

PAINT AND FINISH REMOVERS

1. Introduction

The term finish denotes the final process of manufacturing. Finishing operations include addition of clear coat polymers like varnishes or lacquers, painting, plating, anodizing, phosphatizing, galvanizing, and blueing, all of which take place at the terminal point of manufacturing. Finishing is defined as the process of coating or treating a surface for the purpose of protecting and/or decorating the product (1). The useful life of most objects is greater than the life of the finish. This results in a periodic need to remove and replace the finish. Many times the appearance of the item is outdated and the finish is removed to allow a more modern finish to be applied. An organic or inorganic chemical solution or a mechanical process, such as media blasting, may be used to lift or remove the finish.

Antiques, household furniture, kitchen cabinets, pianos, aircraft, and buildings can have their useful life extended by removing the old coating and applying a new one. Original equipment manufacturers (OEMs) remove coatings from rejected parts to avoid scrapping the items. Finish removers are used to remove lead paint from woodwork, windows, or entire buildings to reduce the risk of human exposure to lead. There are >104 different industries that use finish removers (2). The use of and need for finish removers will probably expand with the increasing importance of recycling (qv), refinishing, and the restoration of durable items.

2. Components of Finish Removers

The physical properties of finish removers vary considerably due to the diverse uses and requirements of the removers. Finish removers can be grouped by the principal ingredient of the formula, method of application, method of cleaning substrate after stripping, pH, viscosity, and hazardous classification. A list of the most common organic solvents used in finish removers was compiled by the Paint Remover Manufacturer's Association (3). Many are mentioned throughout this article. Formulators are becoming sensitive to the U.S. Environmental Protection Agency (EPA) Pollution Prevention Act of 1990. Green chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances (4).

Finish removers are applied by brushing, spraying, troweling, flowing, or soaking. Cleaning the substrate may be by water rinse, wipe and let dry, or solvent rinse. Removers may be neutral, basic, or acidic. The viscosity may be water thin, thick enough to spray-on and cling, or a paste to be troweled on. Hazard classifications, such as flammable, toxic, or corrosive, are assigned by the U.S. Department of Transportation (DOT) for the transportation of the hazardous materials contained in the remover.

2.1. Formulation Helps. It is possible to formulate paint removers relying on experience and trial and error. The use of solubility parameters may speed up the trial and error portion of the formulation (5,6). The Hildebrand parameter is divided into three component Hansen parameters. These solubility parameters

are dispersion, polar, and hydrogen-bonding force. Many manufacturers of film-forming polymers (wood or metal finishes) will supply a polymer solubility window for their product. If this is not available, the solubility window can be experimentally determined by observing a film with many solvents under a microscope and classifying the film as soluble, slightly soluble, or insoluble in each solvent. These data are used to plot a three-dimensional (3D) irregular sphere that includes all solvents that dissolve the polymer and exclude those that do not. If the formulator wants a stripper that dissolves a finish, the weighted average for the three Hansen values of the stripper solvent should fall in the middle of the sphere. If the formulator wants a stripper that loosens the finish without dissolving it, the weighted average of the three Hansen values for the stripper solvent should fall on the margin of the graph. Another solubility scale that is widely reported and may be useful is the Kauri-Butanol value.

2.2. Major Ingredients. The major ingredient of a formula is the chemical of greatest volume. Current formulas include approximately five major ingredient formulas: methylene chloride [75-09-2], petroleum base, oxygenates, aqueous alkaline, and other organic blends. The petroleum base removers include ingredients, such as toluene [108-88-3], xylenes [1330-20-7], and monochlorotoluene [25168-05-2]. Oxygenates may include ketones like acetone [67-64-1] or methyl ethyl ketone [78-93-3], that are both aggressive finish removers and are often major ingredients. Other oxygenates include glycol ethers, like propylene glycol methyl ether [107-98-2]. Esters are also common oxygenates and include dimethyl adipate [627-93-0], ethyl 3-ethoxypropionate [763-69-9], and ethyl lactate [678-47-8]. Aqueous alkaline removers are used in soak tanks or as a paste. The major ingredients are sodium hydroxide [1310-73-2] or potassium hydroxide [1310-58-3]. Other solvents that are popular and successful in paint remover blends are *N*-methylpyrrolidinone [872-50-4], furfural alcohol [98-01-1], dimethylformamide (DMF) [68-12-2], tetrahydrofuran (THF) [109-99-9], and dimethyl sulfoxide (DMSO) [67-68-5].

