DOD REPORT

PAINT STRIPPING METHODS

29 Sept 1997

Joint Service Report

Robert L. Tipton, Col, USAF
Director, Aging Aircraft and Systems Ofc
Subsystems Product Support Group

EXECUTIVE SUMMARY

House-Senate Conference Committee directed the Department of Defense to perform a comprehensive evaluation on the cost effectiveness of mechanical methods of paint stripping aircraft compared to recently developed chemical methods drawing on the expertise of all experienced parties in the DoD. The DoD designated the Air Force's Aging Aircraft & Systems Office to lead the joint Service effort.

This study includes all the DoD depot airframe paint stripping activities from Feb 97 through June 97. The multi-service team developed this report based on independent studies and inputs provided by the Air Force, Army and Navy (representing the Navy and the Marine Corps). This report presents the strategies and operating mode of each military Service; identifies the paint stripping technologies available and their use (by installation and aircraft); and, addresses the comparison factors related to environmental compliance, operating cost, capital investment, and performance that influence implementation decisions.

This study highlights that the DoD is continually looking for improved methods to strip paint from aircraft. Various weapon system parameters such as substrate material, varied coating materials, and past investment decisions dictate more than one paint removal system. The report shows the Air Force uses six methods to strip paint from aircraft, the Navy uses four, and the Army uses five methods. As part of the study, the DoD surveyed the commercial aircraft industry to determine their paint removal methods and strategies. It was found that installations and weapon system managers give consideration to all of the possible alternatives in their efforts to reduce the health risks, potential environmental hazards and costs associated with their depainting operations. Finally, this report shows the DoD performs cost studies and incorporates the results in the decision process. Even though specific costs may be competition sensitive, there was sufficient data to support the study's conclusions. Ultimately, each weapon system manager is responsible for considering all relevant factors when selecting a paint stripping method.

The decision process to select a paint stripping method considers many complex issues including method effectiveness, cost, OSHA and environmental factors. The decision processes used throughout the DoD for aircraft paint stripping are thorough and complete. The current selection processes have been effective for many years and will continue to remain effective in the future.

DoD PAINT STRIPPING REPORT

I. OBJECTIVE AND TASKING

1. Senate Appropriations Report 104-286 expressed concerns about the cost effectiveness of mechanical methods of paint stripping compared to recently developed chemical methods. Congress directed the Department of Defense to perform a comprehensive evaluation of the issue and to draw upon the expertise of all experienced parties in DoD.

2. The House-Senate Conference Committee provided specific directions to the Secretary of Defense and the Deputy Under Secretary of Defense for Environmental Security (Attachment 1). Subsequently, the Air Force's Aging Aircraft & Systems Office was designated to lead the joint Service effort.

II. INTRODUCTION

1. This report encompasses the strategies and operating mode of each military Service; identifies the paint stripping technologies available and their use (by installation and aircraft); and addresses the comparison factors related to environmental compliance, operating cost, capital investment, and performance that influence implementation decisions.

2. DoD representatives held a meeting at Eglin AFB FL, on 14 Mar 97 to discuss the report and plan the development. Attachment 2 is information on the evaluation planning and activities related to the development of the report (i.e. meeting minutes, with attendees lists identifying team members, progress report to the Pollution Prevention Committee, and data call).

3. It was known going into this evaluation that since the early 1980's the aerospace industry, supportive of the necessity to protect the environment, has been requesting proposals for paint removal methods that are less hazardous and more environmentally friendly than the chemical strippers in use. Then, in 1986, methylene chloride (MC) was added to the National Toxic Products list of chemicals that were suspected of causing cancer. As a result, complying with the regulations on personnel safety and disposal of waste containing MC became very difficult and expensive. Initially less hazardous chemicals were the desired replacement for the MC products, but these were not available. Since that time, facilities and equipment have been built and or modified to use non-chemical depainting techniques so the preference for a drop-in replacement for MC is less clear.

4. More recently, chemical companies have been developing environmentally acceptable products to replace chlorinated solvents, phosphate cleaners, and other hazardous chemicals with reformulated compounds containing no known carcinogens. Alternative paint strippers incorporating solvents, N-methyl pyrrolidone, alcohol, di-esters, and others have also been in development. However, the performance of approved environmentally compliant chemicals has not been good, and qualification requirements for new products are stringent. The paint stripping rate criteria in the performance specifications are tight because they are based on the performance of methylene chloride and have been the basis for sizing depainting facilities. The performance decrement a given operation can accept is a complex issue that is being examined in the process of establishing more realistic performance criteria for paint stripping chemicals.

