Renovating an Interior Part Four: Understanding Corrosion

DENNIS WOLTER continues his series of articles about interior renovation with a deep dive into how corrosion occurs, as well as where you're most likely to find it.

WITH all the interior components and insulation removed, the clock has been turned back to the day your airplane went down the assembly line. Think of how many years it's been since anyone has seen what you are now looking at: a completely bare inner cabin with all its aging airplane issues in plain view.

I can't tell you how many owners have insisted we will not find *any* corrosion in their airplane. They often tell us that they have assisted in every annual since purchasing the airplane and have found no evidence of corrosion in the cabin area.

After a week of disassembly and evaluation, we send a teardown report to every renovation customer that includes (guess what?) several photos of hidden corrosion that no one found on routine annual inspections.

So, now I'm going to get up on my soapbox and discuss this somewhat complex and very important subject of corrosion. If left untreated, corrosion is the most irreversible threat to the longevity of the airplanes we love so much.

When most of these airplanes were built, industry in America—Cessna included—was operating in "planned obsolescence" mode. Marketing and production costs were a higher priority than long-term durability. The mindset at the time was that these airplanes would be recycled in 10 or 15 years; corrosion-proofing didn't seem to be a major concern.

Well, I'm happy to say my Cessna 172 Skyhawk is 46 years old and counting. Cessna definitely built a sturdy airplane, but the insidious nature of corrosion is beginning to rear its ugly head.

If there is any part of this series of interior renovation articles that applies to every older Cessna out there, it's this subject of corrosion. Even if you have no intention of installing a new interior, or if you just had your interior redone, I urge you read this and my future articles on corrosion, and do the recommended inspections.

If left untreated, corrosion is the most irreversible threat to the longevity of the airplanes we love so much.

If you've been told by your mechanic that your airplane is corrosion-free, chances are likely that you will uncover some evidence of corrosion in the cabin area if you follow the suggestions I present in these articles.

But I thought my airplane was corrosion-free!

In the course of doing about 25 interiors a year at our shop (maybe half of which are Cessnas), we get a very close look at corrosion-prone areas. In the past three years, we found one Cessna 182 and one 1947 Beech straight 35 that I would consider to be nearly corrosion-free. The Cessna had lived in Arizona all its life, and the Bonanza was a lifelong resident of northern Minnesota. Both places have dry climates with clean air.

At the other end of the corrosion scale was a float-equipped 206 we took in from Michigan. The owner relayed to me that his mechanic insisted that the airplane was corrosion-free.

Knowing that Cessnas are prone to corrosion in the upper areas of the cabin, I unzipped the spanwise headliner access, pulled down the original fiberglass insulation and found a mess. The top photo on Page 25 says it all. On a scale of 1 to 5, I would rate this level of corrosion an unhealthy 4+. I'll detail the cleanup and treatment of this particular airplane in a future article.

We see one or two Cessnas in this unhealthy condition every year. How could the owner have been told his airplane was corrosion-free? The answer is both objective and subjective.

The objective answer has three parts. First, the airplane was getting regular treatments with a popular and effective spray product like CorrosionX or ACF-50. Properly applied, these products do a fine job of stopping corrosion in its tracks, but they are typically applied everywhere *but* those hard-to-access cabin areas.

The airframe, wings and fuselage look good with this type of treatment, but these petroleum-based corrosion sprays are damaging to upholstery materials, and since access to the inner cabin structure and skins is so difficult anyway, the cabin doesn't get treated.

Second, the cabin is normally the most corrosion-prone part of the airplane because it is closed up, insulated and upholstered with moisture-absorbing hydroscopic materials. It stays warm when the airplane goes through thermal cycling as it's taken to altitude, or as the temperature changes when it is stored.

General Aviation airplanes often sit in uninsulated, humid T-hangars or out on the flight line. Add to this the fact that these airframes leak when it rains, and the result is the cabin becomes a flying humidor.

When you take an airplane from a surface temperature of 85 F to a cruising temperature of 40 F, condensation forms on the inner cabin skins. This moisture is absorbed by the hydroscopic insulation, upholstery foam and finish materials. When the airplane is subsequently stored in a hangar or out on the tiedown with the doors tightly closed, the moisture in the cabin cannot easily escape.

