Final Report

POLLUTION PREVENTION RESEARCH PROJECT

Evaluation of Alternatives to the Use of Fast Evaporating Solvents for Cleaning and Flushing of Painting and Coating Equipment

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DISCLAIMER

This report presents the findings of research and surveys conducted by Capsule Environmental Engineering, Inc. (Capsule) under contract with the Minnesota Office of Waste Management. Much of the information included in this report was obtained through interviews with companies. In the preparation of this report, Capsule has relied upon the information supplied by those companies and does not warrant the accuracy and reliability of the information provided. Further, Capsule does not warrant the effectiveness of the processes described for any general or specific purpose.

INTRODUCTION

This report presents the results of work conducted by Capsule Environmental Engineering, Inc. for the Minnesota Office of Waste Management to investigate pollution prevention alternatives to the use of fast-evaporating solvents for cleaning and flushing of painting and coating lines.

The work conducted under this project involved three steps. The first step involved identifying present and evolving waste reduction options and process alternatives. Tasks within the first step included researching available alternatives through a variety of databases and interviewing various organizations on the status of any public or private research activities into alternatives to fast-evaporating solvents for cleaning and flushing of painting and coating equipment. Those groups interviewed included 15 various state pollution prevention organizations, 10 Environmental Protection Agency regional pollution prevention contacts, and personnel from the EPA Office of Research and Development and one trade association.

The second step entailed evaluating the extent of industry implementation of alternatives and the industrial barriers to further implementation. Tasks within the second step included interviewing 14 Minnesota facilities that either use or have used fast-evaporating solvents for cleaning and flushing of painting and coating equipment, followed by on-site interviews with 10 of these companies.

The third step involved analyzing the results of the first two steps and developing options to increase implementation if necessary.

The findings from this work are presented in two sections in this report. First is a discussion of existing pollution prevention alternatives, including presentation of the available options, the extent of implementation of these options, the barriers to further implementation, the overall potential of alternatives, and strategies to overcome barriers. The second section evaluates new and emerging technologies, including the need for new technologies, possible technologies that could address this need, the feasibility of any new or emerging technologies, and strategies to investigate and promote new technologies.

BACKGROUND

Successful cleaning of painting and coating equipment depends largely on the type of coating used and the application method. This study has focused on waterborne coatings, conventional solvent-based coatings, high solids coatings, and powder coatings. The carrier method, water or solvent, appears to be more important in cleaner selection than the resin type. Coating types that are not included in this study are porcelains, fluoropolymer coatings, inks, and silk screens.

Liquid coatings can be applied by spraying, flow coating, roll coating or dipping. There are many different technologies available for spraying, including conventional air, airless, air electrostatic, airless electrostatic, high volume/low pressure, two-component, electrostatic bell, and disc. Spray applications take place in spray booths in order to confine the overspray, eliminate airborne dirt, and exhaust solvent-laden air.

Dip coating involves immersing parts in a tank of coating material, draining off the excess in a solvent-saturated atmosphere, and then drying or curing. This method can also be used for electrodeposition.

Roller coating uses coated rollers to apply coatings to a flat sheets and coiled materials.

Flow coating floods the part with coating through large nozzles positioned at all angles to the part. The coating material flows down the sides of the part into a reservoir. From the reservoir the coating is pumped back over the part.

Powder coating may involve fluidized bed, electrostatic spray, electrostatic fluidized bed, or flame spray and consists of the application of finely ground thermosetting and thermoplastic powders to a part. The parts are then cured by heating to melt and fuse the powders into one continuous coating. Powder booths can reclaim the overspray for reuse.

Electrostatic spray applications use a small fluidizer to mix air with the powder which allows it to be transported to the gun. The powder is charged as it exits the gun and is applied to a grounded part where it adheres by electrostatic attraction. The part is then conveyed to an oven where the powder melts, fuses, and cures.

Fluidized bed powder coating uses an open-top container containing the powder coating. Air is introduced in to the bottom of the container to suspend and surround the powder. The part is preheated to above the melting point of the coating and dipped into the fluidized powder which melts and fuses to the parts. The part is then heated to cure the coating. An electrostatic fluidized bed charges the powder particles and then a grounded part is dipped into the powder.
Flame spray application of powdered coatings involves heating the powder to melting as it is sprayed. The powder cures as it cools on the part.
Wastes associated with coatings processes can be in the form of solid wastes or emissions. Solid wastes accumulate from paint filters, overspray, paint wastes, and equipment cleaning

wastes. Emissions result when solvents volatilize during the coating, curing, and cleaning processes.

