in area equipped according to local building codes and/or as outlined in the Kwick Kleen Operations Manual. For on site use: TURN OFF all gas appliances, stoves, water heaters, furnaces, and pilot lights. VENTILATE area until all odor of fumes are gone before turning on electric and gas service. DO NOT smoke while in use. Vapors may produce toxic gas when in contact with hot surfaces. Destroy rags, newspapers or drop cloths after use to prevent spontaneous combustion.

Date of Preparation: October 30, 1985
Date of most recent update: August 1, 1987
Notice: Kwick Kleen Industrial Solvents, Inc. believes that the information contained on this Material Safety Data Sheet is accurate. The suggested procedures are based on experience and best material at the date of publication. They are not necessarily all-inclusive nor fully adequate in every circumstance. Also, the suggestions should not be confused with nor followed in violation of applicable laws, regulations, rules, or insurance requirements. NO WARRANTY, EXPRESSED OR IMPLIED, OF MERCHANTABILITY, FITNESS OR OTHERWISE IS MADE.

APPENDIX B

STATISTICAL ANALYSIS OF THE REAL TIME DATA

Using the SAS General Linear Model Procedure, a model based on a material balance of contaminants in the air, was developed. This theoretical model, as generalized, fit with a multiple R squared of 0.938.

Generalized model: $C(t) = B1*A(T_i) + B2*B*C(t-1) + \epsilon$

where:

C(t)	=	concentration at time t;
C(t-1)	=	concentration at time t-1 (previous time interval);
B	=	a constant determined by the theoretical material balance/dilution ventilation model;
$A(T_i)$	=	a level which depends on the task (T_i) and determined by the theoretical model;
ϵ	=	an error term; and
B1 & B2	=	constants estimated to adjust the theoretical ones.

then:

B1	=	-0.0174 with a standard error of 0.00118; and
B2	=	0.8549 with a standard error of 0.0226.

DILUTION VENTILATION MODEL

The concentration of a vapor at any time can be expressed by a differential material balance. The starting fundamental material balance, assuming no contaminant in the supply air, is:

Rate of Accumulation = Rate of Generation - Rate of Removal

$$VdC = Gdt - Q'Cdt$$

After rearranging the differential material balance and integrating from C(t-1) to C(t), the following evolved:

$$\frac{G_{T_i} - Q'C(t)}{G_{T_i} - Q'C(t-1)} = e^{-Q'\Delta t/V}$$

where:

$C(t)$	=	concentration of vapor at time t (ppm);
$C(t-1)$	=	concentration at time t-1 (previous time interval);
G_{T_i}	=	rate of generation of contaminant during task or process T_i (ppm-cfm);
Q	=	rate of ventilation (cfm);
K	=	design distribution constant, allowing for incomplete mixing;
Q'	=	Q/K = effective rate of ventilation, corrected for incomplete mixing (cfm); and
V	=	volume of room (cubic feet).
T_i	=	task (1 = stripping; 2 = rinsing; and 0 = other)

Solving the equation at the top of the page for C(t) results in the following equation:

$$C(t) = K_{1T_i} + K_2 * C(t-1)$$

where:

$$K_{1T_i} = \frac{G_{T_i} - G_{T_i} K_2}{Q'}$$

$$K_2 = e^{-Q'\Delta t/V}$$

note:

K_{1T_i} is a function of the room size, room ventilation rate, and contaminant generation rate.

K_2 is a function of only room size and room ventilation.

This form of the model has three intercepts, one for each task (K_{1T_i}), but the slope of the line showing the relationship between current concentration (C(t)) and concentration in the previous interval (C(t-1)) is the same for each task.

The least squares estimates for K_{1T_i} and K_2 are as follows using the generated data:

$\hat{K}_{11}$ = 0.1764 for stripping with a standard error of 0.0119;

$\hat{K}_{12}$ = 0.0889 for rinsing with a standard error of 0.0089;

$\hat{K}_{10}$ = 0.0588 for all other tasks with a standard error of 0.0056; and

$\hat{K}_2$ = 0.7108 for all tasks with a standard error of 0.0187.

The assumption that the slope, K_2, was the same for all tasks was tested and not rejected ($p < 0.11$).
The estimates of the generation rates (G_{T_i}) and design distribution constant (K) are obtained by inserting the estimates for K_{1T_i} and K_2 where Q = 860 cfm and V = 2,300 cubic feet. The resulting estimators of G_{T_i} and K are neither least square nor maximum likelihood and computing of standard errors was not performed.

$\hat{G}_1$ = 9,580 ppm-cfm for stripping;

$\hat{G}_2$ = 4,830 ppm-cfm for rinsing;

$\hat{G}_0$ = 3,190 ppm-cfm for all other tasks; and

$\hat{K}$ = 0.0548 for the room.

The generation rates (G_{T_i}) appear reasonable, but the room mixing factor (K) is quite small which results in a large effective ventilation rate. The normal range for K is 3-10. Obviously, the ventilation rate is greater than that of the local exhaust ventilation alone. This may be due to the large open window and the two open doors in the stripping area. Assuming an average wind velocity of 200 fpm and a open window area of approximately 24 square feet, the average flow rate through the window was 4,800 cfm or four times the exhaust rate of the local ventilation. Air movement through the open doors was calculated using a velocity traverse of the doorways, and at the time of measurement, contributed an additional 3,000 cfm to the rate of ventilation for the stripping area. This additional flow increased the room mixing factor to 0.5, which indicates that we are still underestimating the flow of air through the room.

