

AD-A011 177

AVIONICS CORROSION CONTROL STUDY

Bendix Field Engineering Corporation

Prepared for:

Naval Air Development Center

January 1974

DISTRIBUTED BY:

**NTIS**

National Technical Information Service  
U. S. DEPARTMENT OF COMMERCE

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER N/A	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER <b>AD-A011177</b>
4. TITLE (and Subtitle) Avionics Corrosion Control Study	5. TYPE OF REPORT & PERIOD COVERED Final October 1973 - January 1974	
	6. PERFORMING ORG. REPORT NUMBER N/A	
7. AUTHOR(s) Bendix Field Engineering Corporation	8. CONTRACT OR GRANT NUMBER(s) N62269-74-C-0168	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Bendix Field Engineering Corporation 9250 Route 108 Columbia, Maryland 21045	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Air Development Center Warminster, Pennsylvania 18974	12. REPORT DATE January 1974	
	13. NUMBER OF PAGES 53	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified	
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report)		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)  Avionics Corrosion Control		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The objectives of this report are to offer the Navy a limited study of some of the problems and possible solutions associated with avionics corrosion control that could be the basis of a manual devoted to that subject. The research methods employed sought information from two sources: (1) published material from secondary sources to take advantage of what is already known and documented in the literature, and (2) primary sources derived from our activities and experiences within the Bendix Field Engineering Corporation. The secondary sources did not prove to be as fruitful or pertinent as had been anticipated prior to the initiation of the search. The conclusion to be drawn is		

**Best  
Available  
Copy**

that the essential difference between corrosion problems in large structures and corrosion attacking avionic equipment is that minute corrosion products that could degrade or disable complicated avionic equipment would go unnoticed on large mechanical structures. The results of the investigation correlate positively with previous Bendix work in corrosion phenomena and control.

## Foreword

The Naval Air Systems Command (Mr. A. J. Koury AIR-411B4) initiated a program at Bendix Field Engineering Corporation under Contract N62269-74-C-0165 for the generation of this document. Before considering the topics treated in this study, it would be well to devote a moment to the research methods employed and something of what the research in itself revealed to the study group.

Two information sources were sought: (1) published material from secondary sources to take advantage of what is already known and documented in the literature, and (2) primary sources derived from our activities and experiences within the Bendix Field Engineering Corporation.

Essentially, the secondary sources did not prove to be as fruitful or pertinent as had generally been anticipated prior to the initiation of the actual search, and what was uncovered was widely dispersed. In view of the time constraints involved, this did not work to our advantage.

The relative scarcity of published information on the corrosion problem pertinent to avionics (or electronics in general) versus that relating to the fields of metallurgy, chemical engineering, etc., may have the following explanation. For many years, the corrosion engineer has been concerned with preventing the corrosive degradation of large structures. The protection of bridges, tunnels, ships, buildings, storage tanks, and oil and gas pipelines has occupied, and will continue to occupy, a large portion of his investigative efforts and talents. Recently, however, the corrosion engineer has become increasingly involved in the prevention of corrosion in electronics equipment. The essential difference between corrosion problems in large structures and corrosion attacking avionic equipment is that minute corrosion products that could degrade or disable complicated electronic equipment would go unnoticed on large mechanical structures. However, the fundamental corrosion processes and associated remedial measures are the same whether the corrosion occurs in avionic equipment or a bridge.

Accordingly, the long-established "in-house" experience of the Bendix Field Engineering Corporation in overhaul and rehabilitation services for electronic and electromechanical systems and subsystems, including airborne electronics and instrumentation (FAA Certification Number 1-21-21), was drawn upon as an important initial resource.

Looking further, the Bendix background in many areas of corrosion phenomena and corrosion control proves to be quite extensive. Our detailed specifications, implemented by depot-level maintenance teams, are responsible for the cosmetic and corrosion control program for NASA's worldwide tracking network. The investigations and recommendations on stress corrosion, concentration cell activity, sealing anodic coatings, new protective coatings, etc., for the tracking stations are accomplished by these corrosion control personnel.

---

<sup>1</sup> Richard G. Baker, "Corrosion and Plating Problems in Electronic Equipment for the Communications Industry" (Murray Hill, N. J.: Bell Laboratories).

We established an instrumented corrosion test site in Bermuda and wrote the manual on corrosion control for the Manned Space Flight Network. It was first printed as Goddard Space Flight Center Manual ME-305, later issued as CR-1492, and subsequently was published by the U. S. Department of Commerce Clearinghouse for Federal Scientific and Technical Information as N70-21420.

Likewise, a significant source of information was the Advanced Technology Laboratory which was established at our facilities in Columbia, Maryland, for the repair and refurbishing of NASA modules and printed circuitry (including etching, gold plating, and potting).

Lastly, the Bendix Flight Operations Group (based at Chesapeake Park, Maryland) which, since the early 60's, has maintained and operated, worldwide, a fleet of instrumented aircraft for NASA, was brought into the project to contribute their fund of knowledge of avionics corrosion control based on years of operational experience in varied geographical environments in both hemispheres.

## Contents

	<i>Page</i>
<b>Foreword</b>	<b>iii</b>
<b>Section</b>	
<b>1 Avionics Corrosion (General)</b>	<b>1-1</b>
<b>A Effects of Environment</b>	<b>1-1</b>
<b>B Description and Identification of Deterioration</b>	<b>1-3</b>
<b>2 Preventive Maintenance</b>	<b>2-1</b>
<b>A Cleaning</b>	<b>2-1</b>
<b>B Water Displacing</b>	<b>2-4</b>
<b>C Protective Coatings</b>	<b>2-5</b>
<b>D Potting Compounds and Sealants</b>	<b>2-7</b>
<b>E Preserving</b>	<b>2-8</b>
<b>F Storage, Handling, and Shipping</b>	<b>2-9</b>
<b>3 Treatments and Protective Coatings</b>	<b>3-1</b>
<b>A Structural Avionic Components (External)</b>	<b>3-1</b>
<b>B Avionic Components (Internal)</b>	<b>3-5</b>
<b>4 Materials &amp; Equipment</b>	<b>4-1</b>
<b>A Consumables List</b>	<b>4-1</b>
<b>B Corrosion Removal and Cleaning Tools</b>	<b>4-6</b>
<b>C Avionics Corrosion Control Kit</b>	<b>4-8</b>
<b>5 References and Bibliography</b>	<b>5-1</b>
<b>A References</b>	<b>5-1</b>
<b>B Bibliography</b>	<b>5-2</b>
<b>6 Glossary</b>	<b>6-1</b>

## Tables

<b>Table</b>		
<b>4-1</b>	<b>Materials Used in Corrosion Control</b>	<b>4-1</b>
<b>4-2</b>	<b>Corrosion Control Materials Used in Advanced Technology Laboratory</b>	<b>4-5</b>
<b>4-3</b>	<b>Corrosion Removal and Cleaning Tools and Equipment</b>	<b>4-7</b>
<b>4-4</b>	<b>Corrosion Control Kit</b>	<b>4-8</b>

## Section 1

### AVIONICS CORROSION (GENERAL)

The objectives of this report are to offer to the Navy a limited study of some of the problems and possible solutions associated with avionics corrosion control that could be the basis of a manual devoted to that subject. A much more detailed investigation would be required to produce a manual containing those procedures that, when conscientiously implemented, would economically extend life cycles, reduce downtimes and mission degradations, reduce or eliminate total failures, and expand safety margins. This investigation would consequently require additional funding and additional time for accomplishment.

Corrosive attack on avionics material can result in devastating effects on communications and navigation equipment performance. Typical end results of corrosive attacks on avionics equipment include such effects as these:

- Antenna systems: shorts or changes in circuit constants.
- Chassis, housings, or mounting frames: infected with contamination, pitted, loss of finish.
- Mechanical or electrical tuning linkage; motor contacts: intermittent operation or preventing frequency selection.
- Water traps: from excessive moisture forming at a faster rate than evaporation time.
- Relay systems: corroded contacts, mechanical action, coil, solder joints.
- Plugs, connectors, jacks: may corrode, short, and become inoperable.
- Multi-pin cable connectors: corroded wire, pins, contacts, shells.
- Cables: disintegrating insulation, corroded wires, connections.
- Pilot lamps: corroded sockets, contacts, lamp bases.
- Waveguide: presence of moisture, internal pitting; also joints, effectiveness of gaskets, finish.

#### A. EFFECTS OF ENVIRONMENT

The environment, material, and protection of equipment determine corrosion rates. Avionic equipment subjected to long periods of temperature changes with humidity, whether unused or operating, frequently develops deterioration and failure from the effect of moisture and fungus growth. When fungus appears, the adverse condition produced by moisture is intensified. Continuous warm, damp air causes condensation of atmospheric moisture within equipment. Condensed moisture forms electrical leakage paths which result in corrosion.

The rate of corrosion on any specific metal varies because of temperature, humidity, and chemicals in the surrounding environment. Variations of the intensity of these factors have great impact on the rate of corrosion. Ferrous metals exposed to arctic



and antarctic temperatures with the absence of fluid electrolytes show practically no corrosion. Those exposed to a dry desert type of environment show a very low corrosion rate. Of all common pollutants, sodium chloride found at seacoast (harbor) environments is the most destructive.

Differences in electrolyte concentration and oxygen concentration promote corrosion. Corrosion does not appear in the absence of moisture. Pure water is not particularly effective as an electrolyte, and corrosion results very slowly in a medium of pure water. However, as water is adulterated with dissolved salts, or particularly acids, the rate of corrosion is significantly accelerated. Dissolved carbon dioxide from the air (carbonic acid) increases the conductivity of water and therefore creates a corrosive atmosphere. From the above, it becomes obvious that in a continuously dry atmosphere, corrosion will not develop.

Corrosion associated with atomics is mainly electrochemical in nature. Three ingredients are required: an electrolyte, a material to act as an anode, and another to act as a cathode. The electrolyte is the medium in which ionization occurs. The electrons flow from anode to cathode through a metallic path. The loss of metal is always at the anode. Anodic reactions are always oxidation reactions which tend to destroy the anode metal by causing it to go into solution as ions or to revert to a combined state as an oxide. Corrosion occurs at the rate which an electrical current — corrosion driving current — can get through the corroding system. The driving current level is determined by the existing electrode potentials.

Galvanic corrosion is the disintegration of the anode in a galvanic couple. A closed electrical path through two connected dissimilar metals joined by an electrolyte occurs in endless variations and provides some very rapid corrosion rates. A difference of potential between two metals when coupled by an electrolyte forms a miniature cell with an anode (metal loss, corrosion) and cathode (protected area). Many such corrosion areas are, in effect, small cells or batteries; hence the term galvanic. If the area of the cathode is significantly greater than that of the anode, the corrosive attack on the contact area of the anode may be greatly intensified. When a continual supply of rust is provided by some external source (for example, bolts, etc.), unsealed or partially sealed aluminum or zinc coatings are severely attacked. Zinc and aluminum are strongly anodic to iron.

Once started, corrosion does not proceed at a uniform rate. Other factors must be considered that also contribute to the corrosion problems. For the environment to succeed in its destructive effort, there must exist materials or equipment that were manufactured or have become vulnerable to atmospheric attack. Included in this category are dissimilar metals that create electrolytic action; poor surface preparation for protective finishes; defective, insufficient, or porous finishes; accumulated soil, salts, water, industrial fumes, moisture, or contaminated air; and damaged protective finishes. Since moisture tends to collect, it becomes obvious that a frequent, detailed inspection program, with immediate corrective activity as required, will retard and in many instances eliminate corrosive action. The task becomes relatively simple with frequent cleaning, elimination of moisture traps, and the immediate implementation of minor repairs to preclude major overhauls.

## B. DESCRIPTION AND IDENTIFICATION OF DETERIORATION

### TYPES OF CORROSION

All the varieties of corrosion attack that occur are not pertinent to this study, which is restricted to corrosion attack upon avionic equipment. For example, this report is not concerned either with low-temperature corrosion of economizers and preheaters in large oil-fired boilers or with high-temperature corrosion, which occurs without the familiar electrolyte. However, there are many forms of electrochemical corrosion that are quite pertinent to this report. Those that do have an impact are detailed and illustrated as follows:

- Uniform attack corrosion is characterized by a general disappearance or dissolving of a metal surface due to acidic or oxidizing conditions; it is a general, uniform wasting away of the surface. It is not necessary to have two different metals or a galvanic couple to have corrosion. The electrical driving force corrosion current can be present in a single metal. The microscopic anodic and cathodic areas on the exposed surface of a metal fluctuate and produce a uniform corrosion, unless any of the anodic or cathodic areas are stabilized; in this instance, severe local corrosion or pitting results.
- Preferential or selective corrosion is exemplified by the loss of one of the metals of an alloy. The corrosion process begins when one element in an alloy becomes anodic to the other and is preferentially attacked. Typical would be the slow disappearance of zinc from a zinc copper alloy (brass); while this phenomenon is seldom seen, it can be disastrous because the porous copper mass, depleted of zinc (its alloying agent), has little strength.
- Local corrosion is a pitting type of electrochemical deterioration. One major cause of local corrosion is a rupture in the protective coating. The exposed metal is stabilized as the anode, and the surrounding metal or the corrosion products act as the cathode.
- Cavitation, once thought to be caused by poor metal alloys and to result from the implosive forces of very small collapsing bubbles, now is believed to result from high-frequency vibration, implosive stress, and chemical action. A combination of the action agents creates a faster deterioration than the resultant of the single actions would indicate.
- Fretting corrosion seems to be a follow-on action of mechanical fretting caused by an oscillating or vibrating motion of small amplitude between two closely fitting surfaces; it has also been called friction oxidation.
- Stress corrosion, which can lead to stress corrosion cracking of metal, is a separate category of metal failure; it is not a straight mechanical failure because its origin is not entirely mechanical. It is thought to be a combination of electrochemical and mechanical action.
- Galvanic corrosion is the disintegration of the anode in a galvanic couple. A closed electrical path through two dissimilar metals joined by an electrolyte occurs in endless variations and provides some very rapid corrosion rates.
- Concentration cell corrosion occurs when differential oxygen concentration cells or differential metal ion-concentration cells attempt to balance concentration differences. Barriers to the ready transfusion of oxygen create the differential of oxygen concentration. The low oxygen area is anodic to the high oxygen area.

if an electrolyte on a metal contains more metal ions at one point than at another, metal enters the electrolyte in the form of ions where the ion concentration is low. This form of corrosion may be more familiarly known as "crevice corrosion."

