Wired for Disaster

This article appeared in the August 2004 issue of Sport Aviation. The author attempts to share insights into the hazards of aged wiring in airplanes. A detailed review of the article raises more questions than answers. The article is long on platitudes and hyperbole, short on data and sprinkled with errors. There have been previous articles appearing in the Sport Aviation with a potential for creating confusion and suppressing confidence. This appears to be another such article. Therefore, I've taken the time to craft and publish the following critical review:

Bob Nuckolls
March 9, 2006

Things were going fine for the pilot of a Piper PA-28-181 on a VFR flight from Nantucket, Massachusetts, to Freeway Airport in Mitchellville, Maryland, one bright afternoon m6ctober 2002. About 27 miles southeast of Block Island (BID), cruising over the ocean at 8,500 feet, the pilot and his two passengers smelled trolllife. Smoke began to fill the cockpit. With a quick call to the Boston Air Route Traffic Control Center (ARTCC), the pilot received vectors to BID for an emergency landing.

No doubt the pilot was anxious, with the waves sweeping below them and the minutes ticking by as he navigated for dry land. Smoke made the visual approach to the 2,501-foot Runway 28 more difficult. The fumes burned the pilot's eyes and nose and caused a headache and dizziness. A direct crosswind of 12 knots gusting to 16 added another challenge to the landing.

The aircraft touched down fast, some 800 to 900 feet down the runway, and the pilot couldn't stop before running off the end of the runway and into a fence. The occupants received only minor injuries, but the airplane wasn't so lucky. The culprit? The plastic housing and associated wiring on the battery box solenoid relay had melted.

How can we use this story? This article wants us to become aware of and understand the evils of "old materials" and "inexpert workmanship". We are not told what got hot and why. Plastic covers don't spontaneously combust. What was the heat source to melt the plastic? What parts were replaced and how did age figure into their failures? I know of relatively new airplanes, automobiles, boats, etc that have suffered failures with similar descriptions. One would hope that this dark-n-stormy-night story would include specifics that help us understand . . . but alas, it's not to be.

As aircraft age, so do their electrical systems, of course. But the wrinkles aren't always obvious. When a control or mechanical component fails, the problem is usually an obvious break or seizing. Missing bolts, nuts, and safety wires are readily seen. Loose control hinges and rod ends are easily detected. Discoloration and bubbling of paint are clear indications of corrosion.

However, when it comes to aging electrical systems, even a thorough pre-flight or routine inspection can easily overlook a serious problem.

Mechanical things not touched during pre-flight come unhooked too. Annual inspections should be expected to probe a lot deeper than pre-flight inspections. It's not unreasonable to depend on judicious selection of materials to run trouble-free between inspections.

Aging electrical systems manifest their problems with a myriad of symptoms. Maybe it's an intermittent radio problem, a flickering light, noise on the radio, or fuses that burn out for no apparent reason. Sometimes the problem doesn't reveal itself until the situation becomes critical, and the result can be an electrical fire. To get the most out of an airplane - and certainly to avoid cataclysm - you need to find the problems, then take the steps necessary to rejuvenate the aging electrical components and restore the system to a youthful, low-resistance condition.

Advice that applies irrespective of the age of the airplane. FBO's make a living working on problems of all description that for the most part, cut across age issues. Goofy things happen on in airplanes of all ages.

Electrical System Corrosion

As with any metallic aircraft components, the electrical system is subject to the effects of corrosion over time. Unfortunately, the points at which that corrosion occurs are not always obvious.

"Corrosion really is the big issue," says Bill Anderson, director of maintenance for Cawley Aviation in LaGrangeville, New York. "Over time, all the terminations and contacts become corroded, and little problems begin to emerge. We've got an old Cessna Cardinal in here now that's a prime example. If you leave the aircraft lighting on and then turn on the master switch, you start popping fuses. The problem is that all the terminals are corroded, which increases the resistance of the circuits. When you turn on the power, you get this sudden power surge."

I am mystified by this paragraph. Yes, parts corrode and joint resistance goes up. Wire resistance doesn't change significantly with age but poorly applied and/or maintained terminals and fasteners may allow "molecules of joint destruction" (MJD) to enter.

I'll suggest further that connections with high risk for corrosion are quite obvious. The joints most resistant to corrosion are the gas-tight joints. This includes soldered, crimped and properly tightened threaded fasteners. The joints most vulnerable are low pressure, often moving joints like switch contacts and pivots, contactor and relay contacts, low-pressure fuse holders and mating surfaces of connectors where male and female pins come together under limited spring tension.

The most mystifying statement in the foregoing paragraph suggests that corrosion in the C-177 INCREASED circuit resistances such that powering up the airplane causes a fist full of fuses to blow. I cannot visualize the physics that brings any degree of understanding to the condition cited. Increased resistance doesn't cause fuse-blowing transients. Further, a fault in a system that blows the fuse shouldn't propagate to fuses of other systems. I am skeptical of this anecdotal information point. It's a spectacular thing to contemplate. However, the article does nothing to explain the physics of how and why this condition was observed.

