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Getting Started . . .

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From time to time, newcomers to the AeroElectric-List ask about soldering versus crimping of wire connections. Quite often, others who may also be new to the list will offer tid-bits gleaned from their own life-experiences and encounters with individuals who offer what they believe is sound advice.

This topic has been discussed at length on numerous occasions and a great deal of study and thoughtful analysis has produced number of explanatory documents. I thought it might be useful to craft this document as a preamble to the study of wire termination science and techniques. I'll quote some past thread material from the AeroElectric-List along with links to the supporting articles and documents. This re-posting of past materials is driven by a re-organization of directories on the website which causes many of the original links to fail.

An AeroElectric-List thread from 2002. Bob's comments in **bold**.

Hi Gang,

What Bob writes (below) is certainly a factual statement and I don't disagree, *BUT*, my original question was simple and has been referenced by many only in spiritual and oblique references that do not qualify for the "Quantifiable Answer" award. Show me the list of rules"?

> **Who's rules are you interested in? I could sit down and write some. AC43-13 proposes a lot of good "advice" that become "rules" in the hands of enthusiastic bureaucrats. Phil Burger offered us lots of "rules" in his SA article. *(Almost none of which was grounded in good science and industry practice - More on these documents later.)***

The statement, "UNDERSTANDING of the physics, and personal responsibility", is certainly relevant to my question and that is why I asked for a reasonable, definitive and irrefutable answer. I am beginning to believe there isn't one, just hyperbola.

> **The "rule" is that 35 + 26 = 61, your consternation seems to arise from having to make a decision as to whether you add it up in your head, use pencil and paper, a scientific calculator, abacus or super-computer to arrive at the answer.**

It appears that Rick provided the best answer that is available "AC 43-13 1b Chapter 11 Section 14 Paragraph 11-174 a. Selection of Wire Terminals, "Pre-insulated crimp type ring-tongue terminals are preferred."

Okay, call this a "rule" if it makes you feel better . . . There have been too many believable "war stories" that have related to wire failing due to a solder connection, particularly larger ones like the type used on starters and other vibration prone areas of attachment. I must pay attention to these subjective accounts as they convey a certain claim of identifiable truth. What subjective accounts are you referring to? I've never seen a single war story that offered an explanation as to the physics of a failure or a rational engineering or systems approach to keeping it from happening again.

Let's take any war story you find "believable" and do a critical analysis of facts cited to see how they add value to our deliberations.

Until I can be shown otherwise, my larger connections will be crimped.

Fine. I hope you select tools calibrated to the task. I've seen some pretty creative suggestions for things you mash in a vise, pound with a hammer, or squash with a wrench. NONE of the articles I've read for building and using these tools talked about slicing open finished joints to inspect for "gas tightness" under the microscope.

The smaller wires will be soldered only when crimping is not possible. Most, where applicable, will be supported physically near the solder or crimped connection. This is based on the most reliable document to date; the FAA AC 43-13 and AC 65-15 Airframe Handbook. I guess this is what the airlines use.

Are you sure? I wouldn't bet on it. Every airframe manufacturer has it's own set of "rules" . . . we have bookshelves of various and sundry process specifications at RAC . . some read sorta like AC43-13, some read sorta like engineering applications manuals from AMP. Most read like the words of people who have been doing something in a successful way for a long time and want to share that knowledge. I'm curious. How has anything I've suggested argued with the documents you've cited above?

I'm a bit amused at the notion of calling AC14-13 "the most reliable document to date." When AC43-13 was being updated about 6-7 years ago, the FAA sent a draft copy to Earl Lawrence at EAA asking that it be reviewed by folks within the OBAM aircraft community for "gross errors . . . we don't want to get off onto any tangents driven by differences of opinion". They asked for responses in two weeks.

Earl sent me the electrical section and asked for a speedy response. I used up the better part of every evening for a week and produced a document detailing about 90 data points where the proposed update to AC43-13 were at best poor practice and in many cases dead wrong.
I have a copy of what Earl sent back to the FAA. All totaled, I think EAA members had several hundred "suggestions" for improvement to the document. The update scheduled for two weeks didn't happen for months . . . in fact I think it was over a year.