- Intergranular corrosion is corrosion action that takes place in the grain boundary areas of certain types of metal. It is generally thought of as stress corrosion cracking; however, although intergranular corrosion is encouraged by stresses, it is not necessarily caused by stress. The corrosion usually starts at the surface in the anodic areas and penetrates the metal, then proceeds probably as an oxygen concentration cell type corrosion; the end result can only be deterioration or structural failure.
- Transgranular corrosion, as the name implies, cuts across or through the grain structure and is not limited to following grain boundaries. The pattern of transgranular corrosion is called the tree effect where growth proceeds by branching. This is stress corrosion and only tensile stresses are effective in promoting the damage. The exact correlation between environments and this type of corrosion has eluded researchers thus far. There is still much controversy about the manner of propagation. One theory advances electrochemical action only, and another proposes cyclical electrochemical and mechanical efforts.

#### CORROSION EFFECTS ON VARIOUS METALS

Each structural metal or alloy has a certain propensity to corrode in a given environment. The endless combinations of metals, alloys, and environments make composing a total corrosion profile of even one alloy a gigantic task. A profile of the corrosion resistance of a single metal or alloy can be correctly plotted only after testing all the metallic variations in the total range of all environments. It can be seen at once that such complete testing would be endless, requiring enormous quantities of money, time, and professional people; therefore, it is unreasonable.

However, enormous quantities of data on the corrosion of metals are available as a result of research and industrial product development work. The interpretation and proper application of the data determine the success of a corrosion control program.

- Ferrous Metals—Once started, rusting does not proceed at a uniform rate. The familiar reddish brown rust on steel is a mixture of hydrated iron oxides. Depending upon the amount of pollution in the atmosphere and the composition of the steel, this oxide film is more or less protective. Of all the common pollutants, sodium chloride, found in seacoast environments, is the greatest destroyer of the protectiveness of the rust film on carbon steel. Oxides of sulfur are a poor second to sodium chloride. When both pollutants are nearly absent, the corrosion of steel is not significant; a rust film forms and assumes a protective nature. Iron and steel are normally not attacked by alkalis, which in fact protect the surface very well. Strangely enough, iron and steel are also not attacked by concentrated sulfuric acid and concentrated hydrochloric acid. This is proved by the fact that concentrated sulfuric acid is transported in steel milk drums. However, it is a different story with all acids where water is present. Dilute sulfuric acid, dilute hydrochloric acid, and dilute nitric acid all attack steel very rapidly indeed, the two former acids bubbling away merrily with hydrogen gas, which is evolved during the reaction. It is fairly obvious, then, why spilled acid from a battery causes such havoc.

- **Aluminum** — Aluminum is basically a very reactive metal, much more so than iron. Yet it does not readily corrode. The reason for this is that the metal is covered almost instantaneously with a minutely thin film of aluminum oxide, which is completely nonporous and which excludes air from contacting the surface. This means that aluminum products are very resistant to extremely polluted air, and aluminum products last virtually forever. Their positions in the galvanic series indicate that aluminum is anodic to steel. One would therefore expect that if steel were coupled together with aluminum, the aluminum would corrode and the steel would be left intact. Unfortunately this is not true. In practice, under most conditions, contact with aluminum makes steel rust much more rapidly than it would if it were left alone. The reason is that the surface of the aluminum is so strongly oxidized that there is no longer an aluminum/steel couple but one of aluminum oxide/steel instead. With such a couple, the steel becomes very anodic and rusts away very quickly. Therefore, never use aluminum as a protector for steel. It does not work. Use zinc or cadmium instead.

While aluminum surfaces are remarkably free from any likelihood of corrosion, the same is not true concerning hidden crevices. These corrode very rapidly indeed, especially if the aluminum is coupled with copper or a copper alloy.

Aluminum must never be kept in contact with even very slightly alkaline solutions that are uninhibited because in such contact aluminum is destroyed very rapidly. Never have aluminum in contact with caustic soda, washing soda, or lime.

One of the most harmful materials when in contact with aluminum is mercury or any of its salts. Mercury forms a compound with aluminum called aluminum amalgam. Because the aluminum in the compound is finely divided, it is immediately attacked by the oxygen in the air. A white powder is formed rapidly, and the aluminum becomes very hot. More aluminum dissolves in the mercury and also oxidizes. Whiskers of the aluminum oxide are formed at a visible rate. Once mercury or a mercury salt has come into contact with aluminum, there is virtually nothing one can do to stop the aluminum from corroding away except to remove every trace of the top surface of aluminum amalgam.

Another chemical which must never come into contact with aluminum is carbon tetrachloride. When aluminum is in contact with this solvent, a violent chemical reaction occurs which can be quite dangerous. Chloroform reacts with aluminum in a rather similar way.

Aluminum is also attacked by strong acids, but it can be safely used with weaker acids such as vinegar, lemon juice, etc.

In general, aluminum and its alloys exhibit a wide range of corrosive attack, varying from general etching of aluminum surfaces to penetrating attacks along the internal grain boundaries of the metal. The corrosion products of aluminum are seen as white to gray, powdery deposits.

- **Copper and Copper Alloys** — Copper is well known as being the most harmful metal with which to couple iron, steel, or almost any other metal. The reason for this is that it is so very cathodic, which means that it is able to get rid of hydrogen ions and electrons that flow to it from the other metals during the corrosion process, but it is not affected itself.

Copper and its alloys are generally corrosion-resistant, although the products of corrosive attack on copper are commonly known. Sometimes copper or copper

alloy surfaces tarnish to a dull gray-green color and the surface may remain relatively smooth. The discoloration is the result of the formation of a fine-grained, airtight copper oxide crust, called a patina. This patina in itself offers good protection for the underlying metal in ordinary situations. However, exposure of copper and copper alloys to moisture or salt spray causes the formation of blue or green salts indicating active corrosion.

Even very dilute nitric acid attacks copper vigorously. To remove the surface tarnishing from copper, a good method is to dip the object into dilute nitric acid solution, followed by very thorough washing in warm water. Copper is also strongly attacked by ammonia solution. Apart from these instances, copper is virtually corrosion-proof, and there is no need to coat it. Like copper itself, the various copper alloys, which are the bronzes (copper/tin) and the brasses (copper/zinc), are free from corrosion troubles. In fact, the alloys behave like copper itself in most respects.

Care should be exercised when dealing with copper, brass, or bronze installations. It is not the copper that one has to worry about, but any iron, steel, or aluminum in contact with it. Corrosion of such metals in contact with copper is extreme unless care is taken to exclude all air from the copper to stop the cathodic reaction. The copper should be thoroughly taped with a bituminized tape to exclude air from it. The iron, steel, or aluminum surface, on the other hand, should be kept completely uncovered; otherwise severe crevice corrosion may occur.

- **Magnesium** — Magnesium is even lighter than aluminum, a metal which it closely resembles. Because magnesium is so light and yet so strong, it is nowadays used for many purposes in aircraft. Magnesium is fairly corrosion-resistant in normal fresh water and in clean air, but it must not be used outside in dirty and polluted air unless it is well painted. Salt water is death to magnesium, which is attacked by it very rapidly. Also, like aluminum, magnesium is prone to crevice corrosion and stress cracking under corrosive conditions.

Magnesium is one of the most anodic metals existing. This indicates that it should never be coupled with any other metal because the second metal will inevitably be cathodic to it. Aluminum is virtually the only metal to which magnesium can be safely joined.

If magnesium must be joined to copper or steel, instead of a direct connection an insulated connection should be made. It has been found that joining of magnesium is often better done by gluing than by normal mechanical methods involving screwing or bolting. The glue to be used is a two-pot epoxy resin which is very tough after hardening.

Magnesium should never be brought into contact with even dilute acids. Similarly, magnesium is severely corroded by boiling water. On the other hand, unlike aluminum, magnesium can be kept in contact with cold and dilute alkali solutions without undue trouble.

Magnesium corrosion products are white and quite large when compared to the size of the base metal being corroded. The deposits have a tendency to be slightly porous, and the corrosion spreads rapidly. When white, puffy areas are discovered on magnesium, prompt attention is required, because the corrosion may penetrate entirely through the structure in a very short time.

- **Nickel** — Nickel has excellent corrosion resistance in all forms of water, including seawater, and in contact with almost all other substances except materials having drastic action, such as nitric acid. However, care must be taken when joining nickel to other metals because severe corrosion cells may form, causing the adjoining metal to corrode away. Nickel/aluminum and nickel/steel couples should be avoided, but nickel can be joined without any ill effects to copper, brass, bronze, lead, tin, and zinc.

Nickel is also used as a protective agent, both in the form of electroplated coatings and as an alloying constituent. Nickel plate protects by forming an actual, physical, noncorrosive barrier. Electroplated coatings are somewhat porous, and corrosion eventually starts at those pores or pinholes unless a supplementary coating is applied and maintained. Nickel-based alloys such as Inconel generally have good corrosion-resistant qualities. Their corrosion products appear as a green, powdery deposit.

- **Silver** — Silver does not normally corrode in the accepted sense, but it is tarnished by hydrogen sulfide and other sulfur-containing gases and solid materials. In a typically polluted atmosphere, silver objects become dulled by sulfur compounds in the air. The tarnish is only minutely thin, so that very little silver is lost when the tarnish is polished off by any standard silver polish.
- **Stainless Steel** — The theory behind stainless steel is that when steel with a high proportion of chromium is used in a corrosive atmosphere, the chromium becomes oxidized to a very tough and well adhering surface film. The film effectively protects the rest of the metal against rusting. This is in contrast to the iron oxide on the surface of normal steel, which is very porous and also flakes off easily, so that it is not very effective in protecting the metal underneath.

If the surface chromium oxide film wears off or becomes torn off, the metal underneath still does not corrode. It simply forms another layer of protective chromium oxide film on its surface. In this way the protection given is permanent, not like chromium plating, which starts rusting severely once a pinhole is formed in it.

It is possible for stainless steel to rust. If it is kept in water which is deficient in oxygen, such as polluted river water or even some seawater, corrosion can occur, because there may be some positions where the adherent and protective oxide film has a pinhole or two. Normally, in air or water which has plenty of dissolved oxygen, such pinholes are not important, because the underlying chromium becomes oxidized and continues to protect the metal underneath. However, if there is no oxygen in the water, there is trouble: The surrounding well-oxidized chromium/iron layer then acts as a cathode, and very rapid corrosion takes place. Although one would expect stainless steel to be very cathodic when in contact with normal steel, its rust-inducing action is only very slight.

If the surface area of stainless steel coupled to normal steel is comparatively small, it makes little difference in the rate at which the steel rusts.

Therefore, it makes sense, for instance, for cars to use stainless steel for bumpers, headlamp cowlings, and other brightwork, as the stainless steel does not generally cause corrosion in the mild steel in contact with it. This is in marked contrast to chromium-plated parts, which induce very rapid corrosion on neighboring steel pressings. The reason for this is that the actual amount of chromium used for commercial plating is quite small. Chromium plating

consists mainly of copper and nickel, both of which are very corrosive in contact with iron and steel.

Apart from the specialized cases of the corrosion of stainless steel in water which is starved of oxygen and in some chemical solutions with which the reader is unlikely to come into contact very often, stainless steel is a material with excellent corrosion resistance. It lasts virtually forever, even in the filthiest atmosphere and in contact with quite corrosive solutions. However, stainless steels (300-400 series) are subject to intergranular corrosion primarily because of improper heat treatment. There is also some tendency toward local corrosion or pitting in a marine environment, the 300 series being more resistant in this environment than the 400 series. Corrosion becomes apparent by the rough surface it creates, or it sometimes appears as red, brown, or black stains.

- **Cadmium** — Cadmium is used as a coating to protect the part to which it is applied and to provide a compatible surface when the part is in contact with other materials. The cadmium plate supplies sacrificial protection to the underlying metal because of its greater activity. That is, during the time it is protecting the base metal, the cadmium is being intentionally consumed. The cadmium becomes anodic and is attacked first, leaving the base metal free of corrosion. Attack is evident by white to brown to black mottling of the cadmium surfaces. This, however, does not indicate deterioration of the base metal. Until the characteristic colors peculiar to the corrosion of the base metal appear, the cadmium is still performing its protective function.
- **Chromium** — Chromium is also used as a protective agent, as an electroplated coating, and as an alloying constituent with iron in stainless steels. It is subject to pitting attack in chloride environments. Chromium, being cathodic to steel, does not corrode itself, but promotes rusting of steel where pits occur in the coating.

#### **OTHER FORMS OF CORROSION**

Before ending the general discussion on avionics corrosion, it is necessary to briefly discuss the other forms of corrosion that can cause significant problems to modern electronic or avionic systems.

