Paint Stripping with Nontoxic Chemicals

by Harvey B. Hans,
McGean-Rohco Inc., Cee-Bee Division, Downey, Calif.

A number of products that do not contain chlorinated solvents or phenol have been developed to remove paint from aircraft. These products are now being used successfully to strip commercial and military aircraft. Acid-activated, near neutral pH, and alkaline-activated products are available. These products usually take longer to remove the paint; however, they have demonstrated the ability to remove the paint efficiently without extending the total time required to process the aircraft.

These new products greatly reduce exposure of workers and the environment to hazardous chemicals. This article presents data on relative strip rates and environmental impact.

INTRODUCTION

Over the last 5 to 10 years, there has been a big move in industry to reduce the use of hazardous chemicals. In the aerospace industry, one of the major uses of hazardous chemicals has been for the removal of paint from commercial and military aircraft. Paint removal is required periodically for aesthetic reasons (change of color scheme or to replace old paint) or, more importantly, for maintenance inspection. Through many years of experience, operators have developed efficient procedures to remove paint from aircraft with the use of chemical paint strippers. With the development of tougher and tougher paint systems to meet the increasing demands of the operators, more aggressive chemical paint strippers have been developed.

Having aggressive chemical products to do the job was good news for some people, but bad news for many others. The good news is the efficient performance of the products. The bad news is the varying degrees of hazards associated with them. Highly toxic materials, such as phenol, are often used in chemical paint strippers, but the key component has always been the primary solvent, methylene chloride. Because of its unique properties, it has been the backbone of chemical strippers for many years. It not only has the ability to penetrate paint films, but it is also nonflammable and suppresses the flammability of flammable cosolvents. A number of years ago, methylene chloride was found to cause cancer in some laboratory animals. Because of this, it was labeled as a suspect human carcinogen. Even though recent findings have led to the conclusion that this is not likely, methylene chloride still poses a significant health risk. It is one of the chemicals subject to reporting under Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA) and is considered a toxic organic material in water under the Federal Clean Water Act.

ELIMINATING METHYLENE CHLORIDE

Because of the unique properties of methylene chloride, as described above, it was believed for a long time that it was unlikely that satisfactory stripping action could be obtained from an application-type product that did not contain this solvent. Pressure to eliminate the use of methylene chloride continued to grow, with actions being taken by some governments in Europe to ban it, as well as a movement by OSHA in this country to severely reduce the allowable exposure level to workers. As the pressure increased, a number of efforts were initiated to find alternate methods for removing paint.

One of the first areas investigated was stripping aircraft by plastic media blasting (PMB). Up until that time media blasting had only been used to clean or strip parts. The Department of Defense (DOD) has been leading the research efforts in PMB, as well as in other areas of nonchemical methods, for removing paint. After considerable effort, the military has set up a number of facilities to strip with plastic media. Some use robotics and others use operator-held blast units.

Because the operators want to avoid the considerable expense of setting up for the use of nonchemical paint stripping methods, and because of their concerns about the mechanical damage to the aircraft, there is a strong desire to stay as close to their former operating procedures as possible and still meet environmental and safety requirements. Therefore, the pressure still exists to develop chemical-based products that will allow the airlines and the military to continue to use established procedures that have worked well for them for many years and which do not require large capital expenditures to get started.

NEW PRODUCTS

During the last few years, considerable progress has been made in the development of chemical strippers that are nontoxic, safe on the aircraft, and not harmful to the workers or the environment. Products are now available that are based on benzyl alcohol. This solvent has a very low vapor pressure, which greatly reduces air pollution, and because of its very low toxicity it does not create hazardous wastewater during use. These new products are neutral to mildly alkaline- or acid-activated. A uniquely activated benzyl alcohol-based product has been used by the U.S. military to strip the polysulfide basecoat paint system from a number of different types of aircraft for nearly 3 years. It has been found that the increased strip time of the benzyl alcohol-based product versus the methylene chloride-based product

Table I. Properties of Benzyl Alcohol-Based Products

Alkaline product:
- Nonhazardous
- Slightly alkaline
- Safe on all metals, including high-strength steel
- Excellent cling on vertical surfaces
- Remains active for extended periods of time, up to overnight
- Excellent rinsing properties
- Contains no water pollutants
- Will remove within 2 hours some standard polyurethane/epoxy polyamide paint systems and some more difficult systems with an extended dwell time
- Can be used to soften paint prior to water jet blasting

