THE SPORTPLANE BUILDER

BY TONY BINGELIS, 8509 GREENFLINT LANE, AUSTIN, TEXAS 78759

WIRE INSTALLATION PRACTICES

WIRING AN AIRCRAFT involves two basic activities:

1. Installing the electrical equipment where it needs to be or where you want it to be.

2. Connecting it to a power source (battery/bus bar, etc.) using wires.

You may not have thought about it, but most of the equipment that you put in your airplane has to go in some specific location and nowhere else.

How about navigation lights and strobe lights? They have to go out on the wing tips and tail in order to produce the proper light distribution patterns required by the FAA (essentially an approved anti-collision strobe light system is one that projects the light 360° around the aircraft's vertical axis and plus 30° above and 30° below the horizontal plane of the aircraft). Of course, we know that slight variations are acceptable - like installing strobes above and below the fuselage. Only two lights are required in that case. But what about the navigation lights? They still have to go out on the wing tips and tail, don't they?

Other equipment like the magnetos (on the engine), the instruments and switches in the cockpit (within your reach and line of sight) as well as radios and antennas all have mandated locations.

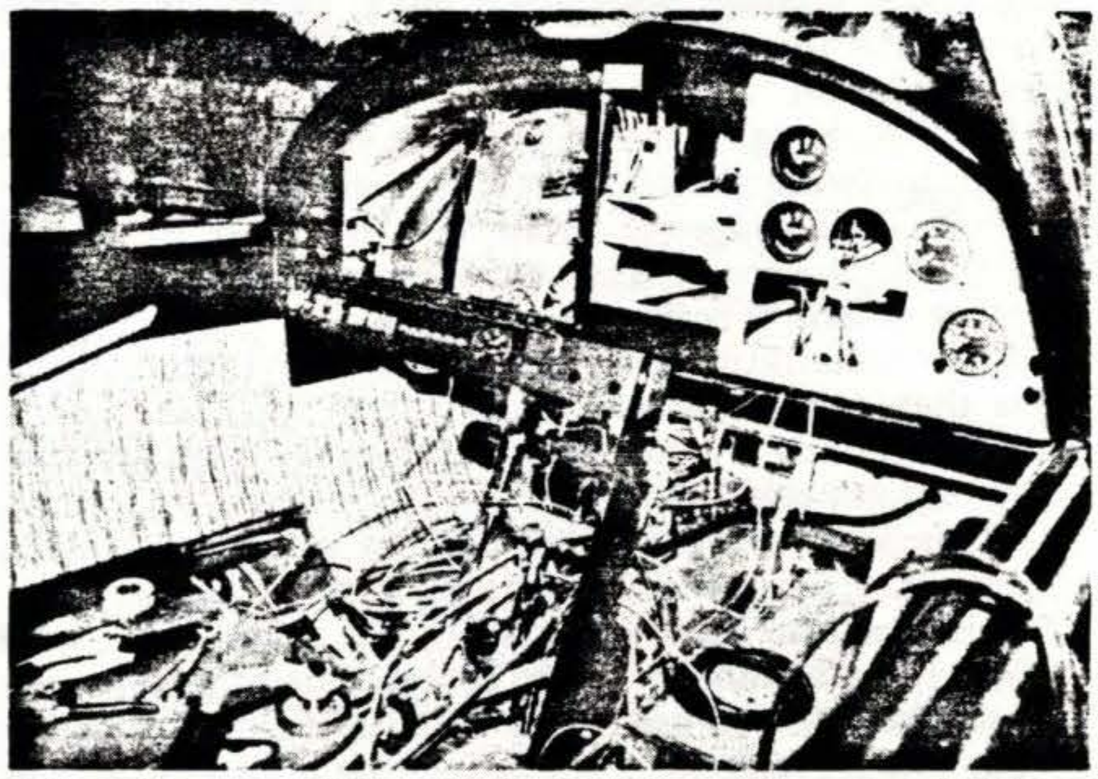
Isn't there some equipment you can install wherever you wish? Sure . . . how about your battery? You can put it in the engine compartment, baggage compartment or stick it way out in the tail. However, even in this instance you may be forced to accept a location that is not your own preference because of weight and balance considerations. Anyhow, it is plain that the point of installation for most of the equipment on board is more or less established for you.

Cheer up, lads, you can still exercise your creativity and run your wires anywhere you want . . . provided, of course, that one end is connected to the installed equipment and the other (end) ends up in the cockpit somewhere.

The point I want to make is that wiring an aircraft is not a complicated or a mysterious ritual requiring profound knowledge. Each piece of equipment requires its own circuit and it is complete in itself.

Get all of the different pieces of equipment wired one by one and you will have a number of circuits comprising what is essentially the life support system of an aircraft - particularly a complex aircraft.

By complex I mean one equipped with at least an electrical system (magnetos have their own self-contained circuit), a starter and a few pieces of equipment. Of course,



A hopeless mess? Sure looks like it even though only 10% of the wiring is in place at this stage. However, the wiring process is not as bad as it always looks if you take one circuit at a time and keep the wires labeled at both ends.

when you add radios, electric flaps and gear, electric trim, instruments, a vacuum system and strobe and navigation lights, as well as an onboard computer, you cannot have any doubt that you will have one complex bird just loaded with electrical wires. Such an aircraft, in the advanced stages of wiring, will present an awesome sight. However, it helps to remind yourself that each electrical unit requires, for the most part, only a simple wire circuit and that each wire has only two ends. This fact serves to emphasize the importance of properly preparing the wire ends so that one end can be securely attached to the equipment and the other to the power and cockpit switching source with the assurance that you will have a reliable electrical circuit.

Terminating Wires

Twisting the ends of a wire to form terminal loops while suitable for some household wiring functions, is not an accepted practice for aircraft wiring.

You should always obtain and use the proper type and size terminal connector for the gage of wire to be installed.

Almost all terminal connectors used in aircraft work are of the insulated solderless crimp-type. Many of these are readily available locally (Radio Shack, auto parts stores, etc.).