The third objective reason for this situation lies in the fact that so little of the interior, other than carpet, is removed during routine inspections. The cabin, especially the upper area, is usually overlooked.

In Cessnas, the cabin top is where we find most of the trouble. Moisture vapor rises. At your next annual, open up the headliner, remove some insulation and take a look. You might be surprised.

In my opinion, there are a couple of subjective reasons why many mechanics either don't know or aren't able to tell you that these airplanes are corroding in the cabin area. Your mechanic probably hasn't seen the evidence.

Many technicians don't particularly enjoy working with interior components, especially headliners. Cessna didn't exactly make access to the headliner area very easy. Stretch vinyl headliners almost self-destruct when you try to remove the edge material from the sharp pointed retainer strips that secure the headliner along the tops of the doors and aft windows. Delicate (and now, quite old) molded plastic headliners are easily damaged when removed and reinstalled.

It's easy to see why mechanics don't want any part of this. To make matters worse, corrosion cleanup and treatment is about as much fun as cleaning a cage of rattlesnakes!

So, with plenty of work to be done in other areas of our aging airplanes, some real corrosion issues can be swept under the carpet (or headliner). I'm going to let the cat out of the bag.

Before getting into the hands-on account of how to remove and prevent corrosion, which will be thoroughly discussed in an upcoming article, I will get off my soapbox and put on my teacher's cap and discuss the chemistry and physics that cause corrosion in the first place.

I'm a big believer in understanding the theory behind what we do. We can either be conditioned or we can be educated; I prefer the latter.

What is corrosion?

To understand corrosion, we must first understand how aluminum alloys are made. In the metal game, alloy refers to the fact that a given metal is made from two or more base metals.

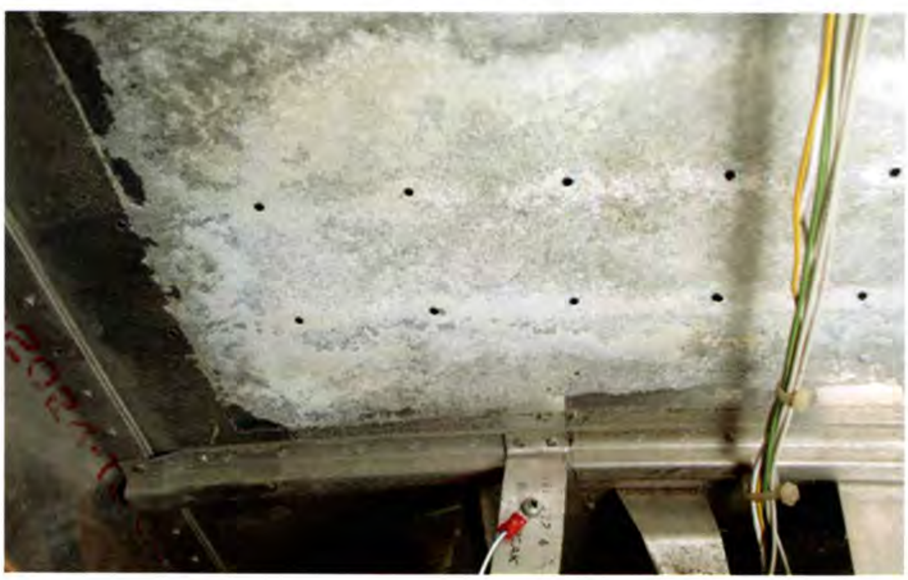
Whenever two dissimilar metals are combined to create an alloy that has the desired properties for the engineering

Surface corrosion on an upper cabin skin.

Severely corroded aft wing spar attach point in an airplane represented to the buyer as being almost corrosion-free.

Corrosion caused by galvanic action under glued-in-place lead vinyl skin damping panels.

Extensive corrosion on belly skin caused by dirt.



Corrosion that was found under a riveted-in-place bulkhead.

task at hand, that alloy has the potential over time to revert to its base metals. During that process, oxides are formed.

A major contributor to the forming of oxides is the fact that all base metals and alloys have different electrical potential.

