AeroElectric Connection
A Critical Review

The following document is a point-by-pont critical review of an article which I reviewed for Jack Cox some time in 1998. The article contain some basic truths. However, aside from my objections to a fear mongering and preachy writing style, many points in the piece argue with aviation wiring practices that have been in place for nearly 50 years. I also detect either disregard or lack of understanding as to the physics of joining conductors for a long service life.

I suggested that the article not be published. Contrary to my recommendations, the piece appeared in the May 1999 issue of Sport Aviation. I was surprised and disappointed. Sport Aviation is the flagship publication of EAA. 135,000+ aviation enthusiasts look to this publication as the standard bearer of technical excellence.

I've been putting off responding to this article. However, advice and words offered as fact have been quoted back to me on too many occasions. I am therefore driven to share my objections and observations of the work with the owner built and maintained aviation community.

The Terminal Advantage

and the Rules to Live By

Peter Burgher
Sport Aviation
May 1999

With all due respect to my friend, Bob Nuckolls, I must advise aircraft builders to follow only time tested and approved methods of attaching terminal lugs to wires for use in their homebuilt or even production airplanes. This article is based on nearly 20 years experience in our business of making extremely high quality power supplies, including transformers, inductors, DC and AC power sources for nearly all of the United States' and Japan's machine tool makers, servo and drive suppliers and OEMs of complex machinery. Our two plants make over 2,000 terminations a day and we have learned what works and what is approved (through experience) by the world's best electrical, electronic and machinery designers.

TERMINALS

First, some words about terminals, "lugs" as they are known in the trade. Lugs come in a wide

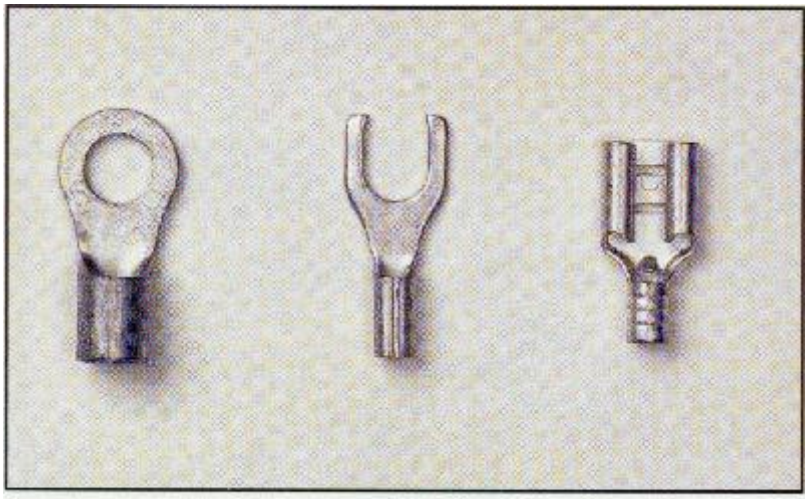


FIGURE 1

variety of forms, including insulated and non-insulated varieties. Lugs come in open configuration and closed shapes. They also can be obtained to fit flanged protuberances called "spaces" (see Figure 1).

I'm unsure as to the significance of the terminals shown in Figures 1 and 2. One might infer that terminals in Figure 1 are not recommended while those in Figure 2 are. Figure 1 includes open spade and Fast-On terminals. In fact, the Fast-On terminal is an electrically and mechanically superior device as I've described in and article on my website which you may download by clicking here. I note that none of the terminals in the first two photos have insulators and insulation support.

For aircraft, auto and marine use, the closed ring lug is preferred since they are less likely to work loose from vibration and even if loose they may provide some connection until the screw holding them is completely vibrated out and gone (see rules to live by at the end of this article). Also (as Bob himself recommends) always use full closed ferrule lugs, never accept a split or open-ferrule (see Figure 2) for reasons that will be obvious when we get into crimping.

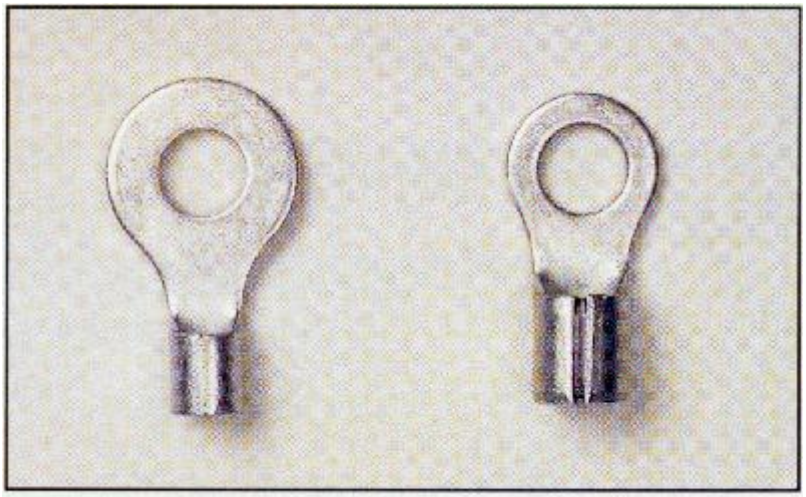


FIGURE 2

Suffice it to say that electrical integrity of the joint is lost when ANY terminal's mate-up forces are reduced below a value required for "gas tight" contact. The concept of "gas tight" is important for a long-lived connection. A study of the physics involved when you torque a threaded fastener down on a terminal shows that the relatively soft copper terminal actually DEFORMS to the extent that the touching surfaces become intimately engaged. No oxygen or moisture can get into that interface and degrade the connection. This is true whether you are bolting or soldering a joint. The ONLY advantage of a ring terminal is that the wire doesn't simply fall off and short out to other wiring or airframe components when the threaded faster becomes loose. From an purely electrical perspective, the ring terminal is no better or worse than other shapes.