The Clean Air Act Amendments of 1990 (CAAA) have the potential for an impact on emissions from coating facilities. Government regulations have led to technical changes in the coatings industry to produce lower VOC coating applications. This is accomplished by adjusting the composition, functionality, and molecular weight of the resins used in the coatings formulation, and by changing the cleaners used in cleaning and flushing the coating equipment.

Historically paint cleaning operations have utilized fast evaporating solvents, mainly due to the high use of solvent-borne coatings. Recently, however, there has been an increase in the use of waterborne coatings. These can easily be cleaned off equipment by using aqueous cleaners. In order to use water-borne cleaners, the coating must be proven capable of being dissolved or dispersed in the cleaning solution. Cleaner selection is dependent not only on the type of coating to be removed, but also on compatibility with the material to be cleaned.

The components needing to be cleaned are dictated by the application method. They may include: spray guns, rollers, or some other form of fluid distributor; a paint pot, dip tank, collection tank, or pan; conveyors, hooks, and racks; and a spray booth, paint heater, oven, pumps, and hoses.

Paint can be stripped off hooks, racks, conveyors, booths, and ovens by pyrolysis, media blasting, or hot caustic dipping. Other exterior or easily accessible surfaces can be cleaned by conventional paint stripping using media blasting, cryogenic stripping, molten salt cleaning, liquid cleaning, or hydroblasting. Hoses, paintlines, and paint distributors can be flushed with various liquid cleaners using slow-evaporating solvents, or caustic, or alkaline cleaners.

EXISTING POLLUTION PREVENTION ALTERNATIVES

Options

A thorough review of technical literature found limited published work addressing alternatives to fast evaporating solvents for cleaning and flushing of painting and coating equipment. *Attachment 1* is an annotated bibliography of selected articles. The technical papers were authored mostly by individuals from both end users and firms manufacturing or selling the commercially available alternative products and/or processes. State and federal agencies have also funded the development of various guide books that present source reduction options in painting operations and paint manufacturing.

Solvent Alternatives

The literature reviewed identified the following alternative chemicals to fast evaporating solvents for cleaning and flushing of painting and coating equipment:

- slow evaporating solvents
- alkaline or caustic cleaning systems
- pyrolysis
- media blasting

Slow-Evaporating Solvents

Slow-evaporating solvents such as n-methyl-2-pyrrolidone (NMP), dibasic ester (DBE) (such as 3M's Safest Stripper), and dimethyl sulfoxide (DMSO) are the only identified alternatives for flushing circulating painting/coating equipment. These compounds are also finding uses as paint and varnish removers although they act slower than typical fast-evaporating solvent mixtures. Mixtures of these compounds have been shown to be quite effective in removing coatings. Increasing the solution temperature increases the effectiveness of these compounds when used in a dip tank application.

The advantage of these compounds is the low evaporation rate compared to typical solvents. They do not possess the environmental hazards, toxicity, or flammability of their fast-evaporating solvent counterparts.

The main disadvantage of these compounds is their high cost. Costs per gallon of DBE, NMP, and DMSO are approximately $10.50, $11.50,and $10.00 respectively, while typically used fast-evaporating solvents cost under $2.00 per gallon. They are expensive to reclaim, as vacuum assisted distillation must be used due to the low volatility of these compounds, although it is possible to use atmospheric distillation without degradation. The addition of vacuum assist to a still increases the cost of the still by 50 to 100 percent. Both NMP and DBE will dissolve or swell some plastics, and the amine odor of NMP can be objectionable.

Alkaline/Caustic Cleaning Systems

Alkaline or caustic cleaning systems are used mainly in the cleaning of painting and coating mixing equipment, but not usually in the flushing of lines. The only application where these systems can be used effectively is with waterborne coatings. The caustic solutions are mainly used as hot dip solutions, while the alkaline detergents can be used in high-pressure spray applications. Concerns about remaining residues preclude the applicability of these processes to flushing application guns and lines.

Pyrolysis

Pyrolysis is a process by which paint is cleaned from ancillary equipment such as racks, hooks, and rejected parts; in this manner, the use of the process is more as a stripper. The equipment/parts are placed in an oven and the oven is heated until the paint on the equipment/parts volatilizes. The vapor enters an afterburner where it is oxidized. The ash resulting from this process can be a concern in two ways. The first is that a residual film of ash must usually be removed from the parts and the second is the proper disposal of the ash itself.

