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NAVAL AIR WARFARE CENTER, AIRCRAFT DIVISION at Warminster ENVIRONMENTAL MATERIALS PROGRAM — PHASE I

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With the recent increase in awareness about the environment, there is an expanding concern of the deleterious effects of current materials and processes. Federal, state and local environmental agencies such as the EPA, State Air Resource Boards and local Air Quality Management Districts (AQMD) have issued legislation that restrict or prohibit the use and disposal of hazardous materials. National and local laws like the Clean Air and Clean Water Acts, Resource Conservation and Recovery Act, and AQMD regulations are examples of rules that govern the handling and disposal of hazardous materials and waste. The Department of Defense (DoD), in support of this effort, has identified the major generators of hazardous materials and hazardous waste to be maintenance depots and operations, particularly cleaning, pretreating, plating, painting and paint removal processes. Reductions of waste in these areas has been targeted as a primary goal in the DOD. The Navy is committed to significantly reducing its current hazardous waste generation and is working to attain a near zero discharge of hazardous waste by the year 2000. In order to attain these goals, the Naval Air Warfare Center Aircraft Division at Warminster has organized and is carrying out a comprehensive program in cooperation with the Naval Air Systems Command, the Air Force and the Department of Energy that deal with the elimination or reduction of hazardous materials. These programs cover a wide range of technology areas including inorganic pretreatments and plating processes, organic protective coatings, operational chemicals, adhesive bond materials and processes, and paint removal processes. A description of these current efforts is provided.

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INTRODUCTION

In recent years, there has been a significant increase in world concern about the state of the environment. Some people have termed the 90's as the "Environmental Decade". International meetings (i.e. Montreal Protocol, Rio de Janeiro Conference, etc) have resulted in an increased awareness of the effects of current materials and processes on the environment. In the United States, federal and local Environmental Protection Agencies (EPA) and state/local environmental agencies like California's Air Resource Board (CARB) and Air Quality Management Districts (AQMD) have issued legislation that governs the handling, use and disposal of hazardous materials and waste as well as the emissions from their use. The Clean Air Act, Clean Water Act, Resource Conservation and Recovery Act, local EPA and AQMD rules are all regulations that limit or prohibit the use and/or disposal of hazardous materials and more stringent regulations are constantly being considered and initiated.

The Department of Defense has determined that the majority of hazardous materials and hazardous waste generated by the DOD comes from its maintenance depots and operations (Ref 1). The bulk of these hazardous compounds are associated with cleaning, pretreating, plating, painting and paint removal processes. The Department of Defense has made a commitment to reduce the amounts of these materials generated through the Defense Environmental Restoration Account (DERA) and Pollution Abatement (PA) programs, as well as other programs. In particular, the Navy is committed to significantly reducing its current hazardous waste generation and is working to attain a near zero discharge of hazardous waste by the year 2000. These goals along with recently enacted laws will no longer allow for "business as usual." Some Navy facilities are facing the imposition of heavy fines or even shut down of their maintenance operations if compliant alternatives are not found.

Three approaches are being taken to attain these environmental goals. The first approach is to eliminate the source of the hazardous material which can be accomplished by material substitution, material reformulation or by the use of alternative technologies which provide the same overall properties. The second approach is to minimize the use of the hazardous material. This can be attained by using only appropriate materials and quantities needed for the specific use or by improving the material's performance so that less of it can be used. Finally, where elimination is not possible, reduce the hazardous emissions from the material by incorporating tighter process controls or by treatment of the process waste to a non-hazardous form.

The Naval Air Warfare Center Aircraft Division at Warminster (NAVAIRWARCENACDIVWAR) has a number of on-going efforts that deal with the elimination or reduction of hazardous materials used in aerospace processes. These programs include a variety of research, development, test and evaluation (RDT&E) projects, participation in a reverse engineering program, joint efforts with other DOD and industry facilities and active participation in technical societies and environmental working groups. The RDT&E programs cover a wide range of technology areas from inorganic pretreatments and surface preparation processes to organic protective coatings and materials to operational chemicals. These programs are aimed at solving both near and long term environmental problems at all levels of fleet operation (depot, intermediate and organizational). The primary hazardous materials being addressed by these efforts are chromium VI, high volatile organic compounds (VOC) contents, chlorofluorocarbons (CFC) and toxic heavy metals. The following is a brief synopsis of the present programs.

