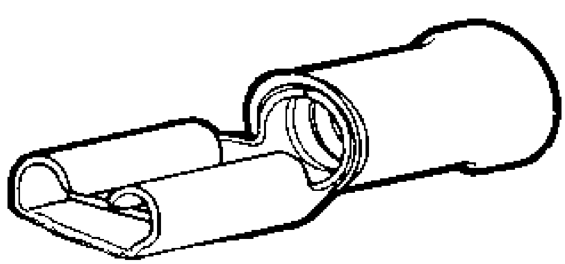
Bob Nuckolls
6936 Bainbridge Road
Wichita, Kansas 67226-1008
Voice/Fax: 316-685-8617
E-mail: nuckolls@aeroelectric.com

FastOn Tabs vs. Ring Terminals . . . What's the Difference?

Attaching wires to components of an electrical system is the most basic of installation tasks. For most connections, the folk who wired your house simply stripped of some insulation and captured the wire under the head of a screw. This technique is well suited to environments where conductors of choice are solid copper and there is no vibration. For vehicles, stranded wire is called for. Generally speaking, as the number of strands in a conductor increases, the wire becomes more resistant to breaks due to flexing. 19 strands is the minimum recommended conductor makeup for aircraft wiring. Further, wires in airplanes should not be terminated by mashing exposed strands under the head of a screw or any other threaded fastener. This type of joint is very susceptible to vibration induced failure. In airplanes, multi-conductor bundles between "black boxes" generally terminate in pin-and-socket connectors with soldered or crimped pins. Simpler components like switches and circuit breakers wired with single conductors terminated with solderless, crimped terminals.



Terminals and Splices
FASTON Receptacles - Insulated

Figure 1.

In this piece, I'd like to explore single-conductor terminations for aircraft. The so called "ring" terminal is familiar to everyone and well suited for attaching wires to a threaded fastener. Traditionally, threaded fasteners have been used on electrical terminals of switches, relays, voltage regulators, alternators, generators, etc. However, there is an alternative fastening method for the smaller wires ranging from 22 to about 12AWG. The technique is marketed under a variety of trade names but AMP, Incorporated's "FastOn" moniker seems to have stuck the tightest. This wire joining technique is characterized by flat, spade-like terminals engaged by formed sheet-metal, female receptacles as shown in Figure 1. Spade terminals may be found in various sizes including .110, .187, .205 and the very common .250 inch widths. Products fitted with these tabs include switches, fuse holders, circuit breakers, lighting fixtures, relays and simple "black boxes" such as lighting dimmers, voltage regulators, etc.

There are several reasons to consider this terminal technology over traditional ring terminals. First, consider a parts count reduction . . . an important measure of system reliability. All other things being equal, a system with one-half the parts count of a comparative design will have twice the reliability. FastOn terminals eliminate the need for a screw and lockwasher at each termination. The FastOn terminals can be reliably mated with bare fingers of one hand by feel alone. Contrast this with the physical dexterity required to juggle terminal, screw, lock washer and screw driver while laying on your back under an instrument panel. It would be nice to actually see what you were doing . . . but cannot because you're hands are in the way. Threaded fasteners are more critical with respect to installation torque. A screw torqued down too loose gets you an open joint under vibration; too tight gets you a twisted off screw-head. There are benefits from a maintenance viewpoint as well; consider being able to replace a landing light switch in two minutes while sitting in the pilot's seat wielding only a nutdriver needed to remove the switch mounting nut on the front!

I presented this same discussion a few years ago in an OSH forum. A gentleman who said he was an IA allowed as how, "those things should never be used on an airplane." When queried he stated something to the effect that they would never pass certification. I pointed out that the rocker switches used on Cessna single engine airplanes since the mid 60's were fitted with FastOn terminals. I estimated that tens of thousands of certified airplanes were flying around with "un-certifiable" connections on their switches! He was unaware of their presence; FastOns have been so successful that no airworthiness directives or service difficulty reports had caused anyone to question their suitability to the task. Given 30+ years of trouble-free history, I see no reason not to take advantage of their features on new airplane construction.

There are a few considerations for the use of FastOn terminals. Like their ring-terminal cousins, you should look for tin plated devices with metallic insulation support liners. Ring terminals are fabricated from fairly soft copper and perform best when clamp-up forces cause the terminal material to yield slightly. This maximizes the area of intimate contact between ring terminal and stud base. A Fast-On works differently. Figure 2 shows a cross-section of a pair of mated, FastOn terminals.