Media Blasting

Media blasting is a stripping process for ancillary equipment. Various types of media can be used such as plastic beads, sodium bicarbonate, crystalline ice, wheat starch, and carbon dioxide.

A combination of pyrolysis and media blasting can also be used. In a fluidized bed stripper, sand is agitated with hot air until the sand particles are virtually suspended or "fluidized." Equipment/parts to be cleaned are placed into this fluidized bed where the combined action of the heat and abrasive media remove the coating.

Sources

The surveys of the State Technical Assistance Programs (TAP) found only one person who had heard of alternatives to fast-evaporating solvents in paint/coating cleanup. This person had heard of NMP as a possible substitute but had no knowledge of anyone using this compound in cleaning applications. Virtually all of the contacts said that solvent-based paint users are using solvents for cleanup. The emphasis on pollution prevention in this area is in either reducing the amount of solvent used for cleanup through process optimization and good housekeeping practices or changing paint chemistries to water-based or powder. The EPA Office of Research and Development is aware of both NMP and DBE (but more for use in the paint stripping area). The EPA pollution prevention contacts provided little information, and several recommended contacting the EPA Office of Research and Development.

The Chemical Coaters Association was contacted to determine the status of any research activities in the area of alternatives to fast-evaporating solvents in the cleaning and flushing of paint equipment. No one with this association was aware of any activities in this area.

Solvent Use Reduction

The literature and TAP surveys revealed only limited knowledge of the use of alternatives to fast-evaporating solvents. More emphasis is placed on minimizing the amount of solvent used in cleaning applications.

The techniques identified to reduce the use of fast-evaporating solvents were:

- equipment modification
- optimizing cleaning methods
- solvent recycling
- optimizing production scheduling

Equipment Modification

Equipment modifications can minimize the amount of solvent needed for cleaning. Changing paint lines from rubber to viton reduces paint clinging in the lines, which reduces the amount of solvent needed to clean them. Making the lines shorter will also reduce the amount of solvent needed. Constructing tanks with mechanical wall scrapers or using a non-stick surface on the tank walls will also reduce the amount of solvent needed for cleaning.

Optimizing Cleaning Methods

Optimization of cleaning methods can reduce cleaning solvent usage. Plastic or foam "pigs" can be used to clean paint lines. Compressed air or inert gas (to minimize drying) is used to propel the "pig" through the lines, pushing paint ahead of it. Less solvent is then needed to clean the line. Another method is pulse cleaning in which a pulse of solvent is followed by a pulse of air. Another pulse of solvent and then air usually follows. The first pulse of solvent does the heaviest cleaning. The second pulse does the final cleaning.

Solvent Recycling

Solvent recycling is used in the flushing of paint guns and lines. Gun cleaning stations are used to flush a recycled stream of solvent through application guns. These stations are usually enclosed to reduce emissions.

Optimizing Production Scheduling

Production schedules can be optimized to use cleaning solvent from one production run as a solvent in the thinning of the subsequent production run. Dedication of a piece of equipment to a specific type of coating also can minimize the amount of solvent needed.

Extent of Implementation

Capsule personnel contacted 20 industrial users of fast-evaporating solvents for paint/coating cleanup to determine what alternatives have been investigated, the extent of implementation of alternatives, and the barriers to implementation. Fourteen of the contacted facilities participated in the survey. Further information was obtained through on-site interviews with 10 of the facilities. Surveyed companies were identified through SIC code, the Yellow Pages, Toxic Release Inventory data, and the personal knowledge of Capsule personnel. The companies were selected to provide a cross-section of industry sizes, product types, and markets served. Industry phone survey forms are included in *Attachment 2*.

Cooperation by the facilities was good, with 11 requesting that their identities be held confidential. Ten facilities also consented to on-site interviews as a follow up to the telephone surveys. The facilities ranged from small job shops with 100 percent OEM production to large facilities with 100 percent in-house production. The substrates included were primarily metal, with two companies coating wood and one company also coating fiberglass composite.

All of the facilities that use solvent-based paints and/or coatings use fast-evaporating solvents for gun and line flushing. Two of the facilities have investigated the use of NMP or DBE for this use, but concerns about contamination, cost, and recycling have precluded their use. Emphasis has been placed on reduction of solvent use and emissions through the use of gun cleaning stations that recycle the cleaning solvent. Seven facilities have investigated powder paint processes while four have investigated water-based paints as methods to reduce solvent use. One facility has converted its painting operation to 100 percent powder paint.