Insulated terminal lugs may seem like a time saving idea, even if they are about twice as expensive as plain lugs. This is a lousy way to save time. Insulated lugs cannot be soldered, they can only be crimped. Crimping isn't enough when your airborne beauty, and your body, are on the line! Should

you try to solder an insulated lug, the plastic insulation will melt and leak all over the place, possibly even ruining the solder joint. Result in a bad job, extra cost and a mess all in one.

This statement argues with the talents and products produced by the likes of AMP (Now Tyco),Waldom, Holingsworth, and hundreds of other manufacturers who have worked diligently to produce a full line of solderless connection systems. It also argues with what has become standard practice in aircraft, automotive and power distribution disciplines for over 50 years.

I first put my hands on an AMP, Inc. terminal crimping tool at Boeing in the summer of 1961. The B-52 was reputed to carry over 500 miles of wire. 99% of my activities to put terminals or pins on wires used solderless crimp techniques. In fact, the use of a soldering iron anywhere near that airplane required the permission and inspection by my supervisor and the Boeing fire department. I used a soldering iron perhaps three times in 13 months. Each of those times I was told to have the proper signed-off solder-permission card in my possession before I plugged that critter in. Some B-52's are pushing 50 years old. If there are ANY original wires in these venerable old birds, my concerns would be NOT for the integrity of their CRIMPED terminals but for the INSULATION. That was the year 20 B.T. (before Tefzel) and the best that 3M and Monsanto could do for the world was PVC!

TERMINAL BLOCKS

Terminal blocks offer the careful builder an advantage in organizing and securing what often can be an unholy mess of wire ends and connections. Tracing faults is easier when terminal blocks are strategically placed. Even though they are not popular in OEM applications, the tried and true "cinch" block (see Figure 3) is preferred for homebuilt projects for a number of reasons. They are cheap in price (you may even be able to scrounge them from your local transformer maker for pennies per terminal) and easily found in industrial distributors nearly everywhere. More importantly, they provide secure screw-type connections. I strongly recommend using a cinch-type block with pre-formed sheet metal jumpers for such things as grounds and buss connections.

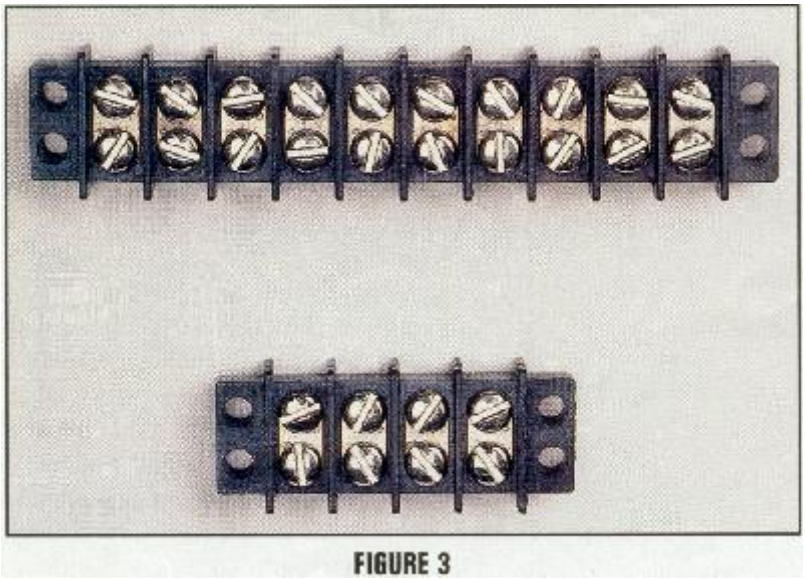


FIGURE 3

These are the barrier terminal strips I mentioned earlier. A number of catalogs with offerings to the owner built and maintained aircraft (OBAM) industry stock them. Without going into a lot of details here, suffice it to say that . . .

(1) the barrier strips illustrated use threaded, non-locking threads to maintain electrical integrity. When the use of such a device is necessary, the terminal strips of choice have threaded studs that are sturdy enough to accept self-locking nuts.

(2) Except for the connection of very fat wires to the threaded terminals of contactors, batteries, starters, and off-the-shelf products, we minimize the usage of threaded fasteners in electrical wiring wherever practical and possible.

I don't mean to imply that it's NEVER done but I've not had to use a threaded fastener terminal block for anything but BIG wires in a new design in over 25 years.

A variation in terminal blocks some constructors use is the increasingly popular international dead-front terminal blocks like those supplied by Phoenix, Entrelec, Altech, etc. (see Figure 4). They all mount on a standard "DIN" rail that can be grounded if needed. With these you merely insert a solder tinned wire end (no lug) into a hole in the block and tighten an internal screw for a positive permanent connection. Problem is they cost a lot more (about a buck per connection) and they take up a lot of space. Their advantage is ease of connection and the fact you can buy fuse blocks, breakers and a host of optional devices that snap on the same DIN rail. Never use "Wago" screwless terminal blocks; they cannot accept more than one wire per terminal and may allow wires to vibrate loose under extreme conditions.

I am not familiar with most of the cited products and I'm not sure why they are even mentioned in this article. They may have good utility in the venue of the author's products. The product illustrated in Figure 4 certainly doesn't belong in an airplane. An optimize design of an aircraft electrical system will have very little if ANY need for such devices.

