EPA/600/A-98/008

POLLUTION PREVENTION FACILITY DEMONSTRATION OF N-METHYL PYRROLIDONE AS A PAINT STRIPPING ALTERNATIVE

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INTRODUCTION

This paper describes the demonstration of n-methyl pyrrolidone (NMP) as an alternative to methylene chloride for stripping cured coatings from metal parts. It contains descriptions of both the old and new processes, a summary of the equipment retrofit, and the results of the operational evaluation conducted at the Marine Corps Logistics Base (MCLB) in Albany, GA, from November 1 to December 21, 1995. RTI coordinated this demonstration with personnel at the MCLB and the EPA Air Pollution Prevention and Control Division. The project was funded by EPA under contract 68-D4-0120.

OBJECTIVE

The MCLB carries out maintenance activities on a wide variety of equipment from small arms to tanks, trucks, and other vehicles. Much of the maintenance on the vehicles requires removing existing paint prior to the repair procedures and applying new paint once the maintenance has been performed. The processes for paint stripping, repainting, and cleaning of paint equipment release significant amounts of hazardous air pollutants (HAPs). By Executive Order 12856, the MCLB is required to reduce these air emissions by 50% by 1999 from 1992 levels. The objective of this task was to demonstrate pollution prevention technologies or processes to reduce the emissions of HAPs resulting from paint stripping via immersion in methylene chloride. This process was chosen because methylene chloride is a HAP, a suspected carcinogen, and one of 17 chemicals on the EPA 33/50 list of priority pollutants. This objective was achieved by replacing methylene chloride with NMP, a non-HAP and less volatile solvent. This process has been implemented and is in use at the Base.

PAINT STRIPPING WITH METHYLENE CHLORIDE

The first step in the paint stripping process was immersing a metal basket of coated metal parts in room temperature methylene chloride for 1-2 hours (depending on the soil loading in the tank). This was followed by three rinses with tap water: 1) an initial rinse to remove most of the methylene chloride residue, 2) a pressure wash and pressure rinse to remove any remaining paint chips, and 3) a final hand rinse. The MCLB estimated that the rinsing operations took 10-15 minutes per load. The basket was set aside to allow the parts to air dry. At least two baskets of parts were stripped per day with this process.

The methylene chloride tank had an approximate surface area of 143 ft^2 (13.3 m^2) and was capable of holding two 48 by 48 in. (122 by 122 cm) baskets side by side. The depth of methylene chloride in the tank was approximately 30 in. (76 cm). A layer of water floated on the methylene chloride, serving as a seal to reduce methylene chloride emissions due to evaporation. The water seal was approximately 2-3 in. (5.0 to 7.6 cm) thick, but was not monitored to maintain a constant thickness. Water from the first rinse was used to replenish the water seal on the methylene chloride tank; water from the second rinse was used to replenish the first rinse. Water from the third rinse contained very little methylene chloride residue and was treated on site at the facility's Industrial Wastewater Treatment Plant (IWTP).

About every 18 months, the tank was shut down and cleaned. Most of the paint chips would settle to the bottom of the tank. MCLB personnel would pump most of the methylene chloride into 55-gal. (208 L) barrels. Then the rest of the sludge would be scooped out into hazardous waste disposal containers, and the methylene chloride from the barrels would be pumped back into the tank.

This tank was shut down and drained in May 1995, because the methylene chloride failed to meet chemical specifications. When the tank was drained, severe damage to the tank walls was discovered. The MCLB decided not to repair the tank but, instead, to switch to the NMP process as soon as it was operational. In the meantime, those parts that would have been stripped in the methylene chloride were stripped with abrasive blasting. This was a labor-intensive alternative because these parts required extensive masking to prevent media from becoming trapped, and usually required multiple passes to remove paint satisfactorily. Other parts, such as the battery tie-down brackets coated with plastic coating Plastisol®, were soaked in hot alkaline solution followed by scraping and blasting, also very time consuming.

