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NAVAL AIR SYSTEMS COMMAND CORROSION CONTROL PROGRAM

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This is an overview of the total program of corrosion control waged by the air arm of the Navy. The NAVAIR approach to corrosion control centers on the interaction of three efforts; R and D, designs and procurement, and maintenance technology. These efforts will be discussed in reverse order.

MAINTENANCE TECHNOLOGY

There are three general levels of maintenance. They are: organizational, intermediate and depot levels. The organizational level of maintenance is concerned with inspecting, servicing, lubricating, adjusting and replacing parts, assemblies and sub-assemblies on equipment. This is performed by the squadron personnel in the fleet trying to maintain the aircraft in their deployed status. The second level of maintenance is intermediate level of maintenance is concerned with calibration, repair or replacement of damaged or unserviceable parts, components or assemblies. The third level of maintenance is performed at the depot. At depot level, the equipment receives major overhaul or complete rebuilding of parts, assemblies, subassemblies and end items including the manufacture of parts, modifications, testing, and reclamation as required. Corrosion control is practiced at each level of maintenance. The current policy requires that each command place special emphasis on the importance of the corrosion control program and lend its full support to ensure that corrosion prevention and control receives a priority for timely accomplishment. The responsibilities for corrosion control is assigned to all work centers and formal training in corrosion control is a requirement. Training of plane "captains" in corrosion prevention and detection is required and it is mandatory that they perform these duties on a daily basis.

In order to aid the sailor at the organizational or intermediate level, a number of technical manuals and publications concerned with corrosion control are provided. These are:

I - NAVAIR 01-1A-509 - Aircraft Cleaning and Corrosion Control

II - NAVAIR 16-1-540 - Avionics Cleaning Corrosion/Prevention Control

III - NAVAIR 15-01-500 - Preservation of Naval Aircraft

IV - NAVAIR 15-02-500 - Preservation of Aircraft Engines

V - NAVAIR 17-1-125 - Ground Support Equipment Cleaning and Corrosion Control

VI - NAVAIR Maintenance Publications Peculiar to Specific Aircraft Models and Related Equipment

In order to assess the damage caused by corrosion on naval aircraft and thus take corrective action, fleet personnel are trained in detecting and reporting the various forms of corrosion. With this in mind a computerized reporting system that is unique for corrosion damage has been introduced to a small sector of the fleet. This new system is called CORGRAPH.

CORGRAPH is an integration of the present Visual Information Display System/Maintenance Action Form maintenance data source document and corrosion graphics. CORGRAPH allows for specific recording of location, type and extent of aircraft corrosion. It provides a computerized data bank of corrosion data for use by cognizant field activities (CFA's) and intermediate and organizational level maintenance activities for use in developing aircraft corrosion trend analysis data.

CORGRAPH utilizes the maintenance requirement card (MRC) format which is graphically laid out in 18 inch squares. CORGRAPH has been designed to provide documentation of corrosion found during special and phase, as well as unscheduled maintenance. The card set provides step-by-step procedures and all instructions for documentation. Each card contains a card number, area title, and alpha/numeric grid used for locating and reporting corrosion. The CORGRAPH deck also lists the codes used to identify the type and extent/treatment of corrosion found. At present, CORGRAPH is in use for the Navy's S-3 aircraft. All other models will ultimately be incorporated in this system.

COST OF CORROSION

Utilizing the existing Maintenance and Material Management System (3M) data reported by the fleet, the cost of corrosion in both dollars and manhours was computed. Some of the data is provided in Tables 1 and II.