CHROMIUM VI ELIMINATION EFFORTS

PRETREATMENT AND PLATING PROCESSES

In the pretreatment and plating processes efforts, the primary goal is the elimination of chromates, cadmium and cyanides. These toxic materials have been traditionally used because of their outstanding performance properties. Chromates, for example, have long been known to be excellent corrosion inhibitors for aluminum. This property is particularly important to the Navy due to the extensive use of aluminum in naval aircraft and aerospace systems and the severe corrosive environment in which these systems operate. chromium VI has been used widely in aerospace inorganic pretreatment processes and materials such as alkaline cleaners, deoxidizers, conversion coatings, anodize films and plating processes. Although chromium VI is a known carcinogen, its use has continued, because there was not an adequate replacement available. Recently, regulatory agencies have enacted rules which makes this practice no longer acceptable, thereby requiring alternative materials to be developed.

Proper surface preparation is an important step in the protective treatment of aluminum and is performed using materials such as alkaline cleaners, etchants and deoxidizers. These materials remove organic contamination along with the existing surface oxide layer of the aluminum to prepare it for future chemical pretreatments. While current chromated materials used in these operations perform satisfactorily, they need to be replaced with non-chromated alternatives.

Alkaline cleaners remove surface contamination and consist of soluble salts with an alkalinity between pH 9 and pH 11. Aluminum, however, is easily attacked by alkaline solutions, requiring inhibitors to protect the Al against degradation. Traditionally, chromates are incorporated for this purpose. In addition, alkaline cleaners can be formulated as etching or non-etching by the addition of sodium hydroxide and sodium salts (i.e. carbonates, phosphates, silicates). The etching rate can be controlled by the addition of silicate inhibitors. However, these silicated cleaners leave silicate residues on the surface which can result in problems in subsequent pretreating steps. Therefore, non-silicated, non-chromated alternatives were investigated (Ref 2). Several viable alternative cleaners identified from laboratory testing were recommended for fleet use and are currently being implemented at several Navy facilities.

Deoxidizers are used to remove any remaining surface oxides prior to chemical treating. These solutions contain chromic acid along with some other acid (usually phosphoric or sulfuric). Although most of the non-chromated alternatives are less active than the chrome materials, higher temperature is used to decrease their processing time. Several materials from the lab study have been incorporated into fleet use (Ref 2). All of the non-chromated alternatives evaluated in this program were coordinated with investigations being conducted through the Aerospace Chromium VI Elimination (ACE) Team. Most of the promising substitutes identified in this effort were suitable for direct substitution into existing procedures.

Inorganic coatings are used as surface pretreatments for aircraft substrates because of their enhancement of the overall protective finishing system. These protective pretreatments are called out for virtually every weapon system, platform and support equipment used by the Navy and are specified by MIL-S-5002 "Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapon Systems." Chromate conversion coatings (CCC) produced in accordance with MIL-C-5541 using materials conforming to MIL-C-81706 are excellent surface pretreatments for aluminum alloys. These materials form a surface oxide film which enhances the overall adhesion and corrosion prevention properties of subsequent protective finishing coatings applied over them. These conversion coatings have been an essential part of the Navy protective finishing system for several decades. However, with recent restrictions imposed by environmental agencies, alternative pretreatments need to be developed.

The non-chromate aluminum pretreatment development effort investigated candidate raw materials as well as numerous proprietary non-chromated surface preparation and pretreatment materials to replace the current chromated materials. The proprietary products were identified from an extensive industry survey and the raw materials included such ingredients as inorganic molybdates, nitrates, phosphates and polymeric treatments. In addition, new alternative non-chromate adhesion promotion pretreatment technologies were investigated as replacements for existing materials and processes. These experimental materials were evaluated on common aluminum alloys and with standard Navy coating systems. Physical performance tests (i.e. corrosion resistance, adhesion, etc.) and electrochemical impedance spectroscopy (EIS) were used to analyze pretreatment performance. The adhesion promotion systems offered practical solutions to this problem since they did not contain heavy metals and most were water based materials. However, their performance in a marine environment significantly deteriorated to an unacceptable level. This water disbondment phenomenon was documented in a previous research effort at NAVAIRWARCENACDIVWAR (Ref 3). Most of the non-chromate conversion coating candidates suffered from either poor adhesion or poor corrosion resistance. Of these, only a proprietary multi-stage bath process from Sanchem Inc. showed promise as a viable replacement to the CCC.

