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Anatomy of a Good Solderless Terminal Connection

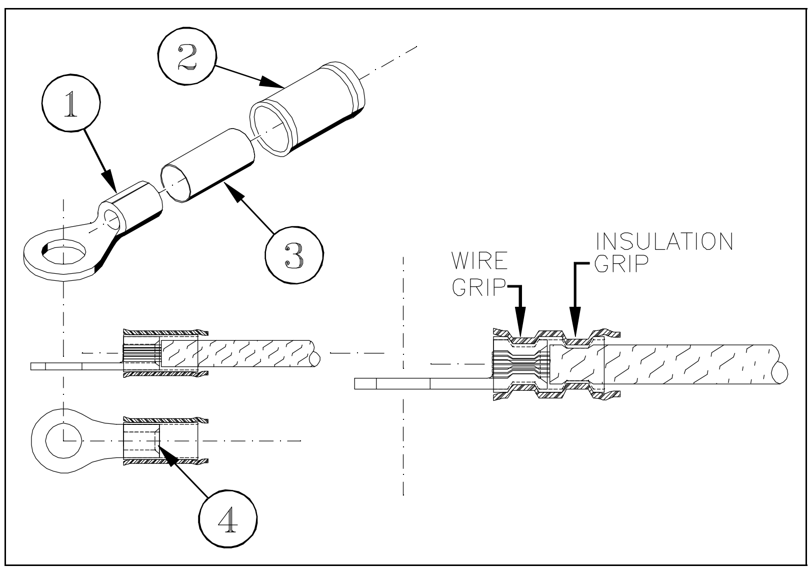
One of the people who looked this article over asked why I didn't title it "***Anatomy of an Aircraft Quality Terminal.***" I would probably have done that twenty years ago; now I'll suggest that the term "aircraft quality" has no quantifiable meaning. But that's a topic for another article. For now, take a few minutes to understand how a really GOOD terminal is made, how it works and what techniques are required to utilize its capabilities.

The first figure illustrates major components of a good terminal. Item 1 is the electrically conductive portion of a solderless terminal. It's made from copper and generally plated with tin to forestall corrosion. Terminals are fabricated in a variety of sizes for both stud size (hole) and wire size (barrel i.d.). In some products, the bare, uninsulated terminal is sufficient for bringing a wire up to a stud. Bare terminals can be used where there are ***no*** vibration concerns. They're commonly seen in a variety of non-vehicular applications.

When any amount of vibration is anticipated, it's important to support the wire close to but separate from the wire grip on the conductors. Flexing of the conducting strands where they leave the back of the terminal barrel must be controlled. Like aluminum, copper is one of those non-ferrous metals that readily stress cracks. When any flexing occurs in the stranding between terminal's wire-grip and end of the wire's insulation, hardening of the wire will occur, precipitating cracked strands and a failed connection.

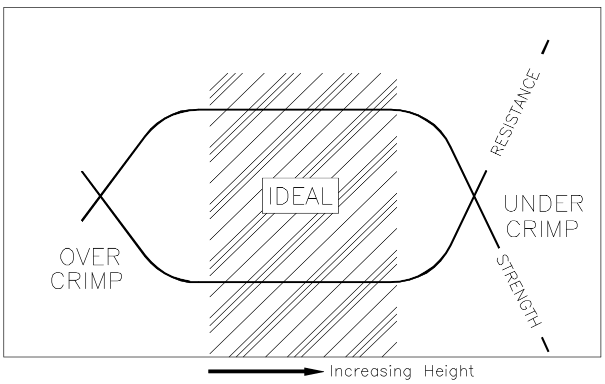
The standard technique for adding support is to slip a malleable plastic sleeve over the terminal barrel and leave it long enough to permit a second, insulation supporting crimp. The plastic sleeve is generally made from nylon but other plastics are suitable. The vast majority of off-the-shelf solderless terminals offered by electrical and automotive parts stores are two piece devices consisting of terminal (1) and insulation support sleeve (2). These terminals are not recommended for use in airplanes. The plastic wire-grip sleeve has a memory. Temperature cycles encourage a pure plastic support sleeve to recover its original round shape! You loose wire support leading to probable failure of the connection.

