An Assessment of Metal Maintenance Workers' Solvent Exposures

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October 1997

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This research was funded with $20,000 from the Center to Protect Workers' Rights (CPWR), as part of a research agreement with the National Institute for Occupational Safety and Health, NIOSH (grant CCU310982). The research is solely the responsibility of the authors and does not necessarily represent the official views of NIOSH. CPWR — the research and development arm of the Building and Construction Trades Department, AFL-CIO — is uniquely situated to serve workers, contractors, and the scientific community. A major CPWR activity is to improve safety and health in the U.S. construction industry.

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Acknowledgments

The authors wish to thank Metal Polishers Local 8A-28A and District Council 9 of the International Brotherhood of Painters and Allied Trades for their assistance with this study.

Abbreviations

ACGIH	American Conference of Government Industrial Hygienists
AIHA	American Industrial Hygiene Association
NIOSH	National Institute for Occupational Safety and Health
OSHA	U.S. Occupational Safety and Health Administration
ppm	Parts per million
TLV	Threshold-limit value
TWA	Time-weighted average

Contents

In 1995, the Center to Protect Workers' Rights awarded a small-study grant to Hunter College School of Health Sciences and the Mount Sinai Center for Occupational and Environmental Medicine. The grant was to be used to characterize flammable atmospheres and solvent exposures to metal maintenance workers during refinishing of metal interiors of commercial elevators and other metal surfaces. The main goal was to assess the use of substitute refinishing materials of lower flammability and toxicity. The investigation was conducted jointly with companies in the metal-polishing industry and Local 8A-28A of the International Brotherhood of Painters and Allied Trades.

Background

The Industry

Metal maintenance workers maintain decorative finishes in commercial and residential buildings in cities throughout the country. Architectural finishes on the interior and exterior of buildings, including elevator interiors, require regular cleaning and refinishing to maintain design appearances. Bronze and other metal finishes are protected with a clear lacquer coating to protect the surface from tarnish and scratches. The materials used to protect surfaces and to remove the protective coatings prior to refinishing contain volatile organic solvents with recognized fire and health hazards.

Nationally, about 1,200 metal polishers are employed at 100 companies. Many metal refinishers work for companies who also provide other cleaning and maintenance services. Most metal maintenance companies employ fewer than 50 workers and do not have the fulltime services of safety and health professionals. Work is performed during day and evening shifts and scheduled so that work activities do not interfere with a building's usual functions.

Many of the metal maintenance companies as well as the union of metal refinishers are members of a national trade organization. The trade group meets regularly to address common issues facing the industry as a whole including the environmental and occupational health impact of industry operations.

Basis for This Study

Industry concerns regarding the use of volatile materials in metal polishing have grown over the past five years for two reasons. For one, in 1992 two refinishers were killed and another was seriously injured in a St. Louis elevator car. The materials they were using produced a flammable atmosphere that was most likely ignited by heat from an electric light bulb or contact with a live electrical component. The elevator doors were closed for refinishing and the controls had been locked out to prevent the car from being summoned to other floors. The work crew was trapped inside. By the time the doors were pried open from the outside, one man was dead from carbon monoxide poisoning and another suffered second- and third degree burns and died 39 days later. A third worker survived first- and second-degree burns.

A second reason for industry concern with refinishing chemicals is environmental regulations limiting volatile organic compounds in architectural coatings. Protective coatings and solvents used in this industry have a high percentage of volatile organic compounds and the industry has been investigating products with reduced volatile-organic-compound content. In addition to regulatory concerns, the presence of volatile organic compounds in commercial buildings and the quality of indoor air increasingly are issues for owners and managers.

Description of Metal Refinishing in Elevators

Although, on the surface, refinishing operations involve simply the removal of old lacquers and the spraying on of new coatings, the work demands great skill. Metal polishers must have extensive knowledge of refinishing materials, methods of using these materials, and precise treatments for surfaces of different metals and different degrees of damage. Although the design and size of elevator cars may vary, the work tasks, equipment, and materials used to refinish most metal surfaces are standardized throughout the industry.

Workers performing metal maintenance in elevators are equipped with air-purifying respirators, gloves, eye protection, and cotton work uniforms. Other safety equipment on site includes fire extinguishers inside and outside the elevator car, lidded plunger cans for solvent dispensing, and covered waste cans.

