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service news

A Service Publication of Lockheed Aeronautical Systems Company-Georgia

Understanding Corrosion

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service news

A SERVICE PUBLICATION OF
LOCKHEED AERONAUTICAL
SYSTEMS COMPANY-GEORGIA

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Vol. 15, No. 4, **October-December 1981**

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Cover: The onset of winter weather in many parts of the world this time of year increases airframe exposure to moisture and chemicals, and makes maintenance activities more difficult. That can be a window of opportunity for costly corrosion damage.

Focal Point


Ted Nissley

Semantics and Customer Supply

What does the word "spare" mean to you? If you look it up in a dictionary, you will find several definitions, but to most people the word suggests something extra, an item over and above what is needed, a replacement reserved for future use.

In the Customer Supply organization at LASC-Georgia we know that such conventional definitions ran fall very wide of the mark. To today's aircraft operator, spare parts are not really "spare" at all. They are crucial to the safe and efficient operation of every airplane in his fleet.

Beyond this, spare parts are a vital fact of business life. Having a reliable and knowledgeable source of quality replacement parts can make the difference between profit and loss, between success and failure. At Lockheed, we have a thorough understanding of what spares and spares provisioning really means.

We have also made it our business to give renewed meaning to another common word that is often too loosely applied. That word is service. Customer Supply at LASC-Georgia can fill your order for every part needed to keep your Hercules aircraft flying, but we are far more than just a parts warehouse. We are a fully developed, full-time service organization, dedicated to providing the total supply needs of each of our customers, everywhere in the world.

We are prepared to support your supply requirements at every maintenance level, whether it is line, organizational, or depot: and we are prepared to do it at your convenience, not just ours. Our 24-hour telephone service, supported by the latest in computerized inventory control systems, ensures that you will get prompt answers to every supply question, and immediate response to your spares requirements.

Our computerized systems ensure speed and accuracy, but the real key to the quality of the service we offer lies in the comprehensive knowledge of the supply business offered by our professional people. They advise each of our customers concerning his supply needs on a one-to-one basis. When you contact us about your supply needs, you are assigned your own, individual supply administrator. This courteous and experienced professional becomes your representative, ready and able to help satisfy all of your supply needs quickly, efficiently, and at a fair price.

Customer Supply at LASC-Georgia is proud to serve Hercules airlifter operators worldwide and we hope that you will give us the opportunity to assist you in solving your total supply and service requirements. We think you will agree that we give fresh definition to yet another word that is often misused in today's world. That word is value.

Sincerely,

Ted Nissley
Director, Customer Supply LASC-Georgia
Lockheed Aeronautical Systems Company

Lockheed PRODUCT SUPPORT LOCKHEED AERONAUTICAL SYSTEMS COMPANY-GEORGIA

H.L. BURNETTE DIRECTOR

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Understanding Aircraft Corrosion

by Everett J. **Smith,** Specialist Engineer
Materials and Producibility Technology Department

The Hercules aircraft has been in production longer than any other large aircraft. Yet outward appearances aside, there is little real resemblance between today's Hercules and its predecessor of 30 years ago. The world's most famous airlifter may still have a familiar face and form, but it has undergone countless changes over the years, changes that continually improve its performance and extend its service life.

A significant number of these changes were made specifically for the purpose of increasing the airplane's resistance to corrosion. Today's Hercules not only incorporates the latest and best technology as far as materials of construction is concerned, but it also includes the latest advances in sealing techniques, protective finishes, and corrosion prevention.

More corrosion-resistant steel and aluminum alloys are now used to prevent fatigue, stress corrosion cracking, and exfoliation corrosion. Today. many fasteners are also made of these durable and resistant alloys. A corrosion- inhibiting finish system consisting of an epoxy polyamide primer and aliphatic polyurethane top coat is applied to all exterior metallic surfaces except those made of stainless steel or titanium.

Every permanent exterior joint, from nose to tail and wingtip to wingtip. is faying surface sealed with a corrosion inhibiting sealant. Corrosion prevention techniques such as an integral fuel tank water removal system, shot peening to minimize stress corrosion cracking, and wing dry bay drainage and ventilation, to name but a few, all contribute to the corrosion resistance of today's Hercules aircraft.

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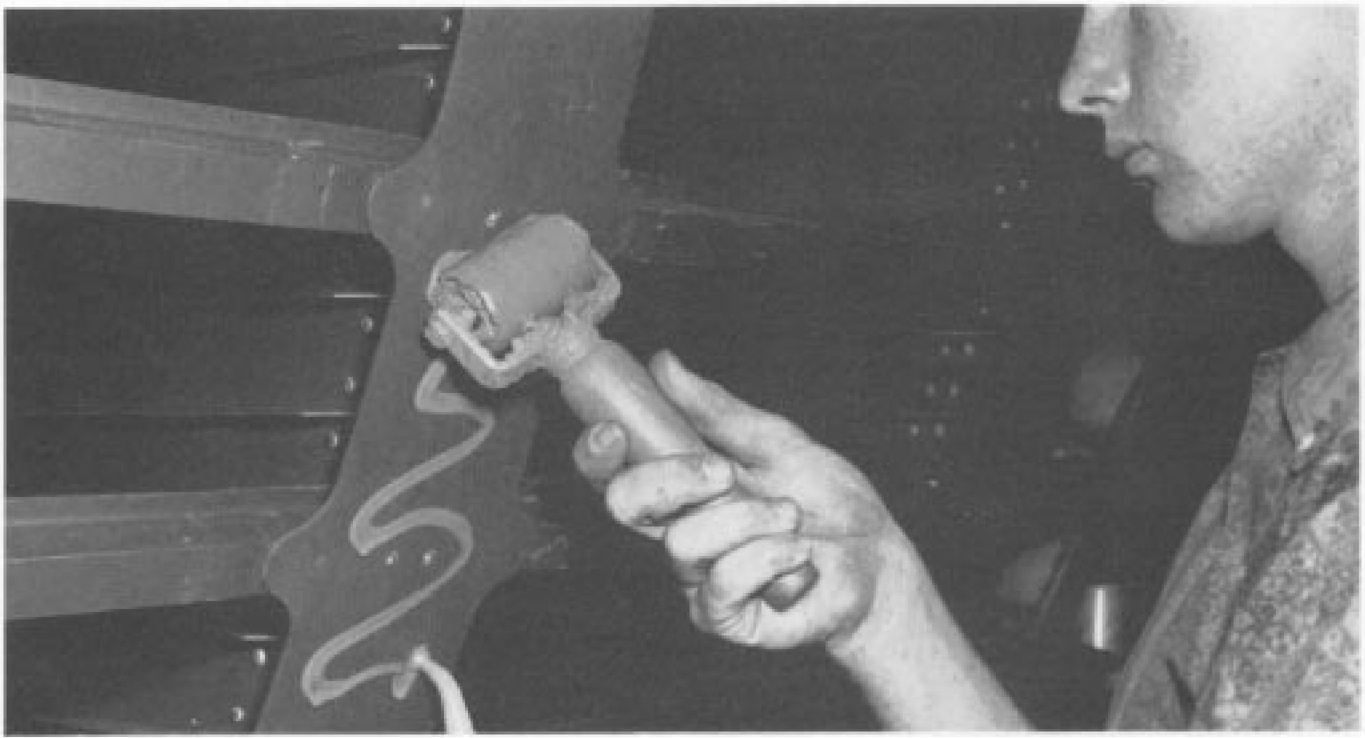