Corrosion cause No. 1: electron flow

That brings us to the first of three major causes of corrosion: electron flow, or galvanic action, caused by the flow of electrons between the differing metals in the alloy.

As the electrons flow through the alloy while the different metals try to revert to their original states, oxides form. These oxides can eventually become corrosion.

Exacerbating this situation is the fact that the manufacturing process of aluminum is not perfect. Any given piece of aluminum alloy can have uneven metallurgical content in different areas of the sheet, causing electrons to flow from one part of the sheet to another, and between different sheets that are riveted together in an airplane.

Compounding the problem is the fact that airplanes are an assembly of parts made of many different alloys (e.g., steel crankshaft; lead and silver engine bearings; bronze landing gear bushings; chromed shock strut components; steel fasteners; aluminum airframe structure). All these different materials combine to make this beautiful object a very complex electron host.

Corrosion cause No. 2: dirt

The second culprit in the corrosion game is dirt. Exhaust residue, oil residue, industrial pollutants, salt air and certain adhesives can all build up over time. Left uncleaned, these destructive contaminants set the stage for corrosion issues. A clean airplane is a happy airplane.

Corrosion cause No. 3: moisture

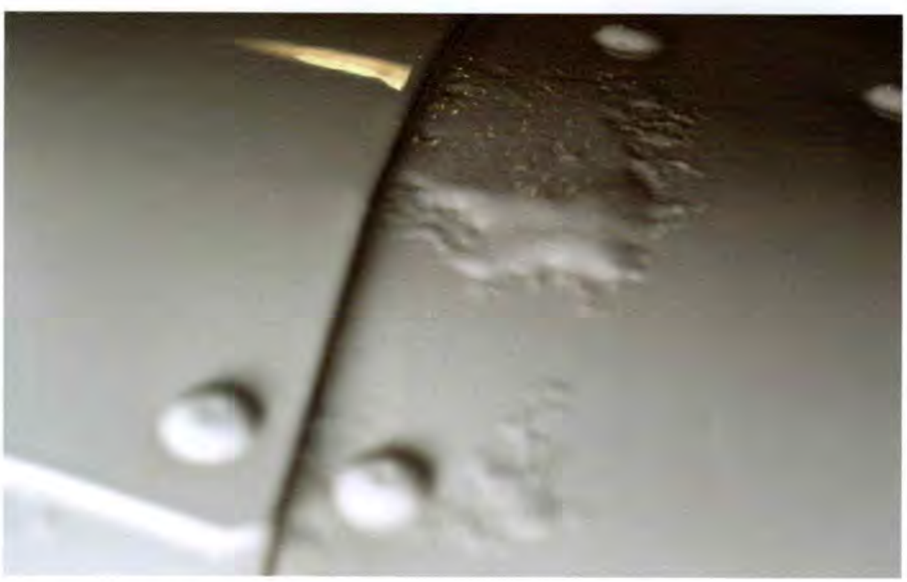
The third major cause for corrosion in an airplane is the addition of an electron flow-enhancing electrolyte in the form of moisture.

The introduction of moisture and moisture-borne contaminants, such as industrial pollutants, salt air and moisture-retaining adhesives, act to increase the flow of electrons not only on the surface of aluminum alloys but also between the various metal components in the airframe structure.

We've all heard that airplanes based near the ocean are known to be very prone to corrosion. However, you don't have to live oceanside to experience the

Moisture-retaining insulation in the cabin of a Cessna.

Serious seat corrosion caused by improperly flameproofed upholstery material coming into contact with an aluminum seat frame.



Filiform corrosion creeping out under the paint of an improperly cleaned lap joint. The joint should have been more carefully cleaned prior to applying primer and finish paint.

problem. If your airplane is exposed to salt air during even one visit, salt crystals remain in the airplane.

These crystals can begin to cause corrosion when the airplane is taken home to an inland environment where humidity creates condensation. The condensation reactivates the salt crystals already in the airplane from its recent stay near the ocean. Seasoned airplane owners know that the best place to look for an uncorroded airplane is in clean air, dry climates.

This entire subject of corrosion is so complex that the FAA devotes eight pages in AC 43-13-1B, Chapter 6, to the subject. This document is available on the internet and is a must-read document for an informed aircraft owner. *(See Resources for a link to download the full PDF. —Ed.)*

What are the different types of corrosion?

