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AVIONIC CORROSION

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SUMMARY

This paper discusses,

The paper will discuss the major causes of corrosion in the Navy's avionic equipment and provides specific examples of corrosion failures. Maintenance and readiness data summaries ~~will be~~ included to denote further the corrosion problem severity. Corrective measures in design, testing and maintenance ~~will be~~ reviewed.

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INTRODUCTION

In today's sophisticated naval aircraft, the avionic systems represent 30-50% of the cost of the total weapon systems and their performance is critical to the overall mission capability. Consistently however, the reliability of such equipment when it is deployed in fleet service is significantly below that predicted during the design and demonstration phases. There are military specifications, standards and handbooks that describe design characteristics of various components that are to be used in new avionic equipment. Also, there are laboratory tests designed to demonstrate the capability of the assembled equipment to meet prescribed requirements relative to shock, vibration, salt spray, temperature, EMI, and other characteristics that can be quantified and measured. These design and test requirements, however, have not been adequate to preclude the recurring increased failure rates when equipment is operated and maintained in the naval environment.

Investigations conducted during the past ten years have increasingly identified corrosion as a major unforeseen degradation factor for electronics placed in the naval aircraft fleet environment. While fleet conditions are difficult to duplicate in a laboratory, it is possible to minimize equipment susceptibility through enlightened design - once the causal factors are recognized and understood. On-site surveys (1) of front line combat aircraft have concluded that the significant design factors contributing to corrosion are; poor resistance to moisture intrusion, numerous unnecessary matings of dissimilar metals, and fluid conduits within the airframe.

MOISTURE AND FLUID INTRUSION

Avionic equipment, whether internal or external to the aircraft, on the repair bench or in storage can be susceptible to conditions such as changing temperatures and pressures, varying humidity, dust, dirt and industrial pollutants in the atmosphere. In addition the Navy's aircraft carrier environment exposes sensitive electronics to a combination of moisture, acidic deposits from stack gases, jet engine exhaust, and salt spray. The equipment that suffers the most from these environmental effects are those mounted external to the airframe such as; antennas, electronic countermeasure pods, photographic pods and lights. There are many situations where avionic devices are installed behind doors and panels that leak during flights through rainstorms or on low level flights over water. If the integrity of the airframe is less than perfect during rainstorms, fresh water washdowns can be equally hazardous. High pressure washing units deluge the aircraft with tremendous amounts of water in a short time. Two prime examples of susceptibility to this condition are the clamshell doors on helicopters and radomes on fixed wing aircraft. These doors and radomes leak like sieves when the gaskets become worn or damaged. In addition, exhaust fan inlet ducts, ram air cooling ducts, and vapor exhaust ports that are designed without a self-sealing mechanism become excellent access areas for water and mositure intrusion. Helicopters, in particular, are designed with minimal consideration for the operational environment. There are numerous flight scenarios that require cockpit windows and cabin doors to be open. Numerous cases exist where control boxes and communication equipment are mounted aft, or below, the door and window openings, allowing water to enter the equipment. Figure 1 provides an excellent example of the effects of water intrusion. This severely corroded power supply sub-assembly, mounted in the turtle back area behind the cockpit on the A-6 aircraft, was victimized by frequent water intrusion soakings.

The external bulkhead electrical connectors, external wire and cable runs, antennas, control linkages and other such areas where the shell of the fuselage is penetrated can become potential sources for moisture and fluid intrusion. The list of airframe integrity problems relative to water intrusion during flight is extensive.

Besides the water intrusion problems occurring during flight, airframe integrity is compromised also in the maintenance periods. Many additional problems are encountered while aircraft are parked on the flight deck. In general during the majority of their ground time aircraft are opened up or unbuttoned to some degree. The need for canopies to be open during certain maintenance functions produces situations where rain and salt-spray may soak cockpit avionic components. The removal of a waveguide or a doppler or ADF antenna from the aircraft exposes the supporting electrical connectors, harnesses and cables to the environment. The troubleshooting of radars on fighter and attack aircraft may require the radomes to be open for hours on end, continually exposing the equipment to rain and salt-spray. The same is true during troubleshooting in avionic bays and compartments.