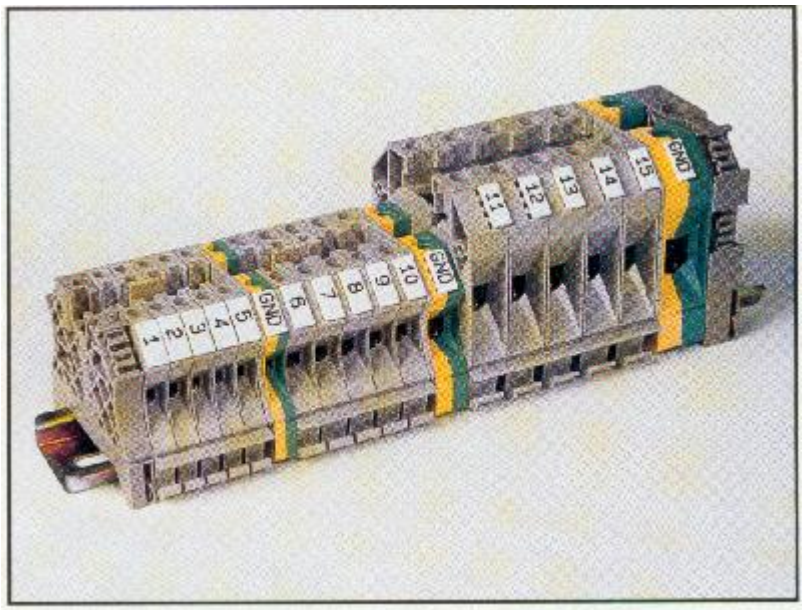


FIGURE 4

Cinch blocks will neatly allow multiple connections, if needed, when ring lugs are used - a time and space saving advantage.

I am suspicious of phrases like "time saving advantage" . . . because they're often used without definitive comparisons with an alternative. If you design the requirement for a terminal strip out of the system, costs go down, parts count goes down, and numbers of joints in your wires goes down. Reliability goes up. I'll further suggest that you will save the MOST time by not using the device in the first place.

CRIMPING

Now let's get on with attaching your lugs to the wires. All terminal lug connections should both be crimped and soldered: Never accept less. Solder is for electrical connection only. Crimping is for mechanical strength. Some will crimp only (like any high production consumer products and some automotive applications) but experience has shown there is no substitute for following the tried and

proven rules:

Rule I - Crimp to keep it from coming loose.

Rule II - Solder well for the juice.

Rule III - If in doubt, go back and repeat Rules I and II.

We will not allow a product to go out of our shop that does not conform to this standard - and we are the largest and fastest growing company in our industry. We will not accept field failures and there is no reason you should either!

These words pay homage to an old saw that has been hanging around for nearly a century, make your joint mechanically secure BEFORE you solder it for electrical security. I have books in my library that illustrate "proper" technique for joining wires used to carry power from pole to pole when the electrification of America was in it's infancy. Solder is not as strong as copper. Some technique that mates two wires so that the joint mechanically as strong as the original wire is called for. Obviously, you cannot simply twist wires together and expect continued electrical integrity . . . bare copper exposed to the weather WILL corrode and degrade the electrical integrity of the joint. Solder ENCAPSULATES the interface of the joint and preserves electrical integrity.

Over the years, elements of this description for "proper" joining of wires have found their way into other disciplines and planted erroneous notions about the properties of copper and solder. The idea that the copper "made it strong" and the solder "makes it connect" is incorrect. I will illustrate in more detail later. . .

There are several ways to obtain a successful crimp on your lugs. The best way is to use a professional quality crimping tool (about $35 to $50 at your electrical jobber) with jaws sized for the lugs you are using. Good tools come with a variety of jaw sizes that are easily inserted in the tool. Alternatively, if you only have a few dozen to a few hundred lugs to attach, you may use an electricians pliers ($12 or so) that has typically three tooth sizes and also several wire stripping points (see Figure 5). That's what I use at home, on car projects and on my own homebuilt restoration project.

The crimping tool illustrated in Figure 5 is readily obtainable from a variety of commercial sources. I own several variants and in the AeroElectric Connection, I describe the techniques for using it. The Tool can produce satisfactory crimps on both insulated and non-insulated terminals. The easiest tools to use are ratchet handled devices that close down on the terminal with hard dies . . . you are not allowed to under-crimp the joint with these tools. The handles must be fully cycled before the tool will open. A line of low cost tools ($35-40 each) with ratchet handles is offered through our website catalog and through other commercial outlets.

Given the low cost of these tools, there is really no reason for not taking advantage of the convenience and repeatability of results for putting INSULATED terminals on your project's wires.

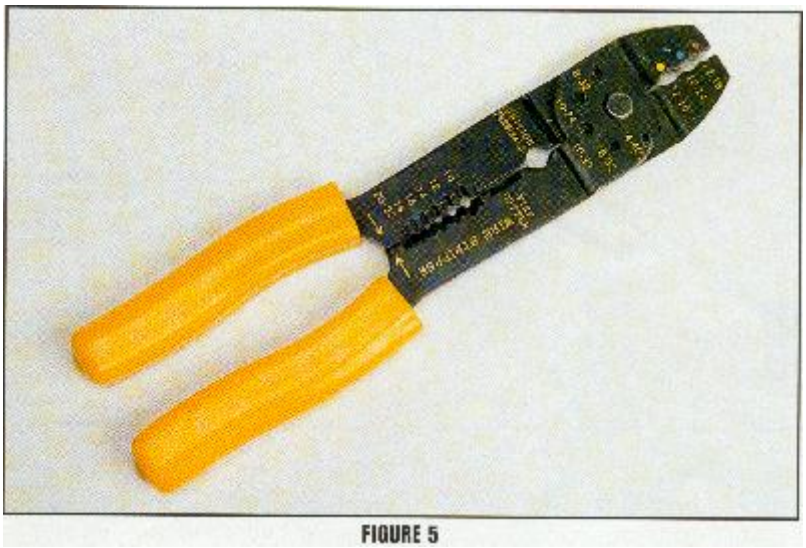


FIGURE 5

You can also buy a neat wire stripper at Radio Shack (for about $10) that will really speed your wiring project (see Figure 6). Never ever strip wire with a knife because you will easily damage some strands of your wire. Every strand is necessary or it wouldn't be there. Lug selection should be sized to the wire - an oversized lug won't crimp properly while an undersized lug will not accept all the wire strands.