There are four types of corrosion. All are described in detail in AC 43-13-1B, Chapter 6. Here is a brief summary of each.

Surface corrosion

Surface corrosion is caused by the natural oxidation process of aluminum and its reaction to oxygen and external contaminants, and, of course, electron flow. It is important to understand that the ability of aluminum to rapidly oxidize is the very thing that keeps it from rusting, and one of the main reasons for its use in airplane structures.

Anyone who has ever had a bare metal polished airplane knows that the beautiful shine is short-lived. Two days after polishing the airplane you can re-buff it with an aluminum polish rag and the rag will be black from oxidation that has built in that very short time.

Left unpolished, the surface will lose its luster and begin to develop a thin light gray haze which, after several months, will become a chalky powder on the surface. Eventually, it becomes a crusty coating. Left indefinitely, it will begin to pit and erode the aluminum.

Surface corrosion is accelerated by moisture, such as humidity and/or polluted rainwater. When water mixes with certain contaminants, it can become an electrolyte that increases electron flow and corrosion.

To make things worse, Cessnas manufactured from the early 1970s through 1986 had lead vinyl skin-stabilizing damping panels. The panels were bonded to the inside surfaces of the bare aluminum skins. Even worse, Cessna used a hydroscopic glue that soaked up and retained moisture. How perfect—all the bad stuff in one place (dissimilar metals and permanent moisture).

Again, the picture is worth a thousand words. (See photo on Page 26, top.) The only good news is that when the corrosion between the damper pad and the skin is as bad as shown in the photo, the pad is easy to remove. This is a common situation, especially in airplanes that are stored in a humid environment.

Surface corrosion isn't limited to the airframe. Over the years, we have seen several severely corroded seats and airframe structures caused by improper flameproofing of upholstery materials.

If the bromide salt chemical that is applied to finish materials during flame treating is exposed to water or high humidity, it will create an electrolytic vapor or water solution that causes severe corrosion in aluminum or steel. The seat frame shown here was so severely corroded by this phenomenon that it had to be replaced. (See photo on Page 28, center.)

Filiform corrosion

This is corrosion that develops underneath a coating such as paint. Filiform corrosion is generally caused by contaminants that were left on the surface or trapped between two mating surfaces before the primer and paint were applied.

Once trapped by the paint, the corrosion develops under the paint and has the appearance of a spidery growth or a lakebed pattern. (See photo on Page 28, bottom.)

Fretting corrosion

Fretting is a type of corrosion that happens when normal causes of corrosion are exacerbated by friction when two surfaces scrape against one another. It is common to see this where cowlings vibrate against airframes, doors rub against door jambs, etc.

The oxides form an abrasive that accelerates the corrosion of the material as the parts rub together, mechanically forcing corrosive oxides into the metal.

Intergranular corrosion

Intergranular corrosion is not caused by surface contaminants but primarily by differential metal content of the alloy or a contaminant that became embedded in the alloy during the manufacturing process.

Intergranular corrosion exfoliating from within a corroding seat rail.

These dissimilar materials cause a very high level of inner electron flow (galvanic action) in the metal, resulting in internal corrosion and oxidation, and eventually causing the metal to swell as the pressure from the corrosion oxides pushes the molecules apart.

At a very advanced stage the metal begins to crack and split open, revealing the presence of powdery gray oxide as seen in the photo above.

What are the various stages of corrosion and what does each look like?

The first stage of corrosion is a discoloration of the metal, usually noticed when a polished bare metal airplane sits outside and begins to look dull. Or, if you remove glue that was used to hold insulation against an unchromated inner surface of a cabin skin, the metal under the glue will turn dark.

The second stage is the presence of visible aluminum oxide starting as a light gray streaking pattern, advancing to a gray powder or crust on the surface of the metal (or under paint in the case of filiform corrosion).

In the case of intergranular corrosion, the first and second stages may only be detected by precision measurement of the component to reveal swelling, or by high-tech nondestructive testing methods, such as ultrasonic tests that can detect an anomaly in the density of an aluminum component.