Environmental control systems add another insidious facet to the overall problem of moisture and fluid intrusion. These systems are not operated on a round the clock basis. The avionics are protected while the environmental control system is supplying conditioned air during flight and then are exposed to a completely different and harsher environment during the more extensive time spent on the ground. The equipment becomes particularly prone to water condensation when the aircraft after sitting for long periods of time on a hot carrier deck undergoes rapid changes in temperature at flight altitudes. Moisture condenses on cooled surfaces, during flight, and then is trapped until natural evaporation mechanisms take over during down time.

After moisture or fluids enter an airframe or avionic compartment it may follow a natural conduit directly into a sophisticated piece of avionic equipment. Hydraulic and fuel lines, control surface linkages, oxygen lines, waveguides, structural stringers and electrical wire/cable runs act as natural conduits to moisture and fluids. It is common to find that antenna and radars mounted in the lower fuselage are adversely affected by moisture intrusion which runs down the antenna coaxial cable and/or waveguide that carry the signals to and from the equipment. As these cables and waveguides pass through deck plates and bulkheads, where water is present, they act as conduits carrying the fluid into the connectors attached to the equipment.

THE EFFECTS OF CORROSION ON AVIONIC COMPONENTS

The avionic systems on aircraft are not isolated 'black boxes' sealed against the environment. There are many components, relays, terminal boards, circuit breaker panels, switches, lights, etc. that make up a complete system. In addition, a sophisticated aircraft may contain miles of wire and coaxial cables and hundreds of electrical connectors. Corrosion attack on the various elements that make up the total avionic systems can create numerous problems in relation to reliability and maintainability. Table 1 summarizes the effects of corrosion on avionic components.

Antennas are the most corrosion prone components in the Navy's airborne electronic systems. The problem of antenna corrosion have become more severe in recent years due to the increased number of avionic systems which has created the need for many additional antennas per aircraft. Corrosion of antennas and associated hardware can cause degradation in system performance through shorts, open circuits, signal attenuation, electromagnetic interference (EMI), or structural damage to the aircraft. Antenna installations show a consistent pattern in the extensive use of dissimilar metals, a lack of consideration during design to the problems of moisture and fluid intrusion, and inconsistencies in the maintenance materials and procedures provided on like antennas installed in different aircraft types. These, problems when considered collectively, have created both system reliability degradation and a significant consumption of maintenance manhours. Antenna and antenna mount corrosion is especially common to pressurized aircraft, and this is particularly true to lower fuselage installations. When the aircraft is pressurized, various liquid contaminants, including toilet leakage, oil and hydraulic fluid, are forced into any crack, crevice, or fitting available; and there, awaiting destruction, is the inverted antenna bottom and antenna-mount fasteners together with cable connectors. The lower fuselage antennas of non-pressurized aircraft are subject to the same problems. Corrosion just takes a little longer. Upper fuselage antennas are subject to infiltration of electrolyte through condensation and aspiration.

In an attempt to alleviate the antenna corrosion problem, a program was undertaken to determine improved corrosion preventive materials and processes. Representative antenna installations were selected for a fleet evaluation of these maintenance procedures. A test plan was developed that provided the guidelines for conducting the fleet evaluations to assess the effectiveness of these materials and processes. Under Commander, Air Force Pacific (COMNAVAIRPAC) and Commander, Air Force Atlantic (COMNAVAIRLANT) sponsorship and in coordination with the appropriate Fleet Wings, the test plan maintenance procedures and material applications were applied to various types of aircraft antennas. The test period covered 180 days.