- **Corrosion Caused by Microorganisms** — Microbial attack was first recognized as a significant problem during World War II. Because of their complexity, modern electronic systems are more susceptible to damage from microbial attack than earlier systems were. Microbial attack, as the term is used in this report, includes actions of bacteria, fungi, and molds.

Microorganisms occur almost everywhere, and they outnumber all other types of living organisms. The organisms causing the greatest corrosion problems are bacteria and fungi.

Bacteria may be either aerobic or anaerobic. Aerobic bacteria require oxygen to live. These bacteria may accelerate corrosion by oxidizing ammonia to produce nitric acid. Aerobic bacteria living adjacent to metals may promote corrosion by depleting the oxygen supply or by releasing metabolic products. Anaerobic bacteria, on the other hand, can survive only when free oxygen is not present. The metabolism of these bacteria requires them to obtain part of their sustenance by oxidizing inorganic compounds such as iron, sulfur, hydrogen, nitrogen, and carbon monoxide. The resultant chemical reactions cause corrosion.

Fungus is the growth of microorganisms that feed on organic materials and generally take the form of molds, rusts, mildews, smuts, etc.

While low humidity does not kill microbes, it slows their growth so that they simply subsist but do no damage. Ideal growth conditions for most microorganisms are temperatures between 68° and 104°F and relative humidity between 65 and 100 percent.

It was formerly thought that fungal attack could be prevented by applying moistureproofing coatings to nutrient material or by drying the interiors of compartments with desiccants. It is now known that some microorganisms remain in spore form for long periods, even under extremely dry conditions. Furthermore, many electrical insulating varnishes and some moistureproofing coatings are attacked by mold, bacteria, or other microbes, especially if the surfaces on which they are used are contaminated.

Dirt, dust, and other airborne contaminants are the least recognized contributors to microbial attack. Usually unnoticed, even small amounts of airborne debris may be sufficient to promote fungal growth.

Damage resulting from microbial growth can occur when any of three basic mechanisms or a combination of these mechanisms is brought into play. First, fungus is damp and has a tendency to hold moisture, which contributes to other forms of corrosion such as electrochemical corrosion. Second, because fungi are living organisms they need food to survive. This food is usually obtained by the decomposition of the material on which the fungus is growing. Third, the microorganism secretes corrosive fluids that attack many materials, including metals.

Optical devices can be damaged by microorganisms. Lens coatings are extremely susceptible to fungal attack, which may take any of three forms: a spider-web, a flat starfish shape which leaves a milky stain, or minute circular spots that etch the glass.

Under proper atmospheric conditions, fungi may grow on almost any surface, including: fiber, laminated plastics, molded plastics, cotton, linen, paper and cellulose derivatives, wood, leather, glass, wax, metals, and soldered joints.

- Normal Oxidation — Normal oxidation of metals is a common form of chemical attack that occurs at all temperatures. For this reason, metals that are easily corroded should not be used when maximum conductivity is required (as in fabricating contacts). If base metals are used for contacts, they should be plated with one of the noble metals.
- Corrosive Vapor Attack — Corrosive vapors may result from outgassing (decomposition) of plastics or other organic materials, or from the presence of corrosive materials in the atmosphere. Some organic materials that produce corrosive vapors include:
  - Adhesives — Ureaformaldehyde, Phenol Formaldehyde
  - Gaskets — Neoprene/Asbestos, Resin/Cork
  - Sealers — Polysulfide, Epoxy
  - Insulation — Vinyl, Polyvinylchloride
  - Sleeving — Vinyl, Polyvinylchloride, Silicone
  - Tubing — Neoprene, Shrinkable



- **Plastics** — Melamine, ABS, Phenolic
- **Varnish** — Vinyl, Alkyd
- **Solder Flux Corrosion** — Solder fluxes may contribute to chemical attack. The exact nature of solder flux is not known, but oxide removal and increased solder fluidity are achieved when solder flux is used. Only noncorrosive, nonactivated solder fluxes such as type W of MIL-F-14256 should be used.  
Residues from activated fluxes can degrade circuitry by (1) corroding solder joints on nearby regions where flux fumes may settle or (2) reducing insulation resistance. Deposition of flux on relay contacts and other mechanical components can cause serious problems within a system.
- **Corrosion Caused by Insects and Animals** — Damage to electronic equipment may be caused by insects and/or animals, especially in tropical environments. Equipment in storage is most susceptible to this type of attack since insects or animals may enter through vent holes or tears in packaging. Once inside, the animals build nests, which tend to absorb moisture. This moisture, plus excretions from the animals or insects may cause corrosion or deterioration that goes unnoticed until the equipment is put to use and a failure occurs. Another type of damage may occur when electrical insulation, etc., is food for the insects. Once bare wiring is exposed, more areas for corrosion and shorting are available.

#### **ADDITIONAL CORROSION INFORMATION**

The subject of corrosion in general is treated in Section III of Technical Manual NAVAIR 01-1A-509 Aircraft Weapons Systems Cleaning and Corrosion Control, dated March 1972.

## Section 2

# PREVENTIVE MAINTENANCE

Fundamental to the preventive maintenance aspects of an avionics corrosion control program is the practice of frequent inspections and spot checks of the equipment by personnel familiar with the detection, analysis, and treatment of corrosion. Of course, the frequency and scope of inspection will be governed by the deployment situation of the aircraft.

The three major followup items of the overall corrosion control program after inspection are these:

- Cleaning
- Treatment
- Protection

Considering the preventive maintenance approach to the corrosion problem — those steps taken before, not after the fact — the following are the common countermeasures:

- Cleaning
- Water displacing
- Protective coatings
- Potting compounds and sealants
- Preserving

Lastly, proper approaches to storage, handling, and shipping of equipment and components must be observed to provide adequate protection until the units are back in service.

Treatment and protection of avionic equipment already corrosion-damaged is covered in section 3 of this report.

### A. CLEANING

#### GENERAL

In the corrosion control preventive maintenance program, cleaning is the first logical action step to be initiated following inspection and analysis of the quantities and distribution of corrosion products, dirt, or other contaminants found on the equipment. In fact, lack of cleaning is responsible for the initiation of a majority of corrosion problems in avionic equipment.

While the cleaning process is fundamental to the chemical corrosion control problem in itself, general cleanliness is, from a broader view, highly important in maintaining the functional integrity of electronic systems. Dirt may exhibit either of two

properties: it may be conductive or insulating. As a conductor, it may provide an undesired electrical path; as an insulator, it may interfere with the proper operation of electrical contacts, for example.

Contamination may begin early in the life of equipment, and it may be traceable as far back as the manufacturing process, where it is subjected to considerable handling. Improper packaging materials can also contaminate. During installation and initial use, external material may settle or transfer; with time, environmental sedimentation may occur from such causative agents as reactive gases in polluted air or such accretions as oxide films can develop from the reaction of base metals with oxygen in clean air.

By definition, cleaning is a broad term covering the methods and materials necessary to remove contaminants from a surface. The degree of cleanliness required is governed in general by the type and function of the equipment, by the type of service conditions to which it will be subjected, and by what further treatment will follow the cleaning process. Fundamentally, the material composition and condition of the surfaces to be cleaned determine the techniques employed in the initial cleaning process. Standard techniques range from mild to increasingly severe, as appropriate; in every instance the mildest practicable method should be employed.

Depending upon operational requirements and the severity of the contamination problem, several courses of action are open: local treatment at the organizational level, at the intermediate-level, and depot-level maintenance in a cleaning facility, or a combination of these.

#### ORGANIZATIONAL MAINTENANCE

It is recognized that certain constraints may exist on the degree and frequency of preventive maintenance that can be performed at the user level due to operational commitments, unavailability of equipment, or other limitations. However, as a very minimum measure, hand cleaning methods can be applied to all accessible areas of equipment removed from service, using Freon cleaners<sup>1</sup> and a brush or a clean, dry, lint-free cloth. A 50-50 mixture of isopropyl alcohol and distilled water is also a good cleaning agent for use at the organizational level. A soft eraser can be useful for the removal of fingerprints and tarnish-type deposits. These cleaning operations should be followed by the application of low-pressure (30 psi), dry air, taking care not to drive loosened contaminants farther into the units. Refer to section 4 for a listing of the more common cleaning agents and their applications.

After being cleaned, bonding straps, shock mounts, connector plugs, cables, and wiring should receive a followup inspection for condition and mechanical security. Particular attention must be directed to the periodic inspection of the aircraft antenna systems and their associated components for cleanliness, security, and condition. Cleanliness and positive contact capabilities of plugs, receptacles, or other types of connectors linking the elements of the antennas are important considerations. All accessible components of each antenna, including the transmission lines, should be wiped clean of dirt and moisture in the course of the inspection process. Antenna problems are treated more specifically in section 3.

<sup>1</sup>Note, however, that Freon cleaners can dissolve certain conformal coatings.

Removal of fungus (by alcohol) should not be overlooked. Fungus accelerates corrosion through the absorption of moisture. Moreover, fungus can act as an electrolyte, destroying the resistance of electrical insulating surfaces. By keeping equipment clean and dry, these problems can be minimized. Cloths that have been contaminated during the fungus-cleaning process should be discarded.

### **INTERMEDIATE- AND DEPOT-LEVEL MAINTENANCE**

If, despite a concerted maintenance program, it is determined that a persistent contamination problem still exists, when feasible, a prudent decision may be to make use of the capabilities of an equipment cleaning/refurbishment facility equipped specifically for this purpose and staffed by specialists in the field, where more elaborate mechanical, chemical, or electrochemical cleaning methods are available.

Intermediate- and depot-level cleaning operations ordinarily are staged and employ a variety of apparatus not practical for use at the organizational level.

It is customary to dedicate one area to precleaning functions and to utilize both mechanical and chemical techniques for application of treatments (after stripping) to the heavier mechanical elements of the avionic systems, such as covers, chassis, housings, etc. Mechanical methods serve to remove all particulate types of contamination through the use of power brushing, abrasive wheel grinding, and various forms of blasting, with sand, vapor grit, or glass bead. Chemical treatment consists of processes involving acid- and base-type (alkaline) cleaners. Such items as a highly caustic cleaner for ferrous alloys, inhibited alkaline cleaner for aluminum alloys, passivation (nitric acid) for stainless steels, and nitric acid baths for aluminum cleaning, plus the usual muriatic and phosphorous acid cleaning solutions, may be employed.

Following the above processes, equipments are employed for agitation washing, using solvent and/or water pressure to remove shop contamination. These equipments can range from simple dip tanks to multistage machines performing several cleaning and processing operations automatically.

At the depot level, the delicate electronic assemblies, subassemblies, modules, etc., are ideally processed in a clean room - controlled environment area. Cleaning equipment could ordinarily be expected to include ultrasonic cleaning equipment of the water-detergent and solvent types, and a vapor degreasing cleaning system using fluorocarbon solvents such as Freon TF. Vapor degreasing is an efficient method widely used for cleaning electronic parts. The component being treated is suspended in a chamber that allows the vapors of a heated solvent to condense on its surface, thereby flushing it clean.

Ultrasonic cleaning is a most effective method, entailing immersion of the part in an ultrasonically agitated solvent bath. Because high energy is imparted to the solvent, contaminants are rapidly and easily dislodged from even difficult-to-reach areas; a very strong scrubbing action takes place. More specifically, a sonic cleaner converts electrical energy at an ultrasonic frequency into mechanical sound energy for cleaning and performing other functions within a stainless steel cleaning chamber. The ultrasonic electrical energy is supplied by an electronic generator that may deliver over one kilowatt of power. Parts to be cleaned are placed in baskets and immersed in the cleaning solution. The magnetostrictive transducers, powered by

the ultrasonic generator, produce cavitation in the cleaning solution, and the exceptional cleaning qualities of sonic energy cleaners are the result of the imploding or scrubbing action on the surface of the part being cleaned.

It is customary practice to incorporate a rinse unit into the cleaning system to remove the last vestiges of contaminant from the parts, and a dryer to dry the rinse water off the cleaned parts so that they may be then assembled or stored. The cleaning system ordinarily has a filter to remove solid particles of contaminant from the cleaning liquid to prolong its useful life and regulate the temperature of the solution.

The choice of solution to be used follows the general rule that the cleaning solution must be a good solvent of the carrier that holds the contaminant to the part being cleaned. Water-base detergents are commonly employed with these systems. The usual water-base cleaning solutions contain up to 2 percent by volume of various constituents added to water. The action of these components may be either to remove the contaminant by detergent action or to attack the corrosion on metal parts chemically. Cleaning solutions of the latter type usually have inhibitors added to them to prevent chemical action (etching) on the base metal of the part to be cleaned. A third type of cleaner in this category dissolves organic waxes, greases, and oils that may be holding grit or shop dirt to the surface of the part.

Organic solvents are usually used in sonic cleaning equipment when a suitable water-base detergent cannot be found to dissolve the contaminant from the parts in all stages of handling.

The cleaning station of the controlled-environment area should be equipped also with electrocleaning/electroplating equipment. Electrolytic cleaning is the process of degreasing or descaling metal by making it an electrode in a suitable bath. Equipment for electroplating and metal "put-on" operations is capable of performing selective anodizing, electropolishing, etching, metal removal, and deburring, simply by reversing the direction of the electrical current flow from the power supply.

Each major step of the cleaning process should be under the monitorship of a quality assurance program to ensure proper compliance with established procedures.