Faying surfaces are carefully sealed during manufacture to prevent moisture from entering

But thirty years of evolution in corrosion prevention technology does not mean that the Hercules aircraft is corrosion proof. Today's advanced anti-corrosion measures make life a little easier for maintenance personnel, but a workable corrosion prevention and control program is still a requirement if maximum service life and economy of operation are to be realized.

It is worth the effort. No aspect of aircraft maintenance pays greater returns in terms of long-range economic benefits, safety, and reliability than the prevention and control of corrosion.

The Corrosion Process

Building an effective corrosion control program requires a working knowledge of some of the basic principles of the corrosion process itself.

In a very real sense, the corrosion of metal components starts the instant the manufacturing process is complete. The speed at which corrosion will proceed is dependent upon the type of material used, the fabrication and assembly methods employed, the environment to which the structures are exposed, and of course, the preventive measures taken by the individual operator.

Corrosion is a complex electrochemical action that causes metals to be transformed into oxides and salts. The driving force behind many of the most common corrosive processes involves the intrinsic differences in electrical potential between metallic elements. The reasons for these differences can be traced to characteristics of the atomic structure of the metals themselves.

Simply stated, differences in electrical potential among metals reflect how readily the individual metallic elements give up electrons in the presence of other metals.

Some metals, for example magnesium and zinc, give up electrons quite readily. Such metals are chemically active and thus corrosion-prone. Other metals, like copper and silver, do not release their electrons as easily. They tend to be more inert chemically, and resist corrosive action.

The Electromotive Series

The relationship between metals based upon differences in their electrical potential and associated chemical activity may be represented schematically in an ordered sequence known as the electromotive, or galvanic, series.

In the electromotive series, differences in electrical potential are normally expressed in terms of electromotive force (EMF) and measured in volts. This provides a systematic way of comparing the electrical effects involved,

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and offers a quantitative basis for predicting the intensity of possible corrosive activity.

The chart below lists a number of metals commonly used in aircraft structure in order of decreasing EME Magnesium, which is an active metal and gives up electrons relatively easily, is shown at the top of the list with an EMF of -1.73 volts.

The Electromotive Series
EMF of Common Metals and Alloys

EMF (Volts)	Metal or Alloy
-1.73	Magnesium
-1.63	Magnesium Alloys
-1.10	Zinc
-0.97	Beryllium
-0.96	7072AluminumAlloy
-0.82	7075AluminumAlloy
-0.82	Cadmium
-0.67	2024-T4Aluminum Alloy
-0.64	Steel
-0.49	Tin
-0.38	Brass
-0.20	copper
-0.15	Titanium
-0.10	Monel
-0.08	Silver

Copper, a much less active metal, is listed near the bottom of the chart with an EMF of -0.20 volts. The difference between these values, or corrosion potential, amounts to -1.53 volts. This means that when magnesium and copper come into contact, there will be a strong tendency for the magnesium to corrode rapidly unless extraordinary protective measures are taken.

The Corrosion Cell

Corrosion that takes place when metals of widely differing EMF values come into contact depends upon the establishment of what is known as an electrolytic, or corrosion, cell. The illustration on page 6 shows a laboratory setup designed to demonstrate the operation of a simple electrolytic cell.

The EMF of the copper bar shown on the left is significantly lower than that of the magnesium bar on the right. If the two bars are immersed in an electrolyte (such as water containing dissolved salts) and connected by a conducting wire, the magnesium atoms in the bar on the right will begin to give up electrons and enter the electrolyte as positively charged magnesium ions.

Electrons freed by the process will flow from the magnesium bar to the copper bar through the connecting wire, where the electron flow can be measured with a milliammeter. An electrolytic cell is fundamentally a voltaic battery, and the forces involved can be surprisingly strong. Under the proper conditions, a laboratory setup such as the one illustrated on page 6 will produce enough current to illuminate a small light bulb.

Anodes and Cathodes

The transfer of electrons from the magnesium bar to the copper bar results in a net negative charge on the copper bar. Viewed from the standpoint of the electrolyte, where the corrosive processes are actually taking place, this has the effect of making the copper bar the cathode of the cell, and the magnesium bar the anode.

The presence of excess electrons at the cathode forges an important link in the chain of electrochemical events that serves to keep the corrosion process going.

These electrons are available to neutralize positively charged hydrogen ions from the electrolyte in the vicinity of the cathode, which are converted into atoms of hydrogen. The hydrogen atoms unite to form molecules of hydrogen gas and then escape to the atmosphere. This process tends to remove electrons from the cathode, but they are immediately replaced by other electrons produced by further corrosion of the magnesium bar.

The corrosion process is also driven forward by chemical action at the anode, where positively charged magnesium ions at the anode react with hydroxyl (OH) and other negatively charged ions in the electrolyte to form magnesium hydroxide and other salts.

Magnesium ions are removed from the electrolyte by the formation of these insoluble, stable compounds; however, they are quickly replaced by additional magnesium ions which enter the solution as the anode continues to corrode.

The corrosion process thus tends to perpetuate itself both electrically and chemically. If left undisturbed, the process will continue until all of the magnesium has been consumed, and the source of the electron flow has been eliminated.