The Sanchem's Safegard CC non-chromate conversion coating process attains the final surface film from an alkaline pathway using a multi-stage process. The new process uses cleaning and deoxidizing steps similar to the current conversion coating, except that all of these materials are non-chromated. In addition, the alkaline cleaner is non-silicated. This differs from traditional conversion coatings, which are based on chromic acid and form the protective film in a single stage process. Furthermore, the Sanchem process is a multi-tank process operated at elevated temperatures. Therefore, additional heated tanks would be required for production line implementation. The waste stream from this process, however, would be void of any chromium and would not have to be treated as hazardous. Full scale laboratory testing has been completed on this process. Joint test programs with the Army Materials Technology Lab, Watertown MA and many industry personnel (Aerospace Chromium Elimination Team members) were initiated from this effort and these process evaluations also show promising results. Based on the laboratory program, a pilot scale Sanchem process line is scheduled to be set up at the National Defense Center of Environmental Excellence to demonstrate the process's capabilities to produce a non-chromate surface pretreatment for aluminum.

Finally, the current chromate conversion coating process can be applied by either immersion or spray application. However, this new pretreatment is a multi-staged, elevated temperature immersion process and is not directly applicable for aircraft skins. Efforts to modify the process for spray application are in progress. Incorporating steam cleaning technology to provide the necessary process parameters has shown some preliminary success and is being pursued further.

Anodized films are another aluminum surface pretreatment currently used on Navy aircraft, weapon platforms and ground support equipment. These anodize processes form a thicker oxide film which provide more protection against degradation than conversion coatings. MIL-A-8625E "Anodic Coatings, for Aluminum and Al Alloys" covers the performance requirements for these kinds of films. Type I of this military specification covers chromic acid anodizing (CAA) which is presently used in production and depot level maintenance operations. Two potential alternatives have been identified: Boeing Aerospace Corp's Boric Sulfuric Acid Anodize (SBAA) and thin film sulfuric acid anodizing (Refs 4 - 6). After analysis of existing test data, the Boeing SBAA process was selected for optimization. An evaluation program was developed to demonstrate this alternative technology as a replacement for CAA.

A lab scale sulfuric/boric acid anodize process line has been set up at NAVAIRWARCENACDIVWAR. This line is being used to compare the performance properties of sulfuric/boric acid anodizing to those of phosphoric acid anodizing, chromic acid anodizing and regular sulfuric acid anodizing processes. The performance properties on various substrates are being evaluated both sealed and unsealed. In addition, these films are being examined as a base for standard Navy coatings. Finally, the fatigue characteristics of these oxides will be characterized to determine any detrimental effects. Specific details of anodizing processes can be found in Reference 7.

A 3,200 gallon production scale SBAA line has been installed at the North Island Naval Aviation Depot in San Diego, CA. This facility will be used to process selected components for evaluation and optimization of the SBAA process. These results will be used to determine the effectiveness of this non-chrome alternative to provide on a prototype level, equivalent corrosion resistance and paint adhesion while maintaining the existing mechanical properties provided by chromic acid anodizing. Upon successful demonstration, this alternative material will be transitioned to full fleet use through specification modification and design changes.

Elimination of chromic acid anodizing will significantly reduce the total amount of chromium emitted from Navy operations and is in direct support of Navy and DOD hazardous waste minimization policies and directives. In addition, the need for expensive control equipment required by AQMD laws effective in 1994 would be eliminated resulting in significant cost avoidance. Control equipment for the six Navy Depots is estimated at $4.5-6M for capitol costs and $2.5-4M for annual operating costs. Furthermore, an adequate replacement would provide protection against excessive environmental degradation which could curtail aircraft operational readiness. This is particularly important considering the severe environment in which the Navy operates as well as the cost of the aircraft, weapon systems and ground support equipment. Finally, this technology could be transitioned to many commercial industries such as airlines, automotive, equipment manufacturers, etc.