Barriers Identified by Industry Telephone Surveys

The industry telephone surveys revealed that the types of barriers to implementing alternatives to fast-evaporating solvents in the cleaning and flushing of painting and coating equipment included, in the order of frequency reported:

- technical
- customer specifications
- economic
- regulatory

The major technical barrier noted was the lack of alternatives to the cleaning solvents for use with solvent-based coatings. Facilities that are investigating the elimination of solvents in their painting operations are looking at alternative paint chemistries as opposed to alternative cleaning solvents. These alternative paint chemistries would eliminate the need for fast-evaporating cleaning solvents. Technical barriers were noted in the replacement of existing painting processes with alternatives such as powder and water-based paints.

Customer specifications were mentioned as a barrier to the changing of paint chemistries. This is especially evident in the case of a job shop painter.

Economic barriers were cited again in the changing of paint chemistries. The high capital cost of process changeover was mentioned.

The lack of regulatory expediency when changing air permits was mentioned by two facilities as a barrier to quicker implementation of alternative paint chemistries.

Barriers Identified by State/EPA Programs

The telephone surveys with the state TAPs gave similar results regarding the real or perceived barriers to implementation of alternatives to fast-evaporating solvents for cleaning and flushing of painting and coating equipment.

The types of barriers cited by industries around the country in order of frequency were:

- technical
- customer specifications/quality
- economics

Technical barriers mentioned were the lack of suitable alternatives to the cleaning solvents and the challenges of implementing alternative paint chemistries. Once again, industries are more concerned with either minimizing solvent usage or replacing solvent-based painting/coating processes to eliminate the need to use solvents for cleaning. Meeting customer specifications and quality concerns were cited as barriers in the changing of paint chemistries as well as the capital cost involved.

Barriers Identified by On-site Interviews

The on-site interviews identified barriers to implementation more specifically. Company A, being a job shop, mentioned that customer specifications determine the products that they use. They have much less flexibility in the use of alternate coatings than a captive shop does.

Company B cited the economics of a major process change in the painting area as a barrier. The timeliness of the air permitting process was mentioned as a barrier. Companies that would like to change to alternate paint processes encounter delays due to the long time that it takes to amend permits.

Company C identified customer specifications as the main barrier to the implementation of alternative coatings. The cost of installing in-house solvent recycling equipment was mentioned as a barrier to the implementation of this type of process.

Company D noted that customer specifications, especially for military applications, dictate the type of coating to be used. As a job shop, Company D must provide products that meet the quality and performance specifications of their customers. In the cases where alternate coatings are identified, there is always resistance to change from proven processes.

Company E encountered a technical barrier to the use of slow-evaporating solvents for the flushing of paint equipment involving residual contamination remaining in the lines. Company E has also investigated many process alternatives to replace the use of methylene chloride (METH) in cleaning conveyor parts. These processes have, for the most part, proven technically feasible but not practical in their application. Company E also feels that the regulatory climate can be a barrier to the investigation of alternatives, as the tracking and reporting burden must follow the one-time wastes and residuals that may be generated. There are also concerns regarding the health and safety aspects of some alternatives.

Company F cited an economic barrier to the implementation of powder coating. Slower line speed and the time requirement for color changes for the particular powder coating system investigated were mentioned as technical barriers.

Company G mentioned the lack of a suitable cleaning alternative as the main barrier to replacing fast-evaporating solvents. Quality requirements have been a barrier to the implementation of alternate coatings as no coating other than solvent-based has been able to meet quality specifications.

Company H has employed solvent minimization methods in the past and is investigating the implementation of powder coating. Company H mentioned that a thorough evaluation of the process and procedural changes required will resolve technical barriers involving feasibility and implementation.

Graco has investigated NMP for some flushing and cleaning applications. The implementation of this material has been precluded due to its prohibitive cost and questions surrounding its suitability for recycling. This material must also be disposed of as a hazardous waste. Graco also cited the inability of water-based coatings to meet its durability and quality specifications. The economics of a major process change in the painting area are not favorable.

Consolidated Container has investigated the use of water-based paints. Barriers to their implementation were technical and included the long drying time and the lack of durability that they have displayed.

Potential of Alternatives

The potential of the alternatives to the use of fast evaporating solvents for the cleaning and flushing of painting and coating equipment is mixed. The use of slow-evaporating solvents (NMP or DBE) for flushing painting lines has been investigated by 2 of the 14 companies contacted as part of this survey. The use of these materials has not been acceptable in these applications due to residual contamination, cost, and recycling concerns. One company has also investigated the use of DBE to clean conveyor parts but found some coatings to be resistant. One company uses DBE in stripping applications.