Breaking the Corrosion Cycle

A careful examination of the electrochemical processes that drive the corrosion cell shown in our example will point up the fact that some rather special conditions must be present before such a cell can become active:

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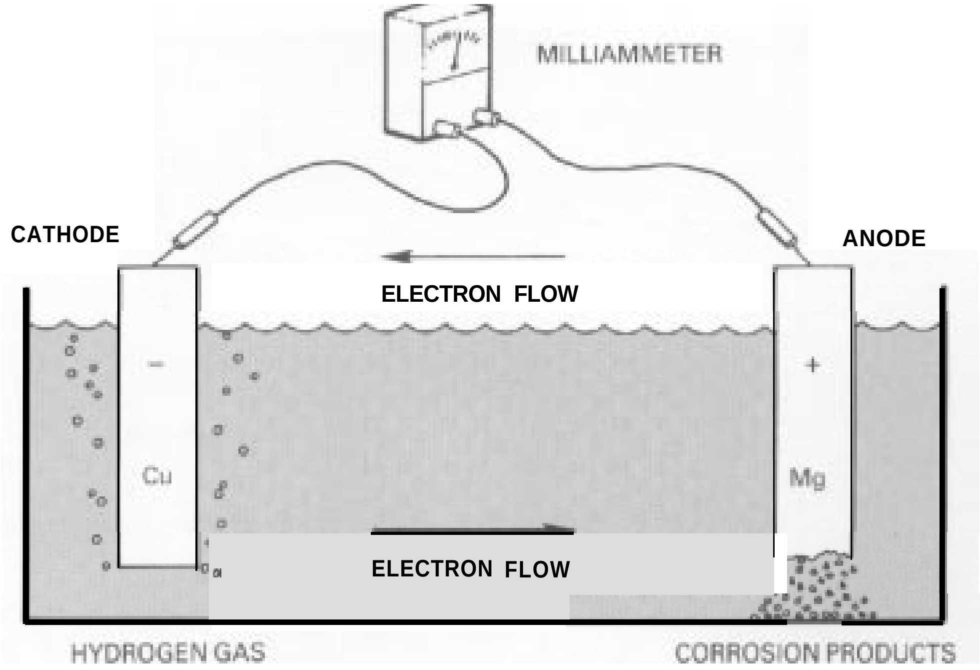
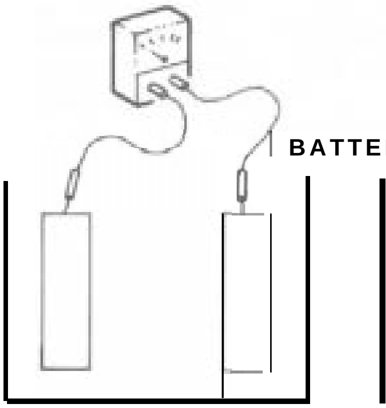
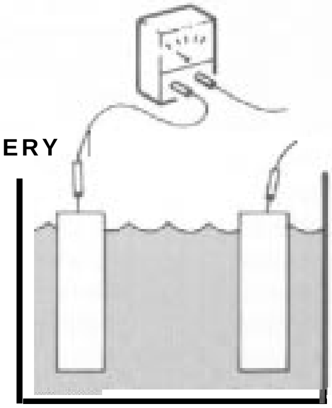


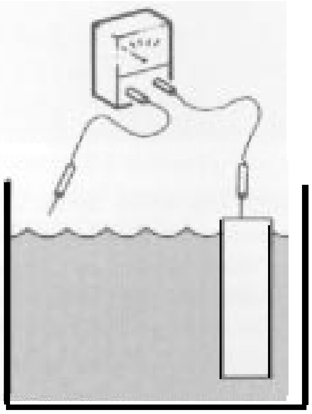
ELECTROLYTIC CELL (SIMPLIFIED)



**NO WATER NO CURRENT
NO CORROSION**



**BROKEN
CONDUCTOR**



**NO DISSIMILAR
ELECTRODES**

1. There must be a metal present which can serve as the anode of **the cell.**

2. There must be a metal present which can serve as the cathode of the cell.

3. There must be an electrically conductive path that allows electrons to flow between the anode and the cathode.

4. There must be an electrolyte (usually water) covering both anode and cathode to complete the electrical circuit.

The elimination of any one of these conditions will prevent a corrosion **cell** from becoming established. and greatly reduce the opportunity for corrosive action to take place.

This is a key point which underlies all corrosion prevention efforts. Virtually every approach to corrosion prevention depends upon successfully interrupting or interfering with one or more of these preconditions for the establishment of corrosive processes.

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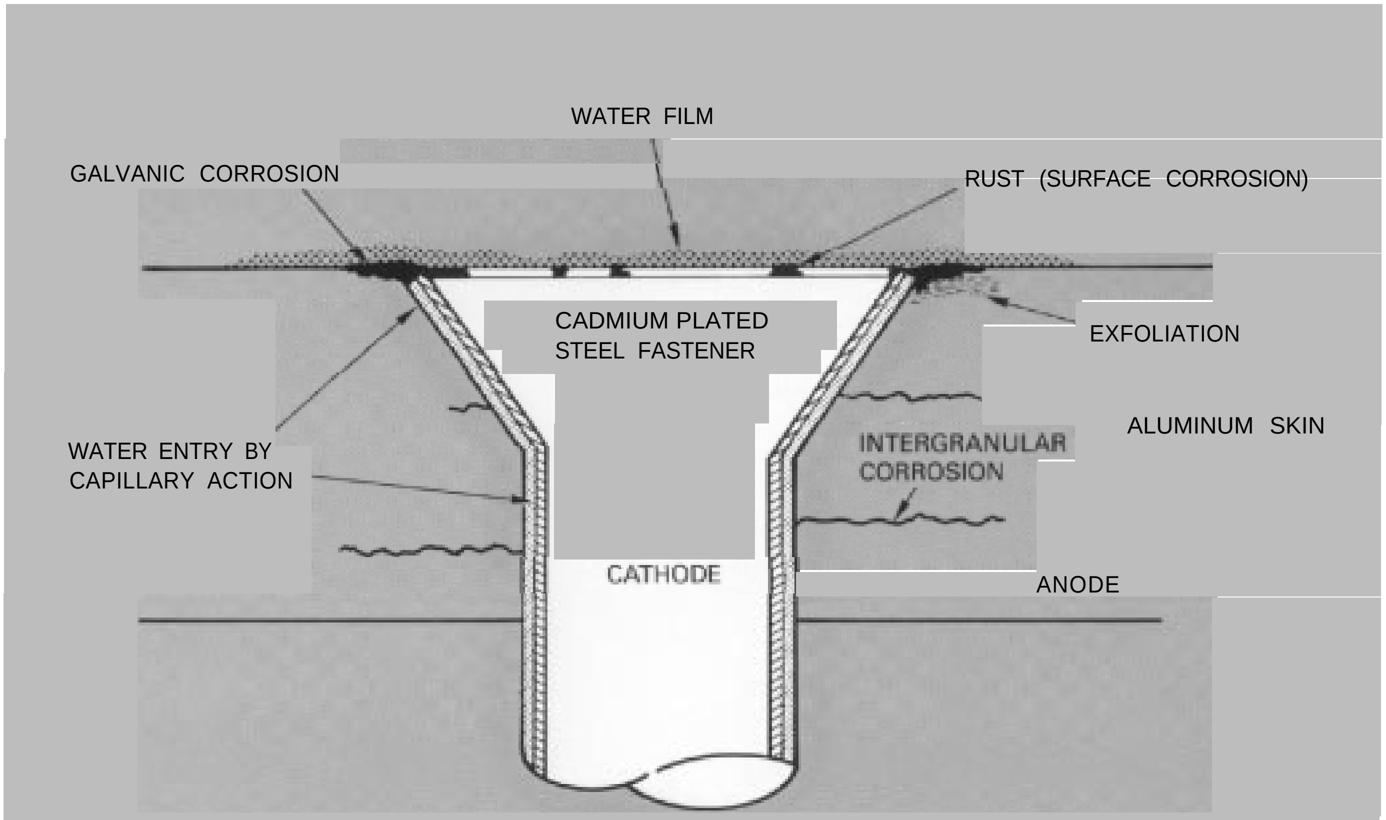