The selection of the correct solderless pre-insulated terminals is simplified because they are color coded to identify the standard wire sizes that can be terminated by each terminal size.

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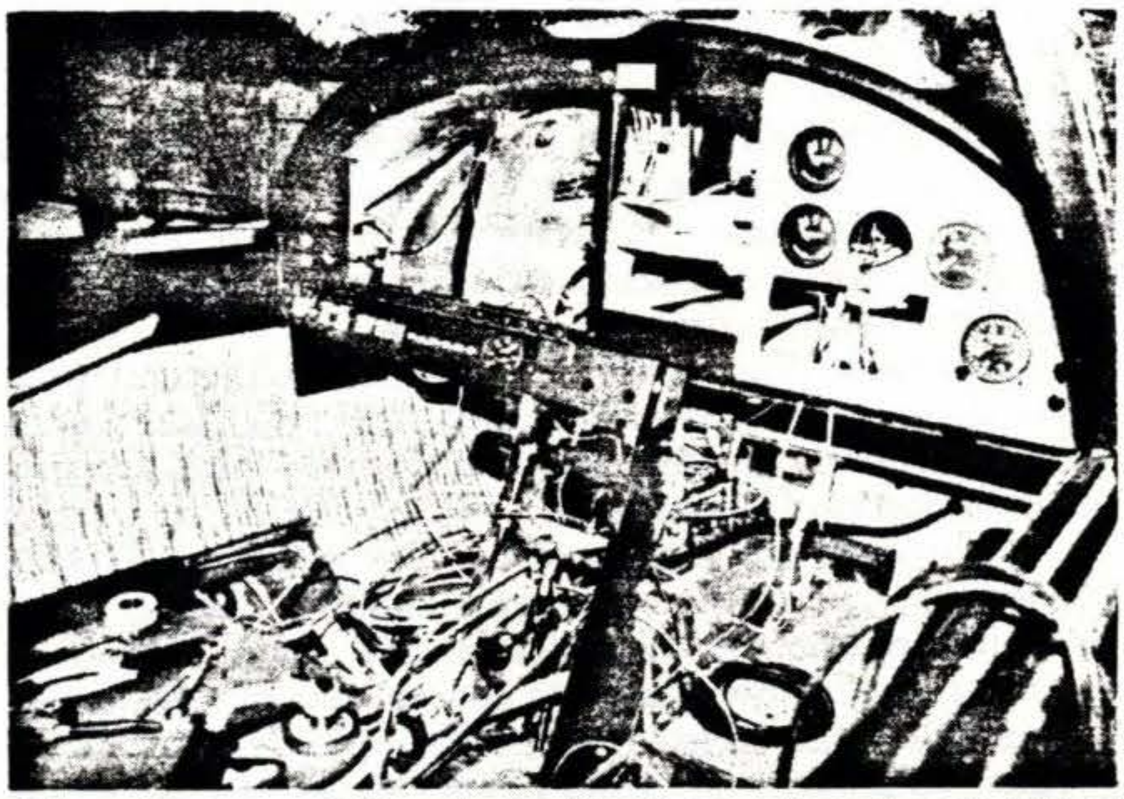

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The selection of the correct solderless pre-insulated terminals is simplified because they are color coded to identify the standard wire sizes that can be terminated by each terminal size.

TABLE 1

COLOR CODING OF COPPER TERMINAL LUG INSULATION

Color of Terminal Lug Insulation	To Be Used On Wire Sizes
Yellow	#26 - #24
Red	#22 - #20 - #18
Blue	#16 - #14
Yellow	#12 - #10

source: NAVAIR 01-1A-505

The insulation forms part of the terminal lug and extends beyond its barrel. This protection makes the use of a separate insulation sleeve unnecessary. In addition to that, better quality lugs have a metal reinforcing sleeve beneath the insulation for extra gripping power on the wire insulation.

Note: Although it is unlikely that you will come across aluminum terminals in the smaller sizes, you should know the rule - use copper connectors with copper wires and only aluminum connectors with aluminum wires to avoid creating potential corrosion problems.

Radio installation work requires more soldered connections than crimp-type connections. The mike and phone jack connections are, for many builders, the most troublesome to make and maintain for this reason.

These jacks are connected by very small wires. As a consequence, when the wires are soldered to the lugs, they are stiffened and become brittle at that point. If the wire is flexed, the bending tends to concentrate at a point just beyond the soldered area. A few flexes of the wire and it breaks. To prevent this from happening to you, try one of the installation precautions illustrated in Figure 2. That is, either reinforce the soldered connections with heat shrinkable sleeves or immobilize the wires against flexing beyond the soldered joints by installing tie-wraps.

You may experience another problem with soldered connections long after your airplane has left your workshop. This happens when you find that you no longer have access to electricity for operating a soldering iron. Hence, no soldering repairs unless you are willing to invest in a battery powered soldering gun.

Crimped Terminals

For the most part, builders usually try to avoid having soldered connections in their electrical wiring and depend almost entirely upon the use of solderless insulated crimped terminals. This is good practice as the typical crimped terminal can be made quickly and will provide a good electrical connection provided the correct size terminal is used for a particular size wire.

To install a small crimp-type terminal, strip away approximately 3/16" of the insulation from the end of the wire (wire strippers are nice), or just enough of it that the wire end protrudes slightly when inserted in the terminal lug. Crimp is with crimping pliers.

Be sure the terminal size is correct for the wire size being used. If not, either the wire will not go in or, if it does, the crimp will be ineffective and the wire will pull out.