## **B. WATER DISPLACING**

When equipment is cleaned by immersion or flushing techniques, all water must be removed. This can be accomplished by the application of clean, dry, compressed air, possibly followed by a spray-dry, water-displacement compound, and finally oven drying to expel any remaining moisture.

A standard ultra-thin-film water-displacement compound is MIL-C-81309A. This is a water-displacing, corrosion-prevention compound and lubricant that is particularly effective on certain components such as hinges, electrical connectors, fasteners, and microswitches. Because it offers only short-term protection, it should be reapplied periodically -- weekly on outside exposed surfaces, monthly on equipment protected from outside environments.

Another ultra-thin-film water-displacing compound for corrosion control, carried in the DOD Index of Specifications and Standards along with MIL-C-81309A, is MIL-C-0081309B.

Different recommended drying temperatures are to be found in the technical documents studied, the highest noted being 160°F (T. O. 12-1-3) for 2 or 3 hours, with an additional hour added to the drying time for each 10° oven temperature below 160°F. Another source — MIL-T-152B — specifies 60°C (140°F), not to exceed 3 hours. It is the practice of the Bendix Advanced Technology Laboratory (engaged in the refurbishment of NASA electronic modules) to operate their ovens at 65°C (149°F) during normal daytime operations and at 50°C (122°F) if the units are to be left to dry overnight. In any event, the drying cycle should not exceed that specified by the applicable technical order, technical manual, or bulletin covering the equipment.

If ovens are not available, a small room equipped with heaters and an exhaust fan might serve as a substitute under certain conditions. However, to be effective, the temperature of the room must exceed the ambient temperature by at least 30°F.

## C. PROTECTIVE COATINGS

### GENERAL.

Coatings may serve numerous functions, but in general the two most important ones are to provide high electrical insulation between conductors, interconnections, components, and other electrical parts, and to provide protection from environmental damage. Severe environmental conditions necessitating protection include moisture, heat, salt spray, oxygen, radiation, microorganisms, chemicals, and solvents.<sup>2</sup> Coatings applied to electronic assemblies, modules, and printed circuits protect against corrosion by acting as moisture and gas barriers.

### CIRCUIT BOARD COATINGS

Polyurethanes, epoxies, silicones, and polystyrenes are the most commonly used coatings for circuit board coatings. The choice of coating material is largely determined by the operating and storage requirements of the circuit boards themselves. (The silicones are most suitable for high-temperature applications, for example.) From the standpoint of reworkability (and since we are concerned in this section with preventive maintenance, this is important) polyurethanes are outstanding. For adhesion and resistance to moisture, epoxies are unsurpassed.

Military Specification MIL-I-46058 classifies the four generic types of circuit board coatings as follows:

- Type ER — Epoxy resin
- Type PUR — Polyurethane resin
- Type SR — Silicone
- Type PO — Polystyrene

---

<sup>2</sup>James J. Licari, Plastic Coatings for Electronics (New York: McGraw Hill Co., 1970).

Types EK and PUR are coatings for general-purpose applications, while type SR is useful for high-temperature applications, and type PO is used when low dielectric loss is important.

Application of a conformal coating greatly improves the reliability of an electronic assembly. It has been demonstrated that otherwise unprotected units will often fail if exposed to unfavorable environments because of the invasion of moisture, a loss of insulation properties, electrical shorts, and the effects of corrosion.

An uncoated circuit board can develop excessive corrosion on components, solder, and conductor lines after a mere 2 days of exposure at 95 percent relative humidity. The same board, coated with 1.5 mils of polyurethane, shows no signs of corrosion and passes all required electrical tests after 6 months in a 95 percent humidity chamber. There is also a marked distinction between the corrosive effects on an uncoated circuit board that has been exposed to 50 hours of salt spray as contrasted to one that has been protected by a 1-mil polyurethane coating and subjected to the same conditions.

### COATING METAL SURFACES

Coatings are applied to metal surfaces to provide the necessary protection from corrosive effects of the surrounding medium. Different metals corrode in different ways according to the nature of the metal itself and the environments to which they are exposed. In most instances, elevated temperatures accelerate the corrosion process. With either chemical or electrochemical corrosion, moisture is a necessary condition in almost every case. Therefore, the moisture-barrier or moisture-resistance properties of a protective coating are extremely important.

Fortunately, inorganic oxide films normally form on many metals stored in air; these oxide films are quite passive, and the effect of their presence is to slow down or prevent further deterioration of the metal. In other cases, it is possible to produce artificial, inorganic coatings that provide the same protection; these chemical-conversion coatings are films formed through the reaction of oxygen, chromates, phosphates, or other chemicals. Common anodized forms of passive films were formed by electrochemical methods. However, for extremely harsh environments or for long-term exposure, organic coatings are applied over these conversion coatings, to form an extremely effective barrier system. For this purpose, lacquers, baking enamels, and highly resistant epoxies, vinyls, polyurethanes, and silicones are often employed.

### PROTECTIVE COATINGS FOR ELECTRICAL CONNECTIONS

Electrical connections may be protected against moisture, corrosion, and damage from metal particles by the application of a strippable polyurethane coating. A typical commercial compound of this type is PR 1532, manufactured by Products Research Corporation. It is applied to a thickness of approximately 1/16 inch minimum.

Because of the probability that components will have to be replaced in the course of service life of almost any electronic equipment, some thought must always be given

to the removability of any compounds used to coat the electrical connections. Moreover, the removal technique must be one that does little or no damage to adjacent components, surfaces, and markings. The polyurethanes are popular because they are thermoplastic and, therefore, can be melted in local areas with a hot soldering iron. In general, removal by solvents is not practical because of the time involved and other considerations.

#### **D. POTTING COMPOUNDS AND SEALANTS**

By definition, potting is a process for encasing a part, or an assembly of discrete parts, within a protective material that is generally over 100 mils thick, may vary in thickness, and fills connecting areas within an assembly. It requires a mold or container to confine the compound while it is curing. In contrast, encapsulation is a process of encasing with a protective material that is not over 100 mils thick, is uniform, and does not require a mold or container for application.

Where severe moisture conditions are to be encountered in service, it may be necessary to moistureproof ordinary electrical connectors by the application of a sealing compound. The exclusion of moisture guards against corrosion and, additionally, the potting process protects against contamination by aircraft liquids, sand, dust, and conductive particles that can reduce the dielectric characteristics of the connector which, in turn, could lead to arcing-over at the back of the pins. The sealant likewise provides mechanical reinforcement for the wiring against the effects of vibration or other forces.

Against the advantages of sealing, certain disadvantages of potted connectors with which the user must contend should be cited:

- Single-wire replacement is either difficult or impossible; for this reason, it is standard practice to provide short wire leads (maximum gauge, 6 inches minimum length) to any unused pins for substitution purposes, or to allow for the addition of circuits.
- Certain potting compounds are not suitable for use at temperatures in excess of 85°C in electronic equipment.
- The sealing process is critical regarding compound mixing and application and usually calls for maintenance personnel skilled in these techniques.

Potting procedures are thoroughly documented by technical orders published by the military services and NASA; e. g., NAVAIR 01-1A-505 (USAF T.O. 1-1A-14), Section X, "Electric Connector Sealing," and various types of sealing compounds are defined and referenced by the following specifications:

- MIL-S-8416      Sealing Compound, Synthetic Rubber, Electric Connectors and Electric Systems, Accelerator Required
- MIL-S-23586    Sealing Compound, Electrical, Silicone Rubber, Accelerator Required
- MIL-I-16923    Insulating Compound, Electrical, Embedding
- MIL-M-21041    Molding and Potting Compound, Chemically Cured Polyurethane (Polyether Based)
- MIL-I-81550    Insulating Compound, Electrical, Embedding, Reversion Resistant Silicone



It is important to note that when potting is used for environmental protection, extreme care must be given to the selection of materials and processes used, to ensure that the potting does not deteriorate in either its chemical, physical, or electrical properties under the specified system/equipment environment.

Potting compounds must not be applied in the field to microelectronic and conventional electronic modules or individual parts. Such potting applications, when practiced, may only be carried out as part of the original, controlled, production process during manufacture.

## **E. PRESERVING**

Certain general guidelines must be observed in the preservation and packaging of electronic components and assemblies to avoid corrosive contamination that may occur as a result of attack by the packaging materials themselves. Corrosion damage resulting from inadequate safeguards in packing can, in fact, contribute to a significant number of corrosion problems that occur in electronic equipment, along with those produced by unfavorable operations environments.

The following are examples of contamination problems attributable to inappropriate packaging:

- On many occasions, organic acids (generally acetic) have emanated from raw wood used in packing cases and caused severe corrosion of equipment.
- Certain cushioning materials often give off sulfurous or acidic vapors that attack silver, cadmium, and other metals; organic vapors, likewise, attack cadmium. For example, corrosion of cadmium coatings has been noted on cadmium-plated articles packed in direct contact with cardboard. Also, paper and cardboard not specifically designed for packaging electronic hardware may emit vapors that tarnish silver and copper. Corrosion can be especially severe if the container materials become wet or are stored under conditions of high humidity.
- Finally, special care should be taken to avoid enclosing incompatible materials within a common package or compartment.

Because certain contamination risks can and do exist in the packaging, storage, and shipping processes, refurbished assemblies and components processed through a clean-environment area are customarily encased in barrier media such as polyethylene bags with a special interlocking closure feature (FSN 8105-837 series), or heat-sealed in polyethylene plastic sheet (FSN 8135-579-6488) before leaving the area for storage or shipping. These media offer dust protection, are highly water-resistant, and moderately vapor-resistant.

## **PRESERVATIVE APPLICATION CRITERIA**

Contact preservatives can be useful when applied to metal surfaces ordinarily subject to detrimental corrosion in any form (oxides, sulfides, etc.), but preservatives need not be applied to metal surfaces that are inherently corrosion-resistant, such as the following:

- Copper, nickel, chromium, brass, bronze, or other corrosion-resistant alloys
- Metals plated or coated with chromium, silver, nickel, cadmium, zinc, or tin

However, the previously cited packaging precautions with certain metals should continue to be observed.

Preservatives must not be applied to items that are vulnerable to these substances. In avionic systems, these definitely include certain types of electromechanical, electrical, and electronic equipment and components such as capacitors, inductors, electrical connectors, fuses, switches, circuit breakers, resistors, rectifiers, transistors, diodes, PC boards, etc. In general, the prohibition of the use of preservatives applies to any items that would suffer damage to their structure or mechanism, or where malfunctioning or unsafe operational conditions would result from the application or removal of the preservative compound.

#### **F. STORAGE, HANDLING, AND SHIPPING**

Any one of a number of conditions, such as a marine atmosphere, excessive moisture, industrial pollution, chemical contaminants, etc., may be a contributory factor in the corrosion process. Therefore, it is extremely important that storage areas for electronic equipment and components be adequately heated, adequately ventilated, and equipped with suitable racks and bins to minimize the damaging effects of these potentially harmful corrosion-causing factors.

For instance, a damp storage area can be a source of considerable trouble from the corrosion aspect, and the worst effects of dampness occur in storage areas where wooden racks and bins are used. Wood absorbs and retains considerable moisture that is released upon an increase in temperature, to the detriment of any equipment or parts in contact with it. Moreover, damp wood may release acetic or formic acid through enzyme action and mold, and this can result in severe corrosion. For these reasons, wooden shelving is not recommended.

Carboys of acid should never be placed in equipment storage areas where escaping fumes could come into contact with the material in storage.

Equipment handling should be kept to a minimum because of damaging effects resulting from perspiration. Corrosive chlorides deposited on a unit through various handling operations can contribute more corrosive materials than any other single factor.

Items that have been processed through a controlled-environment facility should be clean-packed before removal from the clean-environment area for either storage or staging for shipment to the user. Fundamental to any successful shipping operation is the proper packaging of the equipment for its mechanical and physical protection. The methods employed must protect not only the equipment itself but the barrier media as well: should the barrier rupture, it may not continue to offer adequate corrosion protection during the shipping cycle. Therefore, cushioning materials (or devices) must be introduced into the package to protect the preservation components from physical damage. The cushioning medium must be located in as close contact to the contents as possible to prevent flexible barrier rupture and free movement of the

---

<sup>3</sup>Howard H. Manko, "Cleners and Cleaning for Components and Electronics," (Jersey City, New Jersey: Alpha Metals, Inc.)

items within their rigid containers caused by transmission of shock and vibration incurred in the shipping process. Cushioning and dunnage must be as clean and dry as practicable. Depending upon the structure and mass of the item being shipped, blocking and bracing may be required to prevent movement inside the container.

Virtually every exigency to be encountered in the preparation of equipment for shipment is covered by Military Specification MIL-P-116F. This document delineates three basic packaging methods plus submethods — each designed to cope with specific requirements and conditions for protection against corrosion, mechanical and physical damage, and other forms of deterioration. The specification also provides appropriate inspection and test procedures to verify conformance with requirements. For example, heat-sealed seams of the barrier material are subject to strength tests; a Method II package is subject to inspection for proper use of desiccants (MIL-D-3464); etc.

Working within MIL-P-116F, a shipping facility handling avionic/electronic equipment commonly assembles packaging configurations around flexible water vapor-proof barrier material (MIL-B-131E) that is heat-sealed to form a protective cover enclosing the item being shipped. The wrapped unit is then encased in a suitably sized fiberboard carton (Federal Specification PPP-B-636) after being surrounded by an adequate amount of cushioning material (dunnage). The shipping container is finally sealed with waterproof tape.