Aircraft structure offers a rich field of opportunity for many differenttypes of corrosive action.

Corrosion in Nature

Studying a laboratory corrosion cell such as the one illustrated on the previous page is helpful in gaining an understanding of the physical principles behind some of the most common corrosive processes affecting metals. The actual course of events in nature is much more complex, however, and involves countless variations and permutations of the process.

For one thing, the components of aircraft structure make use of a variety of metallic elements, used in numerous alloys of diverse composition. The same materials may then be subjected to many different kinds of treatments, tempers, finishes, and coatings during manufacture, all of which have an effect on susceptibility to corrosion.

For another, aircraft structure is physically intricate. Parts of every conceivable size and shape are manufactured for use in aircraft, and then riveted, welded, bolted, and bonded together to make up the final assembly. Such complexity and diversity yield a rich field for corrosive action, and it can show up in many different ways.

It is also important to remember that corrosion cells do not always involve such relatively straightforward processes as our example of dissimilar metals coupled through an electrolyte. Differences in electrical potential sufficient to give rise to corrosive action can sometimes be traced to small variations in chemical composition on or at the surface of the same piece of metal.

Impurities, inclusions, and foreign substances adhering to metal structure as a result of surface damage may have a similar effect. Differences in oxygen potential that can develop between two areas of the same metal structure are also an important cause of corrosive action. Another major source of damage involves direct exposure to corrosive agents such as acids, alkalis, and atmospheric contaminants.

Types of Corrosion

When corrosion takes place, the visual evidence varies with the metal involved. In the case of aluminum and magnesium, corrosion usually appears as surface flaking,

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etching. or pitting, often combined with a gray or white powdery deposit. On copper and copper alloys, the corrosion forms agreenish film called patina. With steel. it is the familiar reddish rust. When the deposits are removed, the surfaces may appear etched and pitted, depending upon the length of exposure **and severity** of attack.

Surface Corrosion

This is the most common type of corrosion. When an area of unprotected metal is exposed to the atmosphere with its contaminants, there will be a uniform attack over the entire area. On polished materials, this is first seen as a general dulling of the surface. If the attack is allowed to continue. the surface will become rough or frosted in appearance.

Pitting Corrosion

If surface corrosion is allowed to go untreated. it can progress to another type of corrosion, called pitting. Pits form **in** localized areas, often hidden under powdery deposits. If permitted to continue, pitting corrosion may work its way completely through the metal.

Fretting Corrosion

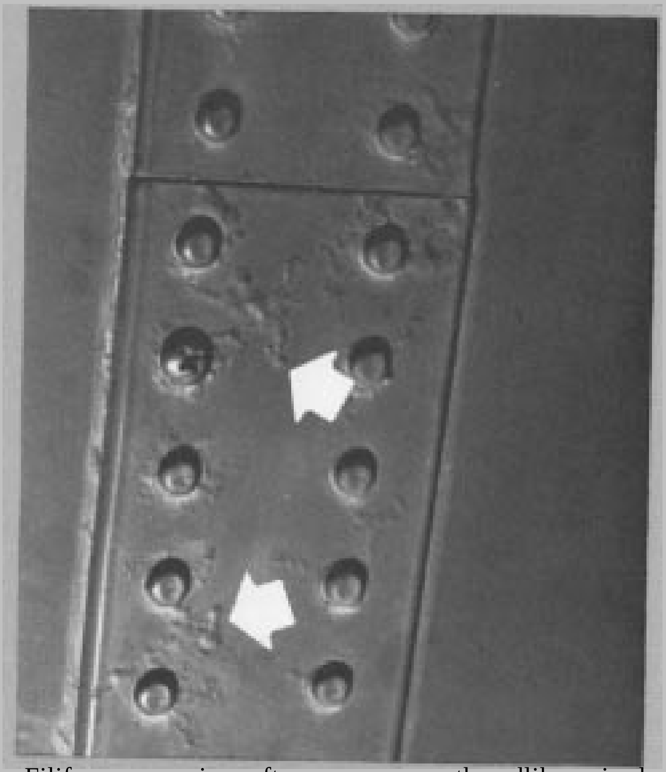
This type of corrosion is caused by close-fitting parts which are allowed to rub together. The results of fretting are removal or pitting of metal in the area of contact: and galling, seizing, cracking. or fatigue of the metal. There is also a loss of tolerance in accurately fitted parts, and loosening of bolted or flanged surfaces.

Filiform Corrosion

Filiform corrosion usually forms on aluminum skin surfaces under an organic coating, especially in a warm and humid environment. It appears on the painted surface as threadlike filaments, and when the filaments are broken, corrosion will be visible on the aluminum skin. New and improved finish systems are making occurrences of this type of corrosion less frequent

Microbial Corrosion

In this case, corrosion is caused by living microorganisms. Microorganisms have demonstrated that they can live quite well at the interface between water and a variety of different hydrocarbons. They feed on fuel hydrocarbons and hydrocarbon-type coatings and materials. As the colony grows, a sludge made up of concentrations of cells and acidic by-products is created which adheres to structure and corrodes it.



Filiform corrosion often appears as threadlike raised areas under organic coatings.

Besides causing corrosion, microorganisms can also cause problems within the fuel system. Once established, it is no easy undertaking to eliminate a microbial infestation. The fuel tank must he drained, purged, cleaned with soap and water, and then sterilized with an alcohol and water solution.