Always check a completed terminal by pulling on it slightly. It should not separate. Should the terminal pull off you should use the next smaller size terminal, or, if you must use the same size terminal, strip off a bit more insulation from the end of the wire and fold it back to

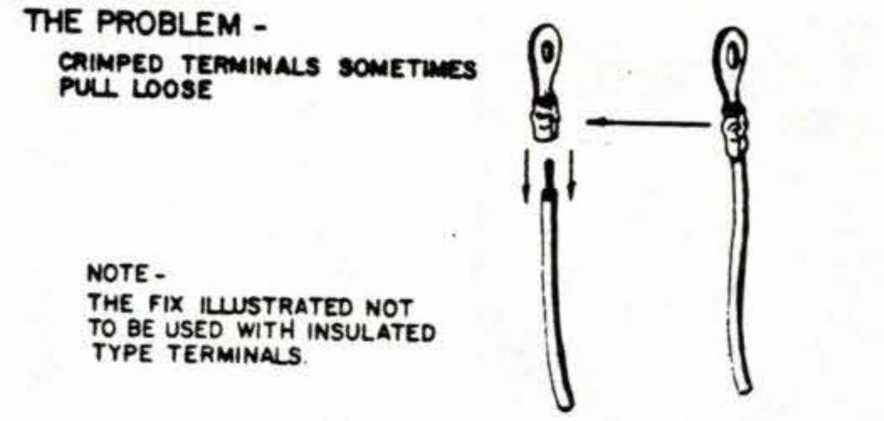
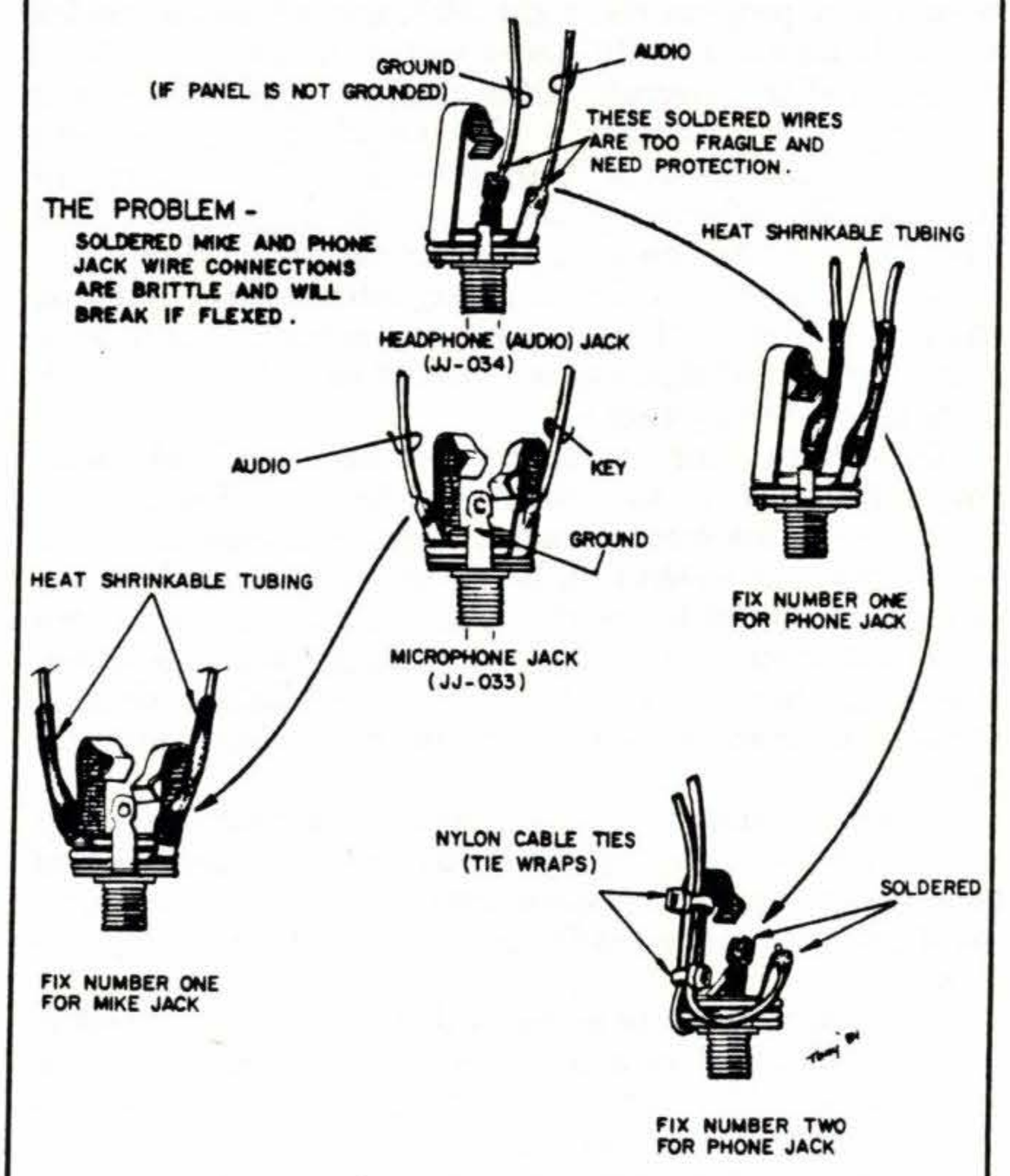