Despite its protective insulation and a lack of moving parts, electrical wiring itself suffers the effects of 'corrosion over time. , Aluminum wiring-often favored in high amperage applications such as starter cabling to minimize the weight-tends to suffer ill effects as cracked and abraded insulation allows moisture to enter and begin its destructive work. The result is an increase in resistance and a corresponding decrease in cranking power.

I'm aware of no certified single engine aircraft where "aluminum wire" should be an issue. The C-177 and a few Piper models had brief romances with plain aluminum conductors. Early on, pure aluminum conductors were a problem. Cessna recalled the aluminum cable assemblies and provided copper replacements. Piper quit using aluminum wire in production and offered kits for replacement of aluminum wires with copper. Not sure why the article even mentions aluminum wire as an aging aircraft issue. The situations I'm aware of treated aluminum wire as a poor design decision that got fixed. The only reason anyone should be suffering the effects of aluminum wire today is not because their airplane is old but because they've not bothered to fix it. In any case, there's no practical reason for any airplane suffering the effects of aluminum wire not to benefit from a total replacement of the wire.

"Terminal blocks are another great place for corrosion to occur,"

Anderson says. Here, dissimilar metals combined with moisture from the air eventually result in corroded terminals and increased resistance. "Even crimped connections will eventually corrode."

By "terminal blocks" I presume the writer is referring to threaded fasteners. I would agree that this is the GREATEST potential for corrosion to drive up resistance of a bolted joint. Corrosion is prevented by proper pressure on joined surfaces that deforms them into each other so intimately that they are for all practical purposes, one piece of metal. When vibration and temperature cycles reduce this pressure, opportunities abound for ingress of MJD. I've observed many crimped terminals with considerable surface corrosion and other contaminants that were electrically sound.

A common practice in old military airplanes was to terminate the connections in potting compound. The idea was to prevent moisture from finding its way into the connections in the first place. It seemed to work for a while, but eventually even those connections failed. "Eventually, moisture seeps into these connections, too," Anderson says, "and the wires corrode right there in the potting compound."

Some commercial ships used potted connectors too but I'm having trouble visualizing the failure cited. Most potted connectors used soldered joints. Yes, given enough time and atmospheric cycles, MJD may enter the area under the potting compound and corrode surface of wire, joint and connector pin . . . I'm having trouble visualizing how the corroded surface of conductors translates to severely weakened conductors that become potential points of failure.

Yes, MJD might degrade the male to female pin junction in the connector . . . but words used in this paragraph don't paint that image. This paragraph leads the neophyte to believe that "corroded wires" are evil.

A Bundle of Frayed Nerves

The electrical system is the airplane's central nervous system, and as an aircraft ages, it can end up being nothing more than a bundle of frayed nerves. Especially where wires rub from vibration, the insulation wears away, causing bare spots that will short out systems intermittently. "In lots of cases, the old insulation becomes brittle and breaks off, or simply rots away," Anderson says.

Yup. There are some very old aircraft still flying with wires installed in the 40's. Cotton covered, rubber with a varnish overcoat was common then. This style of insulation certainly degrades faster than PVC and faster still than modern Tefzel. However, presence of varnished cotton over rubber is not an automatic recipe for disaster . . . I have samples of this style of wire removed from recent re-wiring projects where the original wire is intact, flexible and did not compromise the system.

In addition to the problem of frayed and abraded insulation, brushes wear, contacts deteriorate, plastic parts become brittle, and switches wear out, all of which can cause gremlins to appear in the electrical system.

"Another place we see problems is with communication and navigation systems," Anderson says. "A guy may come in here wondering why he can't receive a VOR until he's 4 miles from it, and he thinks it's his radio or the antenna. But a lot of times it's the cabling that is to blame. Especially where the connectors are mounted vertically, water will eventually find its way into the coax cable. This changes the capacitive reactance of the cable, and degrades the performance of the radio. The only way to get rid of the problem is to replace the coax cable."

The discussion thus far speaks to pretty common knowledge. Yes, loose fasteners allow ingress of MJD, organic/plastic materials degrade under environmental stress cycles. Yes, EVERY component of every machine has a service life.

Quality Matters

One particular problem faced by owners of aircraft-especially those with which nonprofessionals have been involved-is the quality of the materials and workmanship found in the electrical system. Here again, the problems aren't necessarily obvious to the untrained eye.

"The problem is that many of the people doing their own electrical work don't realize they're doing a less than first-rate job," says Terry Pearson, a 25-year veteran avionics technician at Westerly Airport in Westerly, Rhode Island. Wiring an aircraft is almost an art, and having the right materials and tooling is essential to the outcome."

A common mistake made in amateur-built aircraft-and home-repaired aircraft-is the use of automotive wiring and components. "We had an RV in here a while back, and although it was a beautiful airplane, the wiring was a disaster waiting to happen," Pearson says. "The whole thing was wired with automotive wiring and fuses."

The primary problem with automotive components is the quality of the materials. Automotive wiring and components typically have PVC insulation, and as Pearson points out, PVC is totally unsuitable for use in airplanes. When it overheats or burns, PVC emits deadly cyanide gas that will quickly overcome a pilot and passengers. Instead, most designs now specify MIL-22759 TefZel wiring, which is rated for higher temperatures (150C), has thinner insulation to allow better cooling of the wires, and the individual wire strands are "tinned" to reduce the effects of corrosion. Even terminal ends and other automotive crimped connectors incorporate PVC insulation, and in addition, may present material compatibility issues that enhance the effects of corrosion.