It is much easier to prevent microorganisms from becoming established in the first place. Use a biocidal additive such as MIL-I-27686 regularly, keep fuel storage tanks as free of water as possible, and drain any accumulated water from the aircraft fuel tanks every day.

Periodic inspection of both the ground storage and aircraft fuel tanks for indications of microorganisms and corrosion is also prudent, particularly when the biocidal additive has not been used regularly.

Intergranular and Exfoliation Corrosion

Intergranular and exfoliation corrosion describe different stages of the same process, which is essentially an attack on the grain boundaries of metal. In the intergranu-

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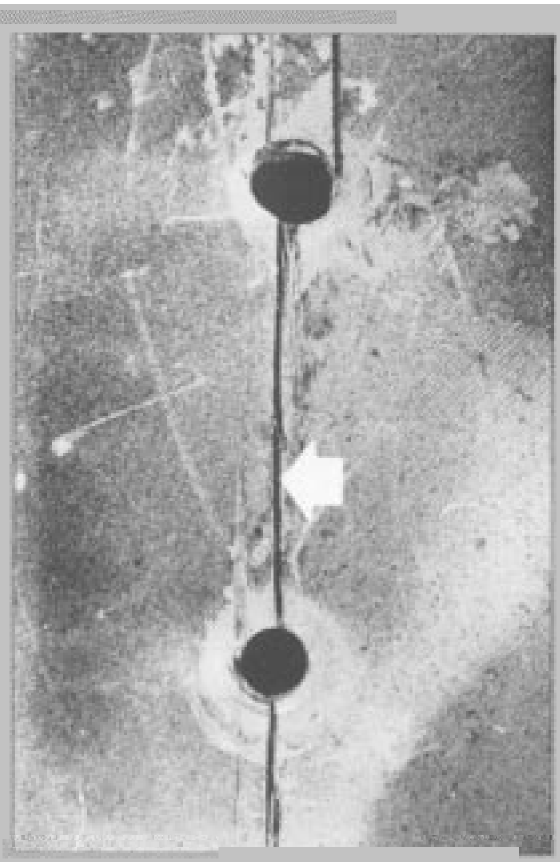
lar-exfoliation process, intergranular corrosion is the first step. and always starts from a surface pit or pinhole that exposes interior layers of the metal to moisture.

The opening may he very small, and there may he little visible evidence of damage. As intergranular corrosion progresses. however, pressure is exerted at the grain boundaries by the corrosion products, causing a lifting and flaking at the surface. At this point, the attack has changed from intergranular corrosion to exfoliation corrosion.

Entrapped moisture caused corrosion in this rainbow fitting.

Stress Corrosion

Stress corrosion cracking is caused by the simultaneous effect of constant tensile stress and corrosion. Residual stress may have been induced during processing of the part, or cracking could occur because of sustained operating or static loads introduced during installation of the part or aircraft operations. To avoid stress corrosion cracking during maintenance operations, do not force fit parts, and always make sure that the finish system remains intact.



Tensile stress and exposure can result in destructive stress corrosion cracking.

Effects of Corrosion

The question asked most often by maintenance managers about corrosion is how long it will take for a corroded part to fail. No one can answer such a question with any degree of accuracy. How fast corrosion progresses depends upon the composition of the materials, the finish, the sealing method, the environment, and how well the part in question is maintained in service.

Left unchecked, however, it is certain that corrosion will eventually cause structural failure. All corrosion must be removed as soon as practicable. The surface then must be chemically treated and refinished. When prompt attention is given to corrosion problems as soon as they are discovered, further damage can be prevented.

The Program Advantage

Piecemeal efforts. no matter how well intended, cannot be expected to keep corrosion in check vet-y long. There is no real substitute for a well organized and highly structured program of corrosion prevention .

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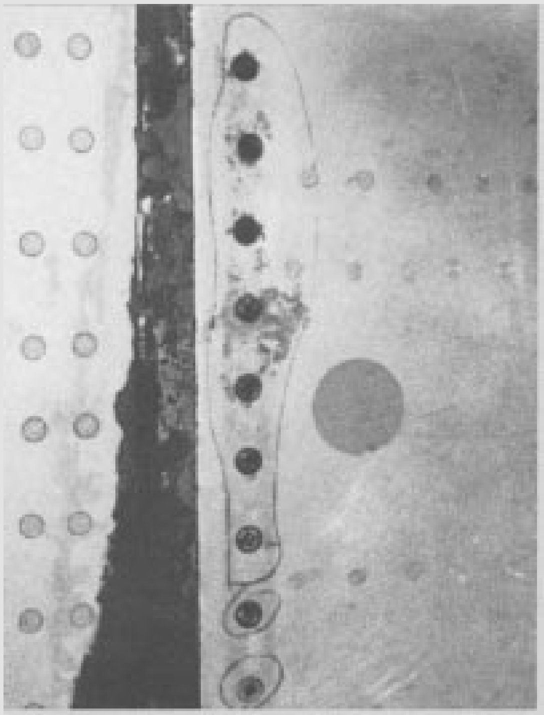
Remember that it is corrosion, more often than anything else, that causes an aircraft to be retired before its full life expectancy has been reached. Many improvements have been made to enhance the corrosion resistance of the Hercules airlifter through the years, but an enlightened preventive maintenance program is still required if its maximum possible service life is to be realized.



Moisture and dissimilar metals led to corrosion in this wing plank.

How much maintenance is required depends mostly on the types of missions flown, and the environment in which the aircraft operates and resides. Each operator should therefore develop his own corrosion prevention and control program, one which will provide a systematic and comprehensive approach that is tailored to his particular operation.

The program must be designed to support the aircraft throughout its service life, but it should not be so rigid that changes cannot easily be made as aircraft missions, materials, and operational requirements change. Once a good program has been established, the payoff in the form of reduced maintenance costs, less aircraft downtime, and improved aircraft safety will be both immediate and enduring.