FIGURE 1.
MAKING FAIL-SAFE TERMINAL CONNECTIONS



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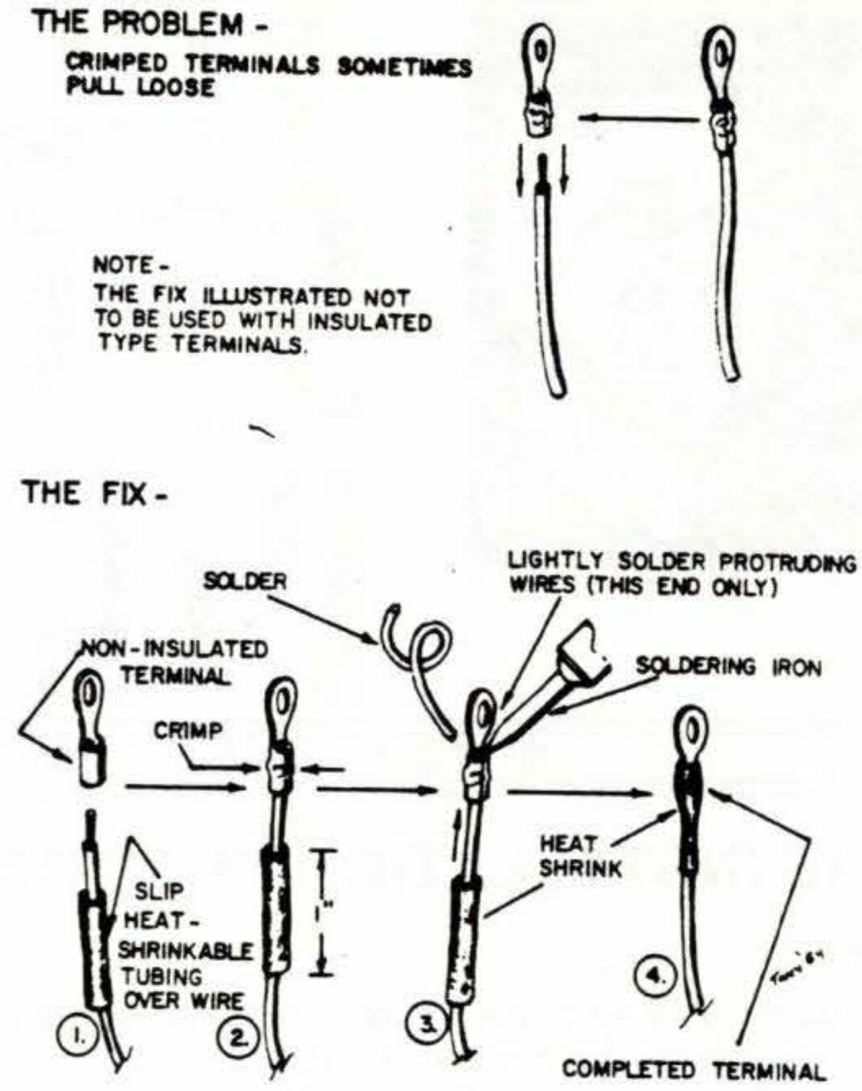

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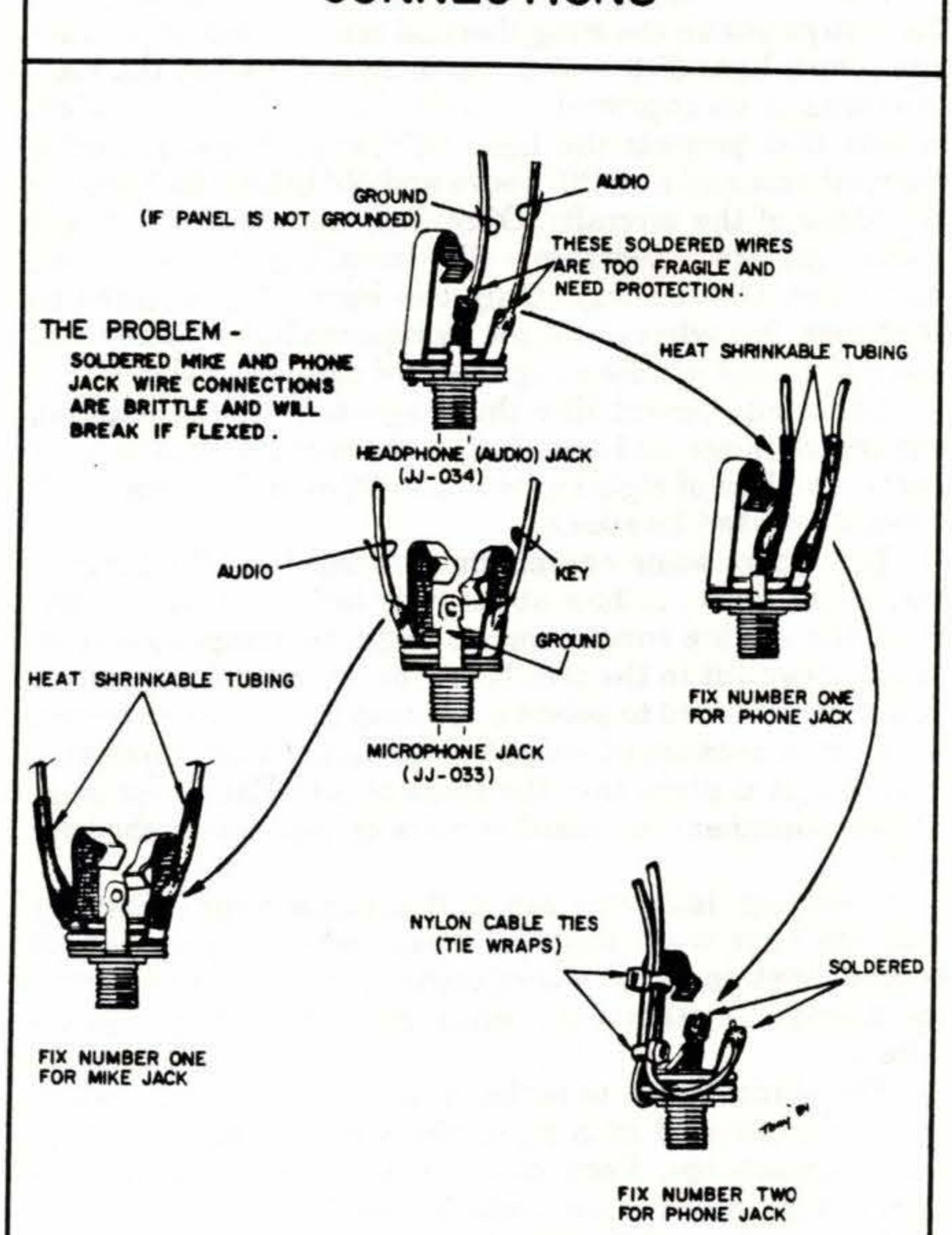