2.3. Cosolvents and Diluents. Cosolvents and diluents are solvents that are added to a remover to increase the rate of stripping (stripability) or reduce the cost of raw materials without unacceptably compromising the performance of the product. Mineral spirits [8052-41-3] and other hydrocarbon solvents are often used as diluents. Cosolvents may not be a significant remover by themselves, but will increase the stripping efficiency of the mixture when added to a major ingredient solvent. Small amounts of alcohol and toluene are commonly used in methylene chloride removers and act as both cosolvents and diluents. Pure methylene chloride is only a fair paint remover. When mixed with methanol [67-56-1] a synergistic effect is produced that results in a solvent blend with removal characteristics far superior to either of the solvents when used independently. *N*-Methyl pyrrolidinone removers utilize middle molecular weight alkyl aryl compounds like aromatic 150 [64742-94-5] as dilutant-cosolvent to both modify the extreme cost of the major ingredients and increase its activity. The maximum stripping efficiency is reached when the mole percentage of *N*-methylpyrrolidinone is between 40 and 50% (7).

2.4. Evaporation Retardants. Volatile molecules that are in many of the most effective paint removers evaporate easily, sometimes before the remover has time to penetrate the finish. Low vapor pressure cosolvents are

added to help reduce evaporation. The best approach is to add a low melting point paraffin wax (mp 46–57°C) to the paint remover formulation. When evaporation occurs, the solvent is chilled and the wax is shocked-out forming a film on the surface of the remover that acts as a barrier to evaporation (8,9). The addition of certain esters enhance the effectiveness of the wax film. Excessive brushing or scraping during the stripping process causes the wax film to break resulting in the evaporation of the active solvent before the remover can penetrate and lift the finish from the substrate. Temperature is an important factor in paint stripping. The optimum temperature is 72°F. Cooler temperatures slow the stripping process and the wax film will become brittle and fracture. Rapid evaporation occurs when the wax film is absent or broken. Warmer temperatures dissolve the wax film allowing volatile portions of the paint remover to evaporate. Evaporation is expensive and reduces the activity of the remover. It also cools the remover that results in reduced activity.

2.5. Emulsifiers. Cleaning the remover from the substrate is just as important as removing the finish. Water rinse removers include a detergent that is compatible with the remover formula. Many organic solvents used in removers are not water soluble, so emulsifiers are often added (see EMULSIONS). Anionic types, such as alkyl aryl sulfonates or tolyl fatty acid salts, are used in neutral and alkaline activated removers. In other applications, nonionic surfactants are preferred and hydrophilic–lipophilic balance is an important consideration.

2.6. Activators. Activators are often added to removers to make them more efficient. Acids such as phenol [108-95-2], phosphoric acid [7664-38-2], acetic acid [64-19-7], formic acid [64-18-6], oxalic acid [144-62-7], and citric acid [5949-29-1] are used to increase the cutting ability on epoxide-type paints and other modern finishes. High pH, alkaline activators are effective on enamel and latex paints. Other activators include ammonia [7664-41-7], monoethylamine [75-04-7], and *N*-phenyldiethanolamines. Acid and base activators shorten the shelf life of some removers.

2.7. Thickeners. Thickeners are added to remover formulas to increase the viscosity and allow the remover to cling to vertical surfaces. They are dispersed and then caused to swell by the addition of a protic solvent or by adjusting the pH of the remover. When the polymer swells, it causes the viscosity of the mixture to increase. Viscosity is controlled by the amount of thickener added. Common thickeners used in organic removers include hydroxypropyl methylcellulose [9004-65-3], hydroxypropylcellulose [9004-64-2], hydroxyethyl cellulose, and poly(acrylic acid) [9003-01-4]. Thickeners used in aqueous removers include acrylic polymers and latex-type polymers. Some thickeners are not stable in very low pH or very high pH environments, so careful selection is important.

2.8. Corrosion Inhibitors. Corrosion inhibitors are added to the formula to promote packaging stability and to protect the substrate to be stripped.

