



Aging Aircraft - Lessons Learned

A car more than 20 years old may be a classic but you likely would not take it on a long trip. In contrast, the backbone of the military aircraft fleet was built more than twenty years ago and is still performing their designed functions. In fact, KC-135 tankers entered service more than 40 years ago and the B-52H, C-130, T-37 and T-38 began their service 35-40 years ago. In the 25-35 year age group are the C-141 and C-5A transports and 20-25 years ago the F-15, A-10 and E-3 entered service.



F-15 Eagle



B-52 Stratofortress



KC-135 Stratotanker

While these aging aircraft have been in service for many years, they are expected to serve for many more. Of the aircraft mentioned, only the C-141 and C-130E/H have a replacement in full production with the C-17 and C-130J respectively. Other aircraft replacements are in various development stages or have no replacements identified.

Flight hours and environmental exposure take their toll on aircraft. As expected, when mechanical equipment ages, detection and repair of normal wear, fatigue cracking and corrosion make up a larger portion of maintenance cost. In 1994 a US Air Force Scientific Advisory Board report noted that airframe corrosion is the single most costly maintenance problem for Air Force aging aircraft.

Military aircraft spend most of their life on the ground, often in warm humid environments and it is well known that metals with corrosion potential will eventually corrode in the presence of an electrolyte. Severe corrosion of an F-86 lower fuselage section shown in the photograph (right) shows the contributing effect of water. While this corrosion was likely due to neglect after the aircraft was deactivated there was clearly much less corrosion damage on the upper section of the fuselage where moisture did not accumulate.



**Corrosion on a non-flight-worthy
F-86 aircraft fuselage built in the late 40's**

It is not practical to keep aircraft dry to avoid corrosion but factors that can be controlled are design configuration, material selection, part processing, assembly practices, protective coatings and maintenance. Much of the corrosion found on aging aircraft can be related to one or more of these factors.

The design phase is the first opportunity to minimize the potential for corrosion. Avoiding dissimilar material contact and designing structures with adequate drainage paths will greatly minimize the effects of moisture. Internal structural components should be designed in such a manner that they can be sealed to avoid moisture intrusion. However, it must be assumed that leaks will occur. When moisture gets inside, the design should permit it to escape quickly. Proper location of drain holes will remove gross moisture. Insulation and other materials that will retain moisture should be well protected from wetting or isolated from materials subject to corrosion.

Aircraft material selection is typically a compromise of strength, weight, corrosion resistance, producibility and cost. The majority of the structure of an older aircraft fleet is made of aluminum. Early aluminum alloys and some heat treatments such as 7075-T6 are no longer used. More corrosion resistant alloys have been developed and are in use on more recent designs.

Detail part surface treatments for aluminum, such as chromate conversion coating and anodizing, are the first level of corrosion protection. In addition to the inherent protection afforded by the surface treatment it also aids adhesion of the paint primers that can only protect if they are in intimate contact with the metal.

Assembly practices can inadvertently negate a good design. Typical assemblies with adequate and properly located drain holes also routinely specify fay and/or filet seals with polysulfide or similar sealant. The sealant can provide an excellent barrier to prevent water intrusion into a joint. However, if the sealant squeeze out during installation blocks the drain holes, the trapped water will likely result in corrosion.

Organic coatings, such as paint primers, are often the last corrosion protection applied to interior structures for the life of an aircraft. Spray applied paint primers containing chromate corrosion inhibitors have been used for over fifty years and have significantly improved since their introduction. The primer requirement for salt spray corrosion protection for current production Boeing fighter aircraft is twelve times that specified for use on the F-4 (a 1960s aircraft). The ability of primer to protect the structure depends not only on the quality

of the primer, but also on correct surface preparation and primer application.

Maintenance cannot prevent normal wear and metal fatigue but it is a vital element in prolonging the life of an aircraft. Maintenance procedures can also negate effective designs in ways similar to the previously discussed assembly practices. In addition, during routine maintenance the original organic coatings and surface treatments are removed. Even with meticulous care it is not likely that the replacement finish will provide corrosion protection equal to the original system.