When tasks (T_i) are considered for each item (I_j), different parallel lines intersecting the concentration axis at seven different points which define a new set of K_1's. The effects of both item and task, by or within item, were statistically significant ($p < 0.0001$).

The estimates of K_2, K, $K_{1T_iI_j}$, and $G_{T_iI_j}$ are as follows:

$\hat{K}_2 = 0.6501$ $\hat{K} = 0.0434$

$\hat{K}_{11C} = 0.3020$ $\hat{K}_{12C} = 0.1447$

$\hat{G}_{1C} = 17090$ $\hat{G}_{2C} = 8190$

$\hat{K}_{11D} = 0.1978$ $\hat{K}_{12D} = 0.1027$

$\hat{G}_{1D} = 11200$ $\hat{G}_{2D} = 5810$

$\hat{K}_{11R} = 0.1539$ $\hat{K}_{12R} = 0.1118$

$\hat{G}_{1R} = 8710$ $\hat{G}_{2R} = 6330$

$\hat{K}_{10N} = 0.0714$

$\hat{G}_{2N} = 4043$

All results are based on serially dependent data, with no correction for serial dependence. An empirical model was developed to assist the investigators in generating hypotheses for investigation in future analyses:

$$C(t) = 0.16 + 0.635 * C(t-1) + I_j(t) * T_i(t) + 0.00133 * STRIP\_TIME\ (|\ ITEM = C)$$

where:

- $C(t)$ is the estimated concentration of vapor at time t (ppm);
- $C(t-1)$ is the estimated concentration at time t-1 (previous time interval);
- $I_j(t)$ is an amount depending on the item I_j (C = chair; D = desk; R = roll top desk; and N = nothing) being processed at time t.
- $T_i(t)$ is an amount depending on the task T_i (1 = stripping; 2 = rinsing; and 0 = other) and item being processed I_j at time t; and
- STRIP_TIME (| ITEM = C) is the number of time intervals the stripping of item C has occurred continuously. This coefficient is positive, which indicates that the concentration increases as the time spent stripping item C increases.

The factors which are statistically significant are:

Concentration in the previous time interval (C(t-1)) was by far the most important ($p < 0.0001$) and there was high autocorrelation among the data;

The item (I_j) being processed alters the intercept or the general level ($p < 0.0001$);

The task (T_i) being performed for each item (I_j) also alters the intercept or general level ($p < 0.0001$); and

The amount of time spent stripping, but only for item C ($p <0.002$).

Pair-wise differences among the four items (I_j) were analyzed using the Least Square estimates of item levels when the concentration of the preceding time interval was set to its average value. Two tailed t-tests were performed for each of the 6 possible comparisons. The significance level required to reject the null hypothesis of no difference was calculated using the Bonferroni method to yield overall Type I error of 0.05 and was equal to 0.06/6 - 0.0086 or lower.

The results can be graphically presented as follows, with the items appearing in decreasing order of estimated concentration level:

I T E M

		C	D	R	0
I	C	+	M	Y	Y
T	D	M	+	N	Y
E	R	Y	N	+	Y
M	0	Y	Y	Y	+

where:

C - chair;
D - desk;
R - roll top desk;
0 - no item;
Y - differences between the items are statistically significant;
M - differences between the items are marginally statistically significant (p - 0.0175);
N - differences between the items are not statistically significant; and
\+ - not applicable.

Task differences were analyzed in the same manner as item differences. There were 21 differences, which required the level of significance to be 0.0023 (0.05/21) to achieve and overall level of 0.05.

The results can be graphically presented as follows, with the items appearing in decreasing order of estimated concentration level:

P R O C E S S

PROCESS		STRIPPING				RINSING				OTHER			
		C	D	R	O	C	D	R	O	C	D	R	O
STRIP	C	+	N	N	+	M	Y	Y	+	+	+	+	Y
STRIP	D	N	+	N	+	Y	Y	Y	+	+	+	+	Y
STRIP	R	N	N	+	+	N	M	N	+	+	+	+	Y
STRIP	O	+	+	+	+	+	+	+	+	+	+	+	+
RINSE	C	M	Y	N	+	+	N	N	+	+	+	+	Y
RINSE	D	Y	Y	M	+	N	+	N	+	+	+	+	Y
RINSE	R	Y	Y	N	+	N	N	+	+	+	+	+	N
RINSE	O	+	+	+	+	+	+	+	+	+	+	+	+
OTHER	C	+	+	+	+	+	+	+	+	+	+	+	+
OTHER	D	+	+	+	+	+	+	+	+	+	+	+	+
OTHER	R	+	+	+	+	+	+	+	+	+	+	+	+
OTHER	O	Y	Y	Y	+	Y	Y	N	+	+	+	+	+

where:

C - chair;
D - desk;
R - roll top desk;
O - no item;
Y - differences between the items are statistically significant;
M - differences between the items are marginally statistically significant ($p < 0.025$);
N - differences between the items are not statistically significant; and
\+ - not applicable.

In general, concentration was greatest for stripping and least for other.