The antenna installations selected for evaluations are listed in Table 2. The main basis of selection was that the antennas should represent the different types each with its own distinctive corrosion problems. For example, the P-3 HF Long Wire antenna is subject to corrosion and arcing due to water intrusion into the tensioner assembly and the insulator; the H-46 radio antenna has a whip antenna mounted on the lower skin that has a particular problem due to water entrapment around the electrical attachment inside of the fuselage; and the A-7 Lower TACAN/IFF antenna has a major problem due to the presence of water and other fluids in a bathtub-like area where the coaxial lead penetrates the fuselage skin to the antenna. Similarly, the H-3 No. 1 UHF/Comm Normal (lower) and Alternate (upper) antennas are skin mounted and require a conductive gasket between the antenna base and the skin. These antennas are subject to the same moisture intrusion as the A-7 aircraft, yet the A-7 installation requires no conductive gasket. The H-3 Doppler has a particularly bad problem because that portion of the antenna interior to the aircraft is located in the fuselage low point area and, therefore, subject to a variety of standing fluids.

Table 2, also, lists the corrosion maintenance data for the selected antenna. The list contains the total maintenance actions reported total related corrosion maintenance actions and corrosion percentage. The numbers are based on the corrective maintenance actions performed at the first two levels of maintenance; the organizational or squadron level and the intermediate level. The numbers reflect the magnitude of the corrosion problem in these antennas. The corrosion maintenance actions attributable to corrosion damage range from 11 to 85%.

Selections of materials for this fleet level corrosion control were based on the following considerations:

1. There should be no detrimental effects on the operation of systems or components.

2. They should possess demonstrated effective corrosion preventive properties.

3. Insofar as possible, they should be materials that presently are available in the Naval Aviation supply system.

During the implementation of the test program these procedures were applicable to any of the rigid type antenna bases (blade, whip, or long wire mast base). The step-by-step actions for cleaning, application of corrosion preventives and sealing of these antenna bases were:

a. Removed dirt, oil, and grease from contact surfaces of the antenna and aircraft skin using cleaning cloth dampened with dry cleaning solvent.

b. Removed minor surface corrosion with an abrasive mat.

c. On areas where the corrosion products were abrasively removed, applied Chemical Conversion Coating, MIL-C-81706, Class 3, to the bared surface. The Class 3 material was used because it provides a thinner coating with lower electrical resistivity.

The procedure is applicable to the A-7 aircraft lower tACAN/IFF antenna, shown in Figure 2, and was evaluated on two A-7E aircraft.

Since the A-7 lower tACAN/IFF antenna installation did not require a conductive gasket, the following mounting procedures were used:

a. Removed anodize on screw countersink areas of antenna base in order to provide good electrical conductivity from the base to the screws.

b. Applied Chemical Conversion Coating, MIL-C-81706, Class 3, on bared countersink areas.

c. Applied an even coating of Corrosion Preventive Compound, MIL-C-16173, Grade 4, on both the aircraft skin surface and the flat side of the antenna base which mates against the aircraft skin. The Grade 4 material is a soft, tacky to the touch, coating when it dries and has been used for many years as a general preservative on naval aircraft.

d. Conducted electrical resistance test to check for a good grounding connection. The grounding specification requires the resistance not to exceed 0.1 ohms. (The milliohmmeter reading for these antenna installations were both 0.02 ohms.)

e. Applied a fillet of corrosion inhibited polysulfide sealant, MIL-S-81733, Type II, around the outside of the antenna base on one aircraft and a fillet of MIL-S-8802 polysulfide sealant without inhibitors on the antenna on the other aircraft to form a watertight seal.

f. Covered the fastener heads with Corrosion Preventive Compound, MIL-C-16173, Grade 4.

Corrosion inside of an antenna coaxial connector is a principal cause of antenna performance degradation (Figure 3). Therefore, the cleaning and preserving of the antenna connectors is important to reduce the effects of moisture intrusion. Throughout the test program the cleaning and preserving of these connectors were accomplished during the various installations by the following procedures:

a. With the connector sections mated, corrosion was removed with an abrasive mat.

b. Connectors were opened and internal sections were cleared.

c. The internal areas were sprayed with a water displaying corrosion preventive compound MIL-C-81309, Type III. The MIL-C-81309 material forms an ultra thin tacky (soft) film that is designed so that it is displaced by the wiping action of a sliding electrical contact, yet the film is self-healing (reforms) in non-contact areas after displacement. The resultant lack of disruption to DC continuity through the male/female type of connections due to the MIL-C-81309, Type III, film has been well established.[3,4]

d. The connectors were then mated and a coating of another water displacing corrosion preventive compound, MIL-C-85054[5], was applied to the exterior surface of the connector. This material dries to a relatively thick (1 to 2 mils) hard, clear finish and has been used successfully on navair aircraft to protect exterior skin surfaces in areas where paint has chipped or cracked leaving exposed bare metal.