Polysulfide basecoat system remover:
- Contains no halogenated solvents
- Slightly alkaline
- Safe on all metals, including high-strength steel
- Contains a unique activator that rapidly digests the polysulfide basecoat, thereby removing the complete paint system

Acid activated:
- Contains no halogenated solvents
- Safe on all metals, except high-strength steel and magnesium
- Performance significantly better than standard alkaline products
- Shipped as a corrosive liquid because of the pH, but does not generate hazardous wastewater if pH is properly adjusted

Table II. Shipping Performance Relative to Methylene Chloride-Based Products

The test panel was coated with the standard epoxy/urethane paint system used by the Military (Mil-P-23377 Primer/Mil-C-83286 Topcoat). The panels were cured for 1 week at 150°F and aged for 1 year or more.

Alkaline:	
Methylene chloride	7–10 min.
Nonmethylene chloride	120–180 min.
Acid:	
Methylene chloride	2 min.
Nonmethylene chloride	105 min.

The polysulfide stripper was tested on a scrap part from a fighter aircraft coated with a polysulfide basecoat paint system (MIL-S-81733 Polysulfide Basecoat, MIL-P-23377 Polyamide Epoxy Primer, MIL-C-83286 Polyurethane Topcoat).

Methylene Chloride	approx. 20 min.
Nonmethylene Chloride	approx. 60 min.

it replaced is not significant in its overall operation. Products made with benzyl alcohol have also been successfully used to strip various types of commercial aircraft around the world.

See Tables I and II for the properties of three different types of these new products and for performance data that represent their stripping abilities as compared with equivalent products made with methylene chloride.

The performance data show that these products require significantly longer periods of times to strip than do the equivalent methylene chloride-based products. Crews are learning to use this extra time for other maintenance jobs when working with the alkaline-type products. This is possible because these products do not generate hazardous fumes and people can work in the area while the stripper is doing its job. In the shops where they do not work three shifts, the stripper can be applied and allowed to dwell overnight or until the next shift starts. This is possible because the low volatility of benzyl alcohol allows the products to remain active for extended periods of time.

Activity of the acid-activated and the polysulfide strippers is fast enough so that the crews can proceed as they had with the equivalent methylene chloride-based products.

IMPROVED PERFORMANCE PRODUCT

Recent development work has led to a new alkaline, nonmethylene chloride product that has significantly better performance than the earlier alkaline, benzyl alcohol products. Strip times have been reduced by over 50%. On some panels the paint was removed with the new product in a few hours, whereas the previous products available to the industry were not able to remove the paint even after overnight exposure. This new product has demonstrated the ability to strip some paint systems as fast as acid-activated benzyl alcohol products. Because this product is alkaline, it is completely safe on all metals, which means that it can be used in place of the less safe acid products. Field tests are planned in the near future to determine its potential.

NEW PAINT SYSTEMS

In Europe, a program has been underway for a number of years among the paint manufactures and the airlines to develop paint systems that are easier to strip so that less toxic chemicals can be used for their removal. A number of these paint systems have been introduced and some have been put on aircraft. They involve the use of a permanent primer, which will not be stripped when the topcoat is removed. By using an intermediate coat that can be easily attacked by the stripper, the paint systems are easier to remove. This approach has not had much acceptance in this country because it is believed that the permanent primer would hide corrosion or cracks, which need to be detected during inspections. At the request of British Airways, Boeing has agreed to apply one of these paint systems to several new planes that British Airways has ordered. Also, British Airways has started repainting some of their planes with this type of paint.

Performance tests conducted on a series of panels prepared by ICI in England using the new paint systems showed that the new benzyl alcohol-based products did quite well (see Table III). The mildly alkaline-type products have shown good results when tested on sections of a Concord that had been painted with one of the strippable intermediate coat paint systems.