Work procedures

During an eight-hour shift, work crews are usually assigned two elevator cars to refinish. Employees spend most of the work shift performing tasks that do not require the use of solvent materials, such as set up, scratch removal, and clean up. The work is normally performed in the following steps:

1. ***Setting up the job.*** Materials and equipment for the job are assembled at a staging area. At this point, the elevator is put out of service so that it cannot be summoned to other floors. Depending on the particular elevator, the opening and closing of doors may be controlled from inside the elevator, from directly outside the elevator, or from a remote-control station.

2. ***Masking nonmetal parts inside the elevators.*** All non-metal parts and surfaces inside the elevator are masked with shop paper and tape to protect plastic, wood, and carpeting from contact with strippers and lacquers. Cover plates on the elevator’s control panel may be removed, which then exposes electric wiring and connections.

3. ***Removing old lacquer finish with chemical stripper.*** Workers moisten cotton shop cloths with stripping solvents and rub the metal surfaces to remove the old lacquer. The shop cloths are saturated with stripper from small plunger cans, open buckets, or small-mouthed containers. As the shop rags become soiled, they are placed in a closed waste can or a plastic bag. This work proceeds in two stages. First, the interior surfaces — including wall and ceiling panels and railings — are stripped with the elevator doors open. Second, the elevator doors are closed and the inside of the doors is stripped. The doors are closed completely during this part of the process, which may last from 15 to 35 minutes depending on the size of the doors and the condition of the old lacquer. Approximately one liter of stripper is used to remove the lacquer from the inside of the doors. Once the doors are closed, the area may become a confined space that requires environmental testing and special work procedures.

4. ***Sanding and buffing metal surfaces.*** After the stripping is completed, scratches are removed by manually rubbing pumice powder mixed with oxalic acid onto the metal with abrasive pads. In some cases, an electric rotary sander may be used to remove stubborn scratches. The metal grain is restored by hand rubbing. As in the stripping operation, the elevator doors are open for work on walls, ceilings, and railing, and closed for work on the doors.
5. ***Spraying new lacquer finish.*** Once the surface preparation is completed, one worker enters

the elevator to spray on the new coat of lacquer. The lacquer is combined in equal parts with a lacquer thinner. The spray gun is attached to a small electric compressor, which may be kept inside or outside the car. As in the stripping operation, spraying is performed in two stages:

- •With the doors open for side panels, ceilings and railings
- •With the doors closed for spraying the insides of the doors.

Although the spraying takes only a few minutes, the doors remain closed for another 5 to 10 minutes after completion of spraying to allow the finish to set. About 8 ounces of material are sprayed onto the doors. Again, the conditions in the work space may change, which might require confined-space entry procedures.

6. ***Cleaning up.*** As soon as the doors are opened, cleanup begins. Masking paper and tape are removed and the elevator is put back into service. The temporary work site is dismantled, and equipment and materials are returned to the work vehicle.

Traditional materials

The volatile organic materials used by most metal-refinishing companies include a stripper, a lacquer, and a lacquer thinner. Abrasives and oxalic acid are used to remove scratches and prepare the surface for lacquer application.

The predominant stripper used in elevators is a Class 1A flammable liquid containing organic solvents with a flash point of 20° F and a lower explosive limit of 1.8% (Gloss-Flo Corporation 1984).

Inhalation is the primary route of exposure to solvents, although some of the components, notably methanol, are readily absorbed through the skin. Health effects associated with acute exposure to the stripper include central-nervous system depression and irritation to the skin, eyes, and upper respiratory system. Chronic exposure may cause peripheral neuropathy and damage to the optic nerve, liver, and kidneys (Hathaway, Proctor, and Hughes 1996).

The lacquer is a nitrocellulose material in an organic solvent with a flash point of 56^0 F and a lower explosive limit (LEL) of 1.1 %. (The flash point is the lowest temperature at which a liquid gives off enough vapor to ignite.) Prior to spraying, the lacquer is diluted with a lacquer thinner that has a flash point of 67^0 F and a lower explosive limit of 1.1 %. Both materials are classified as Class 1B flammable liquids (Agate Lacquer Manufacturing 1986).

The lacquer is a complex mixture of toluol, butanol, isopropanol, amyl acetate, butyl acetate, n-propyl acetate, glycol ether, methyl isobutyl ketone, and ethyl 3-ethoxypropionate. The lacquer thinner contains methyl isobutyl ketone, toluol, butanol, amyl acetate, butyl acetate, and n-propyl acetate.

Inhalation and skin contact are the primary routes of exposure. Health effects associated with these materials include central nervous system depression and irritation. Chronic exposure may cause permanent damage to the nervous system, liver, and kidneys (Hathaway, Proctor, and Hughes 1996).