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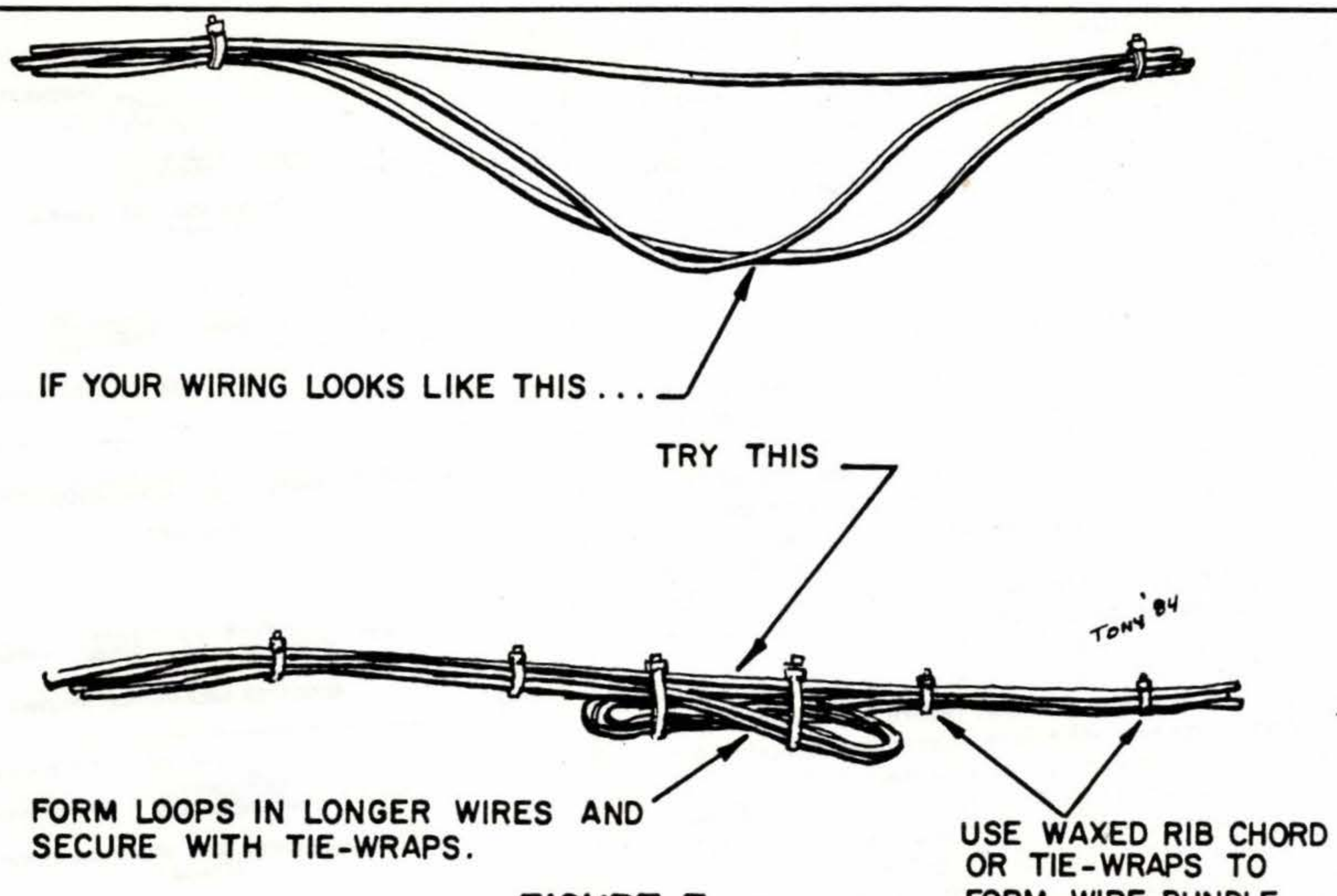


FIGURE 3.
TWO OR MORE WIRES SHOULD BE BUNDLED

increase its diameter. Fit the wire and crimp the terminal in the usual manner.

Other situations may arise where you will have to make an odd-ball connection like splicing a heavy wire to a thin wire or joining two wires to a single heavier wire (see Figure 4 for these and other examples).

If you are experiencing trouble in obtaining a reliable crimp on your uninsulated terminal connections, you can be assured of good connection with just a little extra work. Crimp the uninsulated terminal in the usual manner and then lightly apply solder to the tongue or ring end only. This will yield a connection that will not pull apart. To insulate the terminal and to further strengthen the connection, slide on a short section of heat-shrinkable tubing and shrink it over the completed terminal and wire.

Heat Shrinkable Tubing

If you are not already familiar with the versatility and usefulness of heat shrinkable tubing in the construction of an airplane, you should give it a try.

This is an excellent material to use on most all electrical wire terminations and splices. The polyethylene tubing (source: Radio Shack, auto parts, etc.) may be shrunk to about ½ of its original diameter or to the desired size by applying dry heat to it. Not only does the heat shrinkable tubing serve to insulate the terminal connection and protect it from electrical faults, it also strengthens the connection.

The hardest part about using heat shrink tubing is in remembering to slip a short sleeve of the material over the wire BEFORE you install the terminal. Then after the terminal has been crimped or soldered, you can slide the sleeve up over the terminal lug and shrink it tightly in place with a hot-air gun or any other concentrated heat source.

A soldering iron is often used as a convenient heat source. Be careful, however, that the iron is not held in one spot too long. Try to keep the localized heating under 300°F (about 275°F to 300°F is about right) or you might start to melt the sleeve and possibly damage the encased wire. Rotate the wire while applying the heat in order to distribute the heat and shrinking evenly.