3. Organic Finish Removers

3.1. Methylene Chloride Finish Removers. Methylene chloride based formulas are among the most common and most effective organic chemical removers. The low molar volume of methylene chloride allows it to rapidly penetrate the finish by entering the microvoids of the finish. When the methylene chloride reaches the substrate the adhesive bond between the finish and the substrate is released and the finish swells. The result is a blistering effect and an efficient lifting action. Larger molecule solvents generally cannot cause this lifting action and must dissolve the finish. When methylene chloride is used in amounts of 78% or more, even with flammable cosolvents, the mixture is nonflammable. A typical methylene chloride base remover includes cosolvents, activators, evaporation retarders, corrosion inhibitors, thickeners, and wetting agents.

Cosolvents include methanol [67-56-1], ethanol [64-17-5], isopropyl alcohol [67-63-0], or toluene. The selection of cosolvents depends on the requirement of the formula and their interaction with other ingredients. Methanol is a common cosolvent in methylene chloride formulas since it has good solvency and may be used to swell cellulose-type thickening agents. Table 1 is an example of a methylene chloride formula used to strip wood (10).

The stripability on catalyzed urethane and epoxy resin finishes can be increased by adding formic acid, acetic acid, or phenol. Sodium hydroxide or potassium hydroxide may be added to the formula to increase the stripability on enamel and latex paints. Other activators include oxalic acid [144-62-07], trichloroacetic acid [76-83-9], ammonia, triethanolamine [102-71-6], and monoethylamine [75-04-7]. Methylene chloride type removers are unique in their ability to accept cosolvents and activators that allow the solution to be neutral, alkaline, or acidic. This ability greatly expands the number of coatings that can be removed with methylene chloride removers.

Paraffin wax vapor barriers are used in many methylene chloride removers. In soak tank applications, water is sometimes floated on top of an all-solvent, neutral pH, non-water rinse remover to prevent evaporation. Flotation devices that cover the exposed surface area may be used with other formulas.

Corrosion inhibitors are used to protect both the container and the metal substrate being stripped. Acid activated removers use inhibitors to block corrosion on active metals. Typical inhibitors are propylene oxide [75-56-9], butylene oxide [9106-88-7], triethylammonium phosphates, and sodium benzoate [532-32-1].

A cellulose ether thickener, such as hydroxypropyl methylcellulose, can be added to thicken a methylene chloride remover. Removers that are acid or alkaline activated require thickeners that will not be hydrolyzed by the acid or the base.

A detergent that is compatible with the remover formula must be developed for water rinse removers. Anionic or nonionic surfactants should be selected, depending on the pH and intended application of the remover.

Health and Safety. Formulas that are nonflammable may be used in any area that provides adequate ventilation. Representative personal breathing zone air samples of persons working with these removers should be taken according to

Occupational Safety and Health Administration (OSHA) recommendations. The current OSHA standard for methylene chloride includes a Permissible Exposure Limits (PELs) of 25 ppm. Expressed as an 8-h time-weighted average (TWA) PEL means that no employee may be exposed to an airborne concentration of methylene chloride in excess of 25 parts of methylene chloride per million parts of air (25 ppm) averaged over an 8-h period. Short-term exposure limit (STEL) requires that no employee is exposed to an airborne concentration of methylene chloride in excess of 125 parts of methylene chloride per million parts of air (125 ppm) as determined over a sampling period of 15 min.

The environment can be monitored with passive detection badges or by active air sampling and charcoal absorption tube analysis. Vapor of methylene chloride produces hydrogen chloride and phosgene gas when burned so these removers should not be used in the presence of an open flame such as kerosene heaters (11).

Persons exposed to methylene chloride removers should wear protective clothing and eye protection. Glove selection varies with the components of the paint remover formula. Natural rubber gloves of 30 mils (~0.75 mm) with laminated polyethylene and ethylene–vinyl alcohol glove liners are normally worn for industrial uses (12). Extended skin contact is usually limited during use because of the immediate discomfort when the remover touches the skin. The work area should be adequately ventilated as recommended by the manufacturer. Canister respirators should not be used for methylene chloride protection because the charcoal in the canister is rapidly saturated. The permitted exposure level is lower than the level at which humans can detect the odor. Therefore, the worker cannot tell when the charcoal in the canister is no longer effectively cleaning the air, resulting in exposure at unsafe levels. Fresh air supplied respirators should be used in areas that cannot be properly ventilated. Tests indicate that long-term overexposure to methylene chloride vapors causes cancer in test animals; further tests are in progress.