There's a difference between a good crimp and a bad crimp. A good crimp will produce a positive detent in the ferrule of the lug (see Figure 7). A good crimp will physically hold the lug on the wire beyond the breaking strength of either the lug or the wire. Test the crimp by pulling on the lug. If the crimp isn't enough and the lug pulls off, throw it away and use a new one. Lean on the crimp tool; unless you have a $100 reflex jawed production tool, you cannot break the lug. Lugs are made to be crushed into and deformed at the point of detent into the wire.

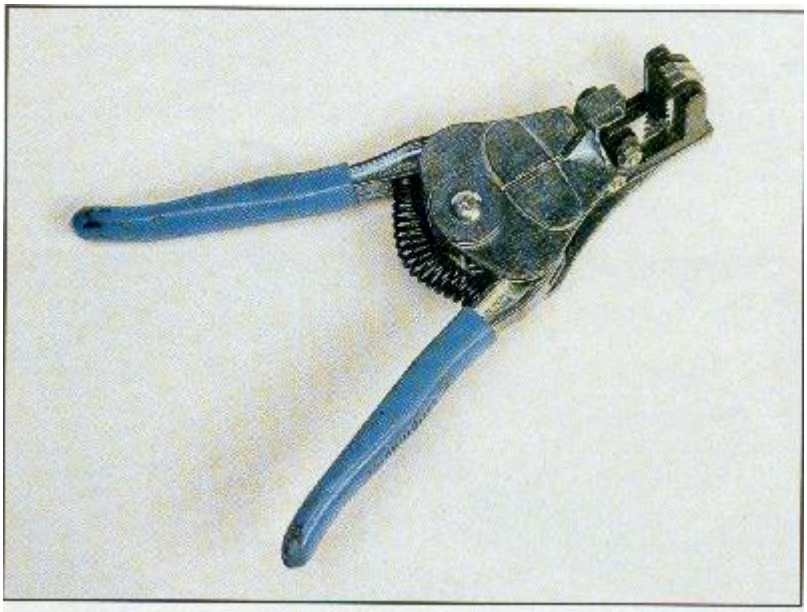


FIGURE 6

This paragraph argues with the published literature from folks like AMP and Waldom. Click here to download an article from my website that speaks to the anatomy of a good terminal. Information used to support this piece came right from the engineerng literature of the folks who manufacture solderless terminals.

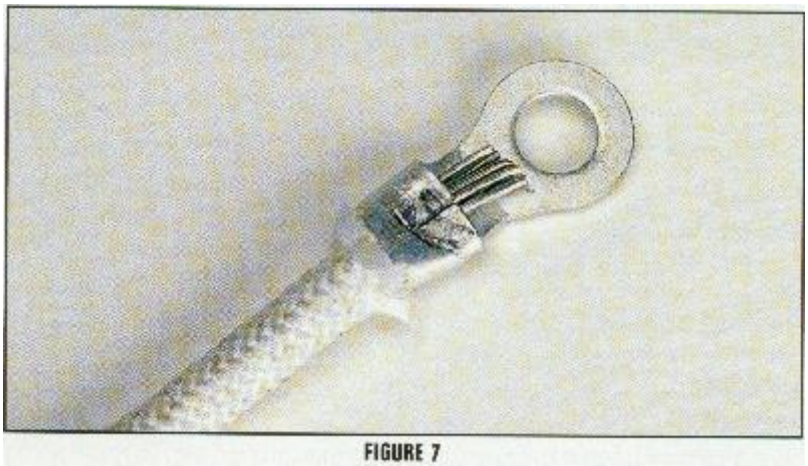


FIGURE 7

Obviously, if you have split ferrule lugs your efforts to crimp can split them open rather than grabbing the wire solidly and securely. Select your lugs for the wire you are using. Lugs come in an infinite variety of sizes and cost only pennies apiece. Good quality lugs are made from soft copper and are plated with a silvery tin based plate for solderability.

Terminals are NOT tin plated for solderabilty, plating IS for corrosion protection. Two perfectly clean copper wires simply

twisted together will conduct electrons from one wire to the other about as well as they ever could. However, exposure to oxygen, ozone, moisture, nitrous-oxides, etc will quickly corrode the shiny copper surface and make the joint something less than optimum.

Once the degradation starts, it is precipitous. As the joint's resistance goes up, heating due to voltage drop increases. Heating increases rate of corrosion which drives resistance up still faster. After a time, the joint fails electrically even if it's secure mechanically.

The trick of securing a long lasting joint is to keep the adverse effects of the environment away from the area where the two conductors are joined. This can be done several ways but by far the most popular are crimping -OR- soldering. Either technique properly utilized will do the job. It is not necessary to do both. It's interesting to note that the terminal in Figure 7 is installed on 7-strand wire insulated with a braided overjacket. NOT aircraft wire.

Most aircraft electrical wiring uses either AWG (American Wire Gauge) 14, AWG 18 or AWG 20. A box of lugs for each will cost only a few dollars per size. Larger wires, such as starter connections, etc., may use AWG 8 for which properly sized lugs are 15-20 cents each. Extra crimping will not correct a wrong sized lug. Beware, lugs also come in a wide variety of screw sizes - do not oversize the screw hole or you will have a bad connection.

Slide the lug on the stripped wire allowing no loose or split strands. A wire strand that is outside the lug does no good at all. Experienced folks give the wire a slight twist to ensure the strands are compacted and slide easily into the lug. This also makes for a better crimp inside the lug because the deformation encounters a twisted group of strands rather than merely crushing the top ones against the bottom ones. We will not ship a product that has a single split strand! You better not either.