EQUIPMENT RETROFIT

The first step in preparing for the demonstration was to retrofit an existing tank at the MCLB. The tank designated by the MCLB was a large stainless steel tank, about 16 ft (4.9 m) long by 8.75 ft (2.7 m) wide by 8 ft (2.4 m) deep. It was located in a pit in the concrete floor with the top edge even with the surface of the floor and about 1 ft (0.3 m) of space between all sides of the tank and the concrete walls. The tank was divided by a steel wall into two areas, each about 8 ft long by 8.75 ft wide by 8 ft deep. Lip vent exhausts were located along the front and rear edges of the tank. It was insulated, but not heated. For successful stripping with NMP, the existing tank required plumbing to heat the bath with steam available from MCLB, and a recirculating pump to provide enough agitation to ensure uniform temperature throughout the bath. The adjacent tank required a pump to draw recycled NMP for rinsing stripped parts. Finally, a vacuum distillation unit was installed to reclaim used solvent from the stripping bath and provide recycled NMP for rinsing. After the tank retrofit was completed, the heating and recirculating systems were tested using water in the tank. The stripping tank was then emptied and filled with an initial charge of 38 55-gal. barrels of technical grade NMP. In parallel, the operators were trained on operating the new process and equipment, and maintaining the system. For the rest of the demonstration period, the operators used the NMP tank for normal stripping operations.

PAINT STRIPPING WITH NMP

The first step in the NMP chemical paint stripping process was immersing a metal basket of painted metal parts in the heated NMP for 2-3 hours. The operating temperature range of the NMP was 150 ±10°F (66 ±6°C). After the basket was raised over the stripping tank, the parts were pressure rinsed with recycled NMP. The pressure rinse removed NMP residue and paint chips, and allowed the NMP to drain into the stripping tank. The parts were blown with an air gun to remove additional NMP before the final rinse. The basket was then moved away from the stripping tank and rinsed with tap water to displace the NMP. This rinse drained to the IWTP. The MCLB estimates that the rinsing operations took 15 minutes per load. The basket was set aside to allow the parts to air dry. At least two baskets of parts were stripped per day with this new process.

DEMONSTRATION RESULTS

The first basket stripped with the new process was loaded with battery tie-down brackets and disconnects. The tie-down brackets were coated with black Plastisol®, a plastic coating that is very difficult to remove. The disconnects were coated with several layers of Chemical Agent Resistant Coatings (CARC). The basket was observed after 1 hour immersion at 140°F (60°C). The Plastisol® was peeling off the battery tie-down brackets, but was not completely removed. Also, the CARC was softening on the disconnects but was not sloughing off. The basket was left in the bath for an additional hour. While the basket was over the NMP bath, the parts were blown with an air gun to force excess NMP back into the tank. The basket was moved away from the tank, and the parts were then rinsed with water. The parts were examined: it was noted that NMP removed nearly all of the Plastisol® from the tie-down brackets and the CARC from the disconnects. Some of the remaining coating sloughed off when the parts were handled. On some parts, the coating had softened but still adhered to the parts; in these instances, the coating had been very thick. Since NMP is absorbed through multiple layers down to the base metal and then lifts the entire coating, parts with very thick coatings or multiple layers would probably need to be left in the stripping tank overnight.

Of an estimated 20 baskets consisting mostly of battery tie-down brackets, disconnects, and filter housings stripped over the course of the demonstration, MCLB reported problems with only two baskets. All the remaining baskets of parts were stripped well enough for the parts to continue through production.

In the first case, the temperature control valve on the steam line stuck, so the NMP was not hot enough to be effective. The second occurred when the steam supply valve was closed instead of the steam bypass valve. (The bypass valve allowed rapid heatup of the tank.) The steam supply, steam bypass, and temperature control valves were labeled and an alarm has been added to alert the operators if the temperature drops below 140°F, the minimum operating temperature.

During the demonstration, a white vapor sometimes appeared over the stripping tank. It would usually appear when the recirculating pump was on and disappear when the pump was turned off, even at operating temperatures. This suggests that the agitation of the pump is increasing air emissions. Research is planned that will investigate the exact cause of vapor formation. The vapor is believed to be primarily NMP, with some water present. Larger eductors may help reduce turbulence in the bath and still maintain an even temperature throughout the bath. Also, the ventilation and exhaust system is to remain on at all times, as it is with other tanks at the MCLB containing caustic or other hazardous compounds.