Work environment

NIOSH defines a confined space as a space having any of the following characteristics: limited openings for entry and exit, unfavorable natural ventilation, or not designed for continuous worker occupancy. Elevator cars that have been taken out of service for refinishing may meet this definition. The cars are large enough and easy enough for workers to enter and perform refinishing tasks. When the doors are closed, however, natural air movement may be limited. Elevator doors are completely closed during stripping and spraying of their inside surfaces. In addition, when a car is deactivated and the doors are closed, workers inside may depend on people outside the car to open the doors, thus limiting the workers' ability to exit easily. And, modern cars are automated and not designed for continuous employee occupancy.

When elevator doors are closed, the cars certainly meet the NIOSH definition of a confined space (see National Institute for Occupational Safety and Health 1987). The definition of confined space used by the U.S. Occupational Safety and Health Administration (OSHA) in its 1994 confined-space standard for general industry has a definition similar to NIOSH's. This OSHA standard requires employers to implement confined-space-entry procedures.

During metal refinishing, flammable and toxic materials are introduced into the space, creating potentially hazardous atmospheres. NIOSH does not specifically define hazardous atmospheres. However, OSHA considers a toxic atmosphere to be greater than the permissible exposure limit and a flammable atmosphere to be greater than 10% of the lower explosive limit. Potential ignition sources include heat from lighting fixtures, exposed wiring, and arcing from power sanders and compressors.

OSHA and NIOSH investigated the St. Louis disaster and recommended that the metal maintenance industry adopt confined-space entry program procedures and training described in the NIOSH publications, *Working in Confined Spaces* and *A Guide to Safety in Confined Spaces.* NIOSH also recommended that employers follow precautions outlined in a publication of the American Society of Mechanical Engineers (1991).

The Preliminary Investigation

In 1994-95, representatives from the industry trade group, several of its member companies, and the union met with the Mount Sinai Center for Occupational and Environmental Medicine to discuss the development of control strategies for elevator refinishing.

Researchers at Mount Sinai performed preliminary evaluations of the nature and extent of the hazards associated with refinishing elevators. Investigators observed work procedures at five elevator refinishing jobs, monitored the elevator cars for flammable atmospheres, and evaluated worker exposures to organic solvents.

Goals

The goals of this preliminary investigation were to observe work practices of metal refinishers in elevators, assess the fire hazard, assess exposure to volatile solvents during stripping and refinishing and develop an approach to hazard control.

Findings and Conclusions

The results of the preliminary investigation formed the basis for the study design of the current investigation. The most important findings of the preliminary investigation are as follows:

Flammable atmosphere evaluation

Atmospheres in excess of 10% of the lower explosive limit were detected during stripping inside all five elevator cars while the doors were closed. The maximum reading was 28% of the lower explosive limit. On the other hand, during lacquer spraying, lower-explosive-limit measurements remained below 10%. This finding ran counter to a common notion in the industry that spraying is the more hazardous operation.

Solvent exposure evaluation

Stripping operation. The exposure assessment results indicated that workers were exposed to concentrations in excess of the 15-minute short-term exposure limit for methanol (table 1). In addition, the combined effects of exposure to methyl ethyl ketone, acetone, and ethyl acetate increase the risk of neurotoxic effects. Several samples for acetone and methanol were discarded due to solvent breakthrough in the charcoal tubes. Sample flow rates were decreased in subsequent sampling to eliminate this problem.

Table 1. Personal sampling results during stripping, preliminary investigation (Parts per million)

Solvent	n	Range (ppm)	Average (ppm)	Threshold limit value (ppm)	Short-term exposure limit (ppm)	Number of results larger than short-term exposure limit
Acetone	3	430-690	547	750	1,000	0
Methyl ethyl ketone	6	64-290	189	200	300	0
Methanol	3	400-910	607	200	250	3
Ethyl acetate	6	37-300	153	400	na	na
Diacetone alcohol	6	3-36	15	50	na	na

n = Number of samples.
na = Not applicable.
Note: The flash point is 20˚ Fahrenheit and the lower explosive limit is 1.8% (see glossary, page 16).

Spraying operation. Exposure to specific organic solvent components of the lacquer and thinner was not assessed. However, in order to get an estimate of vapor generation, sampling for total hydrocarbons was conducted in four elevators. The results averaged 114 parts per million (ppm) with a range of 43 ppm to 370 ppm. Approximately eight ounces of the lacquer and thinner mixture, containing nine volatile materials, is applied during spraying. Because of the low lower-explosive-limit readings obtained during spraying (<10%), the short time of exposure (15 minutes), the small quantity of material used, and the high costs associated with analysis of the volatile components of the lacquer, exposures to the specific solvents were not assessed. However, the authors are not confident that a more-sophisticated exposure assessment protocol that could account for both the solvent vapor and mist components would yield different results.