About 50 years ago, a third component was added to solderless terminals to prevent this problem. Item 3 is a copper sleeve slightly shorter than the plastic sleeve; a metal liner inside the plastic. When the insulation grip crimp is made, the copper liner becomes a permanently formed wire support, effectively overriding any memory characteristics of the plastic insulator. A more obscure feature of a good terminal is a "funnel" shaped entry (item 4) at the back of the wire grip barrel. Not every terminal with a metal lined insulation grip will also have funnel shaped wire guides but they are really helpful. Square entry to the wire grip barrel will more likely snag single strands of wire causing them to fold back under the insulation where they are difficult to detect.



The best terminals are readily identified by inspection: Just look to see if there's a thin copper liner inside the plastic. These terminals are manufactured by many manufacturers including AMP, Incorporated as their "Pre-insulated Diamond Grip" (PIDG) brand and Waldom-Molex in their "Avi-Crimp" brand.

There's a range of styles in crimping tools. MOST will properly install a terminal. The trick in terminal application is to achieve the proper HEIGHT of finished crimp.



The figure above illustrates the relationship between crimp height and two important terminal parameters: electrical resistance and mechanical (tensile) strength. As crimp height decreases, electrical resistance goes down while tensile strength goes up. At some point, both parameters level off showing that further crimping doesn't make the joint any better. Continued reduction in height will eventually upset the strands too much. Strength goes down and electrical resistance starts to go up.

The best tools have ratchet handles. The mechanism prevents under-crimping by forcing the user to operate the tool through its total stroke. When the tool is fully closed, sculptured dies enclosing the terminal barrel work against hard stops thus insuring uniform crimp height. Ratchet handled, hard-die tools from AMP and Molex can start at $100 and go up from there. One of my favorite tools from AMP cost me about $150 in 1965; it costs over $500 now! There are some excellent alternatives in imported ratchet-handled tools offered on our website for $40. Ratchet handled tools will also do a complete terminal installation with a single stroke.

The Low Cost Alternative

Just about everyone has a stamped, sheet metal, rivet-jointed crimping tool in their toolbox. These tools are commonly supplied with a kit of terminals and splices by automotive parts stores in a compartmented container. These tools ***are*** capable of producing satisfactory crimps but they require some practice. The terminals that are sold with them need to be saved for use on your washing machine or stereo speaker system.

First, strip outer insulation from the wire so that when fully seated in the terminal, the ends of wire stranding should just protrude from the stud side of the crimp barrel. Center the appropriate die on the tool over the wire grip section, approx 1/3 of way from stud end to entry end of sleeve. Apply firm grip pressure but it won't take a great effort. When you think you've done it about right, tug on the wire to the tune of 5-10 pounds for 22AWG wire and up to 20 pounds for 10-12AWG wire. What?? you don't know what an 8 pound pull feels like?

Here’s an accurate, poor-man’s pull test for terminal application: (1) Drive a finish nail into the front of your workbench. (2) Hang the terminal lug on the nail and tie a plastic gallon milk jug of water onto a 22AWG wire (red terminals). For 18AWG (blue) use two jugs. For 12AWG (yellow) use three jugs. The task is to do is "calibrate" your grip. The range of pressures required to produce an adequate crimp are quite large and for the most part, you have to really work at over-crimping with low-cost hand tools.

The second crimp is 2/3 of the way along the barrel closed just enough to grip the wire's insulation . . . generally MUCH less pressure than the amount required to grip the wire. There's some ol' mechanic's tales wandering around out there suggesting that wire grip and insulation grips should be put on 90 degrees displaced from each other. This is ***not*** a helpful technique and, in my not so humble opinion, makes for a crummy looking terminal.

The plastic insulator of a finished crimp should have a smoothly sculptured appearance; no sharp indentations or cracked insulation. Some low cost tools ***punch*** an indentation into the side of the terminal barrel. These tools are for ***uninsulated*** terminals on ***solid*** wire. The shapes of proper crimping dies range from oval to rounded-rectangular but in no case is the resulting crimp anything but smoothly molded around the terminal barrel and wire.

Dispelling a Myth

Some folks recommend a combination of soldering in addition to crimped joints for reliability. Keep in mind that the Boeings, Beeches, Pipers and even the lowly Cessnas haven’t soldered a terminal on a wire in over 30 years. People like AMP and Molex have carved an honorable place for themselves in the aviation marketplace selling termination systems that do not require solder to achieve the highest levels of reliability. Please forget the solder.