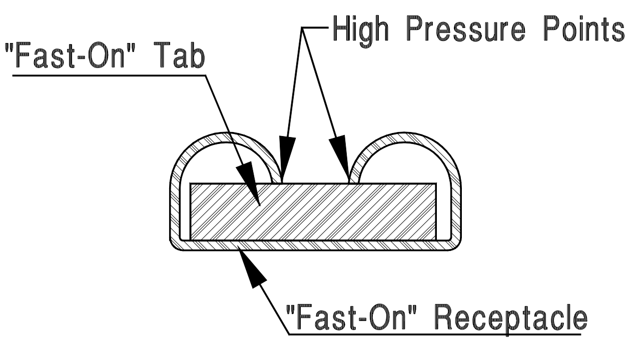


Figure 2.

The secret to good electrical is a product of area times pressure. If a joint is made up with too little pressure, moisture and air will penetrate the joint an promote corrosion which raises resistance which increases heating which accelerates corrosion . . . you can see where this is leading. Obviously, a properly torqued threaded fastener on a ring terminal gets you lots of pressure and in most cases, the cross section of metal in the bolted up join exceeds the cross section of the wire.

In a FastOn joint, satisfactory pressure in the joint is achieved by application of a nominal force over a very small area where edges of the wrap-arounds contact the tab. The pressure in this area is very high; the female terminal actually plows tiny grooves in the surface of the male tab as it slides into place. Of course, the back side of the terminal contributes a significantly to the joint's conductivity but the high conductivity, corrosion resistant connection occurs in the bottom of furrows plowed by wrap-around ends.

There are obvious concerns for vibration resistance . . . FastOns appear as if vibration, shock or a good tug on the wire would pull them right off. But consider the following: I just went to my workbench and gathered the following data: 125 red, FastOn terminals weighs right at 100 gms so each terminal is 0.8 grams. I found a 12-foot piece of 22AWG, Mil-W-22759 wire that weighed in at 25 grams or 2 grams per foot, .17 grams per inch. Let's assume that 18AWG wire weighs twice that. A red terminal was pushed onto a tab and removed using a spring scale where I measured a force of greater than 300 grams to slide it on the terminal tab! So, take 2 inches of 18AWG wire and the weight of a red FastOn for a total of about 1.5 grams. A little basic math shows that it takes an acceleration of over 200 times the force of gravity to dislodge a red FastOn and its 2" service loop of 18AWG. As an added protection against inadvertent disconnects, FastOn terminals have a small circular barb that engages a small hole on the centerline of the tab. This feature substantially increases the force required to remove the terminal.

The nicest feature about this wire termination technology is the convenience. Fuse blocks available from B&C and others perform a complete power distribution and circuit protection function in a single unit that installs in about 10 minutes and a cost of under $2.00 per protected circuit. Use of FastOn terminated fuse blocks makes it possible to install and wire a 30-circuit main and essential bus system in minutes compared to hours for the contemporary compliment of breakers. Best yet, fuse blocks provide equivalent protection of circuit breakers for about one tenth the cost! Many other components such as flashers, relays and switches are readily available with FastOn terminals. I am so sold on FastOns as a wire termination system that virtually all basic system components offered from our inventory feature FastOn terminal tabs. For ease of installation and maintenance along with increased reliability, I recommend you incorporate this technology were ever possible. Looking in on recent list-server conversations about FastOn terminals . . . .

Some people have criticized the FastOn terminals as FastOn FastOff. They feel that they can come off just as easily as they are pushed on.

They're EXACTLY right . . . now how many g's vibration/acceleration do you have to put on them to make 'em move? Consider that a red .25" FastOn weighs about 0.8 gm, 2" service loop of #18 might weigh about 1.0 gm . . . it takes over 200 gm of force to move the terminal on the tab . . . that figures out to more g's than I ever want to experience. . . . They're "easy" to install and remove but not likely to move under normal service conditions.

Do these terminals have a positive locking component to prevent inadvertent withdrawal? How reliable are they in terms of maintaining good, low resistance contact over time and not disconnecting?

They do have a circular detent that provides a sharply increasing force gradient to resist removal . . . it approximately doubles the linear removal force. How reliable do they NEED to be? Did you know that they've been used on the backs of Cessna rocker switches for over 30 years? Probably not . . . because they've never come to light as a service problem . . like the Energizer Bunny they keep going . . going . . going . . .

. . spade terminals ... should not be used but instead, use hole terminals and bolt them on. I work submarines here and "spade" or any type of slip on terminals are not used anywhere.