The challenges facing the military operators of an aging aircraft fleet will continue to grow as the average age of the fleet grows older. Also, most protective coatings and surface treatments currently used on aircraft contain hazardous materials that are or will be more highly regulated in the near future, driving the need for further material replacements or the use of more personal protective equipment.

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Latest Scoop on MIL-PRF-680 Degreasing Solvent

P-D-680 was a Federal Specification for dry cleaning and degreasing solvents. It was widely used by the Department of Defense in general cleaning applications. Numerous federal, state, and local environmental regulations impacted P-D-680 solvents as a hazardous waste, as an air pollutant, as a toxic substance, and as a flammable material. Another problem was that the specification was too general. MIL-PRF-680 for degreasing solvents replaced P-D-680 as of December of 1999.

P-D-680 solvents were classified into three types, primarily based upon the solvent's flash point. Type I had a minimum Flash Point of 100 F, Type II had 140 F, and Type III had 200 F. Up to 20% by volume of aromatics were allowed for Types I and II. Also, there were no vapor pressure limitations for Types I and II. Basically the MIL-PRF-680 is the P-D-680 specification with improvements which now classify the solvents into four types as compared to the previous three.

	<u>MIL-PRF-680</u>				
<u>Characteristics</u>	<u>Type I</u>	<u>Type II</u>	<u>Type III</u>	<u>Type IV</u>	
Flash Point, C	38-60	61-92	93-116	61-92	
Kauri-butanol value	27 to 45	27 to 45	27 to 45	27 to 45	
Aromatic content, vol%, max	1	1	1	1	
Dichlorobenzene, mg/L, max	0.5	0.5	0.5	0.5	
Benzene, mg/L, max	0.5	0.5	0.5	0.5	
Tetrachloroethylene, mg/L, max	0.7	0.7	0.7	0.7	
Trichloroethylene, mg/L, max	0.5	0.5	0.5	0.5	
Non-volatile residue, mg/100 mL, max	8	8	8	8	
Vapor Pressure, mm Hg @ 20 C, max.	7	2	0.4	2	
			<u>P-D-680</u>		
<u>Characteristics</u>	<u>Type I</u>	<u>Type IA</u>	<u>Type II</u>	<u>Type IIA</u>	<u>Type III</u>
Flash Point, C, min.	38	38	60	60	93.3
Kauri-Butanol value	29 to 45	29 to 45	29 to 45	29 to 60	27 to 45
Aromatics, max % by volume	20	1	20	1	1
Non-volatile residue (mg/100 ml), max.	10	2.5	10	2.5	10
Vapor pressure, Torr @ 20C, max.	-----	0.2	-----	0.03	-----

Note: Types IA and IIA were created by the Navy (under interim amendment) for a low residue P-D-680

Fig. 1 - Key Characteristics of MIL-PRF-680 vs. P-D-680

Figure 1 highlights the differences between the two. A new Type IV, d-limonene/hydrocarbon blend solvent, was added. The lower aromatic content limit of 1% by volume is required to reduce the toxicity of the solvent. Carcinogenic chemicals, such as benzene, are further restricted to a 0.5 mg/L maximum. A small amount is allowed so as not to eliminate all current materials from use. Previously only the P-D-680 Type III had a vapor pressure limit. In the new PRF specification, all four types have a vapor pressure acceptance limit to control VOC levels. The non-volatile residue limit was only slightly lowered in the new spec. Also, a soil cleaning test has been added to assess solvency of MIL-PRF-680 solvents.

The military's need for more environmentally compliant P-D-680 solvents, led to the formation of a tri-service (Army, Air Force, Navy, and DLA) working group. In Phase I of the working group's plan, they conducted user surveys for these solvents. Fifty-four responses were received from various military headquarters. Twenty-five percent of the users surveyed used P-D-680 Type I; 63% used Type II; and 12% used Type III. The users identified P-D-680 as an excellent degreaser, but knew that it had

environmental problems, such as high VOCs, and was somewhat toxic, etc. The users also preferred hydrocarbon-based solvents to other types, which often did not perform as well.