## Section 3

### TREATMENTS AND PROTECTIVE COATINGS

#### A. STRUCTURAL AVIONIC COMPONENTS (EXTERNAL)

The effect of corrosion and corrosion products upon the internal components of avionic equipment can be devastating and possibly catastrophic, and even though most structural parts can withstand more severe attack than the internal components, corrosion of structural avionic components can cause destruction and possible failure of what would otherwise be a perfectly serviceable piece of equipment. For example, a transmitter is just so much excess weight if the antenna connected to it is lost or destroyed by corrosion.

Structural component protective coatings are susceptible to abuse or inadvertent damage by handling, accidental scratching or bruising, and ambient corrosion-inducing products (i.e., perspiration, battery fumes, etc.). Since it is the function of boxes, housings, chassis, and frames to enclose, protect, and secure the vital internal components of any particular avionic unit, it is imperative that structural integrity be maintained.

Speed and cleanliness are the watchwords to follow in inhibiting or correcting corrosion before appreciable damage is done. As mentioned previously, structural component protective finishes are subject to abrasive damage. Immediate repair to the finish forestalls the initiation of corrosion. In the case of paint finishes, the Navy has simplified the repair tremendously by adopting a compatible touch-up paint system which can be used with all present Naval paint systems. Reference to NavPers 10310 B is suggested for procedures and use of this system which consists of the application of epoxy-polyamide primer (MIL-P-23377B) and acrylic lacquer topcoat (MIL-I-81352).

#### PRIMERS

If a metal surface of either clad or anodized aluminum or magnesium has been abraded or scratched, it should be given a chemical-conversion coating before it is painted. If the original surface is unpainted, the chemical-conversion coating itself is the protecting medium.

Again referring to NavPers 10310B, the Navy prescribes (at depot level) a satisfactory conversion coating for aluminum using MIL-C-5541A and, for magnesium, Chrome Pickle (MIL-M-3171A, Type 1).

Additional suggested conversion coatings for magnesium are Dichromatic (MIL-M-3171A, Type 3); Galvanic Anodize (MIL-M-3171A, Type 4); Sealed-Chrome Pickle (MIL-M-3171A, Type 2); Caustic Anodize (MIL-M-3171A, Type 5); Anodize

(MIL-M-4520C); and Dilute Chromic Acid (MIL-M-3171B). Military Specification MIL-M-3171A is being revised and will include some additional treatments. Two of the listed treatments will be deleted. The new military specification will be MIL-M-3171B and will list as Type I, Chrome Pickle treatment; Type II, Chromic Acid Brush-On treatment; Type III, Dichromate treatment; Type IV, Galvanic Anodizing treatment; Type V, Anodizing treatment; Type VI, CR-22 treatment; and Type VII, HAE treatments.

If the metal involved is ferrous, a protective coating of zinc chromate is recommended. If the surface is not conducive to the use of paint, a protective coating of polar oil should be applied. Reapplication of the polar oil coating should be a part of regular routine maintenance.

## **BOXES AND HOUSINGS**

Boxes and housings are meant to protect the avionic equipment contained therein. This protection should not be construed to mean protection against mechanical damage only, but also against environmental damage. They should be sealed as tightly as practicable to prevent the admittance of dust, dirt, insects, vermin, and corrosive atmospheres.

Nevertheless, despite all preventive and protective efforts, corrosion and/or fungus growth persists.

## **CLEANING AND CLEANING MEDIA**

Since, in this section, we are discussing structural components, mechanical removal of the corrosion and corrosion products is probably the most practical procedure to adopt. Of course, always bear in mind that a severely corroded part may require removal of so great a quantity of metal that structural failure becomes a possibility. In this event, replacement is the only alternative.

Depending upon the area and depth of the corroded area, the removal medium may range from a rubber eraser, to a fiberglass eraser, to aluminum wool, to nylon webbing impregnated with aluminum oxide abrasive, to aluminum-oxide-abrasive-coated paper or cloth. The use of aluminum-oxide grinding wheels, rotary files, metallic or carbide scrapers on heavy structural sections is conceivable, but not likely in the context of avionic structural members. For clad aluminum, removal of the pure aluminum cladding is to be avoided. Rubbing or polishing of clad surfaces should be performed with nothing more abrasive than fine pumice or suitable cleaners.

After removal of the corrosion and corrosion products, the previously recommended protective procedures should be followed.

Protective finishes on access panels or covers are particularly susceptible to mechanical damage which, if left untreated, results in corrosion. In addition to handling damage, salts and moisture from perspiration deposited on the covers also promote corrosion. Detergent washing and air drying of covers after each handling are recommended procedures to be followed if possible. When corrosion

occurs, treatment should be as previously described. Removable fasteners, if attacked by corrosion, should be replaced.

A particular problem exists in the case of hinged covers. In most cases the hinge pin is manufactured of a metal that differs from the metal of the hinge body, creating a potential electrolytic cell. Frequent cleaning and lubrication are suggested. In addition, a diaphragm seal should be applied to the exterior face. This provides the twofold function of sealing the hinge lubricant from contamination and in addition preventing the aspiration of dust and dirt into the box or housing.

### **COATINGS AND SEALANTS**

Still another corrosion problem is present where covers and boxes or housings are concerned. Fretting corrosion can occur where the covers impinge upon the companion frame. To inhibit or prevent this form of corrosion, if sufficient clearance exists, a bulb-type seal can be installed around the perimeter of the opening, or, if there is insufficient clearance, a double layer of electrician's tape between the cover and the frame serves very well. Again, two benefits accrue: fretting corrosion is inhibited, and, by installing either corrective treatment, a gasket is formed which inhibits the infiltration of dust or dirt into the box or housing.

Chassis serve as mounting panels for most of the electronic components that interconnect to form an avionic unit. They are also the primary targets of the troubleshooting technician. Unfortunately, while a faulty electronic part is being searched out and replaced, the chassis is being handled, subjected to abrasion, solder splash, and solder flux. If a box or cabinet is not sealed, the chassis, with all its crevices, nooks, and crannies, is a collecting ground for infiltrating airborne contamination.

Frequent, thorough cleaning is imperative if corrosion is to be forestalled. Cleaning processes reveal corrosion and/or fungus growth before it develops to a critical stage. Cleaning should be accomplished using vacuum, low-pressure dry air, brushing with a fine-bristle brush, and/or scraping with a nonmetallic scraper.

When corrosion does occur, its removal is mandatory, using the most gentle methods compatible with the area and depth involved, and corrosion removal must be followed immediately with restoration of the surface protective coating(s) as previously described. Extreme care must be exercised, both during the cleaning operation and during the coating restoration procedure, to ensure that no corrosion products, oxidizing chemicals, or paint causes contamination of other parts of the chassis or electronic components attached thereto.

### **HARDWARE**

Frames anchor and support the various component assemblies that comprise an avionic unit. By serving this function, obviously much of the frame is hidden by equipment. It is mandatory that inspection be performed as often as possible to ascertain if hidden corrosion is eating away. In addition, because the frames are hidden, they make excellent collecting areas for dust and dirt. Frames are subject to fretting corrosion if movement occurs because of loose bolt connections.

Loose bolting or stresses caused by bolting may also result in intergranular or intercrystalline corrosion. If dissimilar metals are involved (for example, a steel bolt assembly fastening an aluminum housing to an aluminum frame), electrochemical corrosion may occur. In the example of the steel bolt assembly, the bolt should be replaced with an aluminum alloy bolt, or it should be separated from the aluminum with a nonmetallic insulator.

## ANTENNAS

One of the most, corrosion-prone components of avionics equipment, if not the most corrosion-prone, is the antenna. Not only is it corrosion prone, but it is frequently the last component to be suspected in response to flight crew complaint. Units pulled and bench tested and found to be operational may be returned and re-installed, and the complaint may be chalked up to crew error. Frequently antenna corrosion causes unit malfunction during inclement weather, yet during fair weather, operation may be satisfactory.

Antenna and antenna-mount corrosion is especially common to pressurized aircraft, and this is particularly true in lower-fuselage installations. It is inevitable that moisture will collect in the lower bays. Condensation and spillage are two sources of such moisture. The Bendix Avionics Division, in response to two complaints of radio altimeter failure on 747 aircraft, found that leakage of toilet waste was one of the contaminants in the lower fuselage bays. The Bendix Field Engineering Corporation's Flight Operations Group reports that various liquid contaminants found in the lower fuselage bay include water, oil, and hydraulic fluid. When the aircraft is pressurized, these liquids are forced into any crack, crevice, or fitting available, and there, waiting for destruction, is the inverted antenna bottom and antenna-mount fasteners, together with cable connectors.

Another example of pressurized fuselage antenna failure reported by the Bendix Flight Operation's Group involved a VHF dorsal fin communications antenna. Walk-around inspection indicated a "like new" epoxy-coated unit. After several bench checks of the communications equipment had disclosed no faults, the antenna was dismantled. Internally, it had been completely destroyed by corrosion.

The problem can be decreased considerably by two steps: first, bed and seal the antenna base, fasteners, and connectors thoroughly in a good quality sealer such as, Military Specification MIL-S-8802C, and/or Military Specification MIL-S-8784; and second, inspect frequently, both externally, and more important, internally within the fuselage where the antenna base is exposed to the liquid contaminants that form the electrolyte for corrosion.

The lower-fuselage antennas of nonpressurized aircraft are subject to the same problems. Corrosion just takes a little longer.

Upper-fuselage antennas, while not subject to having a base mounted in liquid electrolyte, are still subject to infiltration of electrolyte through condensation and aspiration. Loop antennas have been checked and found to contain, or even be filled, with infiltrated electrolyte. Again, it must be stressed: seal the antenna when it is installed, and thoroughly and constantly inspect for infiltration and corrosion.

## **OTHER COMPONENTS**

Shock mounts are subject to many forms of corrosion. Frequent inspection and cleaning are important; corrective procedures previously described should be followed. If severe corrosion occurs or if the tolerable shock mount strengths have been exceeded or impaired, the mount should be replaced.

Gears, too, are subject to many forms of corrosion, not the least of which are fretting, stress, and pitting. Lubrication is a must, but contaminated grease and oil can harbor the electrolyte that initiates and continues corrosion. Corrosion products can act as abrasives and can cause mechanical jamming. Frequent inspection, cleaning, and lubrication are mandatory. Unless it is severe, corrosion on the nonbearing surfaces of gears may be removed and treated, using the procedures previously described; however, when corrosion attacks bearing surfaces, immediate replacement should be initiated.

Connectors, while not necessarily describable as structural components, do electrically connect electronic units housed within structural components. Because of their configuration, in most cases they are difficult to clean and difficult to keep clean. Because of their function, that of completing an electrical circuit, a little corrosion or fungus can create havoc within the avionic system. Because of the frequency of failures traced to connector corrosion, Bendix Field Engineering Corporation's Flight Operations Group has made connector inspection one of the most repeated items on the inspection list. Cleaning and inhibiting corrosion by using one of the dip cleaners described in section 2 is recommended. This maintenance regimen applies to bulkhead connectors as well as unit connectors. Potting is generally considered a cure-all treatment for connectors; however, experience has proved that corrosion can and does still occur. An unpotted connector can be cleaned, but a potted connector usually must be replaced, which can be a time-and-labor-consuming operation.

Cable corrosion occurs if cables are improperly protected; however, with use of proper protection techniques, cable corrosion can be virtually eliminated. Plastic coverings prevent moisture from becoming embedded within the cable insulation. No cut end of cable should ever be left exposed. Through capillary action, or gravity, moisture (electrolyte) can work well into the cable end. Conformal coatings at exposed connectors are helpful. If nothing better is available, a thorough wrapping with electrical tape should be applied.

A stringent and frequent inspection program, coupled with cleaning and corrosion removal and restoration of protective coatings, not only forestalls expensive replacement of units, but also averts potential trouble.

### **B. AVIONIC COMPONENTS (INTERNAL)**

#### **GENERAL**

**A most useful tool for the treatment for corrosion in internal avionic components is the human eye. Visual inspection can reveal the existence of corrosion and fungus**



in their initial stages, when treatment is relatively easy. When presence of corrosion and fungus is ignored, the results can be serious. Not only will an affected unit eventually be destroyed, but its operation in the aircraft is meanwhile being degraded. Degrading constituent units can slowly reduce overall system performance through their cumulative marginal operating characteristics, while they may bench-check individually to the minimum acceptable limits. As a possible consequence, consider a VOR or glide slope receiver presenting false information to a pilot on an ILS approach.

Whenever equipment is removed from an aircraft for bench check and repair, it becomes the logical time to remove dust covers, boxes, and housings for a corrosion check and treatment whenever appropriate.

Experience has demonstrated that the location of the electronic units in the aircraft has an effect as far as corrosion and fungus are concerned. Units placed in the cargo compartments and aft of the most rearward bulkhead (pressure dome in pressurized aircraft) have a tendency to have more severe internal problems than the units mounted in radio racks in the cabin area. This is because the cabin areas have a better air-conditioning system; also the forced ventilation is much better. Cool, dry air is the best environment for electronics.

Cleaning and corrosion removal techniques for internal components normally range from mild to what may be termed the severest, as follows:

1. Cleaner (Freon) and brush
2. Rubber eraser
3. Abrasive pad, aluminum oxide impregnated
4. Aluminum oxide cloth
5. Abrasive blast (on removed components only!)

An ideal system for the application of the abrasive-blast method to small modules and components—because it can work into restricted spaces—is one that uses a gas-propelled stream of finely graded abrasive particles, closely controlled by a precise tungsten carbide nozzle, that is driven against the contaminated or corroded surface. Material is removed by the impinging particles virtually without shock because of the low inertia of the particles. Propellant pressure is variable, as is the abrasive powder feed. Where a mild action is desired, glass beads are used; aluminum oxide powder is employed when a stronger abrasive action is required. Work with this jet unit is carried out in an exhaust chamber to remove expended abrasive powder and loosened particles. The unit is referenced in section 4, paragraph B of this report, "Tools and Equipment."