When the revision did hit the streets, many of the suggestions EAA made had been incorporated into the document . . . but far too many did not and new problems were generated in the rewrite. One of these days, I plan to do a "Layman's Guide to the use of AC43-13 Electrical Section" . . . it's going to be a big chore and I'm not looking forward to it.

Bottom line is that what you've proposed for your airplane is going be just fine. Should this be carved in stone to make it a set of "rules" . . . are you looking for a consensus suggesting that anyone who decides to do it differently has placed his future in jeopardy? It's precisely this sort of quest for comfort in traditional techniques and/or bureaucratic decision making that has brought certified aviation to the point it is today

Independence, Kansas: Your #1 source for brand new, 50-year old airplanes . . .

You guys are without a doubt, building the best airplanes to have ever flown . . .

Thanks for your reply and I do appreciate the time you have spent.

No problem. It's what I do . . .

IF I knew anything about this subject I wouldn't have asked for help with *specifics*. I don't have the time to experiment and see who is right (or wrong). You are generally regarded as a guru in your discipline and I had hoped there would be a "reasonable, definitive and irrefutable answer", Since I have not been shown anything (by anyone), I guess I need to choose what seems to be the safest course of direction.

I am not trying to argue or diminish your knowledge on the subject in any form or fashion. I simply need a document that will be an accurate guide and keep me out of trouble. The 43-13 is generally regarded as the "accepted" methodology, not withstanding an heretofore unseen document that would supersede the 43-13 handbook.

You mention that you could sit down and write some. Let me tell you that would be welcomed with open arms throughout the experimental community. I have read a lot of what you have wrote and it makes a lot of sense. A document about wiring in an vibrating environment would be a great asset to our community. "To Solder or Not to Solder". <g>

Okay, fair enough. Here are the "rules" by which Bob Nuckolls would wire his own airplane:

RULE 1:

First choice for joining/terminating any wires up through 22 through 12AWG are PIDG style terminals as described in

http://aeroelectric.com/articles/terminal.pdf

. . . using tools like those illustrated in:

http://aeroelectric.com/articles/CrimpTools/crimptools.html

. . . or better.

But avoid anything that looks like:

http://aeroelectric.com/Pictures/Tools/Crimp_Tools/crimp_pliers_1.JPG
http://aeroelectric.com/Pictures/Tools/Crimp_Tools/crimp_pliers_2.JPG
http://aeroelectric.com/Pictures/Tools/Crimp_Tools/crimp_pliers_3.JPG

Further, be aware that many journals of stature (Sport Aviation) and publishers of edict (FAA, etc) are not infallible. Excellent examples are illustrated here . . .

http://aeroelectric.com/articles/rules/review.html

and (Caution! 28 MByte Document! Takes some time to download)

http://aeroelectric.com/Reference_Docs/FAA/AC43.13-1B_Change1.pdf

There are “rules” in AC43.13 that are poorly crafted and/or cannot be complied with . . .

RULE 2:

Where there is a choice, I would select fast-ons over threaded fasteners in the 22 to 14 AWG range using

terminals like:

http://www.aeroelectric.com/Pictures/Terminals/fastons.jpg

. . . with features as explained in

http://www.aeroelectric.com/articles/faston3.pdf

. . . while avoiding terminals like:

http://aeroelectric.com/Pictures/Terminals/NonPIDGFastOn.jpg

RULE 3:

When I have to live with a treaded fastener then these terminals are in order . . .

http://www.aeroelectric.com/Pictures/Terminals/s816p.jpg

RULE 4:

For wires larger than 12AWG, then I would solder and heat shrink joints as described in . .

http://aeroelectric.com/articles/big_term.pdf Using materials like . . .

http://www.aeroelectric.com/Pictures/Terminals/s812.jpg

and use with double-wall heat shrink for finishing.