From the reports submitted by the designated fleet squadrons at the start, at the 28 days inspection intervals, and at the completion of the evaluation when the antennas were removed the following results were summarized.

a. Throughout the 180 day evaluation, all the test items were reported from excellent to satisfactory, and none showed evidence of corrosion or problems with the materials used.

b. All reports indicated that the solvents, cleaning materials, and other maintenance chemicals, had no effect on the sealants or corrosion preventive materials applied to the test items.

c. Throughout the evaluation period, there was only one reported failure. This was on the ADF antenna on the SH-3H helicopter. The failure was discovered during troubleshooting of a discrepancy in the system. When the antenna was removed approximately 3 ounces of water ran out of the antenna installation area. No corrosion, however, could be detected on the antenna and there was no indication that the presence of this water was the cause of the functional failure of the ADF antenna.

Upon removal of the A-7E lower tACAN antenna it was observed that a combination of fluids, mostly hydraulic oil and water had collected on the internal contact surfaces, however, the corrosion preventive compound MIL-C-16173 Grade 4 prevented the fluids from affecting the antenna and the aircraft mounting area. There were no visible signs of corrosion.

When the antenna connectors were disconnected they were in the same condition as when they were connected at the beginning of the evaluation period. There was no evidence of external connector corrosion. As Figure 4 shows the antenna coaxial connector appears to be clean after the six month test even through fluids and foreign matter from the inside of the aircraft are all around the base of the connector.

While it is significant that corrosion was prevented, no method evaluated was able to seal the lower fuselage skin opening through which the co-ax cable connects to the antenna. In many installations there is no practical access to the skin opening from the inside of the fuselage, hence sealing around the coax cable after the antenna was installed could not be done. In such cases, sealing around the outside base of the mounted antenna stopped moisture intrusion into the antenna base to skin interface from only one of the two possible entry areas.

SPECIAL COAXIAL CONNECTOR TESTING

Special testing of coaxial connectors was conducted[6] to assure that the MIL-C-81309 type III water displacing corrosion preventive material used on the internal contact areas would cause no detrimental effects. Traditionally no preservatives have been used inside of a coax connector because of fears that any foreign material would alter the characteristic capacitance created by the spacing and insulation between the inner and outer conductors. This characteristic is particularly critical in those lines for which changes in capacitance is used as a sensor in the system-such as in a capacitive type of fuel quantity indicating system. Any change in the dielectric between the inner and outer conductor also can affect the impendance of an antenna line (connector).

Special tests with relatively sensitive measuring equipment were made to determine the electrical (RF transmission) effects incurred by the use of MIL-C-81309, Type III, Water Displacing Corrosion Preventive Compound in coax connectors. The tests were conducted using TDR (Time Domain Reflectometry) and FDR (Frequency Domain Reflectometry) equipment to sweep a coax assembly over a frequency range. Two runs were made on the line/connector read assembly with no corrosion preventive applied to determine the repeatability of the test. Following that, runs were made with MIL-C-81309, Type III, Class 2, applied to both sections (male and female) of the contractor. No attenuation of signal or change in characteristic impedance resulted from the presence of MIL-C-81309 material in the coaxial connectors over the frequency range measured.

Considering the large number of electrical connectors in a modern aircraft, connector water and corrosion damage cause some of the most costly repairs in the Navy's avionic maintenance business. The major problem with connectors is that of water intrusion or fluid contamination that causes corrosion, insulation damage, short circuits, fire, signal loss or intermittancy, wire failure through insulation and/or connector damage and grommet seal swell or shrinkage.

Connector shell corrosion occurs when protective finishes are damaged and expose the base metal. Visual inspection of the outer surface of connectors is not always a good indication of their condition. Many connectors that outwardly appear acceptable are in fact heavily corroded internally and are impossible to decouple without component damage.