III. PAINT STRIPPING TECHNOLOGY

1. The military departments have adopted strategies to guide their policy and planning decisions related to coating removal processes (attachments 3-5). The strategies are based on current depot operations and a broad variation in operating conditions and facility capabilities where each depot is responsible for different aircraft, and each aircraft has unique paint stripping requirements. These strategies identify the elements that weapon system managers must consider in selecting the most appropriate paint stripping methods. They also address issues such as capital investment, life-cycle cost, structural integrity of the weapon system, environmental compliance of the process.

2. A comprehensive list of 28 paint removal technologies is included as an attachment to the Air Force's paint removal strategy, attachment 3. Each method is categorized in one of four areas based on its current maturity level. Non-Methylene Chloride (non-MC) chemicals continue to be part of the Services' strategy.

IV. CURRENT TECNOLOGIES USED BY EACH SERVICE

1. Air Force Air Logistics Center Aircraft Paint Stripping Processes

Aircraft	Depot	MC Chemical	PMB	HPW	SS	MPW with/wo Agitation	non-MC Chem
A-10	SM/SA/OO/OC		X(SM)		X (SA)		
E-3	OC	X				P*	P
F-4	OO		X				
F-16	OO/SA		X				
F-15	WR		X				
F-111	SM		X				
B-1	OC			P	X		
B-52	OC	X			X	P*	P
C-5	SA		X				
C-130	WR					X	
C-135	OC/SM	X		P		P*	P
C-141	WR					X	P*
KC-10	Contractor support						
OV-10	SA						
T-37	AETC		X				
T-38	AETC		X				

X - Processes Currently in use P - Process planned for future use.
(PMB) plastic media blast (M/HPW) medium/high pressure water (SS) scuff sanding
(OC) Oklahoma City Air Logistics Center (ALC), OK, (00) Ogden ALC, UT,
(SA) San Antonio ALC, TX, (SM) Sacramento ALC, CA, (WR) Warner Robins ALC, GA,
AETC (Air Education and Training Command)
*-non-MC Chemicals with Medium Pressure Water

2. Naval Aviation Depot Aircraft Paint Stripping Processes

Aircraft	Depot	non-MC Chemical	PMB	MC Chemicals	SS	Flashjet
E-2C	NI		X	S	S	P
S-3	NI		X	S		P
C-2	NI		X	S	S	P
F/A-18	NI			S	X	P
A/V-8	CP		X		S	P
H-60	CP		X	S	S	P
H-53	CP		X	S	S	P
H-46	CP		X	S	S	P
H-47	CP		X	S	S	P
T-2	JX	X	S	S		P
F-14	JX	X		S	S	P
EA-6	JX	X	S	S		P
P-3	JX	X		S	S	P

X - Processes Currently in use S - Secondary process P - Process planned for future use
(PMB) plastic media blast (non-MC) non- methylene chloride (MC) methylene chloride (SS) scuff sanding
(CP) Naval Aviation Depot (NADEP) Cherry Point, NC, (JX) NADEP Jacksonville, FL,
(NI) NADEP North Island, CA

3. Army Depot Aircraft Paint Stripping Processes

Aircraft	Depot	MC Chemical	PMB	SS	Wheat Starch	Flashjet
UH-1	CC	X	X			P
AH-1	CC	X	X			P
OH-58	CC	X	X	X		P
CH-47	CC	X	X	X		P
UH-60	CC			X	X	P
AH-64	CC			X	X	P
SH-60	CC			X	X	P
BLADES	CC			X		P

X - Processes Currently in use S - Secondary process P - Process planned for future use.
(PMB) plastic media blast (SS) scuff sanding
(CC) Corpus Christi Army Depot, TX

V. CURRENT TECHNOLOGIES USED IN COMMERCIAL AIRCRAFT INDUSTRY

1. Five air carriers and ten service organizations were surveyed (see attachment 7). Three of the carriers surveyed contract their paint removal operations to service organizations. Two carriers, Delta and TWA, are currently conducting their own paint stripping operations using non-MC chemical strippers. Delta has constructed state-of-the art facilities for these operations, which include temperature controls and other (mechanical) depaint processes. TWA uses two types of non-methylene chloride chemical strippers for paint removal on their aircraft excluding wide body aircraft. TWA's wide body aircraft can be stripped

with methylene chloride if the service provider elects to use this process. United approved the use of both a methylene chloride and a non-methylene chloride for the depaint work done by their paint stripping contractor. The depaint work done for Continental Airlines by the Dee Howard Company is done exclusively with methylene chloride.