RULE 5A:

Permanent splicing of single conductors to be accomplished with butt splices like . . .

http://www.aeroelectric.com/Pictures/Terminials/s816.jpg

or lap splicing as shown here . . .

http://aeroelectric.com/articles/Solder_Lap_Splicing/Solder_Lap_Splices.html

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RULE 5B:

But if it was deemed desirable to break the splice open for future convenience, a knife splice and heat shrink would be used thus . . .

http://www.aeroelectric.com/Pictures/Terminals/ksplc2.jpg

RULE 6:

When the accessory items are supplied with nylon connectors like AMP Mate-n-Lock or Molex, pins are installed with a tool like . . .

http://aeroelectric.com/Pictures/Tools/Crimp_Tools/bct-1.jpg

http://aeroelectric.com/Pictures/Tools/Crimp_Tools/obc-1.jpg

and installed thus . . .

http://aeroelectric.com/articles/matenlok/matenlok.html

These connectors would only be used as an accommodation for the use of an accessory that comes with them already installed. They are not my connector style of choice for any other applications. Now, is this "rule" accepted by anyone else? Probably very few places. Are the open barrel pins ugly, evil or unsuited to the task? Not necessarily, they're just not my personal first choice of technologies and I don't stock the parts in my shop except to address repairs.

RULE 7A:

When working with accessories supplied with D-sub connectors, the first choice of mating connectors is the removable pin variety that will accept machined pins like . .

http://aeroelectric.com/Pictures/Connectors/s604.jpg

installed with a tool like . . .

http://aeroelectric.com/Pictures/Tools/Crimp_Tools/rct-3.jpg

http://aeroelectric.com/Pictures/Connectors/RCT-3_Male.jpg

and removed with a tool like . . .

Http://aeroelectric.com/Pictures/Tools/dse-1.jpg

http://aeroelectric.com/Pictures/Tools/dse-1a.jpg

RULE 7B:

If for any reason the crimped-pin mating d-sub is not available, then soldering is my second choice using techniques described in . . .

Http://aeroelectric.com/articles/dsubs/d_solder.html

. . . and tools like

http://aeroelectric.com/Pictures/Tools/s101_1.jpg

or better

RULE 7C:

If options 7A and 7B are not practical, then the lowest order choice for working with d-subs is open barrel crimped pins installed with a tools and techniques like those described in RULE 6.

RULE 8:

Installation of connectors on coaxial cables to antennas are installed per

http://aeroelectric.com/articles/bnccrimp.pdf

using tool . .

http://aeroelectric.com/Pictures/Tools/Crimp_Tools/rct-2.jpg

RG-400 coaxial cable and crimp-on connectors like . . .

http://aeroelectric.com/Pictures/Wiring_Technique/custcab.jpg

http://aeroelectric.com/Pictures/Connectors/crimpbf.jpg

http://aeroelectric.com/Pictures/Connectors/crimpcf.jpg

http://aeroelectric.com/Pictures/Connectors/s605cm.jpg

But if you really need to get a connector installed TODAY and all you can find is the venerable solder-on . . .

http://aeroelectric.com/Pictures/Connectors/clampcm.jpg

. . . these would be fine too

RULE 9A:

A single point ground system shall be established behind the instrument panel with sufficient attach points for all accessories in the cockpit area. In deference to RULE 2, a forest-of-fast-on-tabs ground block similar to . . .

http://www.aeroelectric.com/Pictures/Grounding/gnd_bus.jpg

The threaded stud on the ground block assembly would penetrate the firewall and be used to terminate battery (-) leads on either side of firewall and the crankcase ground strap on the engine side of the firewall.