TABLE I

COST OF NAVAL AIRCRAFT CORROSION*

Aircraft	Corrosion Maintenance DMMH/YR (Thousands)	Corrosion Maintenance Cost (Thousands)
A-6E	445	$ 7,414
A-7E	811	$13,511
F-4J	491	$ 8,180
F-14A	498	$ 8,292

Period JUL 79 - JUN 80 — Labor Rate: $16.66

* Includes Organizational and Intermediate Levels of Maintenance Only

TABLE II

EFFECT OF CORROSION ON AIRCRAFT MAINTENANCE*

Aircraft	Total Maintenance DMMH/YR (Thousands)	Corrosion Maintenance DMMH/YR (Thousands)	% Corrosion Maintenance
A-6E	3600	445	12.4
A-7E	4349	811	18.6
F-4J	3328	491	14.8
F-14A	3086	498	16.1

* Includes Organizational and Intermediate Levels of Maintenance Only

From Table I we see that it costs $13.5 million per year for direct maintenance manhours for corrosion control of the A-7 aircraft. From Table II we find that 19 percent of all the direct, scheduled maintenance performed on the A-7 aircraft is corrosion related. It should be noted that these figures are conservative since they are based on a reporting system that does not always pinpoint the cause of malfunctions. Thus, as an example, when a piece of avionics gear malfunctions it is reported as an electrical failure although in reality corrosion of the connector pins may be at fault.

CORROSION CONTROL IN AIRCRAFT PROCUREMENT

From the direct feedback of the maintenance community, those responsible for naval aircraft materials acquisition formulate the necessary corrosion control/prevention requirments for new aircraft. These efforts are incorporated into the manual design engineering/contractual requirements for the procurement of aircraft. Specifically, the process of corrosion control in design engineering is approached as follows:

- Corrosion resistance requirements contractually imposed on manufacturer
- Design and development phase requires corrosion control engineering efforts
- Materials and process design review of all new weapons systems
- Preproduction reliability design review (PRDR) - evaluate design adequacy based on Navy technical and operational testing.

An effective method for imposing corrosion control is to establish pertinent requirements in procurement contracts. The pertintnt documents that are cited in these contracts are:

- SD-24 - General specification for design and construction of aircraft weapon systems
- MIL-F-7179 - General specification for finishes and coatings: protection of aerospace weapons systems, structures and parts

- MIL-S-5002 - Surface treatments and inorganic coatings for metal surfaces.

Additionally, corrosion control design teams consisting of appropriate service personnel as well as performing contractors are established during the design stage of new aircraft to attempt to minimize in-service corrosion problems. This has been the widely used approach on the F-18 aircraft. A capsulized example of the F-18's corrosion prevention and control plan is as follows:

F-18 CORROSION PREVENTION AND CONTROL PLAN

Chemical Treatment of Aluminum Alloys

- MIL-C-5541 ("Alodine")

  ALCLAD SHEET
  ALCLAD SHEET CHEM-MILLED, above Z90.15

- Chromic Acid Anodize

  Welded Assemblies

- Sulfuric Acid Anodize

  All structure fabricated from extrusions, bar, plate, forgings, and castings except as below, bare sheet, and chem-milled ALCLAD below Z90.15

- IVD Aluminum Coating

  All "fatigue critical" structure

FINISH SYSTEM

EXTERIOR

- One coat MMS-425 epoxy primer
- Two coats MMS-420 polyurethane enamel
- Fay surfaces, butt joints, fasteners sealed

INTERIOR

- Two coats MMS-425 epoxy primer
- Fuel tanks coated with MIL-C-27725 polyurethane

RESEARCH AND DEVELOPMENT FOR CORROSION CONTROL

The research and development effort in combatting corrosion of naval aircraft is active and aggressive. This part of the overview will address materials and processes developed by the research and development community that have provided advances in corrosion control of naval aircraft. The subjects to be covered will primarily apply to airframes, although they may also be useful for electronic equipment. First, materials currently available will be discussed, then materials still under development which look promising for the future.

Classical corrosion control involves attacking the problem from three standpoints: interfacial (coatings), internal (metal selection), and external (inhibited environment). All three aspects will be covered here.

AML-350 (MIL-C-81309) - an ultra thin water displacing corrosion preventive compound which dries to a soft film;

AMLGUARD (MIL-C-85054) - a water displacing, corrosion preventive which dries to a hard, clear finish.