Obviously, a and open ended "spade" terminal can slide out from under a loose screw head. In addition to the poor connection (which will happen under any loose screw irrespective of terminal type) the open spade terminal can allow the wire to become totally detached with attendant hazards for getting into other troubles. The government may not use slip-on terminals . . . but not necessarily because of their reliability. The US Govmt/Military can afford anything it WANTS for ANY reason . . . I'll suggest that a 30+ years track record for using FastOn tabs in single engine airplanes has been exemplary.

On critical terminals such as the ignition switch I use ring type lugs, I also use solder on throughout the airplane, I don't think hand crimp are a good idea for anything critical to flight safety. In addition I use star lock washers on all of these type connections. . . .

. . . which increases parts count and difficulty of installation in cramped spaces which in turn, drives reliability DOWN. The reason solder gave way to crimped terminals was because the later was LESS process sensitive. Periodically calibrated tools could be used o apply terminals in a factory environment unfriendly to solder and hot soldering irons. In terms of reliability, EITHER system of termination can be good or bad. Over or under-crimping a terminal can lead to early failure. Support of the wire behind a solder joint is just as important as the "second" crimp on a terminal that supports the insulation. . . . When comparing properly installed ring terminals with the FastOn spade terminals, reliability becomes a parts count and failure modes issue . . . FastOn spades win.

I disagree. I've worked building mil-spec and rugged computer systems for the last 23 years for Rolm Mil-Spec, then Loral and now Lockheed Martin and while, I'll grant you, a ring terminal w/internal tooth star washer (or binder head screw in terminal blocks) is always the preferred attachment on mil-spec hardware, (non-the-less) commercial practices are creeping into defense systems everyday.

This is happening because folks are beginning to realize that modern commercial techniques have equaled or exceeded Mil-Spec technologies that have been stagnant for 30 years. I won't even bring up how stagnant FAA mandated technology has become. Many of the specifications to which I've designed most recent projects at Raytheon have been canceled. We're qualifying a new target under the "old" rules but it may never be purchased that way. By the time this critter makes it to production, we expect it to be purchased as an "off the shelf" commercial product. This means we build to a performance requirement . . NOT to a pile of paper that may or may not add value to the product. Just because a device is dubbed "mil-spec" simply means somebody took the time to describe it in a document . . . further, the product will be more expensive and suffer from lack of timely updating. It DOES NOT mean the part will never fail.

That said, I agree with you that a mil spec terminal properly crimped with a properly set tool is the best. Unfortunately the majority of people building don't have that equipment and use the cheap hand crimpers and terminals you find at the car parts store.

I own a couple dozen kinds of crimp tools including the types found at the car-parts store. If you UNDERSTAND what you're trying to accomplish with these tools, they're okay . . . but the reason for development of crimp termination in the first place was eliminate the need for craftsmanship . . . you don't have time to become experienced so use ratchet-handled tools with dies that come down on hard stops . . . these will deliver consistent crimps from one terminal to the next.

I'd prefer a soldered connection with a little heat shrink sleeving anytime over that (referring to the cheapie car-parts tools).

If I had to pack a tool box for repairs in remote locations and had very limited space and weight allowance, crimp tools would NOT be part of the selection. Butane powered soldering tools, heat shrink, solder and BIC lighters would definitely be included . . . . But I'd have no problems using the inexpensive tools to install crimp on terminals if they were available. Either technique will produce very reliable terminations for wire.

If you look inside the modern rugged OTS (off-the-shelf) or NDI (non-developmental item) computers the DoD buys and places in those submarines and aircraft, you WILL see slip-on terminals used. Slip-ons are not the problem per se. Nor is the use of terminals with non-noble metal platings. Further, a properly crimped solderless termination on STRANDED wire is actually more reliable than a soldered one (look in the reliability mil-spec, if you don't trust me).

If there's a difference in reliability between properly soldered and crimped joints, it's so small as to be insignificant with respect to amateur built airplanes. I was talking about FastOn (push on spades) in an Oshkosh forum about four years ago. A gentleman purporting to be an IA jumped up and chastised me soundly for recommending such a thing in airplanes . . . he allowed as how, ". . . you'd never get such a technique certified in a production airplane." As gently as I could, I reminded him and the audience that Cessna had been using the FastOns for over 30 years. The reason that he was UNAWARE of this condition is because in 30 years, it's never posed a problem worthy of an Airworthiness Directive . . . he didn't immediately buy into the idea . . . but peek behind the panel of a 1965 C-172 and tell me what kind of terminals you find on the rocker switches . . .