The use of a thin electroless nickel plating over 6061 aluminum on connector shells has caused serious corrosion problems as shown in Figure 5. Cracks develop in the nickel plating and when the surface is wet a galvanic cell is created with the aluminum corroding sacrificially. Figure 4 illustrates the effects of this galvanic corrosion on two coaxial connectors.

In an attempt to correct this problem, Jankowski[7] evaluated coatings for electrical connector shells. The effort led to the use of a duplex nickel-cadmium plating, which, while not preventing corrosion, does provide improved corrosion protection. The use of water displacing corrosion preventive compounds provides additional protection. The use of non-metallic connector shells, however, represents an approach which may completely eliminate this problem.

New developments in injection molded reinforced polymeric materials make them viable candidates for connector applications, avionic enclosures and fittings. Ease of fabrication and promising mechanical properties are some of the reasons these materials are attractive alternatives to metals. Additionally, these resins can be reinforced with chopped conductive reinforcements such as graphite, metallized graphite and stainless steel to provide electrical conductivety and EMI shielding.[8] [9] [10] Secondary schemes such as metallic coatings and platings can be utilized to supplement shieldings from conductive reinforcements. Connectors with shells fabricated from a 40% graphite chopped fiber reinforced polyphenylene sulfide thermoplastic composite material were installed in the right wheel well switching assembly on four F-14 aircraft in September 1983. This connector performs a non-critical function in the counting accelerometer system and due to its location is exposed to the severest environmental conditions. After more then three years of exposure to the service environment that there is no evidence of deterioration, as shown in Figure 6, and no electrical problems have occurred and no maintenance has been performed on any of the connectors.

Some 40-50% of the weapon removal assemblies removed from an aircraft for cause are returned to a servicable condition by printed wiring board reseating. In a sense, reseating is a form of localized cleaning of corrosion from edge connectors. The vulnerability to this failure mode for the typical blade plug-in type of edge connectors is dependent upon the positioning of the PWB within the equipment and the severity of the environment within the equipment. PWBs mounted horizontally are especially susceptible to accumulations of dust, dirt, debris, moisture condensation and spillage. Vertically positioning PWBs minimizes such an accumulation of contaminants on the board (and allows better convection cooling). From a corrosion and reliability stand point, the poorest location for edge connectors on a vertically mounted PWB is along the lower or bottom edge. Moisture and hygroscopic debris will collect along this edge. There are a number of instances, where, due to inadequate housing drainage, the lower edge of the PWBs and the edge connectors have been immersed in standing water. It is recognized that, from a convenience viewpoint, it is very handy to be able to remove a lid, lift out a PWB, and drop in (pressing down to seat) the replacement PWB. To minimize susceptibility to corrosion, however, the PWB edge connectors should be mounted on a vertical edge or the back of the board - not the bottom.

Normally, equipment bay doors must maintain r.f. and d.c. electrical continuity between the door and the surrounding airframe to prevent EMI (electro-magnetic interference) both from entering installed equipment as well as radiating externally to the aircraft from the installed equipment. Because of the large size of most equipment bay doors, very close spacing of fasteners as a means of controlling EMI becomes impractical due to maintainability penalties. Indeed, the space between fasteners can act as a slot antenna greatly increasing the EMI problem.

To prevent EMI leakage, conductive gaskets are often used to provide the continuity needed to preclude the passage (in or out) of r.f. or other forms of radiated energy. The conductive EMI gaskets achieve their conductivity by metallic particle or mesh embediment in the gasket or seal. Frequently, this embediment is a dissimilar metal that is very cathodic to the door and airframe skin. Typically, silver, copper or graphite has been placed in electrical contact with aluminum skin. The products of this corrosion are insulative and severely degrade the electrical effectiveness of the EMI gasket. The wire mesh embediment type of gasket also can be subject to wicking of moisture along the embedded strands with resultant corrosion. The inclusion of the conductive materials in the elastromeric gasket degrades the capability of the gasket to perform the sealing function, and the mating of the highly conductive metals to the aluminum housing, doors, aircraft skin, etc., creates bimetallic couples that will severely corrode (and destroy the EMI function) if the seal is less than perfect. In short, the two functions being attempted with an EMI gasket appear to be mutually incompatible.