Control options

Based on the findings of the preliminary exposure assessment, control strategies were directed at eliminating the fire hazard and reducing exposure to methanol and other solvent vapors during stripping operations. Three control approaches were considered:

Substitution. Substitution of water-based strippers and lacquers having lower flammability for the traditional solvent-based materials was the preferred control method. The industry began to investigate the availability of water-based products that met safety and performance requirements.

Ventilation. Ventilation of the elevator car during closed door stripping operations was also considered. However, providing enough design air capacity to dilute flammable concentrations and to control the airflow into and out of the elevator car posed logistical and practical problems.

Work practices and personal protective equipment. Another possible control strategy was to combine work practices and personal protective equipment with an ongoing monitoring program.

The concentration of solvent vapors generated could potentially be reduced by adhering to strict work
practices, such as minimizing the amount of stripping solvent used, keeping stripping containers closed, placing soiled solvent rags in closed containers and stripping smaller areas of the doors at a time. Implementation of these work practices could be coupled with constant lower-explosive-limit monitoring so that work could be interrupted if 10% of the lower explosive limit was reached. This approach is cumbersome for the metal polishers doing the work and requires close supervision and specialized training.

Based on this review of possible control options, substitution of materials was considered to be the most efficacious and protective approach. In the interim, the industry developed elevator refinishing procedures involving a combination of work practices, personal protective equipment, and more-frequent door opening.

The Study

Goals

Fire and toxic hazards

The goals of the current study were to characterize and compare:

- The fire hazard associated with the use of traditional solvent-based products and water-based substitute products during stripping and spraying operations in closed elevator cars, and
- Worker exposure to solvent vapors generated during stripping with solvent-based and water-based solvents.

The preliminary investigation clearly highlighted the fire and toxic hazards associated with the stripping operation in closed elevator cars. Given the limited resources for the study, the authors decided to focus on work in closed elevator cars and not to characterize the hazards during refinishing of other metal surfaces (surfaces that are not in elevators). As mentioned above, the authors decided not to assess exposures to individual substances associated with lacquering.

Alternative materials

Industry representatives identified several water-based products with low flammability. The term "water-based" does not mean safe or hazard-free. Many water-based products contain toxic and flammable substances. Therefore, in addition to low flammability, other criteria for substitute materials were established. These materials were assessed by the investigators and industry representatives against the criteria listed below:

1. Elimination of flammability hazard
2. Elimination or significant reduction of toxicity
3. Reduction of volatile-organic-compound content
4. Compatibility of stripper with different lacquers
5. Production of the desired finish
6. Competitive costs.

Most of the alternative products identified have proprietary formulations and many contain substances that do not have exposure limits set by OSHA, NIOSH, or the American Conference of Government Industrial Hygienists (ACGIH). Confidentiality of product ingredients has been maintained for this research and specific substances are identified by chemical class when required. Descriptions of ingredients appear below. Exposure limits are provided when available.

Strippers # 1-3. These three strippers have flash points of 126^{0} F, 199^{0} F, and 212^{0} F respectively, as indicated by the manufacturer. All of the strippers contain d-limonene along with other solvent components. D-limonene is a well known alternative solvent widely used in degreasing operations and as a substitute in other petroleum-based solvent applications. The American Industrial Hygiene Association (AIHA), the only organization that has established an exposure limit, issued a workplace environmental exposure level of 30 ppm as an 8-hour time-weighted average (TWA) in 1995. (See Glossary, page 16.) The most notable health effects of d-limonene are irritation to skin and eyes. Sensitization to the skin may also occur. Inhalation can cause headache, dizziness, nausea and upper respiratory irritation. Chronic exposure may cause drying and cracking of the skin. Animal studies have shown adverse effects in the liver at high exposure levels. AIHA considered this finding in setting the workplace environmental exposure limit for d-limonene at 30 ppm. The other components in these strippers also cause eye, skin and mucous membrane irritation and may cause systemic effects when inhaled (American Industrial Hygiene Association 1993).

Strippers # 4 and 5. These two strippers are manufactured by the same company and each one has different ingredients. Both strippers have very low vapor pressures (less than 1 millimeter of mercury) and flashpoints above 200^{0} F, as indicated by the manufacturer. Both strippers contain materials that cause irritation to the skin and eyes.