Applying additional heat after the sleeve has shrunk (allow about 30 seconds) is useless. It will shrink no more. If after the shrinking the tubing does not snug up around the wire, it was too large and you should have used the next smaller size tubing. There's nothing to do but to repeat the procedure with a smaller heat shrinkable tube. **Note:** Use heat shrinkable tubing over Nicopress control cable terminal cut ends and you will never again suffer the pain of being stabbed by the inanimate but vicious wire strands.

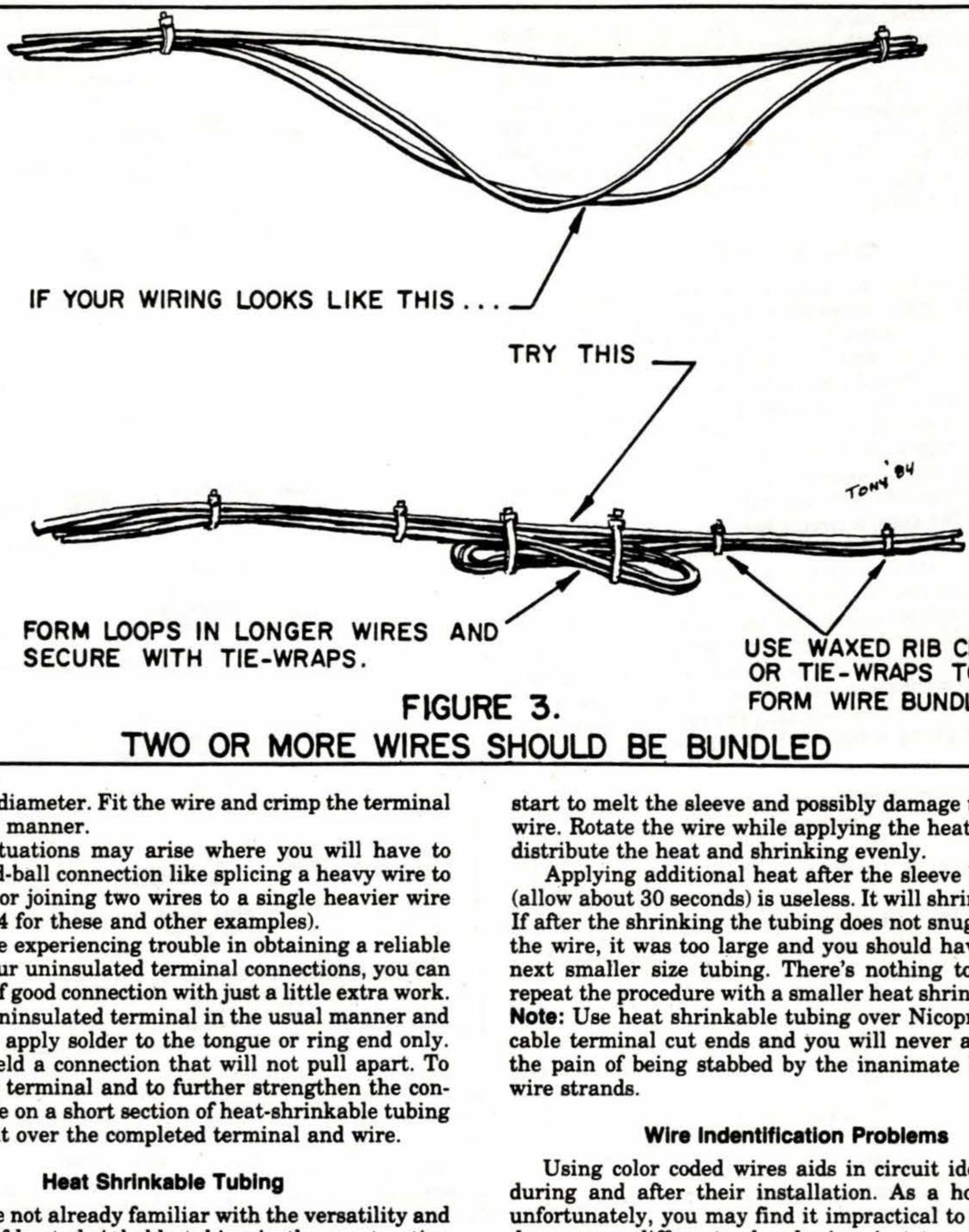
Wire Indentification Problems

Using color coded wires aids in circuit identification during and after their installation. As a homebuilder, unfortunately, you may find it impractical to purchase a dozen or so different colored wires just to accommodate this luxury . . . even if you could locate a source you wouldn't be needing a whole roll of each color. But wire identification should not be a great problem as most home-built wiring installations are usually uncomplicated and the wire runs comparatively short.

You can, therefore, get by quite well by using any colored or white wires and rely on printed tabs for positive identification of the circuit. Use small pieces of adhesive tape folded across the wire and labeled with a fine point black ink (waterproof) pen. After labeling, trim the excess from the tab with scissors. Ignition wires are almost always of the shielded type and are, therefore, easily recognized. However, you might still find it helpful to label one wire "L. Mag." and the other "R. Mag.".

In wiring a wood or composite aircraft, you will find that using wires with black insulation for all the ground wires will be most helpful. Any time you see a black wire you will know it goes to "ground".

It is difficult to identify wires and terminals behind the instrument panel much less secure them to terminals.



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It is difficult to identify wires and terminals behind the instrument panel much less secure them to terminals.

I would, therefore, suggest that you pre-wire your ignition switch terminals with lengths of wire (about 4 feet long should be long enough) and label the free ends to identify each circuit (switch to batt/switch to gnd/sw to L. Mag., etc.). It will then be an easy matter to secure the switch to the panel and connect the various free ends to the proper units. You should do the same for a flap switch, if installed, or any other hard-to-reach switch, circuit breaker and the like.

Circuit Protectors

Don't think for one minute that you can install any kind of a fuse or circuit breaker in a particular circuit and that it will automatically protect it in the event of an electrical fault. It won't, of course, unless the circuit breaker (or fuse) has the correct capacity for the wire size. The presumption that circuit breakers and fuses are used to protect the installed equipment (flap motor, landing lights, wing lights, etc.) is not correct. They protect the cable from becoming over-heated and any protection afforded the equipment is incidental.