In the case of canard pushers with the battery up front, the ground bus would be mounted forward of the instrument panel. If the airplane's firewall is metallic, then a brass bolt and appropriate washers and nuts would be used to provide an engine compartment ground stud and connection of the ground lead to the firewall. A ground strap like . . .

http://aeroelectric.com/Pictures/Wiring_Technique/bbs.jpg

or

http://www.aeroelectric.com/Pictures/Wiring_Technique/sbl.jpg

. . . will be used to connect the crankcase to the firewall ground stud. The welding cable illustrated in the

last photo above would also be used to make the short, VERY flexible jumpers from battery (+) and (-) terminals.

Any ground straps provided around the rubber biscuits of an engine mount will be removed. Engine mounts are for holding engines on airplanes and not use for any part of the electrical system.

RULE 9B:

Avionics and other electrowhizzies on the panel would benefit from an "avionics/panel ground bus" as described in the latest revision of the 'Connection. See:

http://aeroelectric.com/articles/Rev11/18Audio_R11.pdf

and . . .

http://aeroelectric.com/articles/Rev11/AppZ_R11J.pdf

and illustrated in . . .

http://aeroelectric.com/Pictures/Grounding/AGB_V.jpg

http://aeroelectric.com/Pictures/Grounding/AVG_RA.jpg

http://aeroelectric.com/Pictures/Grounding/Avionics_Bus_3.jpg

http://aeroelectric.com/Pictures/Wiring_Technique/Avionics_Ground_3.jpg

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RULE 10:

Tefzel wire used throughout with the exception of cranking circuit fat wires where 4AWG or 2AWG welding cable would be used. An alternative FAT wire could be one of the new copper-clad aluminum wires. These new materials are as solderable and crimpable as pure copper conductors.

Caution
To get the same electrical performance, you need to use about 2AWG steps larger wire than for copper but the installed wire will still be lighter.

Here endeth the reading of Bob's rules. In parallel universes there are differing rules which may well prove to be as useful or perhaps even better than those cited in Bob's universe. Given what Bob has learned up to and including today, Sunday, February 12, 2006 (and revised in January 2007) the rules cited above are his personal choices for practical, solid techniques using moderately priced materials, and tools. Adherence to these rules is likely to produce an electrical system where (1) component wear-out and failure are the sole causes for maintenance and (2) the wiring can be expected to perform as intended over the lifetime of the airplane.

Here is how I perceive the question, "When can you use solder on a #2 wire?" Answer, "Well, that depends!". I can't deal with that kind of an answer. Unfortunately that is all I have been getting from our canard community rank and file.

Yes, it does depend . . . on only one thing. Whether or not YOU WANT to solder wires. If any of the rank and file disagree with this, please invite them to bring the facts as they perceive them over to the AeroElectric-List. If I'm unaware of some critical information on the matter, I and about 1,300 others on the AeroElectric List are interested in knowing what it is.

This isn't a battle of wills or a turf war. We need to be constantly evolving the art and science of building airplanes based on physics. If I am in error, nobody is more interested in knowing about it than I am.

> An earlier statement: Let's take any war story you find "believable" and
> do a critical analysis of facts cited to see how they add value to our deliberations.

Bob, you are getting picky here, I must have hit a nerve, I didn't mean to. Take my word for it however, there have been recent posts of this and breaking because they were soldered. I just am not going to find them at this time as most were bad work anyway. One fellow emailed me and stated a bad crimp is just as bad a bad solder. Hummmmm?

Not at all . . . and I don't leave my nerves hanging out for anyone to hit. You brought up war stories as having an influence on your deliberations. I've written many times and with extreme disfavor upon what I call "Dark and stormy night" stories as useful data for the design and fabrication of an electrical system. I'll suggest that most of those stories came about due to a lack of understanding on the part of pilots, manufacturers and bureaucrats as to what it takes to produce a reliable flight system. See:

http://aeroelectric.com/8-%3E9/ch17-9.pdf

Our goals for crafting airplanes that stand head and shoulders above the spam-cans are easy: (1) design for failure tolerance and (2) take on the responsibility to learn how to use ANY chosen assembly technique effectively. There will ALWAYS be failures of one kind or another in ANY system. Yeah, you might even burn a soldered terminal off the end of a wire cause you didn't put it on right . . . but you might burn a crimped terminal off too for EXACTLY THE SAME REASON.

