CORROSION CONTROL REQUIREMENTS FOR UK MILITARY AIRCRAFT

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SUMMARY

Within AvP 970, Design Requirements for Service Aircraft, the designer is given advice on the selection of materials based upon their resistance to corrosion, and mandatory requirements for processes and materials to be used in aircraft structures so as to minimise deterioration and corrosion. Details are given of these requirements and the various sequences of operations required for corrosion control purposes.

To achieve a satisfactory level of corrosion resistance in aircraft structures the designer must consider, not in isolation but in relation to each other, the detailed design of the structure, the selection of structural materials, and methods of protection. Mandatory requirements to ensure acceptable performance of military aircraft appear in various Chapters of Aviation Publication 970, Design Requirements for Service Aircraft. The relevant Chapters are:

Chapter 400 - General Detail Design (paragraph 4 requires approved specifications for all materials and processes used, and paragraph 9 requires MOD approval before magnesium alloy components are used).

Chapter 409 - Exfoliation Corrosion of Aluminium Alloys (requires MOD approval before certain susceptible alloys are used).

Chapter 410 - Stress Corrosion Cracking (requires MOD approval before certain susceptible alloys are used).

Chapter 801 - Precautions Against Corrosion and Deterioration (contains most of the mandatory requirements for corrosion control).

These Chapters, together with associated advisory leaflets, have all been written or revised in the past 3 years after detailed discussions with the UK aircraft industry, with the Royal Air Force and experts within the Ministry of Defence.

BASIC DESIGN CONSIDERATIONS

In Chapter 801 there are mandatory requirements which cover the following design aspects:-

The structure must be effectively sealed to prevent water and other liquids gaining access to the internal aircraft structure. An integral part of this requirement is that all static joints must be wet assembled.

The structure must be drained and vented, both in flight and on the ground so that any liquids generated within the aircraft are not trapped within the structure.

Any pockets in the structure must be filled with inert, low density materials so that water traps are eliminated.

Access for inspection must be provided so that all parts of the structure can be inspected for corrosion or loss of protective coatings, and can be accessible for reprotection.

Sharp corners and edges, places where paint is too easily lost, must be eliminated.

SELECTION OF MATERIALS

Airframe materials are chosen primarily to achieve a light, strong structure. Unfortunately, high strength alloys are often the ones that given rise to major corrosion problems. For example, severe exfoliation corrosion can occur within a few years on maritime aircraft. Chapter 409 provides the designer with information on the susceptibility to exfoliation of all of the aluminium alloys currently used in the UK aircraft industry. Alloys are classified from A to D:- A materials are very resistant to exfoliation, D materials are very susceptible and these alloys cannot be used without the agreement of the Aircraft Project Director. The philosophy is not to ban the use of susceptible alloys but to give the designer information which helps him to select more resistant alloys. Having considered possible alternatives the designer may still have overriding reasons for using a D classified alloy. He will then have to persuade the customer that there is an advantage in doing so. This same approach is taken with magnesium alloys and materials susceptible to stress corrosion - the designer must make a good case for using materials which are potential corrosion hazards.

Bimetallic or galvanic corrosion can be a problem in aircraft structures. For example, an aluminium alloy will have a more negative corrosion potential than a steel fastener, and an electrolyte, bridging the two materials, allows a galvanic cell to form - the light alloy forming the anode, the fastener the cathode. The rate of corrosion of the light alloy is increased, but the fastener is cathodically protected - just as steel is cathodically protected by cadmium plating or by galvanising.

APPROXIMATE CORROSION POTENTIALS IN CHLORIDE SOLUTIONS

Corrosion potential (mV *vs* SCE)	Element	Material or Alloy
+500		
	Gold, Carbon	Carbon Fibre Composite
ZERO	Silver	Titanium Alloys
		Corrosion Resisting Steels (18/8)
	Copper	Brass (70/30)
	Chromium	
-500		
		Low Alloy Steels
	Aluminium, Cadmium	Aluminium Alloys
-1000		Aluminium-1% Zinc
	Zinc	
-1500		
	Magnesium	Magnesium Alloys

Corrosion potentials indicate which of two metals will form the anode and therefore suffer galvanic corrosion. Thus, aluminium alloys will suffer galvanic corrosion in contact with steels, brass, corrosion resisting steels, titanium alloys, and carbon fibre composite. Conversely, aluminium alloys can be cathodically protected by cladding with aluminium or aluminium-1% zinc. But corrosion potentials only tell half the story and it is far better to give the designer information based on experience of bimetallic corrosion, and such information is available in the British Standards Institute publication PD 6864, commentary on Corrosion at Bimetallic Contacts and Its Alleviation.