The problems that you are having are related to proper stress relief of the wired connection, proper harness support and/or the terminal is not a quality item. Stress relief loops in the wire must be provided regardless of terminal type. There should be wire length adequate to allow for two field re-terminations. The wiring harnesses must be immobilized by proper attachment to the structure (adel clamps, tie wraps or similar). The auto store slip-ons (and ring terminals for that matter) are GARBAGE. Get high quality Thomas and Betts or Hollingsworth terminals at an industrial supply house. Make sure that you use the proper slip-on configuration and ensure that the joint is tight.

All excellent points. Crimp-on terminals suited for use on airplanes have METAL liners inside the plastic sleeve that grips the insulation just behind the wire crimp. Any terminal which includes this feature is likely to have been manufactured to more stringent industrial/military requirements (See another article elsewhere on this website for a detailed discussion of solderless terminals). The cheapie tools are useful if you take the time to learn . . . the automotive/hardware store crimp on terminals (no metal liners in their insulation grips) should not be used in airplanes . . . this applies to both RING and FASTON types! The all plastic wire grips tend to "remember" that they were once round. Over time, temperature cycles cause the insulation grip to relieve stresses induced during the installation of the terminal and the plastic tends toward its original shape . . . thus losing a grip on the wire's insulation.

Properly crimped joints do not require soldering as a form of "insurance". When you DO use solder to fasten wires, admonitions against wicking" solder under insulation is easy to comply with by simply applying solder sparingly and getting the job done with minimum time in contact with the hot iron. In any case, a little wicking will happen . . . this is why both soldered AND crimped joints need insulation support.

Use a good quality crimping tool (I like the Thomas and Betts WT-145 for solderless lugs). Don't use a cheap tool from the auto store. With solderless crimp pins (Molex, AMP and similar) use the proper crimp tool. The right ones cost about $80 and maybe someone in your chapter has one (I like the Palladins). . .

The pins being referred to here are formed from sheet metal and require a totally different crimp philosophy for proper installation. These pins are easy to install with $20, non-ratchet tools but it does take some practice. Watch for an upcoming article on the installation of sheet metal pins.

. . . . . . If you have crimped properly, it is as reliable as the wire itself, DON'T solder it or you will reduce the flexibility of the termination. If you must solder to a solder type terminal (solder cup or pierced terminal) be careful not to wick solder up under the insulation and don't "birdcage" the wire strands. Use flexible polyolefin (black or other colors) heat shrink sleeving to complete the attachment so as to provide some gentle support for about 1/4 - 1/2".

Insulation support is equally important in crimped -or- soldered terminals. Whether you crimp or solder, the joint becomes susceptible to vibration induced failure if the wire is allowed to flex right at the crimp -or- the point where solder had forced a stranded wire to become solid. In both cases, support of insulation immediately behind the crimp is important.

I live in Boeing-land here in Seattle, and there is not a solder-joint to be found in any terminal connection in any Boeing jet. The reason is that older causes the wire to *become brittle at the end of the terminal, as well as promotes corrosion of the wire. AND it's heavier.*

The gross weight differences in a single engine light aircraft for crimp versus solder would be measured in grams . . . the major incentive for using crimp terminals is reduced training and skill for consistent results. I'd have no problem using properly assembled soldered joints in lieu of crimp . . but I've been soldering these things together for over 40 years. . .

I know the "Amp" crimping tools are expensive, but we get to go to the Boeing Surplus store to get their used tools for about $5-10 each.

The only caution I have for surplus tools is to know WHY they were discarded . . . some are WORN OUT and do not meet pull-test requirements (. . . again, see crimped terminals article for poor-man's pull tests). About 1/3 of the tools I own were purchased surplus . . they CAN be a good deal. By the way, we stock new, three-pocket, ratchet handled tools suitable for installing terminals on wires 22 through 10 AWG. They are $40 each. We also stock Red (22-18AWG) and Blue (16-14AWG) .25" FastOn terminals in bulk at very low prices compared to most of the world. At the bottom line, I'll suggest that the FastOn terminal is very well suited to aircraft applications. They're reliable, low parts count, and easier to maintain than ring terminals. Components in our future wiring kits will feature the lowly FastOn terminals where ever possible. This is at least ONE case where something used on 20,000 Cessnas is worth repeating!!!!!

Comments and alternative views welcome!