The need for such materials is occasioned by the difficulty of performing corrosion control procedures in a marine environment. Areas where paint has cracked or chipped leaves bare metal exposed. The mechanism by which these compounds function is to displace water from the surface. The essential elements involved are: (1) the compound spreads over the substrate completely wetting it, (2) it is immiscible with water, therefore does not retain water, and (3) it is preferentially adsorbed, penetrating under the water droplets.

AML-350 is applied to a film thickness of 2 to 5 μm. It is composed of a petroleum sulfonate and a mineral spirits type solvent. AML-350 is intended for use on internal metallic parts and electrical connectors. It has widespread use on airborne electronic equipment.

AMLGUARD contains polymeric resins which, upon application and cure, form a dry, hard film with a thickness of 25.4 to 50.8 μm (1 to 2 mils). It is a combination of organic solvents, silicone and silicone alkyd resins, barium petroleum sulfonate, and several other additives. It also displaces water by spreading over the metal and creeping uner the water droplets. Drying occurs via solvent evaporation, leaving a solid film. Although AMLGUARD dries to the touch in 18 hours, it continues to cure for 1 to 3 months, forming a hard, flexible finish. Corrosion protection is provided by the physical barrier of the coating and also by barium petroleum sulfonate and alkyl ammonium organic phosphate performing as corrosion inhibitors. This material is intended for temporary use on external aircraft parts where if offers excellent corrosion protection.

SEALANTS

Elastomeric sealants are widely used on naval aircraft to seal out the environment. The most popular at the present time are the polysulfide sealants which contain soluble corrosion inhibitors. These are covered by military specification MIL-S-81733. Ordinary sealants can minimize corrosion of metals in high humidity environments, but cannot prevent it completly because all polymers are permeable to moisture. The inhibitive sealant is very effective when used in faying surfaces and butt joints, for wet installation of fasteners and over fasteners patterns and to insulate dissimilar metals.

It is anticipated that the use of elastomeric sealants (polyurethanes and silicones as well as polysulfides) will increase in the future due to their ability to accommodate the dynamic loads imposed on aerospace equipment without cracking.

SURFACE TREATMENTS AND COATINGS FOR ALUMINUM ALLOYS

Wit regard to surface treatments for aluminum alloys, there has been a return to anodizing for new weapons systems rather than chromate conversion coatings. Both sulfuric and chromic acid anodizing are being used. Anodized surfaces provide more corrosion protection, abrasion resistance and long-term durability than chromated surfaces.

The paint system used on naval aircraft, the MIL-P-23377 epoxy primer and the MIL-C-82386 polyurethane topcoat, has performed better than any previous system. It is durable, abrasion resistant, retains its gloss well, does not chalk or craze, and is easy to clean.

ALLOY SELECTION AND HEAT TREATMENT

The advent of the heat treatable 7000 series aluminum alloys provided a boon to aircraft designers. The high modulus, high strength, and low weight of these alloys made them ideal for the high performance of advanced aircraft. Their susceptibilities to intergranular corrosion, exfoliation, and stress corrosion cracking made them less than desirable in marine environments. It was discovered that if these alloys were systematically overaged, their susceptibilities to these forms of attack would be materially lessened if not totally eliminated. Thus the T73 temper was born. As is usually the case with most "fixes," a price had to be paid. There is an approximate 10% strength loss accompanying the T73 overaging treatment. The T73 temper replaced the standard T6 temper on many military aircraft where designs could be altered or the strength loss tolerated.

More recently newer 7000 series alloys have been developed with specific resistance to intergranular attack and environmental embrittlement. Most of these new alloys such as 7050 and 7010 owe their lessened susceptibility to the presence of zirconium and a cleaner microstructure.

The preceding paragraphs have described materials currently in use, or available, to minimize environmental deterioration of airframes. Materials and processes under development in the laboratory will now be addressed.