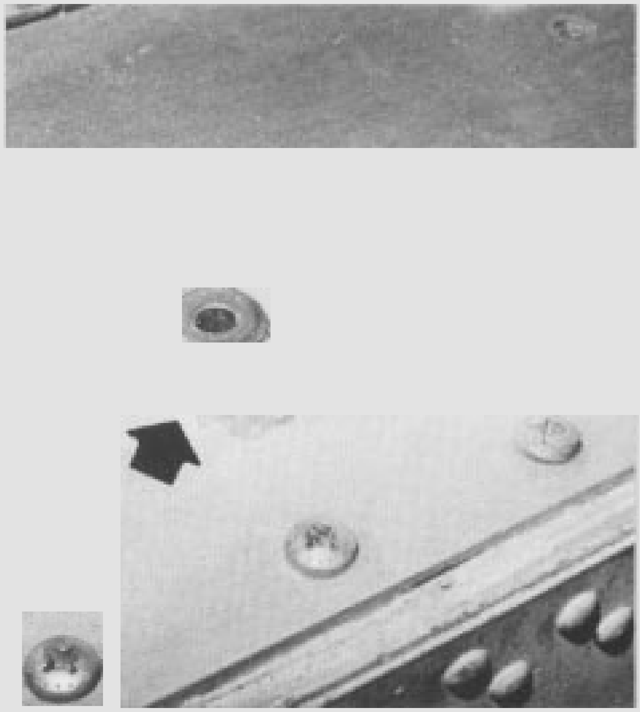
Building a Program

The term "program," as used here, refers to more than just a written plan, although appropriate documentation is an important part of a successful program. Rather, the program concept in this application is intended also to encompass overall management, training of personnel, maintenance of adequate manpower; as well as proper facilities, equipment, and tools. Although the program should include both prevention and control measures, it should be centered on where the most benefit may be realized-prevention.

It is also important that every person associated with the corrosion prevention and control program be highly motivated, and committed to getting the job done properly. Without such personal commitment the program is doomed to failure from the start.

The first step in corrosion-control planning should be to conduct an objective review of what is already being done and how well it is being accomplished. This review should include, as a minimum, the following items.

- Determine the type of environment in which the aircraft operates. Although the home station may be in an acceptable environment, where the aircraft actually operates may not be as acceptable.
- Include the quality of water used for washing aircraft in your survey. Aircraft should never be washed with brackish water or water containing significant levels of chemicals or mineral salts. A check on the contents of the local **water** supply is a must.



Inspection during PDM revealed corrosive action hidden under a skid pad.

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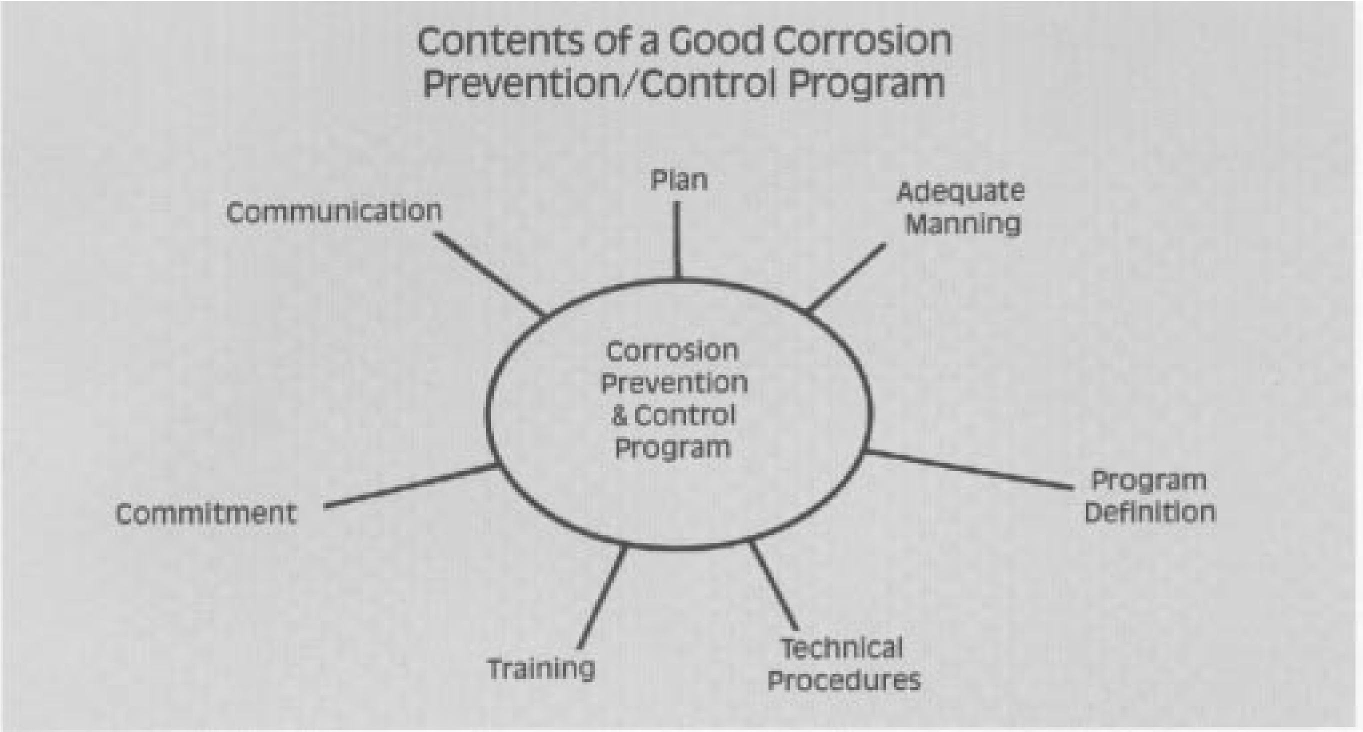
Contents of a Good Corrosion Prevention/Control Program

- Compare job requirements to the training and background of all personnel within the maintenance organization. Those people directly involved with corrosion inspection and removal, and quality assurance personnel, normally require more in-depth training than other maintenance personnel.

- Review facilities, equipment, and tools required to perform corrosion prevention and control operations. The best way to do this is to compare what is being done to what is required in maintenance manuals. This statement may seem a bit strange, but there are some organizations that perform corrosion prevention maintenance in a manner that barely resembles the true requirements, often because of shortfalls in one or more of these areas.

Once all of the reviews have been completed and a clear pattern of needs and requirements has been established, formalize the corrosion prevention and control program. It is always best to develop a written plan of action so that everyone concerned will understand what is expected.

As the old saying goes, "Don't sweat the small stuff." Concentrate the effort on primary structure of the aircraft, and take care of the other structure afterward. This is not to say that secondary structure is not important. It is important, but sound primary structure is of critical importance for safety, and extending aircraft service life and safe operations.

Lockheed Aeronautical Systems Company strongly encourages every Hercules operator to establish a comprehensive corrosion prevention and control program to protect the investment he has in his aircraft. Lockheed also stands ready to help. Factory corrosion engineers are available to provide the expertise required to develop an effective program for each operator's particular needs.

For further information, please contact:

C-130/Hercules Service Department
Attention: C.R. Kelley
D/64-21, Z/668
Lockheed Aeronautical Systems Company
Marietta. GA 30063

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STATIC DISCHARGER MAINTENANCE

There is an old saying that good things come in small packages. Certainly this applies to airframe components: some of the smallest and simplest parts do their jobs faithfully day after day, attracting little attention and requiring minimal care. A case in point are the static dischargers.