In addition, automotive components just aren't up to the punishment doled out in the aviation environment. For example, automotive switches don't stand up well to the vibration common in aircraft. The internals finally disintegrate, leaving a hazardous connection prone to sparking, arcing, and other modes of failure.

This broad treatment of so-called "automotive" components and materials is a canard that just doesn't fly. First, there is no such thing as an "aircraft quality" component. Nor are there "marine quality", "spaceship quality", or "tricycle quality" components. There are just components manufactured with various materials, design skills and offered with certain test results that hopefully verify functionality and service life of the product.

There are parts and materials flying on 40 year old airplanes that some bureaucrat might sanctify as "aircraft quality" that won't begin to withstand the environment encountered under the hood of an automobile. Many such parts don't even work well in airplanes that carry them around. They get worked on regularly by mechanics with "trained eyes" . . . but it matters not . If the part is listed on the aircraft's type certificate, then in the regulatory sense, it's "aircraft quality" irrespective of how poorly it performs.

When these parts break, the mechanic is OBLIGATED to return it to original configuration. The part receives the coveted "yellow tag" pronouncing it suitable for service. It matters not that dozens of sources for better,

modern parts popular with the AUTOMOTIVE industry are readily available at a fraction of the cost.

The authors readily bash PVC wire as unsuitable for use in airplanes. So I suppose EVERY one of over 100,000 Cessna, Piper and Beech airplanes that left the factory with Mil-W-16878 Type BN (nylon over PVC) wire has been updated with the latest and greatest version of Tefzel wire . . . yeah, right.

Okay, are we suggesting that all those airplanes should be immediately grounded until their harnesses are upgraded? Yeah . . . right.

When considering materials choices for a new project, one would do well to consider the most modern, robust and useful components. Ignore marketing hype and labels that suggesting that any particular material is or is not "aircraft quality" . . . there ain't no such thing.

Striving for failure-tolerance is easier, cheaper, and safer than any system designed with "failure proofness" as a goal.

Let's Get Wired

Even when aviation-grade materials are used, the quality of the workmanship can be a major issue. Sloppy workmanship, poor grounds, and loose connections have been the downfall of electricians since the days of Edison. "The big mistake that people make is they over-tighten the clamps," Anderson says.

Unfortunately, many of the problems are hidden behind panels and interior furnishings, making them difficult to detect. Pearson tells of an EMI filter in a Mooney 231 that suffered damage from a loose connection. "We found melted wire and charred connections where a 1/4-20 stud had loosened, causing serious arcing. It looks like someone just tightened it up again and kept on going."

Well duh . . . this only happens on electrical terminals and never on prop bolts, cowl screws, or hydraulic fittings? Any fool with a wrench can tear up a threaded fastener whether electrical, plumbing or mechanical. Just because the author has observed the actions of an electrical fool or two in the wild has no significance to the OBAM aircraft fabricator who understands what it takes to confidently produce good workmanship.

One of the worse cases of poor workmanship Pearson has found was in a Cessna in which the power feed to the buss bar had been cut and repaired. "The two pieces of No. 6 wire had just been laid side by side, held together with safety wire, soldered with a torch, and wrapped with electrical tape," says Pearson, shaking his head.

Hmmm . . . if I encountered a need to accomplish a splice in the wire cited, I don't see a thing wrong with solder. Solder-sleeves routinely demonstrate the structural/electrical integrity of solder in accomplishing lap-joints. Safety wire won't solder . . . but it will fixture the wires as they are soldered. If I had to use safety wire to fixture the joint, at least I'd take the wire off later. Alternatively, one could use a single strand of tinned copper to fixture the joint . . . the fixture becomes part of the finished joint. Finally, electrical tape has a very poor service life. Several layers of heat-shrink, or perhaps some very robust double-wall heatsrhink would cap off this job very nicely and produce a repair that would last the lifetime of the airplane.

Another surprise came when he found the wires for a strobe light had been connected with wire nuts-like those used for household wiring.

I'll agree, this is pretty bad . . . given the availability of low priced soldering and crimp tools, there's no good reason for using cheesy materials like wire-nuts to make connections.

"Then we had this S-35 Bonanza that suffered some burned wires due to loose connections in the instrument lighting," Pearson says. "We had no idea there had ever been a problem until we pulled the panel out to do some other wiring work and accessed the wiring bundle."

For the homebuilder, it's important to assess your true capability to do the job right. "You really want to have someone involved that's an expert in aviation wiring-not automotive, residential, or marine wiring," Pearson warns. "The best thing to do if you really aren't a wiring expert Is to ship your panel out and have it wired by an expert."

Pardon my French but . . . Bull Hocky. If you are not a wiring expert, then get some books, join the AeroElectric List, take some seminars, talk to other builders and strive to become sufficiently skilled to accomplish satisfactory workmanship.