Lacquers #1-3. All substitute lacquers have flashpoints above 120^{0} F and contain proprietary mixtures of organic materials. Inhalation and skin contact are primary routes of exposure. Health effects include irritation to skin, eyes, and mucous membranes and potential long-term effects to liver and kidneys.

Methods

Assessment of traditional, solvent-based strippers and lacquers

A Biosystems PHD Flammable Vapor Meter was used to measure the maximum percentage of the lower explosive limit reached during the performance of stripping and spraying tasks. The meter was calibrated with methane gas according to manufacturer's instruction. The meter was positioned inside the elevator cab during the entire time that elevator doors were closed. The manufacturer has determined that the accuracy of the meter reading of the instrument is +/- 5%.

Personal air samples were collected to assess worker exposure to specific solvent vapors during closed door stripping and to total hydrocarbons during spraying using the traditional solvent- based materials. MSA Flow Lite pumps were calibrated at approximately 50 milliliters per minute in order to minimize the possibility of breakthrough of acetone and methanol, as occurred during the preliminary study. Sampling times were determined by the time period necessary for the completion of each task (e.g., stripping, lacquering). All solvents were monitored using charcoal tubes (50/100 mesh) except for methanol for which silica gel tubes were used. Stripping and spraying tasks were monitored separately.

Two workers engaged in the removal of the old lacquer finish from the inside surfaces of the elevator doors were monitored for exposure to acetone, ethyl acetate, methyl ethyl ketone and methanol. The elevator doors remained closed during the sampling period. Diacetone alcohol was excluded from the sample collection because preliminary sampling indicated that concentrations of this substance were extremely low.

The samples were analyzed in accordance with NIOSH analytic methods P & CAM 127 for volatile organic compounds, NIOSH method 2000 for methanol, and modified OSHA M139 for solvents (National Institute for Occupational Safety and Health 1984). All samples were analyzed by a laboratory accredited by AIHA.

Assessment of substitute, water-based strippers and lacquers

Flammable atmospheres were evaluated during the application of five water-based strippers and three lacquers. Worker exposure to specific solvent vapors were evaluated during use of three new strippers and samples for total hydrocarbons were taken during spraying with three water-based lacquers. All monitoring was done in closed door conditions. Although water-based stripping and lacquer materials are characterized by low vapor pressures, samples were taken to evaluate exposure in closed-in areas. The methods used to assess worker exposure were essentially those described above for the solvent-based materials.

Exposure to the materials in the water-based products is brief, less than 20 minutes. Most of these materials do not have short-term exposure limits. However, it is important to control exposures within some reasonable limit, even if the 8-hour exposure limit is not exceeded. For substances with threshold-limit value time-weighted averages (TLV-TWAs) that do not have short-term exposure limits, the ACGIH recommends "excursion limits." This study uses the excursion-limit concept for materials that do not have short-term exposure limits, but have an 8-hour limit set by ACGIH, AIHA, or the manufacturer.
ACGIH defines excursion limits as follows:

> Excursions in worker exposure levels may exceed 3 times the TLV-TWA for no more than a total of 30 minutes during a workday, and under no circumstances should they exceed 5 times the TLV-TWA, provided that the TLV-TWA is not exceeded. (American Conference of Government Industrial Hygienists 1996)

Results

Flammable atmospheres

Solvent-based materials

Lower-explosive-limit measurement results confirm the findings of the preliminary investigation described above (see table 2). Lower-explosive-limit measurements were obtained in six closed elevator cars during stripping with solvent-based materials. Results indicate that four of the six operations resulted in concentrations above 10% of the lower explosive limit. Of those, two were above 20% of the lower explosive limit. In all cases in which 10% of the lower explosive limit was exceeded, the 10% level was reached within two to five minutes of door closure.

Table 2. Percentage of lower explosive limit during solvent-based stripping and spraying

Task	Number of measurements	Highest measurement (% of lower explosive limit)	Number of measurements below 10% of lower explosive limit	Number of measurements exceeding 10% of lower explosive limit	Number of measurements exceeding 20% of lower explosive limit
Stripping	6	47	2	4	2
Spraying	5	10	5	0	0

Atmospheres generated during spraying operations did not exceed 10% of the lower explosive limit. However one sample reached the 10% level, indicating the potential for creation of a flammable atmosphere in confined space locations.

Due to equipment difficulties, measurements were not taken in four of the stripping operations and five of the spraying operations.

Water-based materials

Lower-explosive-limit measurements were taken during stripping and spraying using water-based strippers and lacquers (tables 3 and 4). Five aqueous strippers in 17 elevator cars and 3 aqueous lacquers in 13 elevator cars were evaluated.