The writer simply doesn't understand how crimping works. If you cross section the squashed area where a terminal's wire grip is formed over the strands of wire, the optimum crimp totally squeezes out all open volume within the joint. The ideal joint is said to be "gas tight" meaning that not a single molecule of air (or moisture) can find its way into the joint. For all practical purposes, the terminal and wire have become a single entity.

Once the ideal crimp is achieved, nothing you can add in the way of solder is going to improve upon the joint either mechanically or electrically. The notion that twisting the strands before inserting them into the terminal's wire grip is intuitively flawed. If the goal is to form the terminal and wire stranding into a homogenous mass of tin-plated copper, how does this goal benefit by causing the strands to lay in anything but neat, parallel bundles to await the supper-squash of your crimping tool? Interestingly enough, the wire manufacturer's goals are similar. If the strands of wire are not disturbed as you strip of the insulation, you find that the strands are tightly stacked with a minimum of gap between the strands. These strands are ready to go into the terminal for crimping with no further attention.

SOLDERING

Now let's talk about soldering. Solder is used to provide a high quality electrical connection, only. Solder will not make up for a poor mechanical connection. Don't even think about it. Your crimp

keeps it from coming loose the solder is for the juice.

These words echo admonitions cited earlier from very old books on wiring. The "make it strong" then "make it connect". These words foster a belief that solder should not be depended upon as a structural material. I went to my workbench and pulled a 0.032" diameter strand of 63/37 solder apart while reading the force on a spring scale. The average of 4 experiments yielded a tensile strength of 63/37 alloy solder as something on the order of 3200 pounds per square inch. It's probably better than that because the solder I measured was hollow so that it could contain flux. But for now, let us use 3000 psi. Obviously, solder is not for fabricating wing spars but let's consider the joining of wires.

Raychem makes a device called a "Solder Sleeve" that is designed to join two wires by simply overlapping the stripped ends about 1/4" and shrinking the sleeve down over the joint. Here is an exemplar spec sheet on Tyco/Raychem Solder Sleeves. Rings of sealant in each end of the sleeve close off the joint for environmental protection while a ring of solder joins the two wires. All in one single operation with a heat gun.

Let's assume the sheer strength of solder is only 2/3 its tensile strength. Let us further assume two 22AWG wires stuck together with a cross-section of solder approximately equal to the diameter of the wires times the length of the joint (0.025 x 0.25) or 0.0063 square-inches. Multiply by 2000 pounds and we get 12.6 pounds. Okay, back to the workbench. I stripped two wires 1/4" and lap soldered them together using a minimum of solder. I pulled on this joint with my spring scale and maxed it out at 25 pounds without opening the joint! A reasonable pull test of a crimped terminal on a 22AWG wire is 20-25 pounds.

Hmmm . . . if solder ONLY good for electrical connections and not to be relied on as a structural element of wire joining, somebody better tell RayChem about this. They sell solder sleeves by the bizillions. However, I'll suggest my simple experiment shows that RayChem is not perpetrating a great evil upon un-suspecting users of their products! In fact, if you like the solder sleeve concept for wire joining and don't want to pay the freight for low quantity purchases of these parts, check out this article I did on "Poor Man's Solder Sleeves".

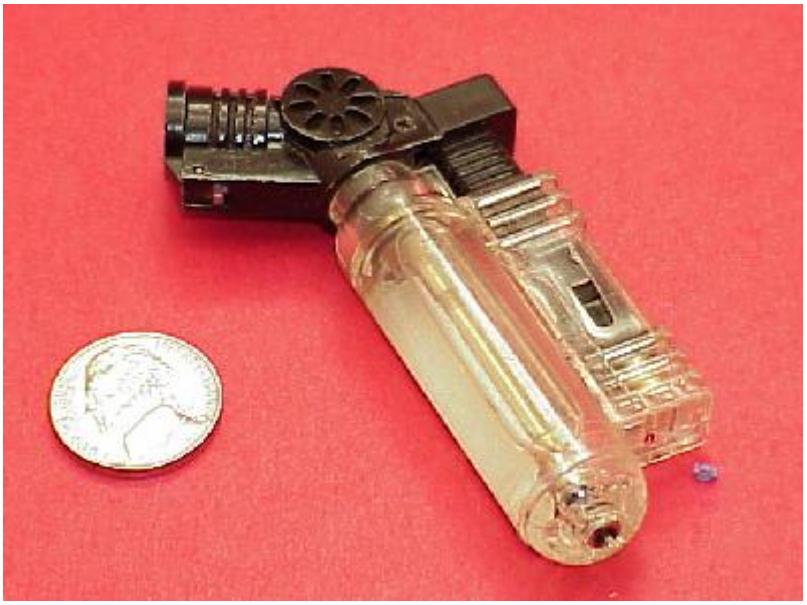
Let us consider that most modern electronics are now put together with surface mount components where solder is both the mounting and connection medium for all of the components on the board. Some of the components like transformers can be quite hefty. Consider also that houses plumbed with copper pipe have joints that are totally dependent on the structural integrity of solder. Let's dispel the notion that solder is some weakly substance akin to peanut butter to be used only as a concession for electrical integrity. This is simply not so. Solder is a material with useful thermal, chemical and structural properties. If used within easily deduced limits, solder as -EITHER- an assembly medium -OR- environmental shield can be quite useful.

Good quality rosin core electrical solder (generally 60/40) comes in a variety of sizes. We use fine wire solder for even the largest connections. This would be about the size of a heavy pencil lead. Only rosin core solder is allowed for electrical connections, because acid core solder (available in

hardware stores for hobbyists, decorative and similar applications) eats away at the plating on your wire and eventually the wire itself. Failure will result(not may, will result) from the use of poor quality and/or acid core solder. We buy ours from Handy and Harman, but Kester and Canfield are good brands. Penny wise, pound foolish - expect to spend $15-$20 per pound for good electrical grade solder. Skimp here and you'll swear later because el cheapo solder can have other alloy metals than pure tin and lead causing high melting point, poor wetting and flowability.