If the OBAM aircraft community observed the prohibition offered by the author, there would be no OBAM aircraft industry. Who among us started out as experts in metal work, installing rivets, putting proper torque on bolts, following instructions, correcting errors, etc. etc?? Learning to string wire is no more difficult or hazardous than learning to lay out some sheet metal, buck rivets and install bolts. Further, the most difficult part of wiring (avionics) is becoming simpler and easier all the time.

The problem of course is that even an electrical connection that looks good to the untrained eye can cause a problem. If the wrong material, the wrong size wire, or the wrong size connector is used, the potential for shorts, fires, and toxic fumes increases. "Every mistake you make is really stacking odds against you," says Pearson.

Upgrading the System

For many older aircraft with limited generator capacity, upgrading the system eventually becomes a key consideration, and there's more than one approach to the problem. The first is to replace high-amperage components with low-amperage devices. For example, changing from incandescent position lights and cockpit lighting to high-efficiency LED lighting systems can help reduce the load on the generator. Modern communication and navigation components use substantially less power than older systems.

Replacing the piece-of-crap-generator with an alternator sounds like a better option. Throughout this article, the author says nothing about upgrading to an alternator with 20-50x the reliability and service life of a generator. While ignoring the advantages of alternators, they readily recommend substitutions of modern technologies with lower current demands just accommodate limited capability of a generator! If anyone is so unfortunate to have a generator equipped aircraft, I'll suggest the first item on the list should be "install new alternator."

"While newer radios can be part of the solution," Anderson says, "the real problem is in the power needed for transmitting, and there's no way around that.

Say what? Transmitters are the straw that's gong to break the generator's back? The largest increase in system loads for any transmitting operation shouldn't be more than 3-4 amps . . . and most of the transmitters I would choose consume less than 2A.

And now with pilots adding downlink weather systems, we see them putting in power inverters to power their laptops, without even thinking about the power demands put on the electrical system."

Again, the numbers don't fit the worry. I run my laptops in automobiles wherein draw from the cigar lighter plug is under 3A.

The bottom line is that the electrical system should draw only 80 percent of the generator capacity, so in many cases, the only real solution may be to upgrade the generator to something with more capacity. Fortunately, many aftermarket upgrades are available. The one caveat is to make certain that the whole system, including the wiring, is upgraded to handle the increased capacity of the new generator. ***New generator ? ? ? ? ?***

Keeping Electrical Systems Current

Probably the biggest dividends can be earned by simply maintaining the electrical system on a regular basis. Make certain the system including the wiring-is included in the aircraft's annual inspection, and replace or repair components and wiring as necessary. Look for signs of wire abrasion, cracking insulation, and loose connections. Avoid the temptation to encapsulate electrical connections, knowing that moisture will eventually find its way virtually everywhere. As Anderson suggests, "Let it breathe, inspect it, and treat it yearly with an anti-corrosion product to keep it clean."

Aha! This is the most profound paragraph in the article. Here is a statement that suggests that even components of the electrical system have a service life and that periodic attention to condition is the best hedge against an in-flight failure ruining your day.

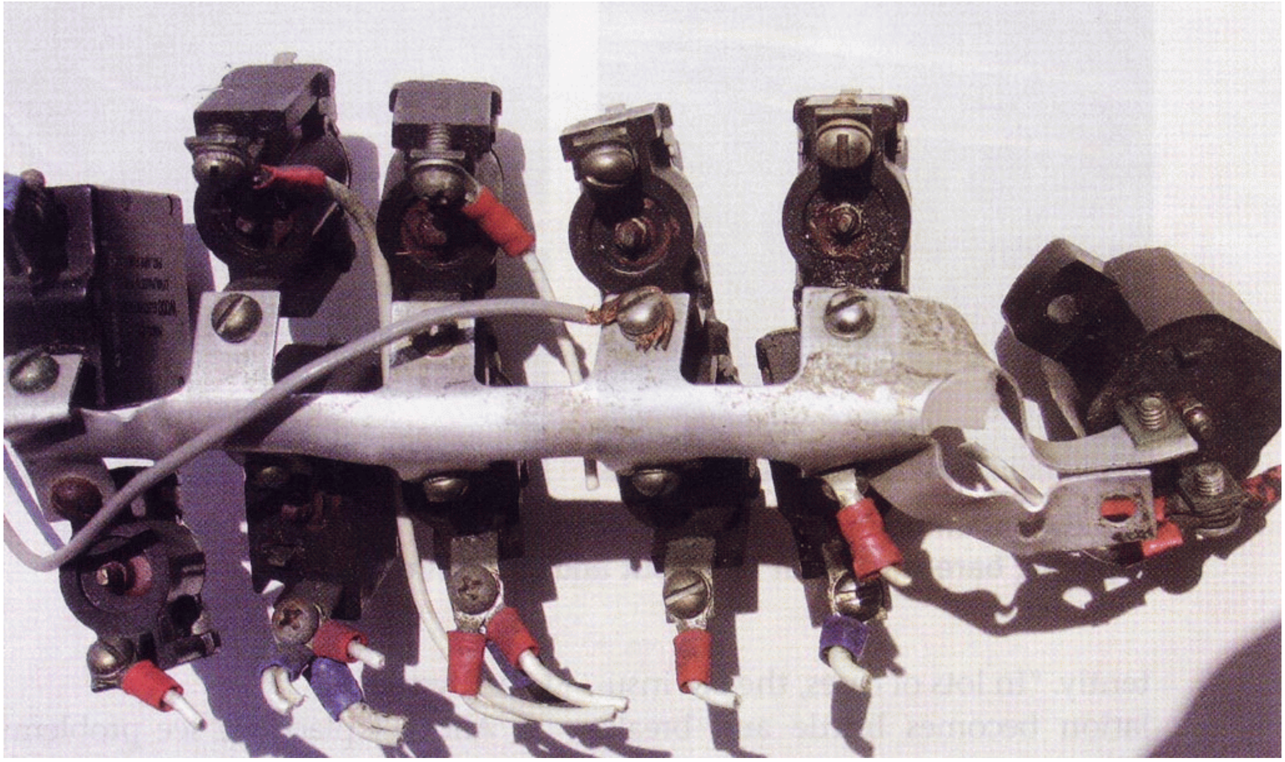
I don't know about the "anti-corrosion" stuff. We had a trade study and some in-house conversation about magic elixirs to improve service life of electrical joints at RAC a couple years ago. This produced no consensus as to what we might recommend for service technicians of our products. But then, if we HAD made a recommendation, it have cost a few hundred grand and a year or two of effort to get the process certified. Maybe there IS something one could use to retard corrosion but I'll suggest that gas tight connections are the all-time best friend to system longevity. If the authors were aware of any suitable products and techniques for using them, it would have been a useful addition to the article.