You mentioned $120.00 for a tool. To me that is not an outrageous price. I'll look into them shortly. I suspect I will need several. Perhaps you could recommend one.

Not $120 for ONE tool but the WHOLE SET of tools. The sum total expenditure for the tools I've cited above should cost about that much . . . maybe a bit more.

When I amuse my wife she becomes exuberant and happy. I hope I have effected you in the same manner. <g> If you consider that no other document has been offered, except the 43-13, to answer my specific question, I guess it accurately fits the description. All I have seen are several multi page documents, although well written, do not answer my original question regarding solder in the vibrating arena.

The exuberance and joy comes not from amusement but as my wife puts it, "from seeing the light bulbs come on". She too is a teacher. We have both noted that the biggest boost a teacher gets is to stand before a class with a task to impart knowledge and understanding of that knowledge. When someone's response from the class shows that a light bulb just came on . . . that's a rush!

I've made the statement numerous times and will repeat it here. There is no significant difference in a properly soldered versus properly crimped joint on a wire. Crimping takes specialized tools and less skill; soldering uses very in-expensive tools and takes some practice. I cannot cite any reason for saying that one technique is better than the other with respect to service life in your airplane.

Further, the citations of photos and articles above should suggest that there's a lot more to crafting a reliable electrical system than deciding whether to crimp or solder your joints.

There's an interesting corollary to this situation illustrated by a very sad accident about 25 years ago. See:

http://www.planecrashinfo.com/cvr721229.htm

Here's an example of how the whole cockpit crew became preoccupied with a detail . . . a burned out lightbulb. Somebody forgot to fly the airplane. Soldering vs. crimping is one of those little details that can be very distracting when you're needing to put your arms around the big picture. It's easy, as I've demonstrated, to put the solder/crimp issue to rest and move on.

> An earlier statement: One of these days, I plan to do a "Layman's Guide
> to the use of AC43-13 Electrical Section" . . . it's going to be a big
>chore and I'm not looking forward to it.

It would appear that it is a badly needed document. Having been inundated with just about every "war story" and Uncle Herbs snake oil remedy for proper wiring, I would personally be relieved to have in my possession such a document. All kidding aside, you should dedicate it to me. I represent the many who don't know but will admit it. <g>

You may be making it more complicated than it needs to be. A good illustration of no-value-added complexity is the EXP-Bus. A few years ago at OSH, a guy behind the counter hands you this whippy assembly that looks really complicated. See:

http://www.aeroelectric.com/Pictures/Misc/EXPBus_1.jpg

. . . and it only costs $300! You hold the thing in your hand an think, "Damn! I'd NEVER be able to figure out something like this," while the guy behind the counter tells you about all the whippy things it will do and how much "time it will save." The question you don't know to ask and he doesn't offer is "Does this product offer the simplest, lowest parts count, equal or better performance result at the same or lower cost of ownership." I.e., is the elegant solution? My answer to that question is, "No, it does not." See:

http://aeroelectric.com/articles/expbusad.html

http://aeroelectric.com/articles/expbusthd.html

I've taken a lot of incoming over these two threads but understand this: The ExpBus is not an unsafe product and it probably delivers on all the operational features offered. My objection is that for the SAME or less money and very little if any difference in time to install, you can craft a system that EXACTLY matches your design goals with a lower cost of ownership.

When you pick up an English language dictionary, one finds perhaps 100,000+ words contained therein of which most literate adults use less than two percent of the total. Yet we communicate very well. AC43-13 is a similar document. It's a real piece of work and LOOKS important because its got this whippy government agency seal on the cover.

There are a handful of core facts, fundamentals, simple-ideas, etc. around which 95% of your system will be designed and built. The dictionary, ExpBus, and AC43.13 toss in a LOT of extra ideas which may not be wrong but stirring them into your design just because they're offered by someone in authority or who claims more knowledge is not helpful. It's precisely this sort of quest for comfort in traditional techniques and/or compliance with bureaucratic decision making that has brought certified aviation to the point it is today . . .