Environmental Impact. Methylene chloride is nonphotochemically reactive and is not listed as an ozone (qv) depleter. Methylene chloride removers do not dissolve paint, but release the paint from the substrate so it can easily be recovered from paint chips and other residue. This allows recovery of the liquid remover and its continued use increasing the useful life of the remover. The used paint remover can be mixed with fresh remover eliminating the need for disposing of the used remover. This process requires no special recovery equipment. The high volatility of methylene chloride allows the waste residue from the stripping process to be easily dried. The resulting waste is normally considered hazardous because of the amounts of heavy metals from old finishes.

3.2. Petroleum and Oxygenate Finish Removers. Many older finishes can be removed with single solvents or blends of petroleum solvents and oxygenates. Varnish can be removed with mineral spirits, shellac can be stripped with alcohols, and lacquers can be removed with solvent blends, such as lacquer thinners. This removal mechanism is dissolving the coating, then washing the surface, or wiping away the finish. This method is often used to reamalgamate or liquefy old finishes on antique items of furniture.

Petroleum and oxygenate finish removers may contain ketones, esters, low molecular weight aromatics, and glycol ethers. Cosolvents include methanol,

n-butanol [71-36-3], *sec*-butyl alcohol [78-92-2], or xylene [1330-20-7]. Sodium hydroxide or amines are used to activate the remover. Paraffin wax is used as an evaporation retarder though its effectiveness is limited because it is highly soluble in the petroleum solvents. Cellulose thickeners are sometimes added to control evaporation by assisting in pulling the paraffin wax from the liquid to form a vapor barrier or to make a thicker formula. Corrosion inhibitors are added to stabilize the formula for packaging (qv).

Wetting agents are used to make a water rinse remover. Water rinse removers include surfactants to help remove paint and remover residue from the substrate. Solvent rinse removers or wipe and dry formulas may be used for stripping clear finishes. A typical petroleum and oxygenate formula is in Table 2 (13).

This is a liquid scrape-off remover for brush or soak applications. Clean up is with a solvent that is compatible with the stripper and finish being used.

Health and Safety. Petroleum and oxygenate formulas are often flammable or combustible. Flammable removers must be used in facilities that meet OSHA standards for use with flammable liquids. Adequate ventilation that meets the exposure level for the major ingredient must be attained. The work environment can be monitored by active air sampling and analysis of charcoal tubes. Extreme caution must be taken to prevent the possibility of fire when using flammable removers. Heating systems should not expose an open flame to the work area. Gas appliances, pilot lights, electric stoves, and water heaters should be turned off. Ventilation should move 2 ft³ of air per minute for every square foot of shop space.

Natural rubber, neoprene, or other gloves suitable for use with the remover formula must be worn. Canister respirators are available for most petroleum and oxygenate remover solvents. Symptoms of long-term exposure should be identified from the MSDS of the stripper.

Environmental Impact. Most petroleum and oxygenate removers are photochemically reactive and classed as volatile organic compounds (VOCs). Air districts, such as California South Coast Air Quality Management District (Ca SCAQMD), restrict the use of these products. There are statewide regulations for VOCs in New Jersey and Rhode Island, and several states are developing their own statewide regulations. Recovery and disposal of the remover after use is difficult because the finish is resolubilized by the remover. The dissolved finish cannot be separated from the spent remover and the whole mixture must be disposed as a liquid hazardous waste. Recovery by distillation of the solvents is dangerous because the nitrocellulose from lacquer finish may cause autoignition in the still (14).