All measurements were less than 10% of the lower explosive limit, indicating that the use of these water-based materials inside closed elevator cars did not create flammable conditions.

Table 3. Percentage of lower explosive limit during water-based stripping

Stripper	Flash point (Fahrenheit)	Number of measurements	Highest measurement (% of lower explosive limit)
#1	212°	4	3
#2	126°	7	8
#3	199°	2	3
#4	209°		8
#5	201°	1	0

Table 4. Percentage of lower explosive limit during spraying of water-based lacquers

Lacquer	Flashpoint (Fahrenheit)	Number of measurements	Highest measurement (% of lower explosive limit)
#1	150°	8	6
#2	120°	4	2
#3	145°	1	0

Worker exposures to stripper vapors

Solvent-based stripping materials

Personal monitoring was performed during use of solvent-based stripping materials (table 5). The results indicate that the short-term exposure limits for acetone, methyl ethyl ketone, and methanol were exceeded in some instances during stripping operations. In 50 % of the methanol samples, concentrations were greater than the short-term exposure limit, with a maximum result of 10 times the short-term exposure limit. As noted above, the combined effects of exposure to methyl ethyl ketone, acetone, and ethyl acetate increase the risk of neurotoxic effects.

Sampling times ranged from 14 to 71 minutes with an average of 33 minutes. The stripping compound contains materials with relatively high vapor pressures accounting for the high concentrations generated in these relatively short work periods. Because of the brief sampling times, 8-hour time-weighted averages were not calculated.

Table 5. Personal sampling results during use of solvent-based stripper
(Parts per million)

Ingredient	Number of samples	Range (ppm)	Average (ppm)	Short-term exposure limit (ppm)	Number of results exceeding short-term exposure limit
Acetone	13	32 - 1,029	520	1,000	2
Methyl ethyl ketone	14	7 - 668	190	300	4
Methanol	10	20 - 3,116	1084	250	5
Ethyl acetate	13	11 - 528	215	na	na

na = Not applicable.

Water-based stripping materials
Personal monitoring was performed during use of three water-based strippers (tables 6-8). Because all of the materials are composed of proprietary mixtures, the results for various ingredients are identified by chemical class when required by confidentiality agreements. Sampling times for strippers #1-3 ranged from 10 to 16 minutes.

Excursion limits (5 times the exposure limit) were exceeded for several of the solvent components in each of the three strippers. Results indicate that the lowest exposures were generated during use of stripper #3. Only one excursion limit (for the ester solvent) was exceeded for that stripper.

Table 6. Personal sampling results during use of water-based stripper #1
(Parts per million)

Ingredient	Exposure limit (8-hr time-weighted average, ppm)	Number of samples	Range (ppm)	Average (ppm)	Number of results exceeding 5 times the exposure limit
d-Limonene	30[1]	10	39-199	129	4
Ester solvent	1.5[2]	10	0-15	7	4

1. AIHA workplace environmental exposure limit.
2. Manufacturer’s acceptable-exposure limit.

Table 7. Personal sampling results during use of water-based stripper #2 (Parts per million)

Ingredient	Exposure limit (8-hour time-weighted average, ppm)	Number of samples	Range (ppm)	Average (ppm)	Number of results exceeding 5 times the exposure limit
d-Limonene	30[1]	10	26-568	88	1
Ester solvent	1.5[2]	11	0-15	7	2
Ketone solvent	50[3]	11	4-134	80	0

1. AIHA workplace environmental exposure limit.
2. Manufacturer's acceptable-exposure limit.
3. TLV-TWA (American Conference of Government Industrial Hygienists 1996).

Table 8 . Personal sampling results during use of water-based stripper #3 (Parts per million)

Ingredient	Exposure limit (ppm)	Number of samples	Range (ppm)	Average (ppm)	Number of results exceeding 5 times the exposure limit
d-Limonene	30[1]	6	18-45	29	0
Ester solvent	1.5[2]	6	5-9	6	1
Cyclic amine	20[2]	6	3-6	4	0

1. AIHA workplace environmental exposure limit.
2. Manufacturer's acceptable-exposure limit.

Worker exposures to lacquers

During spraying operations, the average sampling time was 16 minutes for solvent-based spraying and 11 minutes for water-based spraying. The results indicate that the amount of total hydrocarbon vapors generated vary greatly between the solvent-based and water-based lacquers (table 9).