Several of the companies indicated that they use a burn-off oven to clean ancillary equipment. This process was generally implemented to avoid the use of solvents such as METH.

One company surveyed had investigated many different processes to replace the use of METH in cleaning conveyor parts. These processes included DBE, cryogenic stripping, burn-off, media blasting and part pre-coating. In every case, the process was somewhat successful, but the practical application was limited.

The use of water-borne and powder coatings was investigated by 11 of the 14 companies surveyed. A process change of this type is much more application specific but seems to have a greater potential for implementation than water-borne cleaning materials. Powder coating was considered by 7 of the 14 surveyed companies with partial or full implementation by two of the companies. The other 5 are still considering the implementation. Four of the 14 surveyed companies investigated the use of water-based coatings and are still in the testing phase. Two of the companies, both job shops, use some powder coating or water-based coatings as specified by customers.

Capsule has been working with Artistic Finishes, under a Pollution Prevention Grant, to identify alternatives to their solvent-coating applications on wood substrates. At this time, the selected alternative is a water-based coating. Flushing and cleaning of the application equipment will be conducted with water.

Strategies to Overcome Barriers

The main barrier to the implementation of alternative cleaning materials in the flushing of painting/coating lines is technical: the lack of a suitable alternative. NMP and DBE have been tried by 2 of the 14 surveyed companies for this application and the results have not been encouraging. More research and development is needed in this area to address the problems cited such as residual contamination, high cost, and questionable recycling possibilities.

Companies have focused on process modifications to minimize the amount of solvent used in flushing operations. These modifications include dedicated, recirculating paint lines, where only the gun needs cleaning, as well as on-site recycling of the solvent. Many companies are using a solvent mixture, reclaimed off-site, in these flushing applications to ease the handling of spent solvent. These practices should be encouraged if a company cannot use an alternate coating technology.

Many companies have replaced solvents for cleaning ancillary equipment. Burn-off ovens are used by several companies to clean hooks and racks. One company uses a hot alkaline dip to clean equipment. One company tried several methods including DBE, burn-off, media blasting, and precoating to clean conveyor parts. None of these methods has proven totally successful or practical at this point.

Customer specifications is a barrier for many companies, especially job shops. Customers could be educated to request compliance coatings for their applications, if possible.

Durability problems have been cited as a barrier to the implementation of water-based paints. This barrier could be addressed on two fronts. Information transfer could be improved to make companies aware of the many products that may meet their needs. Continuing research is also needed to solve durability problems with water-based coatings. One company suggested that the University of Minnesota be more involved in research to solve practical problems such as this.

Several companies are investigating powder coatings to replace their solvent-based paints. These facilities are captive shops, which have the most control over their processes and their required specifications. Increased information and technology transfer could make the applicability of this type of coating more visible.

The cost associated with a major process change, such as the conversion to powder coating, was cited as a barrier by several companies. More emphasis should be placed on the

complete economic analysis that must be performed, including chemical cost, waste disposal costs, emission controls, and the impact of future regulations.

One company suggested some sort of "vendor qualification" process in which the many coating products available could be compiled and summarized to make it easier to research alternate coating technologies.

EMERGING POLLUTION PREVENTION APPROACHES

Options

The use of the slow-evaporating solvents NMP and DBE is minimal at this point and can be considered an emerging technology to replace the use of fast-evaporating solvents.

The Need for New Technologies

The implementation of NMP, DBE, and DMSO was neither widespread nor successful among the surveyed companies. There are concerns with residual solvent contamination in the coating lines, high cost, and the recyclability of these products. The approximate cost per gallon for DBE is $10.50 while NMP is $11.50 and DMSO is $10.00. More commonly used equipment cleaning solvents such a xylene, toluene, and mineral spirits are all priced less than $2.00 per gallon. The low volatility of DBE and NMP require the use of vacuum distillation for efficient recycling, although atmospheric distillation can also be used. There have also been questions raised as to the quality of the recycled product. Until these problems can be solved, the use of these materials for equipment flushing applications will be minimal. More research and development is needed to develop alternate materials to flush painting and coating lines. Many companies, especially job shops, will continue to use solvent-based paints to meet customer specifications.

The state could possibly assist in the development of new products through pollution prevention grants aimed at the alternative product development.