3.3. Other Organic Finish Removers. Concerns for the health effect of methylene chloride have stimulated research on alternative solvents in remover formulas. *N*-Methylpyrrolidinone [872-50-4] and dibasic esters (dimethyl glutarate [1119-40-0] or dimethyl adipate [627-93-0]) have been used in removers. They remove single-component finishes and work slower than methylene chloride, petroleum, and oxygenate removers. They have little success on epoxy and catalyzed finishes. The area of greatest use appears to be as special-purpose removers for known finishes that are compatible with the remover formula. Cosolvents for *N*-methylpyrrolidinone removers include diacetone alcohol

[123-42-2], γ -butyrolactone [96-48-0], and ethyl 3-ethoxypropionate [763-69-9]. Monoethanolamine [141-43-5], citric acid [5949-29-1], formic acid [64-18-6], and acetic acid [64-19-7] are used as activators. Strong bases, such as sodium hydroxide [1310-73-2] or sodium methoxide [124-41-4] cannot be used since they react with *N*-methylpyrrolidinone causing oxidation and polymerization. Alkyl aryl sulfonates, tolyl fatty acids, and varieties of nonionic surfactants are used in water rinse formulas. Cosolvents for dibasic ester finish removers include *N*-methylpyrrolidinone, aromatic 150, cyclohexanone [108-94-1], acetone, diacetone alcohol, and methanol. The same surfactants and activators are used with dibasic ester removers as with *N*-methylpyrrolidinone removers. Table 3 is a typical *N*-methylpyrrolidinone formula. It is a semipaste, water rinse finish remover.

The "Green Chemistry" approach to paint removers is laudable, but not easily accomplished. There are many solvents that have "green" characteristics used in paint removers. Acetone and *tert*-butyl acetate are not VOCs or are VOC exempt. They are not hazardous air pollutants (HAPs) nor are they SARA 313 reportable and do not contribute to ground-level ozone formation. All are non-ozone depleting.

Ethyl lactate and methyl soyate are biosolvents and are renewable resources. They are not HAPs nor SARA 313 reportable and they are non-ozone depleting. They have low vapor pressures, so they evaporate slowly. These solvents are nonflammable, but other green solvents have low flash points and present a serious health risk.

Dimethyl sulfoxide is used in many paint removers and has many green characteristics. It has low toxicity, a high flash point, and is not a HAP nor listed under SARA 313. A risk associated with DMSO removers is that it is readily transported through the skin and may readily carry toxic compounds present with it.

A paint remover with a solvent that is green, but has an objectionable odor or other undesirable physical property, will limit its consumer acceptability and therefore use of the final product. When the final solvent blend of a paint remover contains one component that is nonbiodegradable, is a VOC, a HAPs, or is SARA 313 listed, much of the advantage of the green solvent is lost.

The formula listed in Table 4 is from the *Green Formulary Guide* published by the United Soybean Board (15).

It is very difficult to find a combination of solvents that meets all of the green criteria and effectively remove finishes in a reasonable time.

Health and Safety. Both *N*-methylpyrrolidinone and dibasic esters have very low vapor pressure that reduces worker exposure to vapors. Manufacturers recommend that the same safety precautions be taken as with other organic solvents. If the formula is flammable, the stripping facility or on-site location must meet local building code for the use of flammable liquids as well as the OSHA standard for use of flammable liquids. Ventilation that reduces vapors to manufacturer's recommended exposure levels should be used.

Protective clothing must be worn during use. Natural rubber or neoprene gloves should be worn with dibasic ester removers and ~0.75-mm (30 mils) natural rubber or neoprene with laminated polyethylene and ethylene-vinyl alcohol liners should be worn with *N*-methylpyrrolidinone. Since both dibasic

ester and *N*-methylpyrrolidinone have low vapor pressures, the off-gassing period on porous substrates like wood extends for a long time period. This may result in longer worker exposure to the solvents. *N*-Methylpyrrolidinone is transdermal and can cause skin and nerve damage from handling porous stripped items while there is significant solvent off-gassing. Symptoms of long-term over-exposure to the formulation should be identified from the MSDS for the stripper.

Environmental Impact. The volume of waste remover from these products is greater than comparable methylene chloride, petroleum, and oxygenate removers, since both *N*-methylpyrrolidinone and dibasic esters have low vapor pressures. Recovery of the remover after use is difficult because the finish is resolubilized by the remover. A representative dibasic ester formula appears in Table 5 for a thickened water rinse finish remover.