Table 9. Personal sampling results, total hydrocarbons as *n*-Hexane during spraying of lacquers (Parts per million)

Type of lacquer	Number of samples	Range (ppm)	Average (ppm)	Avg. sample time (minutes)
Solvent-based	8	163-1,351	402	16
Water-based	19	0-28	7	11

Discussion

The assessment of the traditional and the new products for metal refinishing in elevators has shown clear differences in worker exposure to flammable and toxic atmospheres. The assessment has shown that:

1. Flammable atmospheres are sometimes created in the confined space of an elevator when traditional, solvent-based strippers are used. Although solvent-based lacquers do not appear to create such atmospheres, one reading of 10% of the lower explosive limit suggests that such peaks might be reached.
2. Short-term exposure limits were exceeded for acetone, methyl ethyl ketone, and methanol during stripping operations using a solvent-based product.
3. Because the time that the polishers spend in the closed elevators is short — typically no longer than 30 minutes — the excessively high solvent concentrations for many of the solvents in traditional products do not exceed the 8-hour TLV-TWAs. High-peak exposures should nonetheless be controlled, consistent with good industrial hygiene practice.
4. Concentrations of flammable solvents were greatly reduced during trials with each of the five newly formulated water-based strippers. In fact, the highest reading obtained was 8% of the lower explosive limit. This is to be expected, given the very low vapor pressure of the major ingredients and the high flashpoints of these products.
5. According to manufacturers' material safety data sheets (MSDSs) and peer-reviewed articles on the toxicity of the major ingredients of the new, water-based products, the primary short-term health concern for workers is skin and mucous-membrane irritation. Any work performed with these materials must protect against such irritative effects. It must be noted that there is not an extensive knowledge base of the long-term health effects or the exposure-response relationship for the water-based products.
6. The authors did not collect enough data to draw firm conclusions about the effect of various exposure variables on exposure levels. Nonetheless based on observations of the work, the authors believe that the most important variables are the quantity of solvent used to remove the lacquer and the dilution ventilation inside the car. On some occasions, workers opened the doors during stripping, which increased ventilation in the car and markedly decreased lower-explosive-limit readings. The implementation of work practices designed to limit solvent evaporation, such as plunger-can dispensers and covered cans for soiled rags did not appear to lower lower-explosive-limit measurements during solvent-based stripping. However, such safety procedures should be in place to prevent evaporation of solvents.

The results of lower-explosive-limit measurements and exposure monitoring presented here might underestimate true exposures. Only two companies participated in the study. One performed refinishing with traditional materials, while the other worked with the water-based products. The crews selected to perform the work with the new products were very experienced and safety conscious. The presence of investigators may also have encouraged especially careful work practices and, thus, affected the results.

This study did not attempt to assess the effects of solvent-based products on the health of metal polishers. The investigation did confirm that workers in this industry are potentially exposed to short-term high-peak exposures to solvents while using traditional strippers. However, these exposures are not necessarily typical of the workers' daily exposures. On the whole, workers in the industry do not perform work tasks only in one setting, but work in a number of indoor and outdoor environments. Those who perform stripping and finishing tasks in closed elevators on one day might be working on building facades the following day. In this outdoor setting, exposures could reasonably be expected to be lower than in closed elevators.

Conclusions and Recommendations

The results of the flammable atmosphere and personal monitoring evaluations indicate that there are several water-based products available for use by the metal refinishing industry that greatly reduce the risk of fire. These products have been shown to be feasible substitutes for use on satin bronze metal and other metal surfaces. While concomitantly reducing the risk of adverse health outcomes, ingredients in these products are not without toxic effects, primarily irritation. Therefore, the safe use of these materials necessitates proper work procedures, personal protective equipment, and worker training.

Based on the results of this study, these measures are recommended:

1. Metal polishing contractors should adopt a policy of exclusive use of nonflammable water-based products in all elevators and other confined-space work areas. Some companies have already abandoned the use of flammable materials in elevator work and others should follow suit. Contractors should also consider phasing in water-based products for other operations.

2. Safe work practices and proper selection of personal protective equipment for use with water-based products should be assessed and incorporated into worker-training programs.

3. Metal polishing contractors should continue efforts to develop confined-space procedures and programs for work in closed elevators. These efforts should include the identification and classification of confined spaces, entry procedures, rescue provisions, and training.

4. Employers should ensure that all work in closed elevators is performed in the safest manner possible.

The introduction of new products represents an important step forward for the industry and workers alike. In the best tradition of toxic-use reduction, the new products will meet or exceed air pollution requirements, and considerably lower the risk to life and health of workers. In addition, the introduction of the alternate products should reassure building owners and managers who are increasingly confronted by both regulators and building occupants regarding the use of hazardous materials on their properties.