2. The DOD survey of the commercial industry verified that conversion to non-methylene chloride strippers requires large capital investments. Another concern of the survey participants was the possible negative impact on production throughput and increased labor expenditures related to non-MC strippers. All of the survey participants that use, or have evaluated non-MC chemical strippers indicated that they continue to search for a better product, and this has been an on-going activity for several years. This is believed to be part of the reason that several sources indicated that without the proper facilities, they continued to use MC to meet production demands. Other factors associated with non-MC strippers which cause some concern regard the high volatile organic compound (VOCs) content of these products, and the potential for future mandates on the materials for health and/or environmental reasons.

3. The DOD survey did not find the majority of the commercial air carriers are using non-MC stripping processes. Also the survey shows the commercial industry questions the cost effectiveness of the non-MC products.

VI. COST STUDIES

I. Most often cost is the deciding factor in the selection of a paint stripping method. The life-cycle cost of a paint stripping method is a complex issue. While the costs for materials and equipment is relatively simple to define, the costs associated with production rates, flow times, labor rates, facility requirements, waste disposal, etc., become more complex, especially when these costs are location specific. No universal cost is associated with any paint removal technique. DOD performs extensive cost studies using a variety of methods that may be done by the military departments or by independent contractors.

a. The Air Force (WR-ALC/TIE) has developed a comprehensive cost comparison model for objective evaluations and economic comparisons of paint stripping methods. The Navy and Army have adopted the model, which calculates an estimated life-cycle cost for a particular paint removal system. The cost comparison model considers many variables, such as labor rates, paint removal rates, equipment maintenance costs, facility requirements, and hazardous material disposal costs when determining the final life cycle cost of a paint stripping method. Attachment 6 lists cost variables used in the model. These variables are dependent on specific site locations and could vary dramatically from depot to depot.

b. Warner Robins Air Logistics Center (WR-ALC) used the cost comparison model in their decision to use medium-pressure water with bicarbonate of soda stripping (BOSS) to strip C-141 and C- 130 aircraft and selected the lowest overall life cycle cost system.

c. The Navy used the same cost comparison model, with the appropriate data entered on strip rates, aircraft surface area, etc, to facilitate their decision to transition to Flashjet, the lowest life cycle cost system based upon the appropriate data. The Navy presented their results and rationale to the Strategic Environmental Research and Development Program's (SERDP) Scientific Advisory Board in Jul 96.

d. McDonnell Douglas assessed the cost per square foot for stripping 20 AH-64 helicopters using Flashjet at their helicopter facility in Mesa AZ. The cost fell between the values for a cargo aircraft and a fighter aircraft as estimated by the Navy for their conditions. The fighters are larger but geometrically more complex than the disassembled AH-64 and, therefore, may require more secondary processes like touch-up sanding or non-MC chemicals.

2. When reviewing the ouputs of the model, there are significant variations in the final predicted life cycle costs. What may be the cheaper process for one weapon system may not be the cheaper process for another weapon system, even for weapon systems at the same depot. If they were to be compared to another depot, varying state regulations may greatly impact the cost analysis. Factors ranging from weapon system substrates, coating systems, facilities, production rates, dedicated personnel to perform **stripping** etc., make each cost comparison analysis unique and independent.

VII. THE FUTURE FOR NON-METHYLENE CHLORIDE CHEMICALS

1. The military departments continually strive to stay abreast of technological advancements and to incorporate the most effective and efficient methods available for their aircraft paint stripping operations. Recently, several vendors have demonstrated relatively non-corrosive, non-MC chemical products capable of adequate performance on current paint systems.

2. The Air Force is conducting separate evaluations on non-MC chemicals at Oklahoma City ALC (OC-ALC).

a. The first centered on two non-MC chemical chosen for extensive requirements testing. Although the two chemicals did not meet current qualification requirements for methylene-chloride (MC)/phenol strippers, the standard, they were approved, with some restrictions, as safe for use on aircraft at OC-ALC.

b. The second effort, conducted by an independent contractor, looked at 14 products from four different vendors (Huntsman, Gage, Turco and Eldorado). Extensive lab tests resulted in a recommendation to evaluate two of the products and plans for OC-ALC to test these products on an aircraft.

c. During the evaluations OC-ALC reviewed current qualification requirements and test procedures and revised the requirements. They decided that they could give some latitude to chemical manufacturers without jeopardizing an aircraft's structural integrity, this encourages the development of even better performing products. A proposed procedure was developed, and validation testing was completed Oct. 96. Evaluation of the proposed qualification procedure demonstrated its ability to objectively discriminate between products. However, several discrepancies were identified that precluded establishment of all essential acceptance criteria and prevented immediate adoption. A second revision of the proposed procedure was completed 3

Feb 97, and validation testing is in progress. Upon satisfactory completion of validation tests (est. completion Dec 97), the new procedure will be implemented as a local description for competitive procurement of compliant chemical strippers.