4. Inorganic Finish Removers

4.1. Liquid Alkaline Removers. This group consists of alkaline materials that are dissolved in water then heated to an appropriate temperature to remove finishes. In a typical application, a hot water bath large enough to submerge an item is used. The tank is heated from 43 to 74°C for stripping wood or metals. Various alkaline materials may be used to provide the desired alkalinity. Sodium or potassium compounds are preferred, such as sodium hydroxide [1310-73-2], sodium carbonate [5968-11-6], sodium silicates, mono-, di-, and trisodium phosphates, tetrasodium pyrophosphate [7722-88-5], and sodium tripolyphosphate [7758-29-4] and potassium hydroxide. Activators, such as phenol, gluconic acid [526-95-4], and alkali metal gluconate are dissolved into a suitable solvent that itself can be dissolved in and added to the caustic solution. Surfactants are added to aid in removal of the solution and increase the penetration of the finish. Various suitable surfactants of the anionic, nonionic, and cationic types may be used, provided they are soluble and effective in the alkaline stripping solution. A typical aqueous alkaline remover formula is shown in Table 6.

This aqueous alkaline remover is used for stripping the finish from wood or ferrous metals at a mix ratio of 30–600 g/L (0.25–5 lb/gal).

4.2. Paste-Type Alkaline Removers. Sodium hydroxide, potassium hydroxide, or other caustic compounds are blended to make these types of removers. Polymer-type thickeners are added to increase the viscosity that allows the remover to be applied with a brush, trowel, or spray. Some of these products use a paper or fabric backing to allow the remover finish mixture to be peeled away. The most common application for this group of removers is the removal of architectural finishes from the interior and exterior of buildings. Long dwell time allows many layers of finish to be removed with one thick application of the remover.

Fused State Baths. Sodium hydroxide and salt can be heated to a fused state in baths to allow the removal of finishes from ferrous metals. The most common use of this method is the removal of heavy concentrations of paint on conveyor parts and hangers used in production spray systems.

Health and Safety. Protective clothing that is compatible with the remover formula must be worn. Caustic soda baths should be ventilated to

remove vapors from the work area. Most caustic removers are corrosive and cause severe burns with minimal contact to the skin. Canister respirators that are compatible with the remover should be worn.

The liquid from spent caustic soda baths must be disposed of or treated as a hazardous waste. The finish residue may contain heavy metals and have a high pH thus requiring treatment as a hazardous waste.

4.3. Manufacturing and Processing. Finish removers may be manufactured in open or closed kettles. Closed kettles are preferred because they prevent solvent loss and exposure to personnel. To reduce emissions from the solvents, condensers are often employed on vent stacks. Mild steel or black iron kettles are used for neutral or basic removers; stainless steel (316 or 317) or reinforced polyethylene kettles are used for acidic removers. The kettles are heated to aid dispersion of paraffin waxes and mixing of other ingredients. Electric or air driven motors drive either sweeping blade or propeller mixers that give sufficient lift to rotate and mix the liquid. Dispenser-type mixers are used to manufacture thick and viscous removers. Kettle, fittings, mixer, and fill equipment must be fabricated with materials resistant to the chemicals in remover formulas.

Standard 0.25 or 0.50 lb (227 g) tin-coated cans are used for packaging liquids with neutral and mildly alkaline formulas; polypropylene is used for acid-activated removers. Steel and polypropylene drums are used for industrial removers. Dry caustic removers are packaged in bag-lined boxes or fiber drums.

The DOT has established standards for the packaging and labeling of hazardous materials offered for shipment by public transportation. The Consumer Product Safety Commission (CPSC) has set standards for labeling and packaging retail products. Both OSHA and the EPA have labeling requirements. States, such as California, have adopted their own independent standards. Manufacturers should consult with regulatory agencies and/or trade associations before marketing finish removers.

4.4. Test Methods. Quality control in the production of organic solvent finish removers is best done by gas-liquid chromatography, which allows the manufacturer to determine the actual ratio of volatile solvent present in the finished product. If the product does not meet specifications, solvents can be added to bring the product to an acceptable composition. A less expensive approach is to use a hydrometer to determine the specific gravity of the product. The specific gravity indicates if the proper blend has been reached. Non-aqueous acid-base titration can be used to determine the amount of acid or alkaline activator present in a remover.