Glossary

Flash point - the lowest temperature at which a liquid gives off enough vapor to ignite, when sparked or lit; a liquid having a flash point below 100˚ F is classified as flammable.[1]

Lower explosive limit (LEL) - the lowest percentage of chemical vapors mixed in air that will burn; lower concentrations are "too lean" to burn; sometimes referred to as lower flammable limit, LFL.

Permissible exposure limit (PEL) - set by OSHA; the time-weighted-average concentrations of a substance that should not be exceeded during any 8-hour workday.

Short-term exposure limit (STEL) - the concentration of a substance that workers may be exposed to for up to 15 minutes without suffering from irritation, tissue damage, or central nervous system effects; this limit is recommended by the American Conference of Government Industrial Hygienists and should not be exceeded during the workday.

Threshold-limit value (TLV- TWA) - the maximum concentration of a substance that most workers may be repeatedly exposed to for 8 hours daily without getting sick, according to the American Conference of Government Industrial Hygienists.

Time-weighted average (TWA) - the average concentration of a substance in the air, calculated for a given period, usually 8 hours.

Workplace environmental exposure level (WEEL) - 8-hour time-weighted average workplace exposure limit of a substance, recommended by the American Industrial Hygiene Association.

[1]Definitions based on Environmental Protection Agency 1989; American Conference of Government Industrial Hygienists 1996; and Plog 1988.

References

Agate Lacquer Manufacturing Co., Inc. 1986. *Material Safety Data Sheet for Thinner #8A*. Long Island City, N.Y.

———. 1992. *Material Safety Data Sheet for #8A Lacquer.*

American Conference of Governmental Industrial Hygienists. 1996. *1996 TLVs and BEIs: Threshold Limit Values for Chemical Substances and Physical Agents; Biological Exposure Indices.* Cincinnati: ACGIH.

American Industrial Hygiene Association. 1993. *Workplace Environmental Exposure Level Guide for d-Limonene*. Fairfax, Va.: AIHA.

American Society of Mechanical Engineers. 1991. *Cleaning, Polishing and Refinishing, Refinishing of Elevators,* Appendix B.

Environmental Protection Agency. 1989. Glossary of Environmental Terms and Acronym List. Washington, D.C.: U.S. E.P.A. Office of Communications and Public Affairs. December, 19K-1002.

Filipson, A.F., A. Lof, M. Hagberg, E.W. Hjelm, and Z. Wang. 1993. d-Limonene Exposure to Humans By Inhalation: Uptake, Distribution, Elimination, and Effects on the Pulmonary Function; *Journal of Toxicology and Environmental Health,* 38:77-88.

Gloss-Flo Corporation. 1984. *Material Safety Data Sheet for Gloss-flo Stripper #6461*. Long Island City, N.Y.

Goldschmidt, G. 1993. An Analytical Approach for Reducing Workplace Health Hazards Through Substitution. *American Industrial Hygiene Association Journal,* 54(1): 36-43.

Karlberg, A. T., A. Boman, and B. Melin. 1991. Animal Experiments on the Allergenicity of d-Limonene - The Citrus Solvent. *Annals of Occupational Hygiene,* 35(4): 419-26.

Hathaway, Gloria J., Nick H. Proctor, and James P. Hughes, eds. 1996. *Chemical Hazards of the Workplace, Fourth Edition.* New York: Van Nostrand Reinhold.

Missouri Occupational Fatality Assessment and Control Evaluation. 1994. Two Metal Refinishers Die When Fumes Ignite In Elevator Car. FACE Investigation 92MO04601-92MO04602. Cincinnati, Ohio: National Institute for Occupational Safety and Health.

National Institute for Occupational Safety and Health, Department of Health and Human Services.1979. *Criteria for a Recommended Standard: Working in Confined Spaces.* Washington, D.C.: U.S. Government Printing Office, DHEW (NIOSH) publication 80-106.

———. *Manual of Analytic Methods.* 1984. Springfield, Va.: National Technical Information Service.

———. 1987. *A Guide to Safety in CONFINED SPACES.* Washington, D.C.: U.S. Government Printing Office, DHHS (NIOSH) Publication 87-113, 20 pages.

Occupational Health and Safety Administration, Department of Labor. 1994. Permit-Required Confined Spaces Standard (29 Code of Federal Regulations 1910.146)

Plog, Barbara A., ed. 1988. *Fundamentals of Industrial Hygiene, Third Edition.* Itasca, Ill.: National Safety Council.