If you find problems, determining how to repair them takes a practiced eye. Part of the restoration or general maintenance of any aging aircraft involves replacing components and wiring, but the scope of the work is often a perplexing issue.

"As with any corrosion repair, the problem is deciding where to start and where to end," Anderson says. "if it's just the wire ends that are corroded, you might be able to get away with cutting off the ends and reconnecting the wires. In some cases, you can splice in a new section of wire. All too often, the best approach is to completely replace the wiring."

Pearson agrees. "Problems often creep in when new things are added later in the airplane's life. There's always the temptation to splice into the old wiring and reuse old breakers when adding new avionics, but the trouble it can cause really isn't worth the savings. If you're wiring into a system that has hidden problems, you're , just complicating them. The best thing to do is take out the pruning shears, cut out all that old wiring, and make it right.

"You really need to be as finicky with the electrical



system as you are with the structure and mechanical systems," Pearson says. "After all, the last thing you want is smoke in the cockpit."

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The photo above was offered as an example of a circuit breaker panel removed from a C-210 . . . it had to be a pretty old one . . . I think this style of breaker was phased out by the time I worked there in the mid 60's . What appears to be an aluminum bus bar is interesting too. NOT a good choice of materials for this application.

Note there is a blue PIDG terminal in the bottom row with a pair of wires in it. A perfectly acceptable practice if accomplish with knowledge and proper tools.

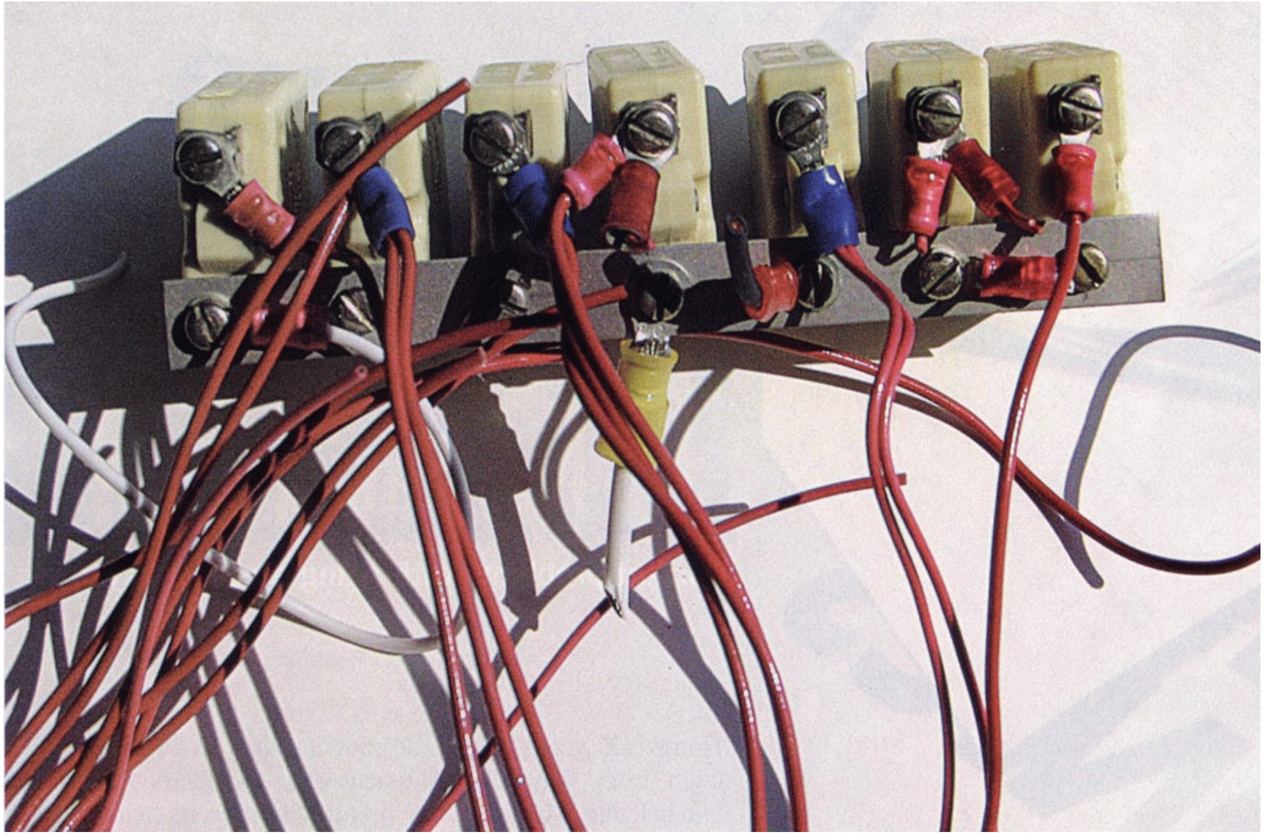
Note also how the plastic sleeve over some of these terminals appear NOT to provide insulation support? This is the magic of the metal liners in the PIDG terminals. The terminals shown are quit old and the plastic (remembering that it used to be round) has migrated toward it's as-new shape. However, if one cross-sectioned any one of these terminals, I suspect we'll find gas tight joints and well supported wires under the plastic insulators.