The rosin core is a flux which chemically cleans the surface of the metal and is pushed away as the molten solder bonds to the plated surfaces of your wire and your lug. A little burned rosin (the characteristic smell of a good hot solder joint) around the edges does no harm. It is benign.

Never, ever use a torch on wire connections. A torch will burn insulation, it may melt off wire strands, it will heat from the outside not the inside and a whole bunch of bad things. The soldering gun is the best tool for fine electrical connections.



Nonsense. I don't know what kind of torch was being described . . . a torch flame can be too large or poorly shaped such that heat is too strong or in the wrong place . . . but the admonition to never use a torch is silly. I've been using gas fired heat including torches, for soldering with great success for decades. Just picked up this little jewel in a convenience store a few weeks ago for about $7. This refillable, self-igniting torch is hot enough to silver solder thermocouples. The flame is tiny enough to let me join very small, 26AWG wires while barely singing adjacent insulation.

For very large wire sizes we use a solder pot. Several brands of soldering gun come with a variety of tip sizes to suit various wire/lug size combinations. Simply select the tip that heats your set-up quickly and cleanly. For production we use temperature controlled soldering irons that are on all day long, but our operators may make a hundred or more connections a day. The advantage of a gun is that it cools off almost instantly, minimizing the potential for damage should you put it down in the wrong place. This could be important when working inside your beauty. Further, a gun will not harm the insulation or anything else not actually touching the tip itself.

I own a soldering gun and find it to be handy in some situations. The last time I used mine, I was soldering some antenna leadwires up in the attic of my house . . . that was about 10 years ago. Low cost soldering guns have copper tips formed of heavy wire. they get hot by virtue of a very low voltage (1 VAC) current at about 150 amps. I bought my first soldering gun from Burstein and Applebee in Kansas City about 1956 for the grand sum of $5.00.

A close look at business end of a soldering gun shows us heating tip fabricated of square wire about 3" total length and 0.080" on a side. While this tool's main virtue is a rapid heating and cooling cycle, it's easy to see that heat generated by this tool is distributed over length of the wire tip. I'd be surprised if this 150W tool delivers more energy at the tip than most 50W soldering irons. This has to be the most inefficient tool

there is for soldering. I've had this one for about 15 years and haven't used it more than a few dozen times. This same model of soldering gun is still made (Weller 8200) and sells for about $50. There are many soldering tools with more utility and efficiency.

Nowadays, an extension cord is not needed to fire up my portable butane fired soldering iron. 99% of my soldering is accomplished with temperature controlled irons at my workbench. About 1% of my soldering is done in the field. Just this morning I pulled the butane fired iron out of my briefcase toolbox to fix a fussy controller board on a Premier I bizjet. I was done with the job in less time than it took the mechanics to get less handy tools from the crib.

Soldering is an art that is easily mastered. The point of the gun (or iron) the tip should be rested firmly on the lug where it will touch the exposed wire end and heat the joint from the inside (see Figure 8). As the assembly heats up, poke the end of your rosin core solder at the backside of the lug where the wire extends into the insulation. When the joint is hot enough the solder will quickly melt and flow toward the heat source. "Solder follows the heat" is the rule. Feed enough solder into the back and then the front of the joint to fill the ferrule and make a smooth filled look at the ring end of the lug. Swiftly remove the gun and the solder and allow the joint to cool with no motion or disturbance. If it moves do it over again for you may have a "cold solder joint" which means the solder crystallized before adhering to the base materials. A cold solder joint will fail in service sometime in the future. A cold solder joint is dull in appearance. A good joint will be shiny and smooth. Accept nothing less.

The paragraph above is generally correct except for the admonition about "cold" solder joints. As I explain in the AeroElectric Connection, "eutectic" alloy solders have no plastic range and are very resistant to poor joints cause by joint motion during cooling. Eutectic solder is 63% tin and 37% lead. 60/40 is close enough if you can't find 63/37. The article I cited

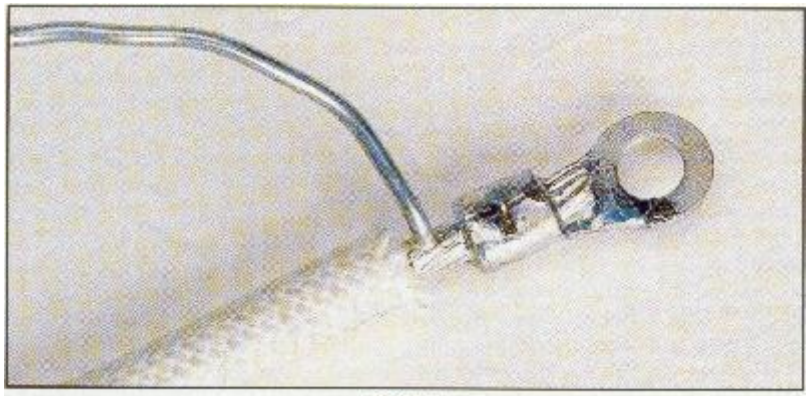


FIGURE 8

recommends that you expand the wire strands inside the barrel of the connector with solid copper wedges before you begin to solder. Keeping the joint immobilized for good soldering results is NO BIG DEAL. Using the right alloy of solder makes it even less likely that you'll have a "cold" solder joint.

BIG WIRE

Wire connections too large for a gun or iron can easily be soldered by use of a solder pot. Don't bother procuring one for your homebuilt project. A small one is $150 or more. Simply collect all your battery cables and starter leads together and go visit your friendly local transformer maker, motor rewinder or electrical manufacturing shop. Chances are one of them will gladly let you dip your half dozen lead ends into their solder pot and go your merry way with the job done properly. If all else fails borrow a soldering iron from your neighborhood stained glass enthusiast. In either case you must first dip your lead ends with lugs attached into a liquid or paste rosin flux before applying heat. Remember the solder follows the heat.