BIMETALLIC CONTACTS - CORROSION HAZARDS IN A MARINE ATMOSPHERE

0	1	2	3
Al-Cd	Cd-Al	Zn-Steel	Al-Cu
Al-Zn	Zn-Al	Al-Ti	Al-Brass
Steel-Cd	Cd-Steel	Al-CRES	Al-Steel
Steel-Zn			

Bimetallic couples are classified from zero to 3; for those classified zero there is no additional corrosion of the first metal due to contact with the second metal; for those classified 3, the first metal can suffer severe galvanic corrosion in contact with the second metal and the designer must avoid such contacts. It is interesting to note that low alloy steels cause more severe galvanic corrosion of aluminium alloys than titanium or corrosion resisting steels do, even though the corrosion potentials would indicate otherwise. The information in PD 6864 also shows the designer how to convert dangerous couples (such as aluminium/steel or aluminium/copper) into relatively safe ones by cadmium or zinc plating the cathodic metal. However, the designer is warned that coatings of cadmium and zinc have a finite life and require further protection.

PROTECTION SCHEMES

Because corrosion is an electrochemical process it can be prevented by making sure that electrolytes do not come into contact with metal surfaces, and insulation of the airframe metals from the environment by painting is, therefore, the most important aspect of corrosion prevention. By incorporating corrosion inhibitors in the form of chromate pigments in the paint primer, corrosion can be controlled even at defects in the paint scheme. However, for paint schemes to fulfil their role they must not be readily detached from the metal surfaces; satisfactory paint adhesion can be ensured by control of metal pre-treatment and painting operations. For aluminium alloys the sequence is:

Initial cleaning by degreasing, abrading, chemical cleaning or a combination of such processes (which are specified in DEF STAN 03-2).

Pre-treating by anodising to the requirements of DEF 151 (usually Type 2 - chromic acid process), by chromate filming (to DEF STAN 03-18), or by etch priming (to DEF STAN 80-15 or approved alternatives).

Painting to the requirements of DEF STAN 03-7 with a chromate-pigmented epoxy primer (to DTD 5567) within 16 hours of pre-treatment. Finish coats will be epoxy (to DTD 5567) or, more usually, polyurethane (to DTD 5580) when high resistance to synthetic hydraulic fluids and lubricants is needed; for external surfaces of most military aircraft acrylic finishes (to DTD 5599) are currently specified.

For steel components approved pre-treatments are:

Cadmium, electroplated (to DEF STAN 03-19) or vapour deposited (to DTD 940).

Aluminium or aluminium-rich coatings (to BS 2569).

Zinc plating (to DEF STAN 03-20).

Phosphating (to DEF STAN 03-11).

Cadmium is the preferred pre-treatment, but the designer may specify one of the alternative treatments above when cadmium is not technically acceptable or feasible. After pre-treatment steel parts are painted using the same schemes applied to aluminium alloys, or using a stoving paint scheme (eg BS X 31).

Magnesium alloys depend on complete encapsulation with organic coatings to prevent corrosion. It is not possible to inhibit the corrosion of magnesium alloys at defects in the coating, nor is it possible to cathodically protect magnesium alloys which are anodic to all other structural materials and to the common plating metals, zinc and cadmium. The sequence of operations required in DTD 911, the UK Ministry of Defence specification for protection of magnesium alloys, includes:-

Fluoride anodising to remove impurities from sand castings.

Chromate filming or anodizing.

The impregnation of the chromate or anodic film with a stoving epoxy resin.

Painting, or application of nylon or other plastic coatings, to give a minimum of 100 m of organic coating.

Many corrosion problems have been encountered with magnesium alloys in both fixed wing aircraft and helicopters, and the designer is required to obtain approval from the Ministry of Defence before using magnesium alloy components. He is strongly advised not to use magnesium alloy in sheet form because of severe problems in the past. However, it is accepted that magnesium alloys have an important role to play in aerospace structures and in some applications their unique properties are invaluable.

Except for fasteners and fastener holes in aluminium alloys, Chapter 801 requires that metal surfaces are painted (at least with primer or, in the case of magnesium alloys, sealed with resin) at the detail stage before being assembled or built into the aircraft structure. During assembly a sealant or a jointing compound must be used on mating surfaces so that potential crevices are filled. The importance of wet assembly to prevent moisture getting into joints cannot be stressed too much. The vast majority of corrosion problems arise at interfaces between components, at fastener holes, or at the edges of panels. In many cases the corrosion occurs because wet assembly has been omitted or carried out poorly. Wet assembly can often be supplemented by caulking seams and any joints which leave ledges and traps where moisture and other contaminants can lodge. After assembly and before final painting, damage to the paint scheme must be repaired. Also, exposed parts of fasteners and exposed sealant or caulk must be primed. Areas which were only primed before assembly must be re-primed before finish coats (or any intermediate coats) are applied.