Static dischargers perform the vital function of combatting the buildup of P-static. If the weather conditions are right, an aircraft moving through the air may pick up electrical charges which can accumulate enough power to cause audible noises in radio equipment. This phenomenon is called precipitation static, usually shortened to just P-static.

Causes of P-Static

P-static usually occurs when the aircraft is passing though bad weather such as freezing rain, ice crystals, dust. sand. or snow. However, P-static may also occur in apparently clear weather. An electrical charge is transferred to the aircraft each time it impacts with a particle suspended in the air.

When charging conditions are present, the electrical potential on an aircraft can rapidly reach values of 100,000 to 200,000 volts or more. If the electrical field around an aircraft becomes strong enough, the result can be ionization of the air at the edges of the structure, and short bursts of electricity called corona pulses will leave the aircraft.

The energy released by the corona pulses, which become coupled to the radio antennas, causes broad-band radio frequency noise. This noise can assume a variety of forms, from popping, to buzzing, to roaring sounds, depending upon the intensity of the charging rate. The effect of the noise generated by P-static can range from merely being a nuisance to making radio communication completely impossible.

Controlling Static Discharge

P-static cannot be prevented, but the effects can be minimized by adequate electrical bonding of the aircraft exterior and by the use of static dischargers. Each component that is installed on the exterior of the Hercules aircraft during manufacture is electrically bonded to the fuselage, wings. or empennage. including all access panels, doors, and antennas. This bonding provides a continuous path for electrical charges to get to the dischargers. and it also prevents gaps which charges would tend to jump, thus generating more P-static.

Each Hercules aircraft is delivered with 17 wick-type static dischargers installed. Four dischargers are installed on each aileron, three on each elevator. and three on the rudder. These dischargers allow P-static which has built up on the aircraft to discharge noiselessly through the multiple strands of a wick. This effectively decouples the noise bursts from the aircraft.

The measures taken at the factory to combat P-static tend to become less effective during normal use of the Hercules aircraft because of everyday wear and tear. Periodic inspection and maintenance are required to maintain the effectiveness of the anti-static protection, and it is important that the condition of the static dischargers not be neglected.

Static Discharger Types

Hercules aircraft built before Lockheed serial number LAC 4432 were equipped with type AN/ASA-3 dischargers. These dischargers consist of a 13-inch conducting cotton wick enclosed in a plastic tube. The tube is flattened on one end and enclosed in a metal sheath which is attached to the airplane skin.

All Hercules aircraft built subsequent to LAC 4432 are equipped with CM3-J2 dischargers. These units are of all-metal construction consisting of a 7% inch braided metal cable inserted in a metal sheath for attachment to the aircraft. The CM3-J2 dischargers are interchangeable with the earlier type.

Discharger Maintenance

The AN/ASA-3 type of discharger is subject to wear and should be inspected on a preflight basis to determine that about 1.5 inches of wick extend from the plastic sheath. If the wick is dirty or badly frayed, trim off the worn portion and trim back the plastic sheath to 1.5 inches from the end of the wick, fraying out the remaining portion of the wick.

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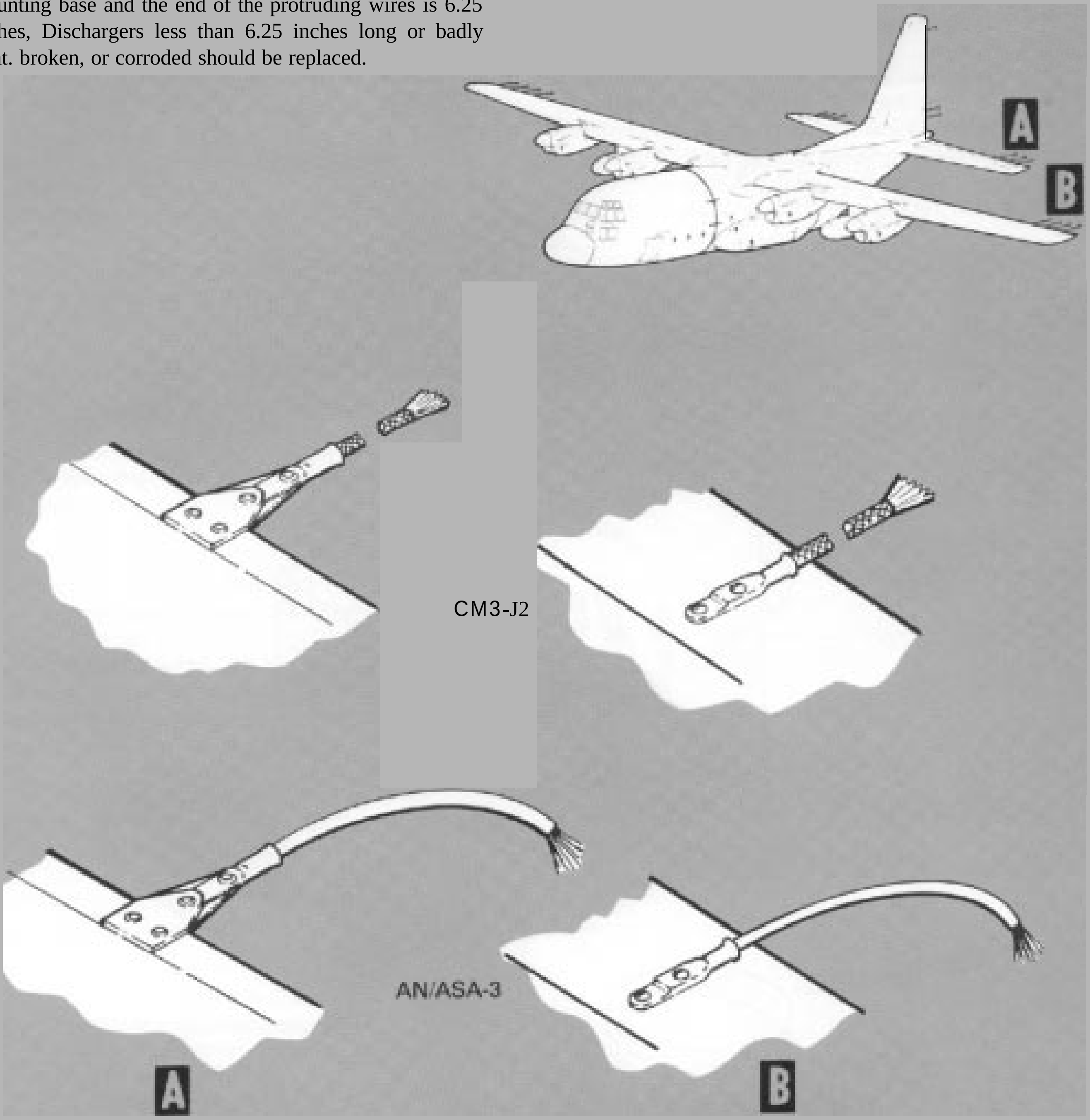
When wicks have been trimmed back to a length **of less** than 6 inches, the discharger must be replaced.