One has to approach this with a quest for understanding and a willingness to take on new tasks and learn new things. If you lack these drives, then the ExpBus or Van's turn-key kits are the way to go . . . and there

is very little to be gleaned from the AeroElectric-List other than the selection and application of wiring tools.

You have a valid point. I only wish my Long will be around as long and respected as the veritable DC-3.

No-biggie. Solar UV is going to rot the poor bugger to dust before any of your wiring falls apart.

Again, thanks for your time. I do feel honored that someone of your stature has taken the time to try and straighten me out and be a help.

Another no-biggie. It's what I do. You've simply fallen victim to a blizzard of non-information that provides job-security for certain classes of worker citizens in other aviation venues. You're really better prepared than you think you are but pouring over a document that is 95% floobydust will only make the answers harder to find and understand. Put down your copy of AC43-13 and let's get started on your airplane. If questions come up along the way, you'll get better answers TAILORED to your situation from knowledgeable folk here on the List than you'll get out of that document.
How to craft your project's wirebook

Begin by selecting one of the Z-figures from the latest version of Appendix Z which may be downloaded from . . .

http://aeroelectric.com/whatsnew.html

Use the SIMPLEST diagram that will meet your mission requirements for OPERATION . . . try to get a grip on perceived mission requirements based on fear of failures . . . I have way too many builders throwing Z-14 into RV-6s and this kind of redundancy just doesn't make sense in that class of airplane.

Be cautious too about enhancing or trimming features shown in the Z-figures. These drawings have been crafted over the past 20 years based on conversations with thousands of builders. I think that taken as-printed, one of these architectures will meet your mission needs. I'm not for a moment suggesting that you should feel prohibited from making changes . . . after all, it IS your airplane. I am suggesting that you fully understand how any changes you think you need to make will benefit your final project. Resist temptations to ADD complexity unless that addition addresses a real mission requirement or probable failure mode. Get on the AeroElectric List . . .

http://aeroelectric.com/consulting.html

. . . and let's talk about your changes.

Make your own version of the selected Z-figure but don't add too much detail . . . show just the distribution paths, hardware and indicate which systems derive power from which busses. Then start a collection of Page per System drawings . . . one for EACH of the proposed systems to be installed. See the collection of drawings at . . .

http://aeroelectric.com/PPS

. . . and specifically. . .

http://aeroelectric.com/PPS/DCPwr/Ground_Power.pdf

http://aeroelectric.com/PPS/Flight/Flaps_1.pdf

http://aeroelectric.com/PPS/Flight/Trim/PitchTrim.pdf

http://aeroelectric.com/PPS/Lighting/Instrument_Lighting1.pdf

These drawings are EXAMPLES of how you take a 3-ring binder and assemble a COLLECTION of single page drawings each one of which describes one of the systems in your airplane. You might sort them by chapters. E.g.,

Chapter 1.0 . . . . . DC Power
Chapter 2.0 . . . . . Engine
Chapter 3.0 . . . . . Fuel Delivery and Gaging
Chapter 4.0 . . . . . Instrumentation
Chapter 5.0 . . . . . Lighting
Chapter 6.0 . . . . . Flight Surfaces
Chapter 7.0 . . . . . Audio System
Chapter 8.0 . . . . . etc

This is very much like we do it in the "big house" on biz-jets. The nice thing about this documentation technique is that while the sum total of your airplane's electrical system has considerable complexity, you can attack the task just like you go about eating an elephant . . . one spoonful at a time.

Further, in later years when you need to troubleshoot a system, everything you need to know about the malfunctioning system wiring is on one sheet un-cluttered with wiring for other systems.

If anyone spots a broken link or has some suggestions about additional materials that could be included in this document, drop me a note at:

http://www.aeroelectric.com/bob.nuckolls/

Keep the dirty side down and the pointy end forward!

'Lectric Bob . . .