The joints that work the hardest are the big ones where high amperage surges take place like where your starter, alternator and relays do their work. Take your time to make them right or make them over until they are right.

I've NEVER found it necessary to use a solder pot. To me, dipping parts to be assembled in a pool of molten solder is akin to painting your airplane by dipping it into a swimming pool full of paint. The solder pot has some useful applications but they get solder EVERYWHERE on the finished parts. Less expensive tools and a little skill are a very satisfactory alternative to solder pot joining of terminals onto wires. Click here to download an article I wrote some years ago illustrating a technique for assembling fat terminals on fat wires with solder and a torch.

Before I turned my parts business over to B&C, I soldered ALL of my ground and battery jumpers with a small butane fired torch. Later on, I built an adapter to plumb the miniature torch burner to a propane bottle by way of a length of hose. A job did not have to be interrupted to refill the torch's tiny tank. A properly sized torch and a little practice are powerful tools for dealing with big wires in your airplane.

SLEEVE INSULATION

Each soldered lug should then be sleeved so bare metal is exposed save the lug ring itself. Plan ahead, slip your shrink tube onto the wire before you crimp on the lug. Size the shrink tube to the wire, as shrinked. Yo want the sleeving to be tight on both the wire and the ferrule of the lug. Shrink tube comes in various sizes and various shrink ratios. A 50% ratio is usually good for the lug that will fit the wire you are using. In other words, a tube that will fit the lug before you heat it will be tight on the wire and the lug with a 50% shrink. Allow four times the maximum diameter of the joint

beyond the ferrule (i.e. a 1/8" OD lug should have 1/2 or more shrink tube beyond the lug on the wire), see Figure 9. Heat the shrink tube with a heat gun preferably. Experienced operators can get by with a butane lighter but there - always a risk of burning the shrink tube or the wire insulation. Be conservative, the heat gun won't hurt either and generates just the right temperature for optimal insulation and appearance of the final product.. That's all we use, for consistency, quality performance and appearance. Shrink wrap or tube can be procured for pennies per foot from your electrical goods jobber (same place as the lugs are stored), dollars per foot in the Fly Market each July, or possibly free from the local motor shop. We buy it by the ton and amazingly spend only a few thousand per year for a product that works so well and consistently. If you burn the shrink tube do it over again. Do not accept brittle or burned results. Sparks may fly someday in the future when you are least ready to deal with the problem. Buy enough shrink tube for the whole job and then some (three or four yards will do) what- ever is left over will always be useful on other projects. Remember to get several sizes. You can even buy color coded tube if you want to get fancy.

FIGURE 9

CONCLUSION

Now look at Figure 10. If any of your terminals look like these, start over again. Properly made wire terminations will withstand decades of severe service without a hint of failure. All of our designs are predicated on a minimum of 25 years to failure, a standard we could not achieve with sloppy terminals. You can easily do as well by simply following the simple suggestions in this article which are summarized in the 16 Terminal Advantage Rules To Live By that now follow. Good going on your project.

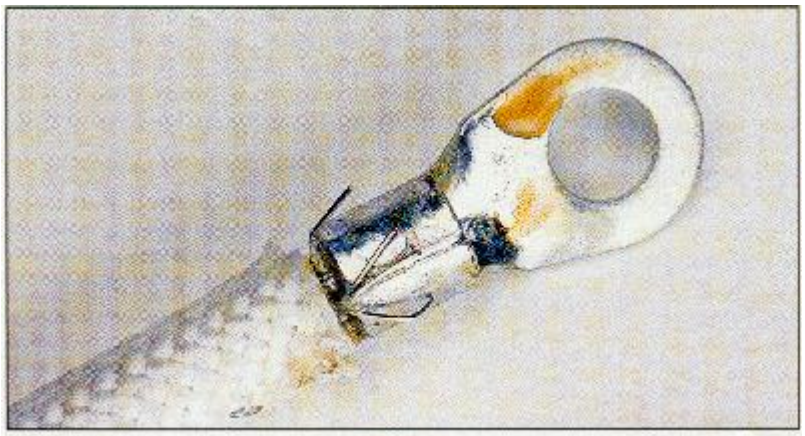


FIGURE 10

THE TERMINAL ADVANTAGE
Rules To Live By

- 1. Always use ring lugs, never substitute.
- 2. Always use full closed ferrule lugs.
- 3. Always crimp and solder all terminations.
- 4. Always use only positive screw type terminal blocks.
- 5. Always avoid spade lugs, open lugs or any connection that is not positive, vibration resistant and permanent.

- 6. Always select the correct lug size for the wire you are using - loose lugs sink ships!
- 7. Always twist your wire strands before inserting into the lug; no split strands are allowed.
- 8. Always use rosin core electronic/electrical grade fine wire solder.
- 9. Always use a soldering gun (or solder pot for very large lugs)never a torch.
- 10. Always remember solder follows the heat.
- 11. Always re-do cold solder joints.
- 12. Always remember a good solder joint looks good - shiny, smooth and fully filled.
- 13. Always sleeve the completed joint.
- 14. Always use a heat gun on your shrink tube, not an open flame.
- 15. Always do it over again if it doesn't look right.
- 16. Always follow Rule 15 if you are unsure about rules 1 through 14!

Many folks are partially correct when they cite "solder wicking" as the #1 evil of soldered wires. They've heard that solder will migrate away from the joint and into the strands leading up to the joint. This sticks all the strands together, turns it into a solid single strand and raises the probability of the wire breaking due to loss of multi-strand flexibility.