Potential alternatives to chrome plating are currently being handled through coordination with the Aerospace Chrome Elimination Team efforts as well as other industry and government programs, although, future in-house projects in this area are planned.

ADHESIVES AND SEALANTS

Adhesives are another area where chromates are used heavily. Adhesive bond pretreatments like Passajel 107, the FPL etch and chromic acid anodizing all rely on the performance properties of chromates. Alkaline peroxide and phosphoric acid anodizing alternatives to these processes have been studied in laboratory programs and found to be acceptable. Current laboratory efforts include the evaluation of sulfuric/boric acid anodizing (SBAA) as well as the P-2 non-chrome etch process. The SBAA effort will evaluate the performance of this process as a pretreatment for F-14 honeycomb structures. Adhesive bond primers also incorporate chromates as corrosion inhibitors, however, no acceptable non-chromated versions of these materials have been identified.

Similar to adhesives, MIL-S-81733 sealants also use chromates as corrosion inhibitors. To date, there is only one non-chromate sealant being investigated (Products Research Corp's #1775). This material is based on a polythioether resin as apposed to the traditional polysulfide resins. Therefore, all performance characteristics of this material are being carefully evaluated.

ORGANIC COATINGS

The primary defense against environmental degradation is the organic coating system. High performance coatings are essential to the overall operational readiness of Navy aircraft. The environmental efforts in organic coatings can be described by two main thrusts: the development of non-toxic inhibited coatings and the development of low volatile organic compound (VOC) content coatings. The development of non-toxic inhibited coatings is concerned with eliminating the lead and chromate pigments used in the Navy protective primer coatings and low IR field green topcoats. The efforts in low VOC are aimed at reducing the volatile organic compound (VOC) content of Navy coatings to meet environmental regulations, specifically California's AQMD rules.

Recently, a material was developed that addresses both of these issues. The coating is called Unicoat and is a self-priming topcoat. This material combines the properties of both the standard Navy primer and topcoat into one coating, thereby eliminating one painting application step. In addition, Unicoat is lead and chromate free and meets the AQMD 420 grams per liter VOC limit for self-priming topcoats. This coating led to the development of a federal specification (TT-P-2756). This specification has been released and two sources have been qualified under it. The development of this material has been documented in a number of sources and will not be discussed here (Ref. 8 - 11). In addition, this technology is currently being applied to a number of other coatings problems such as non-chromate coatings for ground support equipment, non-chromate coatings for space shuttle applications, etc (Ref. 12).

Other on-going efforts in this area include the development of non-toxic inhibitor systems for use in standard Navy corrosion inhibiting primers and coatings and the development of non-toxic inhibited, low VOC touch-up coatings. These materials are based on phosphate, molybdate and zinc compounds which have shown promise as replacements for chromates. Laboratory testing is being completed on these materials and the optimum candidates are scheduled for service evaluation in the near future.

VOLATILE ORGANIC COMPOUND REDUCTION

ORGANIC COATINGS

The efforts in the development of low volatile organic compound (VOC) content coatings are aimed at reducing the VOC content of Navy coatings to meet environmental regulations like the California AQMD rules. Low VOC versions of the standard Navy primers and topcoats have already been developed using water-borne and high solids technology and have been transitioned to fleet use through specification modifications. The following is a list of these specifications and their VOC contents:

	Specification	Classification (Type)	VOC Content
PRIMERS:	MIL-P-23377F	Class 2: High Solids	340 g/l
		Class 3: Exempt Solvent	
	MIL-P-85582A	Water-Borne	340 g/l
	TT-P-2760	Class 2: High Solids	350 g/l
		Class 3: Exempt Solvent	

	Specification	Classification (Type)	VOC Content
TOPCOATS:	MIL-C-22750E	Type I: High Solids	340 g/l
		Type II: Exempt Solvent	
	MIL-C-85285B	Type I: High Solids	420 g/l
		Type II: High Solids	340 g/l