A possible solution to this problem is the application of water-displacing corrosion preventive compounds such as MIL-C-81309, Type III, on the exposed aluminum surfaces where the EMI gasket metallic particles can penetrate the compound so as to maintain the integrity of the system. This method requires reapplication of the compound each time the integrity of the seal is broken. This puts the burden of continued reliability on the repair technician. A gasket configuration with separate provisions for the EMI and the environmental protection requirements is the best technology available at the present time. This requires an environemntal gasket on both sides of the EMI gasket. Assure the outside protective surface finishes go around the corners and under the environmental gasket.

CORROSION PREVENTION

When an avionic corrosion prevention/control program was established by the Naval Air Systems Command, a major emphasis of the program became the preparation of a Fleet maintenance manual. The lack of preventive maintenance guidelines had been recognized as a contributing factor for the high maintenance requirements for airborne electronics. In May 1978, NAVAIR 16-1-540, Avionic Cleaning and Corrosion Prevention/ Control Manual, was issued to the Fleet. The manual provides instructions for inspecting for and recognizing corrosion in its early stages and identifies materials and procedures necessary for cleaning and corrosion control. The manual[11] revised in 1981 has been adopted by the U. S. Air Force and Army as a tri-service document.

A prototype cleaning facility was established to evaluate the effectiveness of various cleaning methods for avionic equipment. The results of this study determined the optimum types of cleaning and corrosion removal equipment to be supplied to the maintenance activities for use on avionics.[12]

Since the best and ultimately least expensive time to stop corrosion is at the design stage, a program was initiated to develop a designers' guide for avionic corrosion prevention and control. The design[13] guide titled, "Design Guidelines for Avionics Corrosion Prevention and Control" was written and issued as NAVMAT P 4855-2, June 1983. The guide identifies critical design features, structural configurations, materials, material combinations and inadequate corrosion protection methods that have led to poor reliability and high maintenance requirements for avionic equipment placed in the Navy's severe operating environment. This guide is intended to provide an awareness of the corrosion problems that develop on the Navy's equipment and provide design methods that can be used to avoid or minimize them. It is not to be the intent of this guide to dictate design criteria, but to document current corrosion problems so that they may be considered and avoided in the future.

CONCLUSIONS

Corrosion and environmental degradation being natural phenomena will never be eliminated, but it is reasonable to expect that the problems that do develop in the avionics systems in the future can be less severe and better controlled than those presently being encountered. However, this goal can be achieved only through an aggressive technological effort directed towards the understanding of failure mechanisms, development of new improved corrosion control materials and methods, and the prudent utilization of innovative protection technology in the design, manufacture and service life of the avionics equipment.

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TABLE 1. EFFECTS OF CORROSION ON AVIONIC COMPONENTS

COMPONENT	FAILURE MODE
ANTENNA SYSTEMS	Shorts or changes in circuit constants and structural deterioration.
CHASSIS, HOUSING, COVERS, AND MOUNTING FRAMES	Contamination, pitting, loss of finish and structural deterioration.
SHOCK MOUNTS AND SUPPORTS	Deterioration and loss of shock effectiveness.
CONTROL BOX MECHANICAL AND ELECTRICAL TUNING LINKAGE AND MOTOR CONTACTS	Intermittent operation and faulty frequency selection.
WATER TRAPS	Structural deterioration.
RELAY AND SWITCHING SYSTEMS	Mechanical failure, shorts, intermittent operation and signal loss.
PLUGS, CONNECTORS, JACKS AND RECEPTACLES	Shorts, increased resistance, intermittent operation and reduced system reliability.
MULTI-PIN CABLE CONNECTORS	Shorts, increases resistance, intermittent operation and water seal deterioration.
POWER CABLES	Disintegration of insulation and wire/connector deterioration.
DISPLAY LAMPS AND WING LIGHTS	Intermittent operation, mechanical and electrical failures.
WAVEGUIDES	Loss of integrity against moisture, pitting, reduction of efficiency and structural deterioration.
RADAR PLUMBING JOINTS	Failure of gaskets, pitting and power loss.
PRINTED CIRCUITS AND MICROMINIATURE CIRCUITS	Shorts, increased resistance, component and system failures.
BATTERIES	High resistance at terminals, failure of electrical contact points and structural deterioration of mounting.
BUS BARS	Structural and electrical failures.
COAXIAL LINES	Impedance fluctuations, loss of signal and structural deterioration of connectors.

