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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

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

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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 explos

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

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

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 7. Personal sampling results during use of water-based stripw2 of water-6P2

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

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.

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