The CM3-J2 discharger should be periodically checked to determine if the ends of the wire protruding from the metal sheath are balled or bent. Damaged wires may be trimmed back until the distance between the end of the mounting base and the end of the protruding wires is 6.25 inches, Dischargers less than 6.25 inches long or badly bent. broken, or corroded should be replaced.



TYPICAL EMPENNAGE INSTALLATION

TYPICAL WING INSTALLATION

CM3-J2 AND AN/ASN-3 STATIC DISCHARGERS

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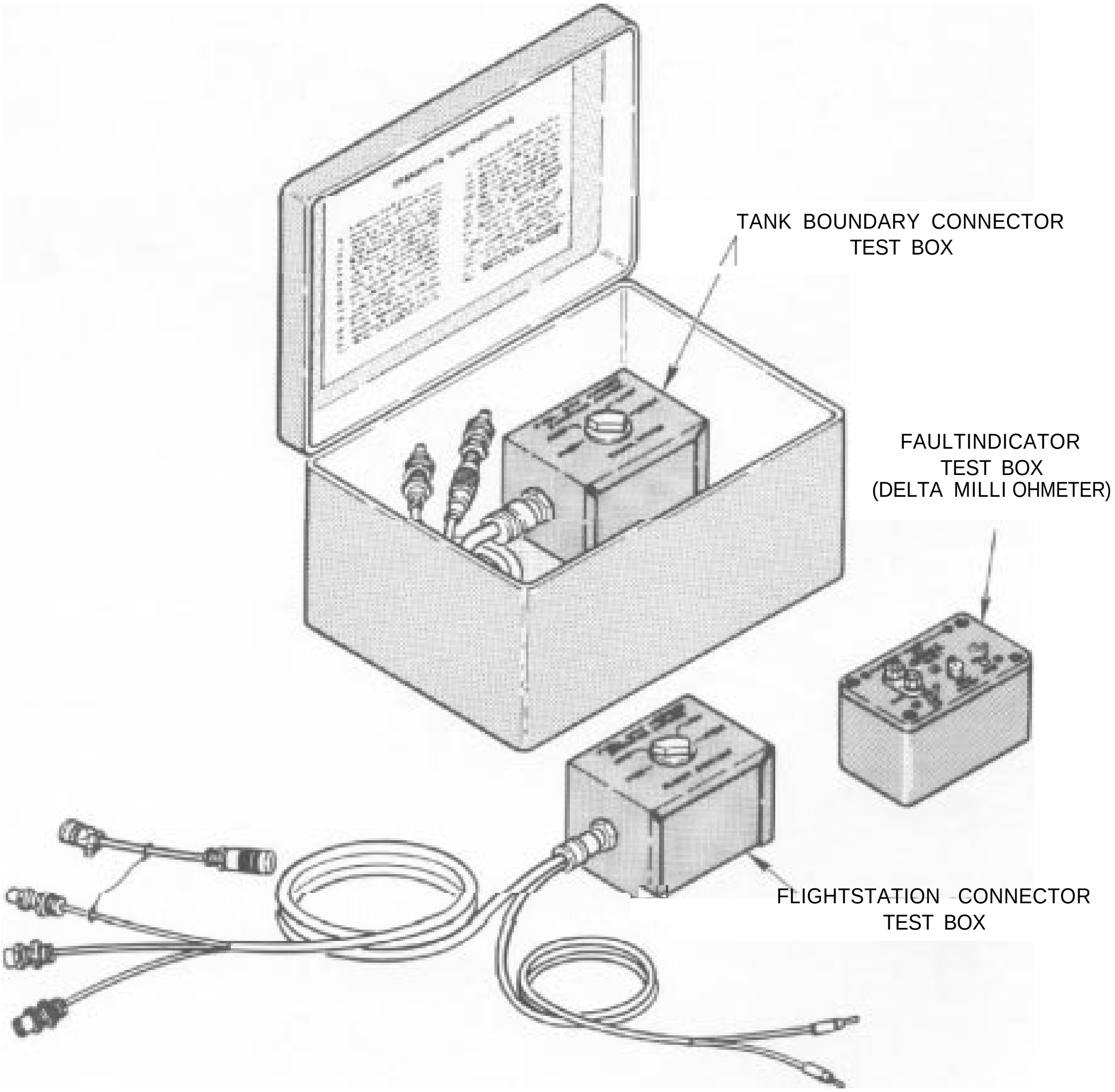
Fuel Quantity Indicator Harness Tester

by E.D. Allen, Staff Engineer
Support Equipment Group

A tester has been developed for checking or troubleshooting fuel quantity indicator harnesses for open circuits and intermittent or improperly fabricated solder connections (shield terminations or “zaps”).



FUEL QUANTITY HARNESS TESTER

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The tester consists of three boxes which are stored in a convenient carrying case. A complete set of operating instructions is included in the lid of the case. One of the test boxes is attached to the fuel quantity harness at the tank boundary connector. The second box is attached to the indicator harness at the flight station. The third box, a fault indicator (delta milliohmeter), is attached to the flight station test box.

Thecircuit being checked is selected on both test boxes. The fault indicator box, a balanced resistance bridge, is adjusted so that its indicator lamps go out. The solder connections on the harness being tested are flexed and the lamp on the fault indicator box comes on if an intermittent or poor connection exists.

An open circuit is indicated when rotating the zero adjust knob cannot extinguish the lamps on the fault indicator test box.

The tester can also be used to check any other harness installed on the airplane for open circuits and intermittent or poor solder connections.

The following circuits can be checked, using the equipment described above:

- Shield to hi-Z wire
- Shield to tank unit lo-Z wire
- Shield to compensator lo-Z wire

The advantage of this method is that it can detect the very small changes in resistance which are indicative of intermittent or poor connections (instantaneous response in the 20 to 70 milliohm range).

Part number 3403184-l has been assigned to the tester. The unit is still in the prototype state, but it will be put into production upon positive response.

If you would like further information regarding the harness tester, please contact the following:

Support Equipment Group
Department 63-51, Zone 451
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