TABLE 2. ANTENNA CORROSION CORRECTIVE MAINTENANCE

Aircraft	Nomenclature	Total Maintenance Actions	Total Corrosion Maintenance Actions	Percent Corrosion
A-7	Lower TACAN/IFF	281	240	85%
H-3	No. 1 UHF/Comm (normal)	155	103	66%
H-3	No. 1 UHF/Comm (alternate)	58	33	57%
P-3	Long Wire DF Sensing	186	21	11%
H-46	Long Wire DF Sensing	133	28	21%
H-3	Receiver Transmitter (Doppler)	653	139	21%

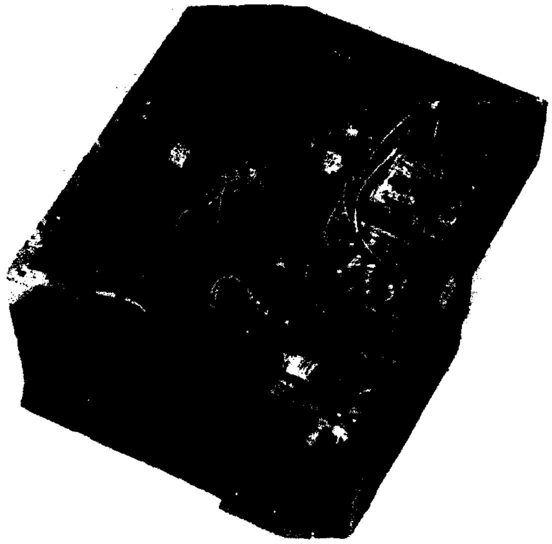

FIGURE 1. CORRODED A-6 POWER SUPPLY SUBASSEMBLY

FIGURE 2. A-7 LOWER TACAN/IFF ANTENNA

FIGURE 3. CORROSION ON LOWER TACAN/IFF ANTENNA COAXIAL CONNECTOR

FIGURE 4. CORROSION PROTECTION RESULTS OF LOWER TACAN/IFF ANTENNA

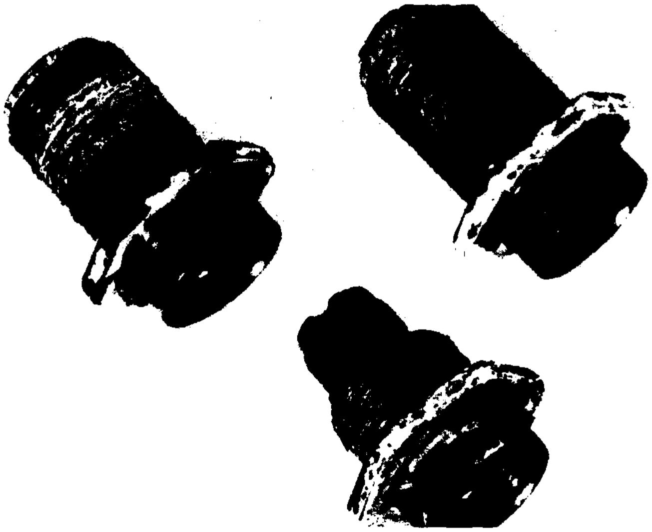

FIGURE 5. GALVANIC CORROSION OF NICKEL PLATED ALUMINUM COAXIAL CONNECTORS

FIGURE 6. COMPOSITE CONNECTOR ON F-14 RIGHT WHEEL SWITCHING ASSEMBLY