Remember the phrase gas-tight? The area immediately adjacent to BOTH soldered and crimped joints is for all practical purposes, a solid wire. This is why the recommended terminals for smaller wires (24AWG to 10AWG) have TWO crimps that grip the wire. #1 crimp is an electrical connection in the wire grip barrel. #2 crimp is a metalic INSULATION grip that supports the wire immediately adjacent to the electrical joint so that bending moments at the joint are minimized. The heat shrink tubing recommended in this article would not be considered sufficient to this task. This is why AMP's pre-insulated, diamond grip (PIDG) terminals have METALIC liners inside the insulation sleeve to provide superior mechanical support. A terminal with plastic insulation cannot also be soldered without melting the plastic . . . Soooooo . . . the best thing to to is install it with the proper tool and DON'T solder it.

ABOUT THE AUTHOR

Peter H. Burgher, EAA 109613, 2 Brambleberry Dr., Howell, MI 48843, is the owner of MARELCO Power Systems, Inc., the country's leading manufacturer of custom transformers, inductors and power supplies. He holds dozens of patents in his field. With 60 World and U.S. National Flight Records, Pete flies a Colemill Baron and also has a Twin Comanche and a Cassutt hIM Formula racer. In 1994 he founded the Flight Freedom Foundation, Inc. to help protect general aviation airports, preserve our airspace, encourage favorable legislation and promote aviation safety. He was inducted into the Michigan Aviation Hall of Fame in 1995 in recognition of a lifetime of service to aviation.

Mr. Burgher's credentials are impressive. Further, I am pleased for him and his employees if his customers perceive his products to be a good value. Credentials and customer perceptions aside, it's difficult to ignore variances between what he suggests in this article and what has become accepted practices by the aviation community and its

most able suppliers.

This article opens with the words, "I must advise aircraft builders to follow only time tested and approved methods of attaching terminal lugs to wires for use in their homebuilt or even production airplanes."

I object to the word "approved" because fabrication of a system based on good physics and understanding requires nobody's approval. I further object to any implication that these "time-tested" techniques are embraced by anyone but the author. I too have a credential that now spans 40 years in aviation experience and my teachers have taught me differently. Instead of holding forth with "do this because I tell you it's the only right way", my teachers expected me to understand how things worked and why things failed. It's my sincere hope that I've been able to share some of that understanding with you.

"Rules" are edicts from people having the power to punish you for failure to comply. I would prefer to offer my own list of talking points in the interest of fostering good art and science of designing, fabricating, maintaining and flying the world's finest aircraft:

- **Whether you are mashing a terminal under the nut on a threaded stud, squashing strands of a conductor in the wire-grip of a terminal or soldering two metals together for electrical conduction, the performance of the joint depends on the exclusion of gases and moisture from the joint. ANY of these techniques hold the promise of long and satisfactory performance if applied with the "gas-tight" goals in mind.**

- **Every joining of components in an current carrying path has mechanical vulnerabilities. The goal is to minimize stresses on those vulnerabilities. This means you don't allow a wire to wave around under severe vibration such that the terminal is at risk of stress fracture. You SUPPORT the wire immediately adjacent to the solder or crimp joints on terminals by selection terminals with metalic insulation grips installed with tools adequate to the task.**

- **The need for insulation grip adjacent to the wire grip goes down as the size of the wire goes up. Generally speaking, 8AWG through 2AWG sizes live quite nicely with simple soldered or crimped terminals. With larger wires, the TERMINAL is the weak mechanical link . . . fortunately, very few of the fat wires are supported by the biggest shaker in the airplane - the engine. For starter feeds and alternator b-lead feeds, it's a good idea to provide mechanical support for the wire within a few inches of the terminal. The crankcase to firewall ground strap should be fabricated of a bizillion strands of very fine wire like the ground straps offered in our website catalog. Once you move off the engine, concerns for support of fat wires goes down sharply. For smaller 24AWG through 10AWG wires, PIDG style terminals with integral insulation grips are readily available and easily applied with low cost tools.**

- **A ring-terminal's greatest virtue is that it keeps the wire from falling off the stud AFTER the threaded fastener has loosened and AFTER the electrical integrity of the joint is gone. Ring terminals are not the holy grail of wire termination technologies.**

- **Minimize parts count. Reliability, labor and dollars to install, and maintenance efforts are inversely related to parts count.**

- **Minimize the use of threaded fasteners where ever practical. Obviously, when the likes of starter contactors and alternators are PROVIDED with threaded electrical connections, you are obliged to deal with them. But when it come to a choice between a copper plate drilled and tapped for lots of screws as a ground bus, it's a no-brainer decision to opt for a forest-of-faston tabs like that offered from our website catalog.**

- **If you're considering a process-sensitive technique, get some extra materials and practice the process. If you're having trouble getting nice crimps with an inexpensive tool, perhaps an investment of a few more dollars will fix the problem. If a particular technique doesn't work well for you, pick another one.**

- **The variety of tools, materials and joining techniques which may be considered to service some task in your airplane is huge. Every choice has its virtues and limitations. Beware of outright pronouncements prohibiting or praising the use of a particular technology in the name of "safety". Be wary also of words like, "time-honored", "certified", "approved", "authorized", or any other bureaucratic platitude. I'll bet not one bureaucrat in 10,000 ever built an airplane. All of us who live with airplanes know there's no such thing as a safe airplane. Airplanes are dangerous as hell. they have whirring things up front that will mince you in a heartbeat. Flown in to ice or mountain sides, they'll ruin your day. Like automobiles, motorcycles, hand-guns and skate-boards, airplanes are simply tools with a great potential for satisfaction and enjoyment and an equal potential for hazard. Building, maintaining and operating an airplane with a lack of UNDERSTANDING is a religious experience . . . one must go forward on faith that all of the sermons you've taken to heart have any relevance in the real world of . .**

    - **skill . . . .**

    - **UNDERSTANDING of the physics,**

    - **and personal responsibility.**

As always, critical review is welcome. If anyone believes I have erred in my understanding or quotation of fact, I would appreciate a heads-up on the matter.

Fly comfortably . . .

'lectric Bob

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