In addition, new materials have been developed that address this issue. Unicoat - self-priming topcoat, discussed earlier, is a lead and chromate free material which meets the AQMD 420 grams per liter VOC limit developed specifically for self-priming topcoats. A water-borne primer (MIL-P-85582) developed in the late seventies also offers a VOC compliant alternative to the standard primer as described in reference 13. Other on-going efforts in this area include the development of: low VOC versions of Navy specialty coatings, non-toxic inhibited, low VOC touch-up coatings and water-based corrosion preventive compounds. Finally, up-coming efforts in organic coatings will address zero-discharge coatings such as powder coatings, radiation curable coatings and electrocoatings to address future VOC regulations.

PAINT APPLICATION EQUIPMENT

With the development and transition of these new coatings it became apparent that conventional air spray application equipment would no longer be adequate for applying these materials. Conventional air spray equipment has a transfer efficiency of approximately 28%. California's AQMDs have begun to impose transfer efficiency regulations which require minimums of 60% to 85% and maximum gun tip air pressures of 10 psi. A number of alternative technologies have been developed to address this need. Airless, air-assisted airless, electrostatic, and high-volume low-pressure (HVLP) spray application techniques all have improved transfer efficiencies over conventional air spray. Each technique has its own unique capabilities and limitations. Furthermore, some of these methods can be used in combination (i.e. air-assisted airless with electrostatic) to yield even higher efficiencies. These application techniques are currently being investigated.

ADHESIVES AND SEALANTS

The VOC content of adhesive bond primers as well as the adhesives themselves is another concern. Current efforts are aimed at water-borne adhesive primers for both 250°F and 350°F curing structural adhesives. Initial laboratory testing of 250°F water based adhesives show promise in both corrosion resistance and stress durability tests. These materials are being investigated further. To date, however, there have not been any 350°F cure adhesives that show potential. Low VOC sealants is another area where compliant materials have yet to be developed or identified. These materials will be addressed as they are developed.

CLEANERS AND SOLVENTS

Present cleaning procedures use a large quantity of organic solvents. The volatile emissions from these materials have begun to be regulated and several efforts have been initiated to meet these new rules. Low vapor pressure and low VOC cleaners are being investigated as alternatives to methyl ethyl ketone used in pre-paint wipe down of aircraft surfaces. Water-based biodegradable turbine engine cleaners have been developed to replace the current solvent based gas path cleaners used on aircraft engines. Water-based engine cleaners are not only environmentally compliant, eliminating the need for engine cleaner equipment permits, they also have the potential for reductions in maintenance time. When used to clean fired engines (a process not yet approved by engine manufacturers or Navy engine CFA's), these cleaners have the potential for saving significant man-hours: 1) no engine cooldown would be required; 2) no dilution would be needed since the products are available in ready for use form; 3) no rinsing is required; and 4) cold weather cleaning (< 40°F) is vastly simplified.

Another cleaner area to be addressed is the replacement of vapor degreasing with processes such as aqueous degreasing. 1,1,1-Trichloroethane (TCA) used for vapor degreasing is scheduled for phase out over the next decade and quantities are being limited. Resulting costs of processing will skyrocket over the next few years. Water-based cleaners combined with cleaning techniques, such as ultrasonics, offer potential alternatives to this material. Finally, a soil resistant treatment for aircraft finishing systems has been developed that renders the surface more cleanable. This will help to reduce the amount of cleaning required and thereby reduce the amount of hazardous waste generated from cleaning procedures. In addition, the improved appearance of the aircraft will minimize cosmetic repainting, thereby reducing VOC emissions even more.

CHLOROFLUOROCARBON (CFC) REDUCTIONS

Ozone depleting chemicals, such as chlorinated solvents and chlorofluorocarbons (CFC's) have been used for many years as non-flammable, fast-evaporating, effective cleaning solvents for avionics, electrical components, hydraulic and oxygen system components, bearings and precision parts, and other miscellaneous applications. Amendments to the Montreal Protocol and Clean Air Act established a schedule for gradual phaseout of CFC's by 2000 and 1,1,1-trichloroethane (TCA) by 2002. The identification, development, testing and evaluation of alternatives for replacement of these materials is vital to the continuation of aircraft maintenance operations at all levels.