Attachment 1

ANNOTATED BIBLIOGRAPHY OF SELECTED ARTICLES

Attachment 1

ANNOTATED BIBLIOGRAPHY OF SELECTED ARTICLES

A NEW SOLVENT FOR INDUSTRIAL CLEANING/ Lucas, David F., E.I. du Pont de Nemours & Company, Inc.

Laboratory tests and plant evaluations of Du Pont DBE (dibasic ester) solvent in a variety of cleaning applications are discussed.

BURN IT OFF!/ Whelan, Kent: Products Finishing, June 1986.

Pyrolysis is discussed as a method to clean paint hooks and hangers. The process, equipment, and limitations are examined.

CASE STUDY: SOAK STEP REDUCES SOLVENT WASTE FROM CLEANING PAINT STRAINING EQUIPMENT/ Minnesota Technical Assistance Program, July 1991.

Results of a MnTAP project, at Crenlo, Inc., to reduce the use of flammable paint cleaning solvents are presented.

CASE STUDY: SPRAY NOZZLE SELECTION REDUCES SOLVENT WASTE VOLUME WHEN CLEANING PAINT STRAINING EQUIPMENT/ Minnesota Technical Assistance Program, June 1991.

Results of a MnTAP project, at Crenlo, Inc., to reduce the use of flammable paint cleaning solvents are presented.

CONVEYOR CARE/ Mahurin, John: Gardner Publications, Inc. 1990.

The necessity of proper preventive maintenance of conveyor systems is discussed, including the need for regular cleaning of overspray.

DOING THE DIRTY WORK/ Graves, Beverly: Products Finishing, April, 1991.

A company that strips and cleans ancillary paint equipment for other companies is profiled. Brief descriptions of the different stripping processes used are given.

ENVIRONMENTAL RESEARCH BRIEF: WASTE MINIMIZATION ASSESSMENT FOR A PAINT MANUFACTURING PLANT/ Looby, Gwen and William Kirsch: United States Environmental Protection Agency, July 1991.

Waste minimization opportunities at a paint manufacturing facility are presented. The minimization of solvent use in cleaning and blending is addressed.

GUIDELINES FOR WASTE REDUCTION AND RECYCLING: SOLVENTS/ Hazardous Waste Reduction Program of Oregon, pp. 22-24.

Source reduction methods for equipment cleaning operations are discussed, including the elimination of solvent use, improving operations and housekeeping, and the reuse of solvents.

GUIDES TO POLLUTION PREVENTION: THE PAINT MANUFACTURING INDUSTRY/ United States Environmental Protection Agency, June 1990, pp. 9-13.

Minimizing equipment cleaning wastes using new systems and modifications to existing systems as well as improving operating practices is described.

GUIDE TO SOLVENT REDUCTION ALTERNATIVES/ Alternative Technology and Policy Development Section, California, October 1986, pp. 4.16-4.25.

Reasons for process equipment cleaning, source reduction methods, and solvent reuse are discussed. The main focus is on the minimization of solvent use.

HOW ARE COATINGS APPLIED/ Izzo, Carl: Products Finishing Directory, 1992.

Background information on the various methods of coating application are discussed.

PAINT STRIPPING TODAY/ Graves, Beverly: Products Finishing, April, 1991.

A synopsis of discussions at the EPA-sponsored "International Conference on Reducing Risk in Paint Stripping" is presented. Various methods are described as possible alternatives to the use of methylene chloride.

SEMINAR PUBLICATION: SOLVENT WASTE REDUCTION ALTERNATIVES/ United States Environmental Protection Agency, September 1989, pp. 31-37.

Minimizing process equipment cleaning waste is discussed. The reasons for equipment cleaning are presented along with ways to reduce the quantity and toxicity of cleaning wastes. A discussion of the cost of cleaning is also given.

THE SUPER SOLVENT ALTERNATIVE/ Taylor, Paul: Hazardous Waste Management Magazine, March 1989.

M-Pyrol, GAF Chemicals Corp.'s brand of N-methyl-2-pyrrolidone (NMP) is discussed. Aspects such as health and safety, handling, regulatory status, and applications are presented.

WASTE MINIMIZATION IN THE PAINT AND ALLIED PRODUCTS INDUSTRY/ Lorton, Gregory: APCA, April 1988.

Waste minimization practices available in the paint and coatings industry are discussed. The wastes generated are described along with source reduction and recycling techniques for them. Equipment cleaning wastes are focused on as the largest category of wastes in this industry.