MATERIALS UNDER DEVELOPMENT

Water Displacing Paint

This material is a pigmented coating which will displace water, dry and subsequently afford corrosion protection. It is composed of a petroleum sulfonate, silicone-alkyd resin, organic solvents, pigments and other organic additives. The mechanism by which this material displaces water is the same as that discussed earlier. This pigmented coating dries to a hard, flexible finish which protects the substrate from corrosion by:

1. The physical barrier of the coating
2. Corrosion inhibiting pigments; i.e., molybdates and chromates.

This water displacing paint is designed as a touch-up paint for exterior surfaces of aircraft where original paint has cracked or chipped and total repainting is not feasible. Such a situation is confronted on operational aircraft deployed on board aircraft carriers where paint touch-up is necessary but must be completed quickly and efficiently. This paint was designed to be applied during deployment and to last indefinitely until total repainting of the aircraft is necessary.

Flexible Primer

The current Navy paint scheme for high performance aircraft includes the application of MIL-P-23377 epoxy primer, MIL-S-8802 or MIL-S-81733 polysulfide sealant, and MIL-C-83268 polyurethane topcoat. This system has several limitations. The primer possessess poor low-temperature flexibility, while the sealant is difficult to apply due to its high viscosity and short pot life. The ideal solution would be a single application of an elastomeric sealant-primer with the adhesion of a primer and the flexibility of a sealant. This would also eliminate the need to handle two separate materials, resulting in a significant cost savings to the government.

A comparative evaluation of a number of inhibitive elastomeric coatings including a plysulfide, a polyurethane and an epoxy-polyurethane system is being made. Such properties as the hardness, adhesion, strength, flexibility, erosion resistance, corrosion resistance and ease of application of these materials will be determined and an optimum material selected.

Development of an Aluminum Plating Process

There is increasing pressure to eliminate the use of cadmium by DoD activities because of its toxicity. While no single coating has been found to replace cadmium in all aircraft application, aluminum has been found to be a very good alternate coating material in many applications requiring good corrosion resistance and minimal effect on fatigue properties. Only two aluminum coating processes are currently commercially feasible, vacuum deposition and ion vapor deposition. Vacuum deposition has relatively poor covering power and adhesion is often only fair. Ion vapor deposition is proprietary and facilities for its application are complex and cannot meet the demand for the coating. Other methods exist, but they have not been developed sufficiently to be of real commercial value.

The Naval Air Development Center is involved in an effort to develop a method to electroplate an aluminum coating from a molten salt bath. To date, the process has been scaled up from a small bath to a forty liter bath. It has been demonstrated that a coating of aluminum-manganese can be deposited on aluminum, titanium and steel substrates with conventional pretreatments and with excellent adhesion. The coating can be chromate conversion coated but not anodized.

Phase Transfer Inhibitors (PTI) in Crack Arrestment

A method was developed at the Naval Air Development Center by which ions could be solubilized in organic media using phase transfer catalysis (PTC). This method has been used to develop an entirely new vehicle for corrosion inhibitors. These have resulted in inorganic inhibitors incorporated in organic phases, i.e., an oxidizing anion dissolved into an organic non-polar solvent, in this case, mineral spirits.

The use of phase transfer inhibitors in pre-cracked stress corrosion cracking in aluminum alloys is presently being studied. Preliminary tests using dichromate, nitrite, borate, molybdate as well ad dichromate, phosphate, silicate inhibitor combinations show the cracking rate to be perceptibly decreased in aluminum alloy 7075-T6 and high strength steels exposed to salt laden moisture.

The field of phase transfer catalysis and organometallic chemistry appears to provide a new class of corrosion inhibitors which will probably have wide applications in materials such as coatings, corrosion preventive compounds and crack arrestment compounds.

This has been a brief discussion of the materials and processes currently being used for corrosion control on naval aircraft. Some of the more important efforts and ongoing research in the air arm of the Navy have been highlighted. Fighting corrosion is a never ending battle, but even small successes can provide a payoff in reduced maintenance manhours and improved reliability.