#### **SPECIFIC COMPONENTS**

Rotary switches are commonly encountered in avionic control pedestals and audio boxes and are usually not covered. This lack of dust covering or housing of some type allows moisture or dust to collect and hold collected moisture in the area of the switch contacts. With this concentration of dust and moisture, fungus and corrosion begins and develops at a rapid rate.

Rotary switches require two cleanings: one to remove dirt and oil-base lubricants from the mechanical assemblies and insulating materials, and the second a brightener-type bath to remove oxidation from the electrical contacts. It is extremely important that the brightener baths be completely removed with water; otherwise the brightener bath will, in itself, produce severe corrosion. The switches should then be thoroughly dried. If it is not convenient to use the bath, some good spray cleaners are available in the Federal inventory. They should be sprayed on the contact points, then dried with forced air.

Little can be done to clean toggle-type switches or other semisealed types; if corroded or otherwise damaged, they should be replaced. Switch and switch-shaft boots and seals can be used as necessary to prevent dirt and moisture from accumulating.

Multiple connectors cause some of the most costly repairs in the avionic maintenance business. Bendix Flight Group operational history in this area shows continuous problems with pressure-seal bulkhead connectors. Moisture is forced into the connector cases, and corrosion starts. Connectors have been completely ruined by corrosion in less than 3 months. The only true repair in the area is to replace the connector. Many forms of sealing and potting of connectors have been tried, and potting seems to be the best method; however, there are times in aircraft maintenance when potting is undesirable. All avionic unit connectors should be checked each time they are opened. There are too many different types of connectors to list them all, but most of the procedures for cleaning serve for all types. Fungus growth between connector pins and on connector insert material can cause degradation in insulation resistance between pins, contribute to an increase in leakage currents, and possibly to the loss of signals caused by contact resistance and arc-over between pins. These items generally suffer from severe corrosion because of their physical locations. Those that show signs of corrosion may be cleaned with detergent bath. Beyond that, little can be done short of replacement. Complete cleaning, thorough drying, and potting may be used to provide some degree of protection. Tube sockets also are a frequent source of problems; they respond very well to the "brightener" treatment.

Corrosion of the silver-plated contact arms and mating surfaces of relays is often caused by exposure to salt atmosphere and other hostile environments. All relays of the open-construction type should be inspected whenever the equipment is being serviced. During equipment refurbishment, varnish may accidentally be deposited on the armature, pivots, or similar components and may cause the relays to bind. The whole relay should be carefully masked until after the spraying has been completed. A brush should be used to coat the coils and leads after the masking has been removed. Relays with palladium-tipped contacts should be removed entirely before application of varnish to a unit.

Relays require special treatment. They may be cleaned with the detergent bath to remove dust and dirt. However, contacts at best may be burnished with an appropriate tool, never filed or sanded to present a "clean" appearance. Filing or sanding the points removes the hard plating and exposes the soft base metal. A relay so treated will perform for only a short period of time. If burnishing does not clean the contact, replace the relay to provide dependable operation.

Assuming the contact points can be cleaned and all other components of the relay are in working order, the relay windings can be cleaned and then coated with varnish (MIL-V-173). Usually corrosion in the relay warrants replacement.

Older avionic units have very few plug-in modules, but the newer state-of-the-art electronics components are almost exclusively designed and manufactured with plug-in modules and printed circuit boards. The boards are ordinarily coated during manufacture, thereby minimizing corrosion and fungus problems during use. The major problems have been with the connectors between boards or between chassis and boards. Plug-in modules and printed circuit boards must be handled according to the discrete components they contain. Generally speaking, they respond very well to the detergent bath, rinse, and dry process, or the previously described method of blasting particles at supersonic speed from a very small nozzle. After cleaning, defective components may be replaced and repairs may be made. When work is completed, the entire board can be given a light coat of moisture fungus proofing (MFP) varnish from an aerosol can. (Contact fingers must be masked.) Units so treated present a good appearance and are protected from further dirt and corrosion.

Capacitor covers and tube covers must be handled according to the type of material. Severely corroded covers should be replaced, but covers with minor surface corrosion can be cleaned by the aforementioned conventional methods and protected with a corrosion preventive. Most covers are of aluminum construction; other materials should be handled in a manner appropriate to their types.

Waveguides are aluminum material with a chemical corrosion-preventive coating on the inside, painted on the outside. Generally, the condition of the waveguide is uniform throughout its length, including the flanges. Small amounts of corrosion can be removed, at depot level, with an acid bath. Severely corroded waveguides must be replaced.

Generally, wiring can be adequately cleaned with the detergent bath. Wires that are damaged can be replaced individually. Entire harnesses may be replaced in severe cases. MFP may be applied to the exterior surfaces of wires and wiring harnesses to prevent further corrosion.

## Section 4

### MATERIALS & EQUIPMENT

#### A. CONSUMABLES LIST

Table 4-1 is a listing of the more common consumables, including abrasives, erasers, special coatings, preservatives, solvents, lint-free cloths, cleaners, polishes, etc. This list is not intended to be a complete list of materials required for a corrosion control program.

**Table 4-1. Materials Used in Corrosion Control**

Nomenclature	Specification	Federal Stock Number	Intended Use
Abrasive Paper, Aluminum Oxide		5350-543-3600	
Abrasive Mat, Aluminum Oxide Abrasive	MIL-A-9962 Very Fine, Fine, Medium	5350-967-5089 5350-967-5093 5350-967-5092	Removal of superficial corrosion products and for paint scuffing prior to touchup.
Abrasive Wheel Nylon Web, Aluminum Oxide Abrasive	Minnesota Mining & Mfg. Co. Unitized & Reinforced Wheels  or Coated Abrasive Div. of Norton Co. Unifield and Reinforced Wheels MIL-W-81319	5345-732-9977 5345-732-9978 5345-732-9989 5345-732-9989 5345-732-3166	
Alcohol, Ethyl, Specially Denatured A.C.	MIL-A-6091	6d10-250-0804	To clean rubber and as thinner for MIL-C-4415.
Alcohol, Isopropyl		6565-205-6513	General-purpose cleaning when mixed with water.
Aluminum wool	MIL-A-4864	5350-286-4851	Corrosion removal from aluminum surfaces (abrasive mat is preferred).

Table 4-1. Materials Used in Corrosion Control (Cont.)

Nomenclature	Specification	Federal Stock Number	Intended Use
Barrier Material, Water-Vapor Proof, Flexible	MIL-B-131, Class I	8134-282-0568	For sealing and masking where water-vapor resistance is required and for shrouding.
Barrier Material, Greaseproof, Waterproof	MIL-B-121, Type I, Grade I, Class I	8135-121-0935	For masking in cleaning, paint removal operations, etc.
Brush, Acid Swabbing	H-B-643	7920-514-2417	For applying acid mixture.
Brush, Wire, Scratch Aluminum		7920-514-0234	Removal of corrosion products.
Cleaning Compound, Aircraft Surface, Alkaline Waterbase	MIL-C-25769	6850-935-0996 6850-935-0995	General purpose cleaning.
Coating Compound Magnolia Magnabond 39		8030-180-5977	Coating of electrical circuit boards, encapsulating, and potting.
Coating Compound, Metal Pretreatment, Resin Acid	MIL-C-5514	6030-082-2425	Treatment of aircraft metals prior to application of primer.
Coating, Corrosion Resistant	MIL-C-81706	8030-104-7763	Prevention of corrosion on aluminum and aluminum alloys.
Coating, Corrosion Preventive	MIL-C-5541	6030-823-8039	Corrosion preventive for aluminum and aluminum alloys.
Compound, Corrosion Preventive	MIL-C-81309	8030-936-1947	Used as water displacing corrosion-preventive compound and lubricant.
Compound, Corrosion Preventive	MIL-C-16173	8030-062-6950	Prevention and arrest of corrosion on copper, brass, zinc, cadmium, magnesium, steel, or aluminum.
Cloth, Cleaning	CCC-C-46	7920-401-8034	Lint-free cloth used for dusting, wiping, or washing.
Cloth, Cleaning, Chemically Treated	DDD-C-130	7920-585-8649	Removal of dirt and rust from electrical contact surfaces.
Corrosion Preventive, Fingerprint Remover	MIL-C-15074	8030-004-4017	Removal of fingerprint residues and temporary preservative for metallic items.

Table 4-1. Materials Used in Corrosion Control (Cont.)

Nomenclature	Specification	Federal Stock Number	Intended Use
Corrosion Removing Compound Prepaint	MIL-C-3834	6850-527-2426	Removal of corrosion from aluminum surfaces prior to painting.
Corrosion Removing Compound	MIL-C-14460, Type I	6850-550-8565	Removal of rust and scale from ferrous items by immersion or electrolytic action.
Detergent, Metal Cleaner	Bendix DURL-TEL613	7930-157-9843	For use in ultrasonic cleaning equipment.
Detergent, Nonionic	MIL-C-16791	7930-728-4143	General-purpose detergent used in preparing cleaning solutions.
Enamel, Alkyd	TT-E-529, Class A	8010-297-0564	General-purpose air-drying semigloss enamel
Enamel, Alkyd	TT-E-489, Class A	8010-515-1596	General-purpose air-drying full gloss enamel.
Enamel, Alkyd	TT-E-527, Class A	8010-297-0567	General-purpose air-drying lusterless enamel.
Enamel, Exterior, Vinyl Alkyd	MIL-E-15936	8010-079-2456	For marine weather surfaces or others subjected to extreme dampness.
Enamel, Gloss	MIL-E-7729 Type I	8010-297-2096	Highly weather-resistant enamel.
Ethyl Acetate, Technical	TT-E-751	6810-062-6954	Stripping paint in confined locations.
Ethylene Glycol	MIL-E-9500	6810-865-2055	For use in organic coatings.
Insulating Compound, Electrical for Coating Printed Circuit Boards	MIL-I-46058A	6810-106361205	Moisture- and fungus-resistant coating for electrical equipment and for use as a clear coating on copper.
Lubrication Oil, General Purpose, Preservative	VV-L-800	9G-9150-258-0075	Lubrication and protection of piano hinges, etc.
Metal Conditioner and Rust Remover	MIL-M-10578, Type III	6850-201-1219	Removal of rust from ferrous metals and to provide a slight etching action to promote adhesion of protective coatings.
Methyl-Ethyl-Ketone	TT-M-261	6810-281-2785	Coating thinner and wipe cleaner for metal surfaces.
Methyl-Isobutyl-Ketone	TT-M-265	6810-285-3785	Coating thinner and wipe cleaner for metal surfaces.

Table 4-1. Materials Used in Corrosion Control (Cont.)

Nomenclature	Specification	Federal Stock Number	Intended Use
Naphtha, Aliphatic	TT-N-95, Type II	6820-236-8119	Acrylic plastic cleaner and wipe-down cleaner of metal surfaces.
Naphtha, Aromatic	TT-N-97, Type I, Grade B	6810-223-9089	Bare metal cleaner and paint thinner.
Nitric Acid	O-N-350	6810-222-9655	Used in chemical treatment solutions.
Polish, Metal	MIL-P-6888	7930-267-1224	Liquid fine abrasive polish for aluminum.
Polish, Metal	MIL-N-22185	7930-634-1364	Cleaner and polish used on steel and other surfaces.
Primer Coating, Inorganic, Zinc	MIL-C-38336	8010-787-8856	Used on steel surfaces that receive severe exposure to the environment.
Primer, Zinc Chromate	MIL-P-8585, Color T, Color Y	8010-209-8034 8010-335-2114	Primer for metal surfaces.
Pumice, Ground, Abrasive	SS-P-821	5350-161-9033	Removal of corrosion and stains from thin metal.
Rag, Cotton	DDD-R-30	7920-205-3671	General wiping purposes.
Remover, Paint and Lacquer	MIL-R-25134	8010-515-2970	Removal of paint finishes from metal surfaces.
Sealing Compound		8030-934-1535	Sealant/adhesive for instruments and accessories in aircraft.
Sealing Compound		8030-433-9032	Corrosion inhibitor.
Sealing Compound	MIL-S-8516	8030-981-2618	For reinforcing back of connectors against vibration. Protection against liquids, gases, dust, and metallic objects.
Sodium Dichromate	O-S-598	6810-262-4566	Used in chemical corrosion treatment solutions.
Solvent, Safety	MIL-S-14718	6850-597-9765	To clean metal surfaces.
Tape, Pressure-Sensitive	MIL-T-28142	8030-NSL	For dissimilar metal separation.
Contact Cleaner		AML-555	Removal of dirt, oil, grease, etc., from electrical contacts.

**Table 4-1. Materials Used in Corrosion Control (Cont.)**

Nomenclature	Specification	Federal Stock Number	Intended Use
Tape, Pressure-Sensitive	U-T-106 1/2", 1", 2"	7510-290-2023 7510-233-0612 7510-266-6694	For paint masking operation.
Thinner, Dope and Lacquer	TT-T-286	8010-180-5786	Thinner for cellulose-nitrate dopes and lacquer.
Trichloroethane	O-T-620	6810-664-0273	Inhibited liquid solvent for cleaning and degreasing electrical equipment.
Varnish	MIL-V-173	8010-510-7494	Moisture and fungus-resistant varnish for electrical equipment.
Water Displacing Compound	O-W-001284	6850-142-9389	Removes water from electronic equipment.
Contact Cleaner Type A		MS-230-Contact Re-Ny, Co Contact cleaner Lectron 13	Removal of dirt, oil, grease, oxide film, etc., from electrical contacts (lubricant not required).
Contact Cleaner and Lubricant Type B		GC Spra Kleen Tuner Cleaner and Lubricant Spray No. 1333 Electronic Contact Cleaner Lubricant Spray No. 1326	Removal of dust, dirt, oil, grease, oxide film, etc., from electrical contacts (lubricant required).