METAL SURFACE CONDITIONS

Painted panels were received from Boeing for evaluation of the performance of the new products. These panels represented several paint systems being used by Boeing on factory parts. One of these paint systems is the same as the system that was reported to be on three 747s that were successfully

Table III. Strippable Coatings

Paint System:

These panels were prepared by ICI (now part of Courtaulds). The panels were oven cured for 24 hours at 70 °C at the time they were prepared, about 7 months prior to these tests. the paint system is as shown below using a permanent primer, an intermediate coating, and two different urethane topcoats.

Panel 4231:

Primer	F580–2080
Intermediate coating	F565–4010
Urethane Topcoat	4231

Panel 4232:
Same as 4231 except with 4232 urethane topcoat.

Performance Data:

Panel 4231:	Strip Time in Minutes	Strip time after 48 hr additional cure at 80°3
Alkaline:		
Methylene chloride	5	6
Nonmethylene chloride	60	75–95
Acid:		
Methylene chloride	2	2
Nonmethylene chloride	40	60–100
Panel 4232:		
Alkaline:		
Methylene chloride	1.5	
Nonmethylene chloride	45	
Acid:		
Methylene chloride	1	
Nonmethylene chloride	35	

Effect of Temperature:

Another set of tests was run on the ICI panels designed to determine the effect of temperature on the strip rate. The alkaline product was tested at 20 and 25°C. The results clearly show that the time required to strip was reduced by 30–60°C by increasing the temperature 5°C.

Time to Strip in Minutes:

Panel	*at 20°3*	*at 25°3*	*% Decrease*
4231	76–80	50–55	32
4232	44–55	15–20	62

stripped with the mildly benzyl alcohol-based product.

Before testing new strippers on these panels, a standard, methylene chloride-based stripper was used to determine how tough the panels were to strip. Because these were freshly prepared panels it was expected that they would be easy to strip. It was surprising to find that they were very difficult to strip even with the strongest methylene chloride-based products available. The panels had a darker than normal conversion coat on them. It was then noted that one panel apparently had not been conversion coated. This panel was stripped easily by the mildly alkaline, benzyl alcohol product.

This experience demonstrates how much the surface preparation of the base metal affects the adhesion of the paint. To evaluate these differences in a more controlled way, two panels were conversion coated in exactly the same manner except for the concentration of the conversion coat solution. Panel 1 was treated with the solution at 0.5 oz/gal and Panel 2 was treated with the solution at 1 oz/gal. The panels were immersed for 0.5 min each. They were then painted with a heavy coat of the standard military epoxy/urethane paint system and cured overnight at about 120°F and allowed to set for a week.

The panels were then stripped with an acid-activated benzyl alcohol-containing stripper. Most of the paint was removed from Panel 1 down to bare metal within 2 hr, whereas only about two-thirds of the topcoat and none of the basecoat were removed from Panel 2. There was a noticeable difference in the appearance of the base metal of the two panels. The color of Panel 1 was light iridescent and Panel 2 was light gold. It should be noted that the concentration differences used on these two panels do not even represent the normal range of concentration recommended for this product. It also should be noted that the color of Panel 1 is about the darkest observed on aircraft surfaces treated by spray application. This experience demonstrates that the strippability of paint is very dependent on the surface condition of the metal that the paint is applied to.

INTERNATIONAL AIR TRANSPORT ASSOCIATION/ INTERNATIONAL STANDARDIZATION ORGANIZATION DOCUMENT

During the 1980s, a task force of representatives from the aircraft operators within the International Air Transport Association (IATA) was established to address the problem of removing paint by safer and more environmentally friendly means. This task force has been working with paint manufacturers, stripper suppliers, and others to find less hazardous ways to remove paint from aircraft. One of the goals of this task force was to establish guidelines that could be used to determine if a paint stripping process is safe to use on aircraft. In January 1993, the IATA Task Force issued a document titled "IATA Guidelines for Evaluation of Aircraft Paint Stripping Materials and Processes." This document outlines requirements for evaluation of methods for removing organic finishes from commercial airplanes and deals with all methods of removing paint. The main goal is to assure safety to aircraft. This document is now being used as a guideline by International Standardization Organization (ISO) Technical Committee 20, Working Group 8 for the development of an ISO document. This work is being coordinated by the Society of Automotive Engineering (SAE) under draft no. AS4872.