The solvent ratio of a semipaste remover may also be analyzed by gas-liquid chromatography by separating the solvents from the thickener. It is also useful to determine the viscosity and flow characteristics of the semipaste remover. A Brookfield viscometer is effective in determining the viscosity of most semipaste removers. Flow characteristics may be determined by a constantometer.

Economic Aspects. The demand for finish removers is increasing due to the profitability of recycling and refinishing durable goods. As the cost of new goods has steadily increased, many items that were previously disposed of are being recycled. The concern of lead poisoning from lead base paints has

created further demand for finish removers in the housing industry. Little data are available on the amounts of finish remover production.

There are ~51 paint remover manufacturers in the United States. Among them are companies that specialize in the manufacture of paint removers only, paint and coating manufacturers that produce a line of paint removers, specialty product manufacturers, and other manufacturers of finish removers for unique or special applications. Each group of paint remover manufacturers can be divided into retail or industrial products. A list of U.S. paint remover manufacturers is given in Table 7.

BIBLIOGRAPHY

"Paint Removers" in *ECT* 1st ed., Vol. 9, pp. 803–804, by B. N. Allnutt, Chemical Products Co., Inc., and J. R. Holland, Wiley & Co., Inc.; "Paint and Varnish Removers" in *ECT* 2nd ed., Vol. 14, pp. 485–493, by R. S. Downing, Sherwin-Williams Co.; in *ECT* 3rd ed., Vol. 16, pp. 762–768, by W. R. Mallarnee, The Sherwin-Williams Co.; "Paint and Finish Removers" in *ECT* 4th ed., Vol. 17, pp. 1069–1082, by D. L. White, Kwik Kleen Industrial Solvents, Inc., and J. A. Bardole, Vincennes University; "Paint and Finish Removers" in *ECT* (online), posting date: December 4, 2000, by D. L. White, Kwik Kleen Industrial Solvents, Inc., and J. A. Bardole, Vincennes University.

CITED PUBLICATIONS

1. G. A. Soderberg, *Finishing Technol.* **3** (1969).
2. *Industrial Users of Paint and Finish Removers*, Paint Remover Manufacturer's Association, 1992.
3. *Solvents Used in Paint Removers*, Paint Remover Manufacturer's Association, Sept. 1991.
4. Green Chemistry, <http://www.epa.gov/greenchemistry/>, accessed June 18, 2005.
5. Hercules Technical Information sheet, A report from the Coatings Service Laboratory, Solubility Parameter Maps of Hercules Film-Formers CSL-204A, Revised May 1984.
6. Part 7 Fractional Parameters, <http://sul-server-2.stanford.edu/byauth/burke/solpar/solpar7.html>, accessed May 26, 2005.
7. U.S. Pat. 4,120,810 (Oct. 17, 1978), D. A. Palmer.
8. U.S. Pat. 1,023,213 (Nov. 13, 1962) (to Omage Chemicals Corp.).
9. U.S. Pat. 4,645,617 (Feb. 24, 1987), T. A. Vivian (to Dow Chemical Co.).
10. *Dow Methylene Chloride—An Effective Solvent for Industry*, Dow Chemical Co., 1981, p. 3.
11. W. B. Gerritsen and C. H. Buschmann, *Br. J. Ind. Med.* **17**, 187 (1960).
12. *Chemical Protective Clothing for Furniture Stripping*, Department of Health and Human Services, Washington, D.C., Mar. 11, 1991.

13. *Exxate Solvents are Setting the Pace in Paint Strippers*, Exxon Chemicals, 1989, p. 3.
14. K. Claunch, *Solvent Recovery From Waste Solvents Containing Nitrocellulose*, Aug. 1, 1985.
15. *The Green Formulary Guide*, Paint Graffiti Removers section Vertec BioSolvents, Inc.