Table 4-2 is a partial list of consumable materials used in Bendix Field Engineering Corporation's Advanced Technology Laboratory in Columbia, Maryland. This laboratory is involved in the repair and refurbishing of NASA modules and circuitry.

**Table 4-2. Corrosion Control Materials Used in Advanced Technology Laboratory**

<b>Electro Clean</b> Selectron (SCM-410) 3426-X41-0650	<b>Trichlorotrifluoro Ethane</b> DU PONT 6850-R70-5222
<b>Eraser</b> Eberhard Faber (37103) 7510-RA2-0589	<b>Gold Solution</b> Selectron (SPS-535) 6810-X40-8790
<b>Eraser</b> Eberhard Faber (80244) 7510-634-5035	<b>Paint Stripper</b> Chemical Products Co. 8010-X44-7683
<b>Freon-TF</b> DU PONT 6830-X21-8907	<b>Varnish, Protective</b> Miller Stevenson Chemical Co. (MS-450) MIL-V-173



**Table 4-2. Corrosion Control Materials Used in  
Advanced Technology Laboratory (Cont.)**

<p><b>"Dab" — All-purpose cream cleaner</b></p> <p><b>Copper (Alkaline) Solution</b> <b>Selectron (SPS-530)</b></p> <p><b>Cotton and Cotton Swabs</b> <b>6510-201-4000</b></p> <p><b>Copper (High-Speed Acid) Solution</b> <b>Selectron (SPS-526)</b></p> <p><b>Activating Solution No. 2</b> — (SCM-430) <b>6850-X43-1544</b></p> <p><b>Baking Soda</b> <b>Armor (S1348)</b> <b>8950-292-9611</b></p> <p><b>Brush, Acid, Swabbing</b> <b>7920-223-8005</b> <b>7920-514-2417</b></p> <p><b>Crystal Clean (Krylon)</b> <b>Borden, Inc.</b></p>	<p><b>Peel Coat</b> <b>Delta Chemical Corp.</b> <b>8030-RC2-0052</b></p> <p><b>Lacquers</b></p> <p><b>Lacquer Thinners</b></p> <p><b>"Twinkle" Cream for Silver</b></p> <p><b>Dow Cleaner</b></p> <p><b>Isopropyl Alcohol</b> — (TT-I-735)</p> <p><b>San-Del #2 Technical Cleaner</b> <b>M. P. Odell Co.</b></p> <p><b>1169-A Insulating Lacquer Base</b> <b>Denflex</b></p> <p><b>1169-B Insulating Lacquer Activator</b> <b>Denflex</b></p>
---	---

**B. CORROSION REMOVAL AND CLEANING TOOLS**

Table 4-3 is a partial listing of the more generally used tools and equipment. It is not intended to be a complete list of tools and equipment required in a corrosion control program.

Table 4-3 Corrosion Removal and Cleaning Tools and Equipment

Nomenclature	Specification	Federal Stock Number	Intended Use
Apron, Acid and Fuel Resistant	AF Dwg 51C3606	9415-753-6419	Personnel protection.
Drill, Pneumatic	OO-D-691	5130-889-9009	Mechanical removal of corrosion
Funnel, Cres., 1 Pt.	RR-F-500	7240-426-0525	To facilitate pouring.
Gloves, Rubber, Size 19	ZZ-G-391	4415-266-8677	Personnel protection.
Goggles, Safety	GG-G-531	4240-276-7343	Personnel protection.
Grinder, Pneumatic	OO-G-669	5130-221-0492	Mechanical removal of corrosion.
Kit, Metal Identification	AF Dwg 61B25042	4920-831-5932	Identification of metals and surface treatments.
Kit, Inspection Penetrant	MIL-I-25135	6650-426-0981	To reveal surface defects in metals.
Magnet		5999-526-4724	Testing for ferrous alloys.
Mighty 1, 5X	GG-M-95, Type III	6650-530-1109	Viewing aid.
Sprayer, Cleaner		4910-567-9559	30-gallon portable air-pressure-type spray unit for applying cleaning solutions.
Spraying Unit, Trailer Mounted, 120 Gal.	MIL-C-8112, Type MA-1	4910-141-8717	For application of cleaning compounds.
Airbrasive Unit	S.S.White Industrial Model K		Removal of corrosion products.
Fully Current Test Set	Magnaflux Corp. Model FM-120	6635-071-0033	Identifying metals by conductivity measurements.
Set, Paint, Electric	Red Devil 3102	5130-333-0123	Paint softener with barnoff knife.

### C. AVIONICS CORROSION CONTROL KIT

An avionics corrosion control kit should be made available for operating activities; such a kit is especially useful for small units. The kit should be designed for use in treating small areas of corrosion and should contain all the necessary materials and equipment.

Mechanical cleaning materials such as abrasive papers, polishing compounds, polishing and cleaning cloths, wools, wadding, abrasive wheels, pneumatic drill, wire brush, etc., should be made available for use in this kit. However, their use must be in accordance with directions supplied with the materials if damage to finishes and surfaces is to be avoided.

Items of personal protection such as rubber gloves, rubber boots, goggles, and aprons should be provided and worn when necessary to protect against splashing and fumes.

Chemical cleaners and detergents for general-purpose cleaning of avionic equipment should be provided for cleaning prior to and also after mechanical removal of corrosion products. Pressure-sensitive tapes, paint removers, etc., also fall in this category.

Finally, some of the various corrosion-preventive coatings and water-displacing compounds should be included for the treatment and preservation of equipment.

Table 4-4 lists suggested items to be included in an avionics corrosion control kit, normal usage of which is intended for occasions when minor corrosion problems occur.

Table 4-4. Corrosion Control Kit

<u>Nomenclature</u>	<u>Federal Stock Number</u>
Abrasive Paper, Aluminum Oxide	5350-543-3600
Abrasive Mat, Aluminum Oxide	5350-967-5089 5350-967-5093 5350-967-5092
Abrasive Wheel	5345-732-9977
Nylon Web	5345-732-9978 5345-732-9988 5345-732-9989 5345-732-3166
Alcohol, Isopropyl	6565-205-6513

Table 4-4. Corrosion Control Kit (Cont.)

<u>Nomenclature</u>	<u>Federal Stock Number</u>
Coating Compound, Metal Pretreatment Coating	8030-083-2425
Corrosion Preventive	8030-823-8039
Compound, Corrosion Preventive	8030-938-1947
Compound, Corrosion Preventive	8030-062-6950
Detergent, Nonionic	7930-728-4143
Lubrication Oil, General Purpose Preservative	VV-L-800
Polish, Metal	7930-267-1224
Polish, Metal	7930-634-1364
Paint Remover	8010-181-7568
Sealing Compound	8030-881-2618
Solvent, Safety	6850-597-9765
Tapc, Pressure-Sensitive	7510-290-2023
Apron	8415-753-6419
Drill, Pneumatic	5130-889-9009
Gloves, Rubber	8415-266-8677
Goggles, Safety	4240-276-7343
Magnet	599-826-4724
Magnifier, 5X	6650-530-1109
Scraper, Paint, Electric	5130-333-0123
Epoxy Primer (Specification MIL-P-23377)	
Acrylic Topcoat (Specification MIL-L-81352)	

## Section 5

### REFERENCES AND BIBLIOGRAPHY

#### A. REFERENCES

Baker, Richard G., "Corrosion and Plating Problems in Electronic Equipment for the Communications Industry." Murray Hill, N.J.: Bell Laboratories.

Manko, Howard H., "Cleaners and Cleaning for Components and Electronics." Jersey City, N.J.: Alpha Metals, Inc.

"Corrosion Control: Manned Space Flight Network Facilities." Bendix Field Engineering Corporation, 1968.

"GSA Supply Catalog." Federal Supply Service, General Services Administration, 1973.

Laboratory Report No. 19309. Applied Research Laboratories of Florida, Inc., 1973.

MIL-C-8514

MIL-S-8516

MIL-C-15328A

MIL-S-8784

MIL-C-61309A

MIL-STD-186C (MI)

MIL-C-0081309B

MIL-STD-454C

MIL-D-3464C

MIL-STD-1250 (MI)

MIL-D-16791

MIL-T-152B

MIL-I-46058

MIL-V-173

MIL-M-3171A & B

NAVAIR 01-1A-505 (USAF T.O. 1-1A-14)

MIL-M-24041

NAVAIR 01-1A-509

MIL-P-116F

PR 1321

MIL-P-8585

T.O. 1-1-689

MIL-S-8202C

T.O. 12-1-3

**B. BIBLIOGRAPHY**

Henney, Keith, and Walsh, Craig, Electronic Components Handbook Vol. II. Wright Air Development Center (New York: McGraw Hill Book Co., 1958).

Henney, Keith; Milleaf, Harry; and Walsh, Craig, Electronic Components Handbook Vol. III. Wright Air Development Center (New York: McGraw Hill Book Co., 1959).

Licari, James J. Plastic Coatings for Electronics (New York: McGraw Hill Book Co., 1970).

McKinley, James L., and Bent, Ralph D., Electricity and Electronics for Aerospace Vehicles. Northrop Institute of Technology (New York: McGraw Hill Book Co., 1971).

Speller, Frank N., Corrosion Causes and Prevention (New York: McGraw Hill Book Co., 1971).

Tringham, T. C. E., Causes and Prevention of Corrosion in Aircraft (London: Sir Isaac Pitman and Sons, Ltd., 1958).

Aviation Electronics Technician 3 & 2. Bureau of Naval Personnel Rate Training Manual. NavPers 10317-D.

Aviation Structural Mechanic H3 & 2. Bureau of Naval Personnel. NavPers 10310-B

Aviation Structural Mechanic H1 & C. Bureau of Naval Personnel. NavPers 10313-B.

## Section 6

### GLOSSARY

The following list of words and terms frequently used by the corrosion engineer is intended as an aid to the student of corrosion control.

- Active Metal:** A metal that is in a condition in which it tends to corrode.
- Additive:** A compound added for a particular purpose — in the case of fuel and lubricants, for such purposes as prevention of corrosion, gum, varnishes, sludge formation, knocking, etc.
- Aeration:** A wind-carried moisture-saline combination (the 30-foot Apollo dish at Bermuda has 12 to 15 aerations per day 365 days per year).
- Aeration Cell:** An electrolytic cell in which the driving force causing corrosion results from a difference in the amount of oxygen in solution at one point as compared to another. Corrosion is accelerated where the oxygen concentration is lowest, for example, in a stuffing box or under packing, etc.
- AISI:** American Iron and Steel Institute.
- Alkyd:** Any of several synthetic resins made from phthalic acid or phthalic anhydride and glycerol.
- Alloy:** A combination of two or more metals.
- Anaerobic:** Capable of existing without air or uncombined oxygen.
- Anion:** An ion that carries a negative charge. The chloride ion in seawater is an anion.
- Anneal:** Subject to heat and controlled cooling to make a metal mass homogeneous in chemical, crystalline, and mechanical properties.
- Anode:** The electrode of a galvanic cell at which oxidation occurs. In corrosion, the electrode being attacked. The less noble electrode of an electrolytic cell at which corrosion occurs. This may be a small area on the surface of a metal or alloy, such as a point where a pit develops, or it may be the more active metal in a cell composed of two dissimilar metals; i. e., the one with the greater tendency to go into solution. The corrosion process involves the change of metal atoms into ions with a liberation of electrons that migrate through the metal to the cathode of the cell.

- Anodic Protection:** The reduction or elimination of corrosion of a metal that can sometimes be achieved by making current flow from the metal to the solution as by connecting it to the positive pole of a source of current. Under most conditions, as the potential of an initially active metal is gradually shifted in a more noble direction as by potentiostatic means, the corrosion current gradually increases. However, with suitable combinations of metal and solution, a critical potential is soon reached. At somewhat higher values of the potential, the current drops to a very low value, and the metal becomes passive. The potential of metal has to be regulated by a potentiostat.
- Anodizing:** A process for thickening the layer of oxide on the surface of metal, especially aluminum. The article is made by dipping the metal as an anode in a bath of chromic or sulfuric acid. It provides protection from corrosion and is a good base for paint.
- ASTM:** American Society for Testing Materials.
- Austenitic:** A term applied to that condition of iron associated with a change in crystal structure that makes it nonmagnetic. This occurs with ordinary iron at an elevated temperature. When sufficient chromium and nickel are present, iron becomes austenitic (nonmagnetic) at normal temperature. This is the case with the many stainless steels that contain about 18 percent chromium and 8 percent or more nickel.
- Binary Alloy:** An alloy composed of two elements, of an element and a radical that acts as an element, or of two such radicals.
- Binder (paint):** Primary constituent of the vehicle; cements pigment particles together and fixes the mass to the substrate being coated.
- Catalyze:** To speed up a chemical reaction by the use of an ingredient (the catalyst) which undergoes no chemical action itself.
- Cathode:** The more noble electrode of a corrosion cell where the action of the corrosion current reduces or eliminates corrosion.
- Cathodic Protection:** The reduction or elimination of corrosion of a metal that is achieved by making current flow to it from a solution, as by connecting it to the negative pole of some source current. The source of the protective current may be sacrificial metal, such as magnesium, zinc or aluminum. The current may also be derived from a rectifier, generator, or battery and applied through an appropriate anode which may be consumed by the applied current, as in the case of steel, or remain substantially unaffected



by the current, as in the case of graphite or platinum. Cathode protection may become complete when anodic reactions are completely suppressed and only cathodic reactions occur on the metal surface.