If this is the case, a circuit breaker or fuse will have to open the circuit (trip or blow) before the cable (wire) gets hot and starts to smoke. It is, therefore, necessary for the time-circuit capability of your protective device (circuit breaker or fuse) to be below that for the cable. That's why you should match the circuit protector to the cable in order to obtain the maximum life out of your installed equipment. Fortunately, somebody many years ago simplified the problem of selecting the proper circuit protectors by compiling a simple chart that anyone can use. See Table 2.

TABLE 2

CIRCUIT BREAKER SELECTION CHART

Copper Cable Size (AWG)	Circuit Breaker Recommended	Fuse Size Recommended
22	5	5
20	5 (7.5)	5
18	10	10
16	15	10
14	20	15
12	25/30	20
10	35/40	30
8	50	50

source: U.S. Dept. of Commerce/FAA

If you disregard the guidance given in the foregoing chart and let's say you install a 15 amp circuit breaker in a circuit connected by an 18 gage wire (when only a 10 amp c.b. is needed) what would happen? Nothing, as long as everything worked correctly. However, should an electrical fault occur, the circuit breaker might not trip before the wire gets so hot that smoke starts streaming into the cockpit.

Here is a converse example. If you have a 3-strobe light system with a central power supply that is rated at 7 ampheres, you will find that a 5 amp circuit breaker is inadequate. That is, it will continue to trip (open the circuit) because it is overloaded. Install a 10 amp breaker and the problem will go away.

Neatness Does Count

As your wiring progresses you will see that not all of the wires have the same amount of slack. Not because you didn't try to avoid that plight but because the wires emanate from different sources and do not always follow a

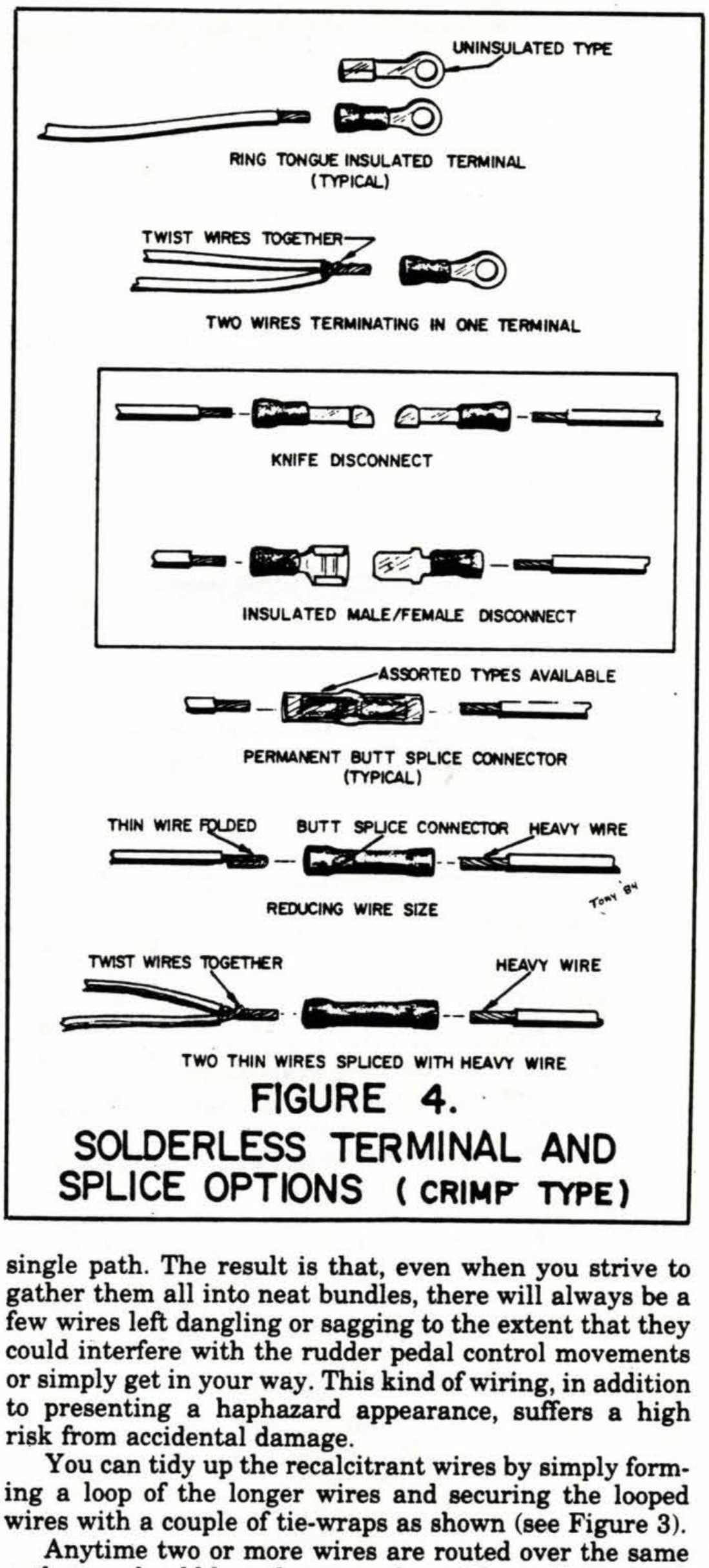

FIGURE 4.
SOLDERLESS TERMINAL AND SPLICE OPTIONS (CRIMP TYPE)

single path. The result is that, even when you strive to gather them all into neat bundles, there will always be a few wires left dangling or sagging to the extent that they could interfere with the rudder pedal control movements or simply get in your way. This kind of wiring, in addition to presenting a haphazard appearance, suffers a high risk from accidental damage.

You can tidy up the recalcitrant wires by simply forming a loop of the longer wires and securing the looped wires with a couple of tie-wraps as shown (see Figure 3).