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Table 1. A Methylene Chloride Formula to Strip Wood

Ingredient	Wt%
methylene chloride	81.1
toluene	2.1
paraffin wax (ASTM 50–53°C mp)	1.6
methycellulose	1.2
methanol	7.8
mineral spirits	6.2

Table 2. A Typical Petroleum and Oxygenate Formula

Ingredient	Wt%
toluene	21
acetone	19
alkyl acetate	31
methyl ethyl ketone	19
butyl alcohol	10

Table 3. **A Typical *N*-Methylpyrrolidinone Formula**

Ingredient	Wt%
<i>N</i> -methylpyrrolidinone	27.5
ethoxylated alkylphenol	2.0
<i>N</i> -butanol	2.0
triethanolamine	4.0
dibasic ester	18.5
aromatic 100	18.0
cyclohexanone	17.0
xylene	8.0
masking agent	1.0
phosphate ester	1.0
thickener	1.0

Table 4. **Methylene Chloride-Free Paint Stripper^a**

Components	Percentage
ethyl lactate	27
DMSO	36
AR 150	33
<i>d</i> -limonene	2
Methocel OS	1
ethanolamine	0.5
Rhodasurf DA-630	0.5

^aCombine the first three ingredients with good stirring, and add the Methocel OS in small portions. Allow 15 min stirring for complete dispersion. Add the remaining ingredients with stirring.

Table 5. A Dibasic Ester Formula

Ingredient	Wt%
dibasic ester	40
<i>N</i> -methylpyrrolidinone	15
aromatic 150 solvent	35–38
monoethanolamine	2
potassium oleate	4
thickener	0.8–4

Table 6. **A Typical Alkaline Remover Formula**

Ingredient	Wt%
sodium hydroxide	87.0
sodium carbonate	6.0
sodium hydrogen phosphates	3.0
sodium gluconate	3.0
phosphate ester	0.5
pine oil	0.5

Table 7. Paint and Coating Remover Manufacturers

Company name	City	State
Abilene Research & Development Corp.	Mercer Island	Wash.
Alpha Processing Co	Clifton	N.J.
American Building Restoration	Franklin	Wiss.
American Finishing Resorces	Chilton	Wiss.
Amity Water Based Products	Waterloo	Wiss.
Benco Sales, Inc.	Crossville	Tenn.
Besway Chemical Systems	Madison	Tenn.
Bill's Paint & Lawn	Toledo	Ohio
Bix Manufacturing Co	Ashland City	Tenn.
Boshco Inc.	North Billereica	Mass.
Charles Paint Research Inc.	Kansas City	Mo.
Chemicals Solvents & Lubricant	Fort Wayne	Ind.
Chemisphere Corp	St Louis	Mo.
Chemix Corp	Glenwood	Ill.
Crest Industrial Chemicals	Houston	Tex.
Dumond Chemicals	New York	N.Y.
El Dorado Chemical Co	San Antonio	Tex.
Farwest Paint Mfg Co	Seattle	Wash.
Finisher's Supply Co	Houston	Tex.
Gemini Coatings Inc.	El Reno	Okla.
G & H & Assoc Inc.	Novi	Mich.
Gloss Flo Corporation	Brooklyn	N.Y.
Green Products Co	Richmond	Calif.
Grinco	Bethel	Comm.
Harford County Restoration	Joppa	Md.
Hood Product Inc.	Sumerset	N.J.
Industrial Finishing Prods Inc.	Brooklyn	N.Y.
Metal Cleaners Inc.	Lexington	Ky
Mid-America Chemical Corp	Cleveland	Ohio
Mohawk Finishing Product Inc.	Amsterdam	N.Y.
Nagel Technologies	Ramona	S.Dak.
National Sandblasting-Coating	Los Angeles	Calif.
Oakite Products Inc.	Romulus	Mich.
Old Masters	Orange City	Iowa
Paint & Lacquer Co	Englewood	Colo.
QRB Industries	Niles	Mich.
Quality Cabinet Doors Inc.	Kingman	Az.
Rap Products Inc.	Bay City	Mich.
Real Products Mfg	Ney	Ohio.
Reliable Finishing Products	Elk Grove Vlg	Ill.
Restoration Chemicals Inc.	Vincennes	Ind.
Savogran Co	Addison	Ill.
Savogran Co	Norwood	Mass.
Seagraves Coatings Corporation	Carlstadt	N.J.
Seymour of Sycamore	Manhattan	Ill.
Shannon Luminous Materials Inc.	Santa Ana	Calif.
Star Ten	Muskegon	Mich.
Strip Joint	Niles	Mich.
Sunnyside Corp	Wheeling	Ill.
Velvit Product Co	Appleton	Wiss.
Wm Barr & Co	Memphis	Tenn.

See Ref. 2.