3. Because aircraft depainting is but one part of its total depainting mission, the Army's depainting Pollution Prevention efforts have concentrated on non-airframe applications while monitoring the airframe depainting activities of the Air Force, Navy and the private sector. This crossfeed has been lucrative in the area of mechanical depainting methods but not as helpful in the area of alternatives to MC (because of the limitations of the non-MC chemicals). Although significant progress has been made in implementing non-MC chemicals for depainting component parts, this progress is not directly transferable to air frames. Since component depainting is performed via immersion tanks, longer dwell times can be dealt with, the chemicals can be heated and agitated to improve their performance, and substrate issues are usually less critical. Non-MC chemicals which look promising for immersion operations are screened for their potential airframe type depainting applications. To date, none of the thickened versions of the immersion tank candidates has performed well enough to consider qualifying them for use on airframes.

4. The Navy is testing non-MC chemicals to make sure they meet the requirements of specification TT-R-2918, which will replace MIL-R-81294. The testing includes in-process effectiveness, corrosion, and hydrogen embrittlement potential for high-strength alloys found in critical components, especially aircraft landing gear.

a. Naval Aviation Depot Jacksonville, which is validating non-MC chemicals for NADEP processes, finds that these chemicals are effective on older, low-solid, solvent-borne paints and primers. The chemicals are far less effective on new, environmentally preferred, high-solid and water-borne coatings systems. Methylene chloride is still required to remove high performance coatings such as chemical agent resistant coatings (CARC) without corrosion or hydrogen embrittlement potential.

b. The Marine Corps does not depaint full aircraft and has totally ceased using MC to strip parts. The alternative chemical in use is more expensive and requires heating and vigorous agitation. They have found that garnet blasting (with a backup of PMB where garnet is too aggressive) is a cost effective alternative. In addition, preliminary studies are promising for using high pressure water for specialized applications due to the efficiency and relatively clean waste stream.

c. Environmentally-preferred coatings, although more difficult to remove with chemicals, will be required for use under the Aerospace National Emission Standards and Hazardous Air Pollutants (NESHAP) beginning in Sep 98. This regulation tool addresses the reduction of volatile organic compounds (VOC) and hazardous air pollutants (HAP).

VIII. CONCLUSIONS

1. Environmentally compliant paint removal technologies fall generically into mechanical (impact or abrasive), energy, or chemical processes. Depots use mechanical processes (water technologies and dry media blast materials), high-energy processes (laser and flashjet), and chemicals (methylene chloride and non-MC chemicals).

a. Mechanical and energy processes normally require special dedicated facilities, process-specific hardware and innovative waste disposal methods. Some, offer very low operating costs, whereas others require expensive media, have high energy consumption, or have high waste disposal costs. All are subject to hardware malfunctions which subject the aircraft to risk of damage or cause system down time. Hand-held processes are personnel intensive, requiring one or more people per blasting nozzle and multiple nozzles per aircraft. Robotic processes minimize labor costs at the expense of extremely high implementation and sustainment costs. Each technology's state of the art is constantly changing, and no single technology is clearly superior for multiple applications. Implementation of a specific technology may constitute a long-term commitment if it costs too much to convert the facility. These processes do offer a degree of immunity to future EPA regulation and while they are anticipated to perform adequately on future paint systems, future performance cannot be guaranteed and investment cost is always a risk. While the underlying goal has always been cost reduction, the necessity behind developing these processes has been impending NESHAP regulations.

b. Until recently mechanical or energy processes were the only acceptable choices. Now, improved non-MC chemicals are a viable alternative. Non-MC chemicals offer a decided advantage over other processes in terms of implementation cost, and potential for minimal structural damage. They also have a potential operational cost advantage dependent upon strip efficiency. reliability, and material cost. However, because they are subject to future environmental regulations, non-MC chemicals may not be able to strip either current or the next generation of aircraft coatings. Also, non-MC chemicals are not approved for use on composite components. To date no non-MC chemical has performed as well as methylene chloride. Still, all of the Services intend to pursue non-MC chemicals for their paint stripping needs. The future for non-MC chemicals depends upon the continued ability to meet corrosion requirements, environmental compliance, and cost effective performance.