All of the wire seen in this picture is the nylon over PVC (Mil-W-16878 Type BN) wire that I mentioned earlier. This was the best-we-knew-how-to-do back then. It was a whole lot better than the cotton-over-rubber wire illustrated on the next page. Aside from the fact that this breaker assembly must have come out of a wreck (I'm assuming this is how it got all bent up) it appears to be in pretty good shape. All the wire insulation is in good shape. The screws were reported to be "loose" but given the unknown pedigree of this assembly, we can't be sure this condition prevailed while the assembly was still in service.

The wire added under the screw head is the most obvious transgression . . . made even worse by the fact that the wire attaches right to the bus. No fault protection!

This is not a very good example of aged materials that might put an airplane at risk. My biggest concerns for an airplane fitted with this breaker assembly center on the breakers themselves. Properly applied PIDG terminals on well tightened screws are going to be just fine. This assembly shows no marked signs of insidious corrosion. The breakers, like switches and relays have low pressure, spring loaded contacts that may not be making good contact. Heavily loaded breakers like pitot heat and landing lights are at risk for smelly failure.

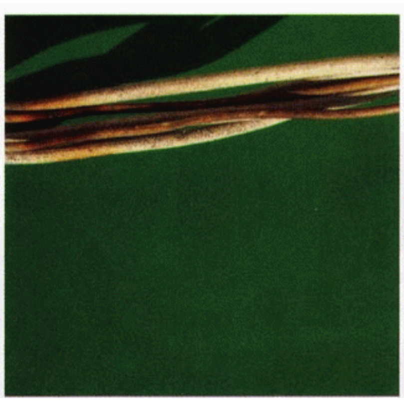
The photo at the top of the next page appears to be out of a OBAM aircraft. None of the terminals appears to have been installed with the proper tool. Many of the PIDG terminals have not been closed down at the insulation grip.. We also see a few "Plastigrip" terminals . . . definitely not recommended for any vehicle where anticipated



service life is exceedingly long.

All the wires are PVC and the authors correctly point out that there are better choices for modern wires but keep in mind that over 100,000 certified singles were wired with this stuff and many of those airplanes are still flying with wires well past the voting age. Should one board these airplanes with fear and trepidation?

There are lots of airplanes I rent that fall in this category. I don't fear these machines . . . nor would I be afraid of a new OBAM aircraft where the builder chose to wire it with PVC wire. The quality of made-up joints with PIDG terminals applied with suitable tools has a lot more to do with system performance than selection of wire insulation.



interesting note in the caption for this picture points out the fact that some terminals are the "wrong color" for the gage of wire. I don't know that this is true. The blue terminals all have two wires crimped into the same terminal. This is an entirely acceptable practice that just MIGHT call for increasing the size of a terminal to the next larger wire range.

The pictures below are the most mystifying. All three shots show cotton over rubber insulation that might have been used in the late 1940's and early 1950's installations. These wires appear to be stained but otherwise in pretty good shape. I'll bet they're still flexible. I don't see any signs of insulation failure. Yes, this is some very old wire but if I were to peek behind the panel of a nicely maintained ol' C-140 and see bundles that looked like this, I'd go flying without a second thought about it.

The biggest problem I have with articles like this is that they tend to generate a lot of concern while offering little in the way of simple-ideas that help us make good decisions. It matters not if you're building a new airplane or maintaining an old one. This article offers little assistance in that endeavor.

What's the alternative? The original article sets out to shed light and understanding on problems associated with poor workmanship and "aging aircraft". Let's consider this mission with a bit more attention to simple-ideas.