- Cation:** A positively charged ion of an electrolyte. Metallic ions, such as iron and copper, are cations.
- Cell:** In corrosion processes, a cell is a source of electrical current that is responsible for corrosion. It consists of an anode and a cathode immersed in an electrolyte and electrically bonded together. The anode and cathode may be separate metals or dissimilar areas on the same metal.
- Chalking:** Deterioration of an organic coating upon exposure that results in a powdery, chalky residue on the painted surface.
- Chemical Conversion Coating:** A film that is deliberately produced on a metal by immersing, brushing, or spraying with a selected chemical solution for the purpose of providing improved corrosion resistance to the metal or increasing the adhesion of organic coatings to be applied later. Coatings covered by MIL-C-5541 are examples.
- Clear Water:** As defined for use in this study, color-free water containing no visible suspended particles.
- Coating System:** The total surface preparation, the application methods, and types of paints used on a structure. The programmed life and environment of the antenna should determine the coating system.
- Concentration Cell:** An electrolytic cell consisting of an electrolyte and two areas of the same metal or alloy that develop a difference in potential as a result of a difference in concentration of ions (most often metal ions) or oxygen at different points in a solution.
- Corrosion:** The deterioration of a material, usually a metal, through reaction with its environment.
- Corrosion Fatigue:** A reduction in the ability of a metal to withstand cyclic or repeated stresses, caused by corrosion.
- Corrosion Rate:** The speed at which a metal or alloy is wasted away because of corrosion. This may be experienced in terms of loss in weight or loss of thickness in a given period of time.
- Couple:** Two or more dissimilar metals or alloys in electrical contact with each other so that they can act as the electrodes of a cell if they are immersed in an electrolyte.

**Cracking:** (a) Localized breaking of a paint film to expose the underlying material. (b) Breaking of a metal or alloy in a brittle fashion along a narrow path or network.

**Critical Humidity:** Under controlled conditions a metal or alloy will not corrode if relative humidity is kept below a certain value. In the presence of hygroscopic (moisture absorptive) solids or corrosion products, the critical humidity is under about 30 percent in a marine atmosphere.

**Elastomer:** Substance having some of the physical properties of rubber. MIL-S-8802 sealants are examples.

**Electrode:** A conductive material that is in contact with an electrolyte and serves as the site where electricity passes in either direction between the electrolyte and metal. The current in the electrode itself is a flow of electrons, whereas, in the electrolyte, ions carry electric charges and their orderly movement in solution constitutes a flow of current in the electrolyte.

**Electrolyte:** A chemical substance or mixture, usually liquid, containing electrically charged atoms (ions) that render the substance or mixture capable of conducting an electric current. Seawater is an electrolyte, for example.

**Electrolytic cell:** A cell which converts electrical energy to chemical energy.

**Electromotive Force:** (EMF) Series: The elements can be listed according to the standard electrode potentials. The more negative the potential, the greater the tendency of the metals to corrode. This series is useful in studies of the thermodynamic properties but does not indicate the rates of corrosion. A hydrogen gas electrode is the standard reference and is placed equal to zero. All potentials are positive or negative with respect to the hydrogen electrode. In this Country the potentials of zinc and iron are written as negative and those of copper and platinum positive.

**Embrittlement:** Severe loss of ductility of a metal alloy that renders the alloy brittle.

**Environment:** As applied to corrosion, includes all the effects of weather, the land, the sea, and the pollutants of man that tend to corrode metals.

**Epoxy:** Epoxy resin used in the epoxy base is a form of plastic derived from petroleum. In the form of paint, the epoxy base is mixed with a catalyst or converter; the chemical reaction is polymerization.

<b>Erosion:</b>	Destruction of a metal by the combined action of corrosion and abrasion or attrition by a liquid or gas with or without suspended matter.
<b>Eutectic:</b>	An alloy with the lowest melting point possible from any combination of the same components.
<b>Exfoliation:</b>	Breaking away from a surface in flakes or layers.
<b>Fatigue:</b>	The tendency of a metal to crack and fracture in a brittle manner under conditions of cyclic stresses, at stress level below its breaking strength.
<b>Faying Surface:</b>	The common surface formed by mating parts.
<b>Ferritic Steels:</b>	A solid solution of chromium and carbon and iron carbides in iron; crystalline structure is body-centered cubic.
<b>Film:</b>	A thin layer of material that may or may not be visible.
<b>Fretting Corrosion:</b>	Corrosion at the interface of two contacting surfaces usually under high pressure and subject to very minute slippage due to relative vibration of surfaces that ordinarily are not supposed to move relative to each other (such as a shrink fit).
<b>Galvanic:</b>	In this manual, the flow of direct current between dissimilar metals.
<b>Galvanic Corrosion:</b>	The corrosion of a metal that is associated with the flow of current to a less active metal in the same solution and in electrical contact with the more active metal.
<b>Galvanic Series:</b>	A list of metals and alloys arranged in order of their relative potentials in a given environment. The order of their arrangement in this list may be different in other environments.
<b>Galvanic Couple:</b>	A closed electric circuit of two connected dissimilar metals joined by an electrolyte.
<b>Hydrogen Embrittlement:</b>	Loss of ductility of a metal caused by the entrance or absorption of hydrogen into the metal as in the pickling of steel.
<b>Impingement Attack:</b>	Corrosion that is associated with turbulent flow of a liquid as at the entrance of a condenser tube or about bends in a pipe line.
<b>Inhibitor (as applied to corrosion):</b>	A chemical substance or mixture which, when added to a solution in small amounts, markedly decreases corrosion.

<b>Inorganic Coatings:</b>	Electroplates, conversion coatings, anodic coatings, phosphates, and oxide coatings.
<b>Intergranular Corrosion:</b>	Corrosion along grain boundaries.
<b>Ion:</b>	An electrically charged atom or group of atoms. The sign of the charge is positive in the case of cations and negative in the case of anions.
<b>Kelvin Scale:</b>	A scale of temperature measured in degrees centigrade from absolute zero.
<b>Local Cell:</b>	A cell in which the driving force is due to difference in potential between areas on a metal or alloy surface immersed in an electrolyte. The potential difference may be due to inclusions, lack of homogeneity, varying concentration of the solution with respect to oxygen or metal ions, etc.
<b>Long-Oil Alkyd:</b>	Approximately 60 gallons of linseed oil per 100 pounds of resin, very flexible.
<b>Martensitic steel:</b>	A solid solution of chromium and carbon or iron carbides in iron; crystalline structure is body-centered tetragonal.
<b>Matte Surface:</b>	A metal with a low specular, or mirror-like reflectivity as in the case of an etched or sandblasted surface.
<b>Medium-Oil Alkyd:</b>	Approximately 30 gallons of linseed oil per 100 pounds of resin, moderately flexible.
<b>Metal Ion Concentration Cell:</b>	A cell established on a metal surface due to different concentrations of its ions in the electrolyte where it is in contact with the metal surface. These variations in concentration result in local differences in potential, thus allowing the establishment of local cells.
<b>Mill Scale:</b>	The heavy oxide layer formed during hot fabrication or heat treatment of metals. The term is most frequently applied to the scale of mixed iron oxides on iron and steel.
<b>Minor Corrosion:</b>	An existing corrosion discrepancy which, by the dictates of good maintenance practice, should be corrected on a basis of noninterference with other activities.
<b>Noble Metal:</b>	A metal that is so inert that it is usually found as uncombined metal in nature. Unattackable or more resistant to corrosion. Platinum, gold, and silver are noble metals.
<b>Organic Coatings:</b>	Paint, lacquer, plastics, greases, etc.

- Oxidation:** Generally speaking, in chemical terms any change involving the loss of electrons by an atom constitutes oxidation; hence, any anode or corrosion process involves oxidation of the metal in a true chemical sense. More specifically, it also may imply the destruction of a metal or alloy as a result of the direct action of oxygen on the metal; e. g., the scaling of steel at a high temperature.
- Passivation:** The process or processes by means of which a metal becomes inert to a given corrosive environment.
- Passivator:** An inhibitor that causes a shift in the potential of a metal in the inhibited solution to a more cathodic or electro-positive value and thereby makes the metal more resistant to corrosion by the solution. Chromates inhibit corrosion of steel by water in this manner.
- Paint Life:** The time required for a new coating system to reach a point where one percent of the total protecting coating system has broken down.
- Passive-Active Cell:** A cell involving conditions in which the EMF is due to the potential difference between a metal in an active state and the same metal in a passive state. The pitting of stainless steel in seawater is due to a cell set up between an active surface within a pit and the passive surface surrounding it.
- Passive:** State of a metal that is active in the EMF Series, or an alloy composed of such metals, when it exhibits an appreciably greater resistance to corrosion and behaves like a less active (or more noble) metal in resisting corrosion and by exhibiting a relatively noble potential in a galvanic series.
- Patina:** A green or greenish-blue coating which forms on copper or copper alloys exposed to the atmosphere.
- pH:** The acidity of a solution as determined by the concentration of hydrogen ions in it. The pH of a solution is a term used to express the effective hydrogen ion concentration. It ranges from pH-0 to pH-14; pH-7 indicates a neutral solution. Values lower than 7 indicate an acid condition. The stronger the acidity, the lower the pH. Conversely, values of pH above 7 indicate an alkaline condition; the higher the pH the more alkaline the solution. Fresh water usually exhibits a pH of about 6 to 7. Seawater ranges from pH-7.8 to 8.4 with an average of about 8.2.
- Pigment (paint):** Usually an insoluble powder carrying the coloring matter. Some pigments are acid-sensitive and some are alkali-sensitive. A lead pigment is unsuited to sulfur atmosphere. Certain titanium pigments catalyze the photochemical decomposition of the binder and produce chalking.

- Pitting:** A form of corrosion that develops in highly localized areas on a metal surface that is not attacked elsewhere to any great extent. This results in the development of cavities of small diameter to relatively shallow depressions.
- Polymerization:** The chemical reaction between the epoxy base and converter. The film formed by the polymerization is chemically tied up or crosslinked, giving great durability and chemical resistance to the coating. Conventional paint dries by evaporation or oxidation.
- Polyvinyl:** A synthetic resin, divided into two general types: polyvinyl chloride and polyvinyl acetate.
- Post Cure:** A coating followed later by the application of a curing solution to speed up the drying process. The drying time is approximately 24 hours.
- Potential Corrosion:** A condition which, if left unchanged, can create a corrosion problem.
- Precipitation Hardening:** The hardening of a metal resulting from the addition of a proper alloying element.
- Primer Coat:** The first coat of a protective paint, etc. Originally applied to improve adherence of the succeeding coat, but now usually containing an inhibitor pigment such as zinc chromate or red lead.
- Relative Humidity:** The ratio, expressed as percentage, of the concentration of water vapor in the air to the water vapor concentration that it would have if saturated at the same temperature.
- Rusting:** Corrosion of iron or iron-base alloys resulting in the formation of corrosion products on the surface that consist mainly of hydrated ferric oxide.
- Resin:** Any of the various solid or semisolid organic substances exuded from various plants and trees or prepared synthetically. Resins are soluble in ether or alcohol.
- Saline Aeration:** A fog, mist, or condensation carrying ionized salts from the ocean.
- Sapon:** A prefix of soap or similar to a soap.
- Saponifying:** The formation of soap in paint film resulting from the reaction of a fatty acid ester with an alkali.

**Scaling:** The formation at high temperatures of partially adherent layers of corrosion products on a metal surface.

**Self-Cure:** All of the curing elements are combined in the coating material when it is applied. The drying time may be from 72 hours to 3 weeks.

**Severe Corrosion:** An existing corrosion condition that has progressed to the point where the structural integrity of the unit is questionable. It should be corrected prior to the unit's next operating cycle.

**Short-Oil Alkyd:** Ten gallons of linseed oil per 100 pounds of resin, very inflexible.

**Slushing Compound:** A nondrying oil, grease, or similar organic compound which, when applied to a metal, protects against corrosion.

**Solvent (Paint):** Keeps the binder dissolved to permit application of paint, after which the solvent dries up.

**Spalling:** The chipping, fragmenting, or separation of particles from a surface.

**SSPC:** Steel Structures Paint Council.

**Stress Corrosion:** Corrosion that is accelerated by stress, either residual internal stress in the metal, or externally applied stress.

**Surface Preparation:** The degree to which the surface to be painted is prepared to receive the coating. There are four classes of surface preparation for metals.

**Tarnish:** Surface discoloration caused by formation of a thin film of corrosion product or oxide film.

**Stress Corrosion Cracking:** Cracking that results from the combined effects of corrosion and stress.

**TT:** A prefix designating a Federal Government Specification, for example, TT-P-636C. Many of the TT specifications are converted from military specifications.

**Urethane:** A white crystalline compound  $C_3H_7O_2N$ , produced by the action of ammonia on ethyl carbonate or by heating urea nitrate and ethyl alcohol.

**Vehicle (paint):** A fluid consisting of a solution or mixture of a binder with a thinner (solvent).

**Vinyl:**

Synthetic resin binder, a monovalent radical,  $\text{CH}_2\text{CH}$ , characteristic of many derivatives of ethylene, its hydride.

**Vinyl Resin:**

A vinyl polymer.