It is possible to obtain excellent protection when operating in the relatively controlled environment of aircraft manufacture and especially when protection schemes are applied to individual components. It is not always possible to restore protection to the same standard to aircraft in service when, for one reason or another, it is necessary to carry out 're-surface finishing' operations. In the UK the aircraft paint industry has developed improved epoxy primers, the major improvement being their excellent adhesion to metallic surfaces which have only been degreased. While the intention is to maintain the current requirements for surface pre-treatment, 're-surface finishing' should yield more durable and reliable protection.

Selective stripping of finish coats to leave the primer coat intact is one of the attractions of acrylic finishes currently used on the majority of UK service aircraft. However, the finish tends to craze and has only moderate resistance to some aircraft fluids. With recent paint developments it is technically possible to use paint schemes with polyurethane finishes which can be selectively stripped to leave the primer, or primer plus barrier coat, intact. These schemes appear to be almost as resistant to fluids as conventional polyurethane paint schemes. Other developments in polyurethane paint schemes are finishes with much increased flexibility. As well as greater resistance to chipping and cracking these paints have good erosion resistance. Service trials of these polyurethane paint schemes are underway. If successful, the paints will be added to the list of materials and processes (see Appendix) currently approved for use on military aircraft.

Finally, for internal areas of aircraft structures which require re-protection but cannot be repainted successfully (for example, when contamination with lubricants or hydraulic fluids cannot be removed completely) increasing use is being made of thin film, corrosion preventive compounds (DEF STAN 80-83). These materials are also used to supplement the paint schemes in areas where experience has shown that additional protection may be necessary. They are applied to give film thicknesses similar to those of paint schemes, dry to give a soft but non-tacky surface, and the coating is transparent. The same corrosion preventive compounds can be used for protection of parts in store and for semi-finished components during the complex process of aircraft manufacture.

APPENDIX

LIST OF PROTECTIVE MATERIALS AND PROCESSES APPROVED FOR USE ON UK MILITARY AIRCRAFT

Note: Specification DTD 900 includes appendices listing proprietary materials and processes approved under its terms for aerospace use.

Title	Specification number
PROCESSES	
Sprayed metal coatings	BS 2569
Cleaning and preparation of metal surfaces	DEF STAN 03-2
Protection of aluminium alloys by sprayed metal coatings	DEF STAN 03-3
The pretreatment and protection of steel parts of specified maximum tensile strength exceeding 1450 N/mm	DEF STAN 03-4
Electroless nickel coating of metals	DEF STAN 03-5
Painting of metal and wood	DEF STAN 03-7
Electrodeposition of tin	DEF STAN 03-8
Phosphate treatment of iron and steel	DEF STAN 03-11
Chromate conversion coatings for aluminium and aluminium alloys	DEF STAN 03-18
Electrodeposition of cadmium	DEF STAN 03-19 (previously DTD 904)
Electrodeposition of zinc	DEF STAN 03-20 (previously DTD 903)
Chromate passivation of cadmium and zinc surfaces	DEF-130
Anodizing of aluminium and aluminium alloys	DEF-151
Chromium plating for engineering purposes	DEF-160
Nickel plating (heavy)	DTD 905
Protection of magnesium rich alloys against corrosion	DTD 911
Identification colouring of rivets in aluminium and aluminium alloys	DTD 913
Process for the external finishing of radomes	DTD 926
Surface sealing of magnesium rich alloys	DTD 935
The cadmium coating of very strong steel parts by vacuum evaporation	DTD 940
Surface coating of parts by use of detonation, flame and plasma spraying processes	DTD 941
Anodizing of titanium and titanium alloys	DTD 942
Electrodeposited cobalt/chromium carbide composite coatings	DTD 943
STANDARD PAINT SCHEMES	
Interior and exterior protective finishing scheme (cold cured epoxy type)	DTD 5567
Exterior and interior finishing schemes - matt and glossy (cold curing polyurethane type) (Scheme I and Scheme II)	DTD 5580
Selectively strippable acrylic finishing scheme for use on aircraft	DTD 5599

Title	Specification number
OTHER PAINTS AND COATINGS	
Varnish for aeronautical purposes	BS 3X 17
Doping and finishing schemes for fabric covered aircraft	BX X 26
Low temperature stoving scheme for aeronautical purposes	BS X 31
Stoving enamel	DTD 56
Paint, pretreatment primer (etching primer)	DEF STAN 80-15
Corrosion preventative compound: aircraft structures. Joint Services designation PX 32	DEF STAN 80-83