Thoughts on Living with Ageing Aircraft

There is a lot of discussion on the problem of "ageing aircraft". There have been numerous incidents in the air transport industry wherein root cause of the event was attributed to wiring. The wiring was, "In service beyond expected service life". A few years back, a major portion of cabin top separated from an airplane in Hawaii. The spontaneous addition of a sunroof to the passenger transport was attributed unnoticed or ignored cracks in the skin.

Numerous groups in aviation's regulatory, manufacturing, maintenance and users of such airplanes are spending tens of $millions$ to gage the magnitude of the problem and decide what should/can be done about it. Anecdotes from various deliberations provide a wealth of material upon which "worry stories" may be considered worthy of the front page of Today or 15 seconds notice on the nightly news.

Without a doubt, those who own and operate large, heavily utilized aircraft are faced with tough questions. The machines are expensive to buy and expensive to maintain. The notion that one should periodically return the airplane's condition to factory-green status (fully functional airplane with no interior) for total refurbishment of major portions of airframe or systems is a horrible thing to contemplate. None-the-less, this is the simple, obviously correct answer.

It's unlikely this will happen very often in the air-transport or military worlds . . . but it's a sure bet that meetings of lots of people will go on for a long time to craft rules and regulations that upset as few bureaucrats as possible while maximizing probability of hiring more staff to oversee new rules and insuring jobs for however many folks it takes to refurbish a fleet of aging aircraft.

It will be up to the marketplace to decide whether refurbishment or scrapping old airplanes is the best thing to do. It's a demonstrable fact that the most competitive products are those touched least by human hands. A device built by machine is less expensive to build in the future. Further, it's easier to evolve machine-built products to stay abreast of latest technologies. The efficiency of machines gets better as the technology evolves.

Conversely, a product fabricated and maintained with hands-on labor is more expensive to build in the future; the cost of labor always rises over time. Further, high-labor products are least likely to enjoy the benefits of improved technology. It seems that there's a fundamental human resistance to change. At some point in the life of large aircraft, return-on-investment for labor to refurbish the machine is too low and will not be considered.

What's all this aging aircraft stuff for small airplanes? Very few small aircraft serve as capital equipment in for-profit ventures. Virtually all small aircraft are owned and operated by individuals who make their return-on-investment decisions on a very small scale. Let's consider the concept of aging . . .

Suppose in 1949 someone had asked Walter Beech, "How long do you expect this new Bonanza to last?" What might he have said? Folks would have been incredulous had he offered: "Oh, probably 30 years". After all, the average automobile and industrial vehicle is pretty much used up at 10 to 20 years. It's pretty audacious to suggest that HIS product would have a service life twice that of a Cadillac or John Deere. What would Walter have said if you said your crystal ball reports that some of his products will be in service after 50 years?

We're all aware of some very old machines that have the appearance and performance of a new machine. This observation may be confirmed on any weekend at steam shows, fly-ins, car-shows, tractor shows, etc. Some of these machines are simply well preserved. Others required an investment of thousands of hours labor and thousands of dollars in a restoration effort. It's easy to visualize a heavily used, 5-year old, poorly maintained machine that's ugly to look at, unsafe and perhaps unserviceable while a similar, well cared for 50-year old machine might be a pleasure to look at and just as serviceable as the day it left the factory.

It is obvious that suitability of any machine to function for its intended purpose is a trade off between (a) effects of wear-and-tear combined with (b) a willingness of the owner to spend time and dollars to maintain and/or restore the machine. The chronological age of the machine is not a limiting influence on the possibilities for the machine's longevity. I'll suggest, therefore, that the term "aging aircraft" has no useful meaning. What we're really discussing is poorly maintained aircraft.

Folks who claim the greatest understanding of service life put routinely repaired, replaced or overhauled components in a separate basket - isolated from parts having demonstrably longer service lives. This means that engines, batteries, tires, brakes, paint, upholstery are treated differently from wires, wing spars, landing gear struts, etc. It seems obvious that EVERY part of EVERY airplane has a service life. Some parts are quite long lived while others are relatively short. Further, based on differences in environmental and service stresses any part may out-perform its clone on another airplane. From the perspective of inspecting an airplane for continued airworthiness, no component should be favored with a low priority for inspection based exclusively on age of the airplane.

With this alternate perspective, let us consider the foregoing article "Wired for Disaster". The article offers four major ideas pertaining to concerns on wiring. Insulation, corrosion, poor workmanship, and choice of materials. We're also encouraged to consider a cursory load analysis that suggests installation of a larger generator may be in order.

Corrosion: Yes, surfaces of most metals change with age . . . and here's the keyword - SURFACE. You can bet that every wire strung from pole-to-pole in our nation's power grid has some corrosion on the outside as do all the fittings associated with carrying the flow of energy from generator to reading lamp. It's a certainty that many of these wires and fittings have been exposed to atmosphere in a totally unprotected environment for decades. Yet, we don't observe cadres of workers running from pole to pole with Scotchbrite pads and wax trying to return all these materials to factory new appearance.