2. The major factors associated with paint stripping of aircraft are qualification for use, environmental compliance, OSHA compliance and life-cycle costs. Life-cycle cost incorporates everything involved in the paint stripping process from personnel wage rates, material/equipment costs, to facility costs, production rates, flow times, and waste disposal. Environmental compliance governs these costs. For example, while the depots will continue to use non-MC chemicals, there will always be waste disposal requirements associated with their use. In stripping an aircraft the ultimate goal is to minimize waste that is generated. Therefore, plastic media blast materials are now being recycled, water technologies are pursuing pure water with no chemical additives, and energy methods only have paint residues and emissions as waste products. This generation of non-MC chemicals is environmentally compliant today, but what about the future? With increasing environmental concerns, NESHAP, OSHA, EPA, and state governments will continue to scrutinize non-MC chemicals.

3. The process of estimating total life-cycle costs and comparing one paint stripping method to another is questionable at best. The issues are complex and the cost estimates must be varied by location. For example, the state laws that influence environmental issues vary from state to state. What may work at one depot may not be the appropriate solution at another depot. Another key concern is facility compatibility, where extensive modifications may be needed if a dry process (such as PMB or energy methods) is put into a facility that handled a wet process (chemicals or water technologies) or vice versa. WR-ALC evaluated a PMB process in a wet facility and the modifications to the facility alone exceeded S8M. The McDonnell-Douglas Mesa Flashjet facility cost approximately $3-3.5M to build. This could not be compared to depots unless military

construction money was available. In evaluating WR-ALC's life-cycle cost analysis, there is great disprarty between chemicals and wheat starch for the F-15 and C-130. Even $\$1/ft^2$ variations could result in millions of dollars over 30-40 years. Thus, these evaluations must be performed for a particular weapon system with a specific locations and specific facilities. The military departments perform these analyses and the cost comparison model is one tool used in this process.

4. Process choices meeting critical qualification and operational requirements remain extremely limited. New technologies are beginning to mature and provide multiple alternatives from which to choose. As the technologies are proven in the production environment, selection criteria will become more definitive for any given application, and risk when committing to a specific process requiring a major capital expenditure will be greatly reduced. Process selection will be based more on sound business decisions than achieving NESHAP compliance. The military departments have working strategies that allow them to address their needs for future paint stripping requirements. Several studies have evaluated non-MC chemicals as alternatives, and future studies will continue to evaluate non-MC chemicals with the other most viable paint stripping methods. The Services will always need non-MC chemicals. They have been and will continue to be part of the Services strategy to effectively and efficiently remove coatings from military weapon systems.

Attachment 2

DoD COATING REMOVAL ISSUES

MEETING MINUTES

EGLIN AFB FL 14 MAR 1997

1. Attendees (Atch 1).

2. Col Tipton, meeting Chair, opened the meeting with introductions of attendees. Col. Tipton described the purpose of the meeting as a method to establish a consensus across the DoD departments for answering the congressional concern relating to the most economical/effective aircraft coating removal technology being employed by the departments. He provided a brief overview of the history.-of the issue, explaining that concern had been expressed by several congressmen from Pennsylvania on the cost of and methods of aircraft coating removal currently in use by the DoD Departments. There was speculation/ allegation that commercial industry is widely using aqueous based strippers (chemical liquid) that are environmentally benign and that the DoD departments had adopted more expensive, less effective non chemical strippers. The primary thrust is to establish a plan to allay the concerns, illuminate the departmental strategies on chemical strippers and eliminate the cause of repeated and unsuccessful attempts to answer the mail.

3. Mr. Dinkins, NADEP JAX, offered that there is no panacea technology for coating removal from all surfaces. The various coating removal technologies are coating system, substrate (type and thickness), and environmental dependent. As a result, the US Navy is focusing its near term emphasis on maintaining the technologies of plastic media blast (PMB), environmentally acceptable chemicals (EA) and medium pressure water (MPW) assisted EA chemicals. These will continue to be utilized in varying combinations even after their long term strategy employing FLASHJET technology *is* implemented. This is a combination of technologies that will comply with the NESHAP and offer an acceptable level of functional effectiveness. The U.S. Navy requirements in the coating removal arena are mission readiness, life cycle cost and long range environmental minimum impact.

4. Lt Lance Reynolds, WL/MLBT, provided a brief history of this issue and what progress has been made to satisfy the issues.

5. The USAF and US Navy are working closely with the OEMs and various coating removal contractors to establish the most effective/efficient/environmentally benign technologies that can be procured. This effort is focused upon the satisfying the unique requirements of the DoD departments in their combat and operation roles, Additionally, aircraft coating removal technology developments are monitored from overseas. Mr. Brian Bell, British Aerospace, is presently engaged in developing a chemical selective stripping technology with Turco. The USAF and Navy are maintaining close contact with this effort. The Air Force experience is that chemical strippers do not perform effectively in the selective scenario. We are evaluating the most current environmentally acceptable chemical strippers available on the commercial market today.