Cleaning of avionic equipment is a major role of CFC's. During the manufacturing of avionic components, CFC-113 is used for vapor degreasing metal surfaces to insure cleanliness prior to plating and soldering and to remove solder flux residues. In maintenance, diagnosis and repair of avionics, CFC's are also used as component cleaning solvents, lubricant carrier solvents, freezing compounds and water displacing agents following aqueous degreasing. Precision instrument bearings and aircraft and engine bearings rely on CFC-113 and TCA for vapor and liquid degreasing and water displacement. Oxygen systems use CFC-113 to flush clean tubing, valves, fittings and converters. For hydraulic fluid contamination testing, CFC-113 is use to wash contaminated filters for comparisons with standards. TCA is used to clean areas suspected of cracks prior to non-destructive inspection (NDI) tests. CFC's are still found in some self-pressurized spray cans as aerosol propellants. Hydraulic and fuel systems components are cleaned with CFC-113 or TCA. Leak detection tests on various systems are performed using CFC-113 as the test fluid and a halogen leak detector. In addition, CFC-113 and TCA are sometimes used as cleaners prior to adhesive bonding, plating and painting where non-residue, fast drying solvents are required. Finally, CFC are used in fire fighting equipment (specifically Halon 1301 & 1211) and as refrigerants. Non-chlorinated cleaners and solvent, non-halogenated fire suppressants, alternative non-CFC refrigerants and refrigerant recovery equipment are all being investigated for the replacement of the CFC materials currently being used.

Six teams were established by the Naval Air Systems Command to identify and implement substitutes for CFC solvents. NAVAIRWARCENACDIVWAR is responsible for avionics applications and specification development. Lead activities for other applications are as follows: bearings cleaning is being handled by the Naval Aviation Depot (NADEP) at North Island; oxygen systems by NAVAIRWARCENACDIVLAK; hydraulic fluid contamination testing by NADEP Norfolk; and NDI applications by NADEP Cherry Point. Each ozone depleting solvent application will be addressed using the same general approach: process identification; description of the performance requirements of the material; identification of supplemental requirements (such as safety and health, material compatibility, and stability); candidate selection or development; performance testing and evaluation (T&E); supplemental T&E; process development and evaluation; and process validation. In some cases, test programs will be coordinated with original equipment manufacturers to facilitate the qualification process. Finally, NAVAIRWARCENACDIVWAR is a participant in joint programs established by the Naval Air Systems Command to handled non-CFC fire fighting and refrigerant alternatives.

OTHER HAZARDOUS WASTE MINIMIZATION EFFORTS

PRETREATMENT AND PLATING PROCESSES

Traditionally in the electroplating area, cyanide has been incorporated into the different electroplating baths to enhance the process. However, due to the hazardous nature of this compound, it is necessary to eliminate it from current electroplating baths. Elimination of cyanide from cadmium process baths has been accomplished by the development of a near neutral pH, non-cyanide cadmium electroplating bath. In addition, the development of a triple rinse counterflow scheme aids in the metal recovery process and significantly decreases the waste water generated from electroplating processes. This rinsing scheme is being demonstrated at the Philadelphia Shipyard and the North Island Shipyard. Alternatives to cadmium plating are being initiated. Aluminum-manganese plating from a molten salt bath and ion vapor deposition (IVD) of aluminum are new efforts undertaken These efforts be coordinated with industry programs.

COMPOSITES

High temperature organic matrix composites used in Navy aircraft applications rely on methylene dianaline as a curing agent. This material is a multiple threat being a carcinogen and a mutagen. Alternatives to this material are being investigated.

ALTERNATIVE PAINT REMOVAL TECHNOLOGY

The protective finishing system on Navy aircraft is completely removed when the aircraft is sent in for reworking at an aviation depot. This process occurs approximately every 3 to 6 years. Traditionally, chemical paint strippers made up of methylene chloride, phenols, chromates and other hazardous materials are used to remove the paint system. This results in the generation of large quantities of hazardous waste. To address this problem, both non-hazardous chemical paint strippers as well as alternative mechanical paint removal methods are being investigated.