Currently, the operators are stripping one basket in the morning, one in the afternoon, and occasionally leaving some parts in overnight. MCLB noted that some parts have corrosion on them that must be removed by abrasive blasting and that loose coatings or small amounts of coatings remaining on these parts after chemical stripping would be easily removed in a single pass. For example, filter housings not chemically stripped required 20-30 minutes abrasive blasting. The NMP-stripped parts need only 1-2 minutes blasting to remove corrosion, a good improvement in time and personnel effort.

ESTIMATE OF NMP EMISSIONS/LOSSES

Over the course of the 6 week demonstration, approximately 3,640 lb (1651 kg) -- about 8 barrels -- were lost to emissions, dragout, and recycling. This is a significant reduction over the previous process, which required the addition of approximately 10 barrels of methylene chloride each month. At this point, over 95% of these losses may be attributed to NMP emissions and dragout because only six distillation cycles were run during the demonstration period. Over time, as the paint sludge accumulates in the still, the MCLB will be able to determine how much NMP is lost in the still bottoms. At least 25% of the loss over the demonstration period may be attributed to tank overheating. Based on these losses, the MCLB will need to add 3-4 barrels of NMP each month to the stripping tank. This amount may vary as the operators become more experienced with controlling the bath temperature. MCLB is considering adding a cover to the tank to further reduce air emissions.

ECONOMIC COMPARISON

A summary comparison of the capital and annualized costs is presented in the following table. Assuming that an existing tank system is either to be cleaned and filled with methylene chloride or to be refurbished for use with NMP, capital costs are significantly lower for the methylene chloride system (about 11% of the NMP system). The high capital costs for NMP reflect the significant investment required for the retrofit. Capital items include the distillation unit (the largest single cost), recirculation pump, rinse pump, heater platecoil, thermocouples, level sensors, recorders and displays, and the initial charge of NMP. Estimated annualized costs for methylene chloride are $86,888, or about 108% that for NMP. The major cost is for the methylene chloride, which is used in much larger quantities than estimated for NMP (almost ten times as much). Labor costs are expected to be similar; although the basket of parts soaks longer in NMP, the operator does not spend significantly more time with the new process. Because NMP is not regulated under the Resource Conservation and Recovery Act (RCRA), a lower disposal charge applies to paint waste sludge containing NMP as compared to paint waste sludge containing methylene chloride.

PROCESS	CAPITAL COSTS	ANNUALIZED COSTS
Methylene Chloride Stripping	$19,683	$86,888
NMP Stripping	$166,260	$80,580

SAFETY CONSIDERATIONS

NMP has a flashpoint of 195°F (91°C); it is classified as a combustible and must be stored in accordance with applicable regulations. NMP is highly biodegradable, and NMP waste may be effectively treated in a IWTP using activated sludge technology. NMP will be classified as hazardous waste only if it contains hazardous components from the stripped parts.

NMP is a skin and eye irritant. NMP will not burn skin on contact but, because of its low vapor pressure, it will not quickly evaporate either. Personnel are required to wear splash goggles, butyl rubber gloves, and butyl rubber aprons when working with NMP. This personal protection equipment (PPE) designed to protect the eyes and skin from direct contact is similar to that now required at the MCLB when working with methylene chloride and MEK. Areas must be properly ventilated to prevent vapor buildup to levels above the Threshold Limit Value of 100 ppm.

ENVIRONMENTAL CONSIDERATIONS

Under Executive Order 12856, the MCLB is required to file an annual Toxics Release Inventory (TRI) of chemicals listed under section 313 of the Superfund Amendments and Reauthorization Act (SARA) Title III. The TRI includes emissions, transfers, and waste management data as part of the community right-to-know provisions of SARA Title III. Methylene chloride is classified as a toxic chemical and is included on the TRI. NMP was added to SARA Title III, section 313, for chronic health effects and became subject to reporting on January 1, 1995. As a result, the MCLB will be required to include NMP on the annual TRI report. However, unlike methylene chloride, NMP is not classified as a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) hazardous substance, or a RCRA hazardous waste.

CONCLUSIONS

The NMP, when heated to 150 ±10°F (66 ±6°C), was able to remove multiple layers of CARC and strip parts to the base metal within 3-4 hours. The heated NMP was able to successfully remove Plastisol®, a plastic coating, from battery tie-down brackets. These parts were previously stripped in a hot alkaline bath, followed by scraping and blasting to remove the coating. The NMP was able to soften epoxy-based topcoats, but removal usually required overnight soaking. Annualized cost of NMP stripping is comparable to stripping with methylene chloride, although the start-up cost is higher.