Phase II of the tri-service group's plan was to conduct field validation tests for DoD maintenance cleaning applications and to revise the P-D-680 specification. Prior to this, 82 commercial solvents were evaluated to determine cleaning performance and environmental effects. The solvents were categorized into eight classifications, such as aqueous, terpene/hydrocarbon blend, petroleum distillate hydrocarbon, ester, etc. Only the petroleum distilled hydrocarbon solvents and the terpene/hydrocarbon solvents met the current P-D-680 performance requirements. Of the original 82 solvents, 23 were identified as candidate alternatives. The group published a technical report, TARDEC (U. S. Army Tank Automotive Research, Development and Engineering Center) No. 13643 – "Replacement of P-D-680 Solvents for General Maintenance of DoD Equipment".

For the actual field demonstration, eight solvents were selected and tested over a period of three

months, using various existing soil cleaning methods (parts washers, ultrasonic cleaner, etc.). All candidate solvents performed well for all applications when compared to the P-D-680 solvents, and all candidate solvents can be potentially recycled. Six of the candidates were accepted by the Army Center of Health Promotion and Preventative Medicine. The citron odor of the terpene/hydrocarbon blend solvents was not a problem in open working areas. The group published two additional technical reports. They are TARDEC No. 13730 – “Field Demonstration for P-D-680 Solvent Replacement” and TARDEC No. 13751 – “Field Demonstration for P-D-680 Solvent Replacement (Part II)”.

The P-D-680 specification was converted to a military performance specification, MIL-PRF-680. It’s name was changed from dry cleaning and degreasing solvent to just degreasing solvent.

One of the most important things to remember about the MIL-PRF-680 solvents is that they are for general purpose degreasing applications and not for final cleaning applications, such as cleaning prior to painting or bonding.

The above information was presented by Dr. In-Sik Rhee at the Air Force Corrosion Program Conference, March 13-17, 2000.

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Glycol Ether Team 'Pride' Recognized

The Boeing St. Louis Glycol Ether Team recently completed an effort targeting these OSHA regulated chemicals in St. Louis and St. Charles operations. Product substitution to reduce or eliminate employee exposure to hazardous materials is the premier method of control recognized by OSHA and our DoD customer as well as the Safety and Health profession. Recognition of the reproductive effects of four Glycol Ethers, (CAS#s 110-80-5, 111-15-9, 109-86-4, and 110-49-6) has heightened pressure to

decrease potential personnel exposure for Boeing employees. Tech Notes (Volume 3 Number 4, November 1998) gives more detail on the subject. An extensive search was done to determine if these four chemicals were in the thousands of production materials used at St. Louis. The search produced the need for two significant substitutions of less hazardous materials.

The Harpoon Program, which maintains a 10,000 gallon JP-10 storage tank, has agreed to substitute a less hazardous non-regulated JP-10 fuel deicer (diethylene glycol monoethyl ether) in place of a more hazardous material stringently regulated by OSHA (ethylene glycol monoethyl ether). The Glycol Ether team proposed this change to Harpoon engineering personnel, who successfully pursued the substitution project with their customer (JP-5 and JP-8 fuels were found to be free of the targeted glycol ethers).

Adhesion promoting primers, Dow Corning DC 1200 (Clear & Red) and DC 1204, applied prior to silicone sealant, required the second substitution. These materials are widely used by virtually all Programs; while they did not contain a glycol ether, they reacted upon application to produce a regulated glycol ether. The replacement material, Dow Corning P5200 (Red), does not contain or produce this hazardous chemical.

These are "real world" risk reductions based on the efforts of the Glycol Ether Team working in cooperation with Program and Surface Finish Team & Laboratory Team experts. Product substitution represents the best approach to risk reduction. Minimal inconvenience, interruption or expense to the Programs and Production Operations resulted from this effort.

Team members were recognized with individual Boeing Pride Program Achievement Awards on April 28, 2000.

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