This is because each joint that was properly designed and properly assembled forms a gas-tight connection through which electrons reliably flow. The same conditions apply in airplanes. Properly applied terminals, tightly assembled threaded fasteners can appear pretty bad on the outside while maintaining perfectly satisfactory current carrying performance inside. Corrosion is a concern for joints where the original gas-tightness has been lost. For old aircraft, cars, boats, motorcycles, this phenomenon is most likely to occur at the threaded fasteners that have worked loose (or improperly tightened in the first place).

This is so poorly understood that even hallowed documents like AC43-13 "Acceptable Methods, Techniques, and Practices – Aircraft Inspection and Repair" offers the following advice: "Bus bars that exhibit corrosion, even in limited amounts, should be disassembled, cleaned and brightened, and reinstalled." Hmmm . . . here's a real cash-cow activity for every FBO in the country:

> *"Gee man, we spotted some corrosion on your bus bar. Wasn't much but you can't be too careful. Corrosion is insidious stuff. We disassembled your whole breaker panel, polished all the parts and put it back together. Looks like brand new. We were kinda worried that this project would get out of hand. I figured we'd need at least 24 hours to do it right but Joe got 'er ship-shape in only 14 hours! He 'saved' you a bundle."*

I'm sure we'd all appreciate the practitioner who carefully follows AC43-13 to the letter.

The paragraph should read, "Bus bars that exhibit corrosion should be inspected as follows: (a) electrical connections to a bus bar should be inspected for evidence of discoloration due to heating. (b) Apply recommended assembly torque to threaded fasteners and watch for movement. If the fastener is loose, the joint is suspect and should be disassembled for closer inspection, cleaning and reassembly. Alternatively, (c) use a low resistance ohmmeter or bonding meter to measure the resistance of joint between bus bar and joining conductor. Low current (10A or less) joints that exceed 1 milliohm should be opened for cleaning and reassembly. Finally, (d) joints carrying more than 10A are more accurately evaluated by measuring voltage drop across the joint when the circuit is energized. 10 millivolts is a reasonable upper limit for voltage drop across a bolted connection.

Insulation: One of my favorite rentals was a nicely maintained C-120 with an electrical system added. This airplane featured original cotton-over-rubber wires. I've had several occasions to put my hands on those wires. They were smooth, intact and flexible. Further, this airplane was so carefully maintained that you could eat your lunch off the inside of the cowl . . . it was bright and clean. The engine compartment was totally free of oil and accumulated dirt. The rest of the airplane was similarly maintained.

That is the oldest airplane I've ever flown fitted with an electrical system. The specter of aged insulation lurking in dark places waiting to ruin my day never entered my mind while enjoying the use of this unique aircraft. Many airplanes in the local rental fleet are products of the PVC insulation era. Still going strong after 40 years. Some of these airplanes (particularly under the cowl) have been updated or repaired in places with Tefzel wire.

Suppose I open the cowl on one of these airplanes and find run of brand new PVC wire? Is there a reasonable cause for concern about this one piece of new PVC wire added to several hundred feet of 30 year old PVC wire? If we understand and respect suggestions offered in articles on aging aircraft, we'll feel MUCH better if the new-wire smoke is "less hazardous" than the old-wire smoke stored in several hundred of feet of original wire still in service.

Choice of materials and workmanship: The article featured a number of anecdotes where terminal sizing, choice of tools, carelessness and craftsmanship were found lacking. I'll suggest this has nothing to do with aircraft age. The same shortcomings are found on machines of all ages and origins. During my first visit to Oshkosh in 1986, I observed airplanes surrounded by trophies, award plaques and blue ribbons that were marvels of mechanical skill and craftsmanship. These airplanes were but a few years old. None the less, some of these prize-winning, show quality machines had examples of wiring technique and materials selection worse than those used to illustrate the article "Wired for Disaster".

The answer for certified singles is stone-simple: DECERTIFICATION. Our brothers in Canada can de-certify simple, out-of-production aircraft. Once de-certified, the airplane can be owned, operated, maintained and UPDATED as if it were an RV-6 or a Long-Ez. This has a huge influence on the owner-operator's perceptions of return-on-investment for repairing or updating the airplane. The likelihood of seeing a factory-new looking Tri-Pacer or C-150 is about 100x greater in Canada as compared with the United States.

In conclusion, I'll suggest that contemporary "aging aircraft" issues are a misuse of aviation industry regulatory and management effort. It's a non-issue in the OBAM aircraft community. Owner-operators of such aircraft are encouraged and permitted to maintain their airplanes in what ever manner their return-on-investment decisions dictate. There's no practical reason for year 2000 RV's not to be flying in the year 2050. There are really nice Thorp T-18's flying now that are pushing 40 years of age.

Finally, keep in mind that "ageing aircraft" deliberations are being conducted by folks who don't own, operate or maintain airplanes. They're crafting a systematic approach to solving a "problem" that arises from regulatory systems already in place. A regulatory approach will produce few (if any) safer airplanes, nor will it encourage rational approach to breathing new life into an old airplane. It's a certainty that the regulatory approach will increase cost of ownership such that more owner-operators simply give up. An airplane in pieces is often worth more than an airworthy machine. The certified side of general aviation is cannibalizing itself for survival. How long can it last?