The distillation unit may provide a convenient method of removing paint sludge. It is expected that pump agitation combined with the solvency of the NMP will dissolve paint chips in the tank; the paint will be separated from the NMP during distillation. It is hoped that this will eliminate the past practice of draining the tank for paint sludge removal as required with the methylene chloride.

The implementation of NMP eliminates a major source of HAP emissions at the MCLB. By eliminating the methylene chloride for immersion stripping, the MCLB can reduce emissions 11%. The MCLB has already replaced 1,1,1-trichloroethane vapor degreasers with aqueous parts washers. This change alone will further reduce emissions from HAPs by another 16%. The MCLB has also replaced methyl ethyl ketone with a propylene carbonate/benzyl alcohol blend for cleaning paint application equipment, reducing emissions from HAPs an additional 21%. These three changes combined result in a reduction of emissions of 48%. The remaining HAPs used at the MCLB are components in paints and coatings. The MCLB plans to replace solvent-borne CARCs with waterborne CARCs in 1996 to achieve over 50% reduction in emissions from HAPs.

NOTICE

Although the information described in this article has been funded in part by the Environmental Protection Agency under contract 68-D4-0120 to Research Triangle Institute, it does not necessarily reflect the views of the Agency and no official endorsement should be inferred.

NRMRL-RTP-P-105

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before complet

1. REPORT NO. EPA/600/A-98/008	3. PB98-137441
4. TITLE AND SUBTITLE Pollution Prevention Facility Demonstration of N-Methyl Pyrrolidone as a Paint Stripping Alternative	5. REPORT DATE
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) J. M. Elion (RTI), J. K. Whitfield (EPA), and D. Gillum (Marine Corps)	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Research Triangle Institute P. O. Box 12194 Research Triangle Park, North Carolina 27709	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO. 68-D4-0120
12. SPONSORING AGENCY NAME AND ADDRESS **EPA, Office of Research and Development Air Pollution Prevention and Control Division Research Triangle Park, NC 27711**	13. TYPE OF REPORT AND PERIOD COVERED Published paper; 11/95-3/96
	14. SPONSORING AGENCY CODE **EPA/600/13**

15. SUPPLEMENTARY NOTES APPCD project officer is J. Kaye Whitfield, Mail Drop 61, 919/541-2509. Presented at National Pollution Prevention Roundtable, 1996 Spring Conference, Washington, DC, 4/10-12/96.

16. ABSTRACT The paper describes a demonstration of n-methyl pyrrolidone (NMP) as an alternative to methylene chloride for stripping cured coatings from metal parts. It describes both the old and the new processes, summarizes the equipment retrofit, and gives results of an operational evaluation conducted at the Marine Corps Logistics Base (MCLB) in Albany, GA, from November 1 to December 21, 1995. The NMP, when heated to 66 +/- 6 C, removed multiple layers of Chemical Agent Resistant Coatings (CARCs) and stripped parts to the base metal within 3-4 hours. The heated NMP successfully removed Plastisol, a plastic coating, from battery tie-down brackets. The NMP softened epoxy-based topcoats, but removal usually required overnight soaking. The annual cost of NMP stripping is comparable to stripping with methylene chloride, although the start-up cost is higher. The implementation of NMP eliminates a major source of hazardous air pollutant (HAP) emissions at the MCLB. By eliminating the methylene chloride for immersion stripping, the MCLB can reduce emissions by 11%. The MCLB has already replaced 1,1,1-trichloroethane vapor degreasers with aqueous parts washers: this change alone will further reduce emissions from HAPs by another 16%. The MCLB has also replaced methyl ethyl ketone with a propylene carbonate/benzyl alcohol blend, reducing HAP emissions by 21%.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Prevention	13B
Paint Removers	Stationary Sources	11K
Metal Products	N-Methyl Pyrrolidone	11F
Toxicity	Metal Parts	06T
Solvents	Hazardous Air Pollutants	

18. DISTRIBUTION STATEMENT **Release to Public**	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

EPA Form 2220-1 (9-73)