The third and most advanced stage of corrosion is evident when the crusty oxidation is removed, revealing severe pitting or holes in the metal surface, or when cracks and de-lamination are caused by intergranular corrosion.

Is aircraft corrosion a nuisance, or is it a major problem?

That depends on how long it is left untreated, and where it is. Probably one of the first encounters a person has with minor corrosion comes from the electrical system, where a very small amount of corrosion can cause a definite electrical problem.

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Think of a connection for a ground wire circuit where a wire is hooked to a grounding terminal that allows the airframe to become the electrical conduit for almost every circuit in the electrical system. At the point of contact, at least three different metals come together: the steel metal fastener, the silver-coated copper terminal and the aluminum airframe.

Add a little moisture in the form of humidity, maybe a little salt from your vacation in Florida last summer and a long winter's nap in a damp hangar, and there is ample opportunity for corrosion to form between those dissimilar metals.

Metal oxides cause resistance at the point of contact, resulting in a non-functioning electrical component or an intermittently-functioning electrical component that can be a troubleshooting nightmare.

Minor corrosion on the structural parts of the airplane is certainly not a problem until the element of time comes into play, allowing the corrosion to eventually eat into the material and weaken the structure.

If left alone, can corrosion degrade its host structure to the point of failure?

Yes, absolutely. You may have read with horror the report of a Chalk's Ocean Airways Grumman Turbine Mallard that had a wing separation in Florida in 2005. When the wreckage was recovered, corrosion was very visible at the point of failure, along with unapproved repairs.

It's not uncommon to see currently

Cleaning corrosion in all the nooks and crannies using small rifle-cleaning brushes.

flying airplanes that appear to be well on their way to being in the condition of the Mallard.

An accepted rule of thumb is that if the depth of the pitting in a structural component is more than 10% of the thickness of the metal, the component must be repaired, properly reinforced or replaced.

These repairs may need to be approved by the airframe manufacturer or a designated engineering representative (DER). Certain critical components may be even less tolerant than the 10% rule, and your technician will have to refer to AC 43-13-1B or the aircraft maintenance manual for data on this condition.

If severe corrosion has occurred to the point where there are holes or cracks in the skins, the surfaces may be so structurally compromised as to fail within the normal performance envelope of the airplane. This is a segue into a serious corrosion situation we are now dealing with involving Cessna 210 and 177 Cardinal aluminum wing spar carry-through structures.

Editor's Note: For more on that topic, see "Service Bulletins for Cessna 177 and 210 Wing Spar Carry-Through Inspections: What You Need to Know" by Steve Ells. The article appeared in the August 2019 issue of Cessna Flyer.

In subsequent installments, we will look into specific corrosion problems common to Cessna piston aircraft, analyzing causes of corrosion and detailing proper cleanup, repair and prevention. I know this isn't much fun, but it's the foundation upon which a successful renovation is based.

If you are doing your interior yourself, don't forget to have your maintenance tech inspect your entire cabin area while it's completely cleaned and exposed for all to see. Until next time, fly safe! CF

IMPORTANT: This article describes work that may need to be performed/ supervised by a certificated aviation maintenance technician. Know your FAR/AIM and check with your mechanic before starting any work.

Industrial designer and aviation enthusiast Dennis Wolter is well-known for giving countless seminars and contributing his expertise about all phases of aircraft renovation in various publications. Wolter founded Air Mod in 1973 in order to offer private aircraft owners the same professional, high-quality work then only offered to corporate jet operators. Send questions or comments to editor@cessnaflyer.org.

Resources:

FURTHER READING

FAA Advisory Circular No. 43.13-1B "Acceptable Methods, Techniques and Practices – Aircraft Repair" Chapter 6, "Corrosion, Inspection and Protection"
https://www.faa.gov/documentLibrary/media/Advisory_Circular/AC_43.13-1B_w-chg1.pdf

"Service Bulletins for Cessna 177 and 210 Wing Spar Carry-Through Inspections: What You Need to Know" by Steve Ells
Cessna Flyer, August 2019

CORROSION INHIBITORS

Lear Chemical Research Corp. (ACF-50)
learchem.com/products/acf-50.html

U.S. Corrosion Technologies LLC (CorrosionX)
corrosionx.com