Non-hazardous chemical paint strippers based on non-chromated, non-methylene chloride formulations have been evaluated. In general, these materials require longer stripping times. In some cases, they have shown coating specific trends where they strip one type of coating but not another (i.e. epoxy vs. polyurethane). Acidic water-based paint removers have been evaluated and although stripping rates are in the practical range, the effects of the removers on high strength steel (hydrogen embrittlement) and magnesium (severe corrosion) are too important to allow their use. Although free of corrosion problems, current alkaline water-based removers are extremely slow in removing coatings but appear promising. MIL-R-81294 chemical paint stripper specification has already been modified with a non-chromate type.

Alternative mechanical paint removal methods under investigation include plastic media blasting (PMB), carbon dioxide pellet blasting, flash lamp, bicarbonate of soda stripping, wheat starch blasting, high pressure water jet blasting and combinations of these technologies. Substrate effects, particularly on thin aircraft skins, are of primary concern in this program since these blasting techniques can potentially cause surface damage which in turn can cause catastrophic structural failure. In addition, stripping rates, waste generation, capitol equipment costs and operating costs all play a part of this evaluation.

REVERSE ENGINEERING PROGRAM

The Naval Air Warfare Center Aircraft Division at Warminster is a participant in a NAVAIR sponsored reverse engineering program designed to address immediate or short term reduction of hazardous materials and waste at fleet intermediate and organizational levels. To accomplish this task, a team of scientists, engineers and experienced maintenance personnel survey the work sites to determine where existing reduction methods can be immediately implemented. This quick fix type of hazardous material reduction incorporates materials substitution, alternative techniques, recycling, usable life extension and general good housekeeping practices.

The following are several examples of the short term solutions from this program. The implementation of spray bottles and bulk material quantities to eliminate the use of aerosol cans for cleaning compounds and lubricants which are used extensively. These pump action, heavy duty bottles replace the need for aerosol propellants like chlorofluorocarbons and from the lab evaluation, have been demonstrated to be effective at dispensing these types of materials. In addition, brush and roller application of touch-up coatings significantly reduces the amount of excessive spray painting currently being performed. Another example is the use of a recycling pump which extracts the remaining gallons of hydraulic fluid from the bottom of the container. This material was previously just discarded as hazardous waste.

Finally, changes in the issued quantities of low usage hazardous items such as trichlorotrifluoroethane (CFC-113). CFC-113 is an excellent fast acting cleaner that leaves no residue on the surface. Despite its performance, the ozone depleting effects of this solvent has resulted in its limited authorization for only a few specific applications. However, excellent performance, ease of application and because it is readily available (issued in 55 gallon drums), have all lead to the excessive use of CFC-113 for many operations. Therefore, changes in the stocking system to allow for only small quantity issuance of this material greatly reduces its unauthorized use.

Upon successful demonstration at organizational and intermediate level facilities of these reduction methods, the new materials and processes are transitioned to fleet wide use through the development or modification of specifications, revision of maintenance manuals and by changing aircraft and system design plans. In many cases, the efforts of this program and general good housekeeping practices have resulted in reductions of 25 to 35 percent in hazardous material consumption and hazardous waste generation.

SUMMARY

All of these programs have lead to the development of non-hazardous or less hazardous materials, processes and equipment for current aerospace maintenance and manufacturing. Many of these materials and processes have been successfully demonstrated at naval aviation depots, intermediate maintenance depots and organizational maintenance levels through cooperation with the Naval Air Systems Command (NAVAIR) and the Lead Maintenance Technology Center for the Environment (LMTCE). Transitioning and full implementation of the materials and processes for fleet maintenance operations use is being accomplished in conjunction with NAVAIR and the LMTCE through the development or modification of military specifications, revision of maintenance manuals and by changing aircraft and system design plans. The use of these new maintenance materials and processes allows the Navy to meet stringent environmental standards while maintaining operational readiness and efficiency of system performance. In addition, significant cost savings are being recognized by the implementation of these environmentally compliant materials.

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