VOLATILE ORGANIC COMPOUNDS

A number of issues have recently been raised regarding these new nontoxic paint strippers that should be addressed here. One issue is the volatile organic compound (VOC) content of benzyl alcohol-based products. Benzyl alcohol is a VOC when tested by the standard EPA test method. This method was developed to test paints for VOC content. When paints are dried or cured, it is expected that all of the solvents will either be lost to the air or tied up by reaction into the paint. The EPA test, in order to be sure it has detected all of the volatiles that must come off of paint as it cures, drives off all volatile matter by exposing a thin film of the product to a temperature of 105°C for 1 hr. When this method is used to determine the volatile content of paint strippers, the results do not in any way represent material that will volatilize under normal stripping conditions because of the low vapor pressure of benzyl alcohol. Tests conducted in our laboratory show that under normal stripping conditions, less than 20% of the solvent present in these strippers is lost to the air. When using the EPA method that was developed for paints, all of the solvent and even some materials that are normally considered as nonvolatile are driven off. The fact that the amount of material volatilized into the air is a factor of the vapor pressure, as well as the concentration, is recognized by the regulatory agencies. In order to demonstrate this we can look at how the South Coast Air Quality Management District (SCAQMD) regulates the use of strippers on aerospace equipment. This is covered in the Rule 1124. SCAQMD has the responsibility for the quality of the air in the Los Angeles area, which is considered by most people to have the strictest rules of any district in the country.

SCAQMD Rule 1124, Section (b) Requirements, (E) states: "A person shall not use stripper on aerospace components unless: (i) it contains less than 300 grams of VOC per liter of material; or (ii) the composite vapor pressure of the VOC is 9.5 mm Hg (0.18 psia) or less at 20°C (68°F).

VOC content of these new products ranges from 250 to over 900 g/L, but the composite vapor pressure of the solvent used is less than 0.5 mm at 20°C. From this it can be seen that these products easily comply with the requirements of SCAQMD Rule 1124.

Some problems have been encountered with other jurisdictional areas in the U.S. and throughout the world. In the state of Washington, for instance, the officials are mistakenly requiring a limit on the VOC content even if the vapor pressure of the solvents is below 9.5 mm. Also, in the San Francisco area, the Bay Area AQMD has an error in their rule that calls for a maximum vapor pressure of the product rather than the solvents used in the product if the VOC content exceeds the established limits. This is significant for some of the new products that contain a large amount of water. In San Francisco they have recognized their error and will correct it next time their rule is revised.

SAFETY TO SUBSTRATES

References are sometimes made to the corrosive nature of chemical strippers. It is well known in the industry that properly formulated and tested strippers are safe on aircraft, and years of experience support this. The industry has documents to assure that all products to be used on the aircraft are safe. Test reports show that the mildly alkaline benzyl alcohol-based products are totally safe on all metals used on aircraft. Recent tests also show that both alkaline- and acid-activated benzyl alcohol-based products may be safe for use on composite materials.

LOWER USE REQUIREMENTS

Field experience with these new products indicates that the usage level is generally lower than what has been experienced with the standard methylene chloride-based products. This is probably because of the low volatility of these products compared with the methylene chloride-based products. The products do not need to be reapplied as many times to get the job done.

TOXICITY

The toxicity of benzyl alcohol, the primary solvent in these new products, is very low, as evidenced by the fact that it is used in cosmetics and flavorings. It does not appear on any lists of hazardous or regulated materials. It has a flash point above 200°F and a boiling point of 392°F. It has been safely used for many years.

SUMMARY

New chemical strippers that have low toxicity and that pose no serious threat to the environment are now available for use in place of methylene chloride-based strippers. These products have successfully stripped a large number of aircraft and their use will continue to increase. As expected, these products usually take longer to remove paint than the equivalent methylene chloride-based products, but the difference is acceptable in most cases. They have low toxicity; therefore, it is not always necessary to totally evacuate the area being used for stripping. Some work that would have to be postponed until after the stripping was completed, if methylene chloride-based products were used, can now be done while the stripper is doing its job. In some cases, the stripper can be applied and allowed to dwell for a number of hours, or overnight, while the crew is busy with other tasks or has gone home. Recent developments indicate that even better performance is possible than what has been observed in the field so far.

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