Anytime two or more wires are routed over the same path, you should lace them together with small tie-wraps or with waxed rib chord. Do this every 4 inches or so. Clamp the bundles at intervals to some structure wherever possible. Bundling the wires increases the strength of the wiring and helps safeguard each individual wire from suffering damage due to fraying by rubbing against something.

Shielded cables, ignition cables and any wires that are not protected by a circuit breaker or fuse should not be bundled with other wires.

Make ever effort to keep metal fuel lines separated from electric wires as an electrical arcing fault between an electric cable and a fuel line could cause the fuel line to be punctured and result in a dangerous fire. If separation is impractical, place the electric cable over the fuel line and clamp it securely to the structure. Never clamp electric wires directly to metal fuel lines.

In summary, keep your wiring neat and immobilized.

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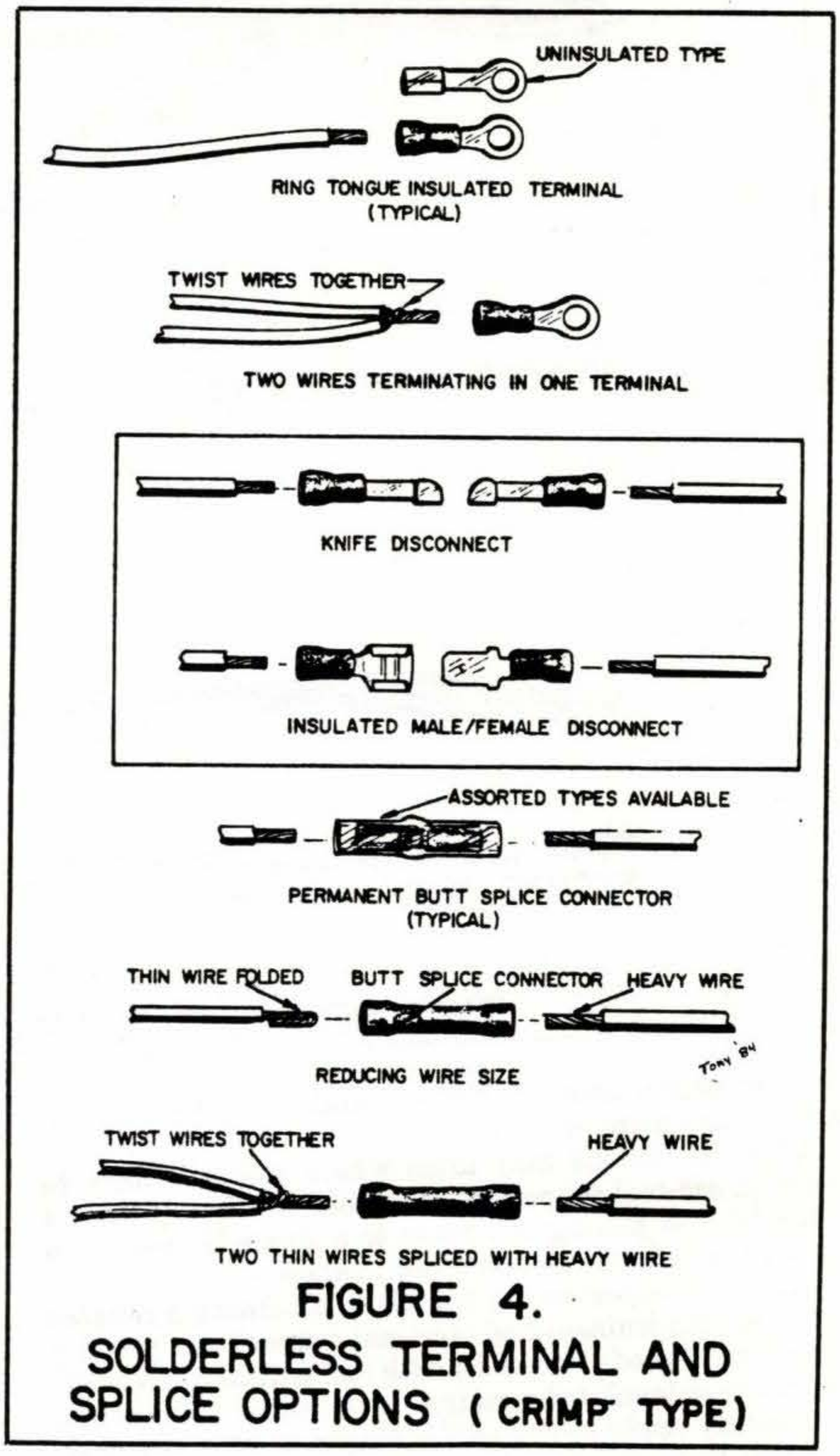

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single path. The result is that, even when you strive to gather them all into neat bundles, there will always be a few wires left dangling or sagging to the extent that they could interfere with the rudder pedal control movements or simply get in your way. This kind of wiring, in addition to presenting a haphazard appearance, suffers a high risk from accidental damage.

You can tidy up the recalcitrant wires by simply forming a loop of the longer wires and securing the looped wires with a couple of tie-wraps as shown (see Figure 3).

Anytime two or more wires are routed over the same path, you should lace them together with small tie-wraps or with waxed rib chord. Do this every 4 inches or so. Clamp the bundles at intervals to some structure wherever possible. Bundling the wires increases the strength of the wiring and helps safeguard each individual wire from suffering damage due to fraying by rubbing against something.

Shielded cables, ignition cables and any wires that are not protected by a circuit breaker or fuse should not be bundled with other wires.

Make ever effort to keep metal fuel lines separated from electric wires as an electrical arcing fault between an electric cable and a fuel line could cause the fuel line to be punctured and result in a dangerous fire. If separation is impractical, place the electric cable over the fuel line and clamp it securely to the structure. Never clamp electric wires directly to metal fuel lines.

In summary, keep your wiring neat and immobilized.