Wire

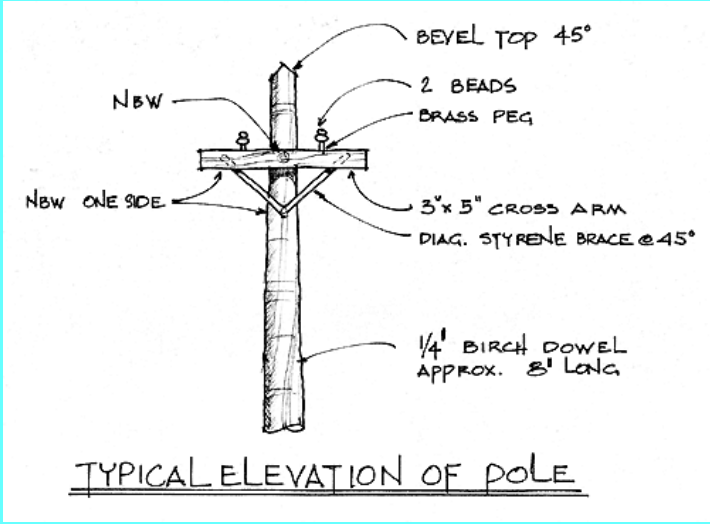
Pipes for Electrons

Wire has two components:

(1) The conducting portion, usually copper . . .

(2) The insulating portion with a rich history of evolution . . .

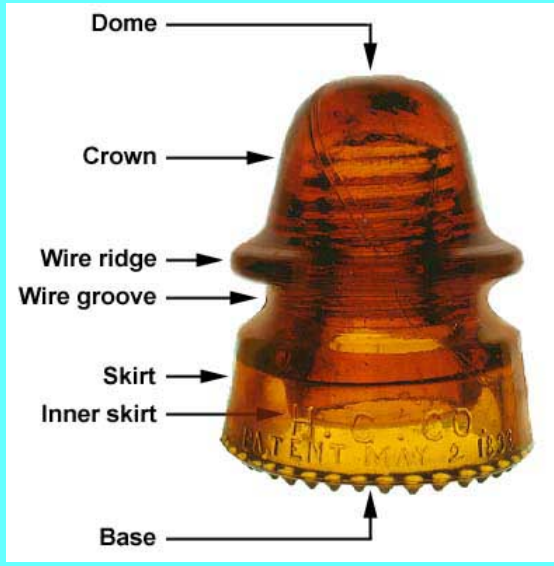
Insulation? I don't need no stinking insulation!



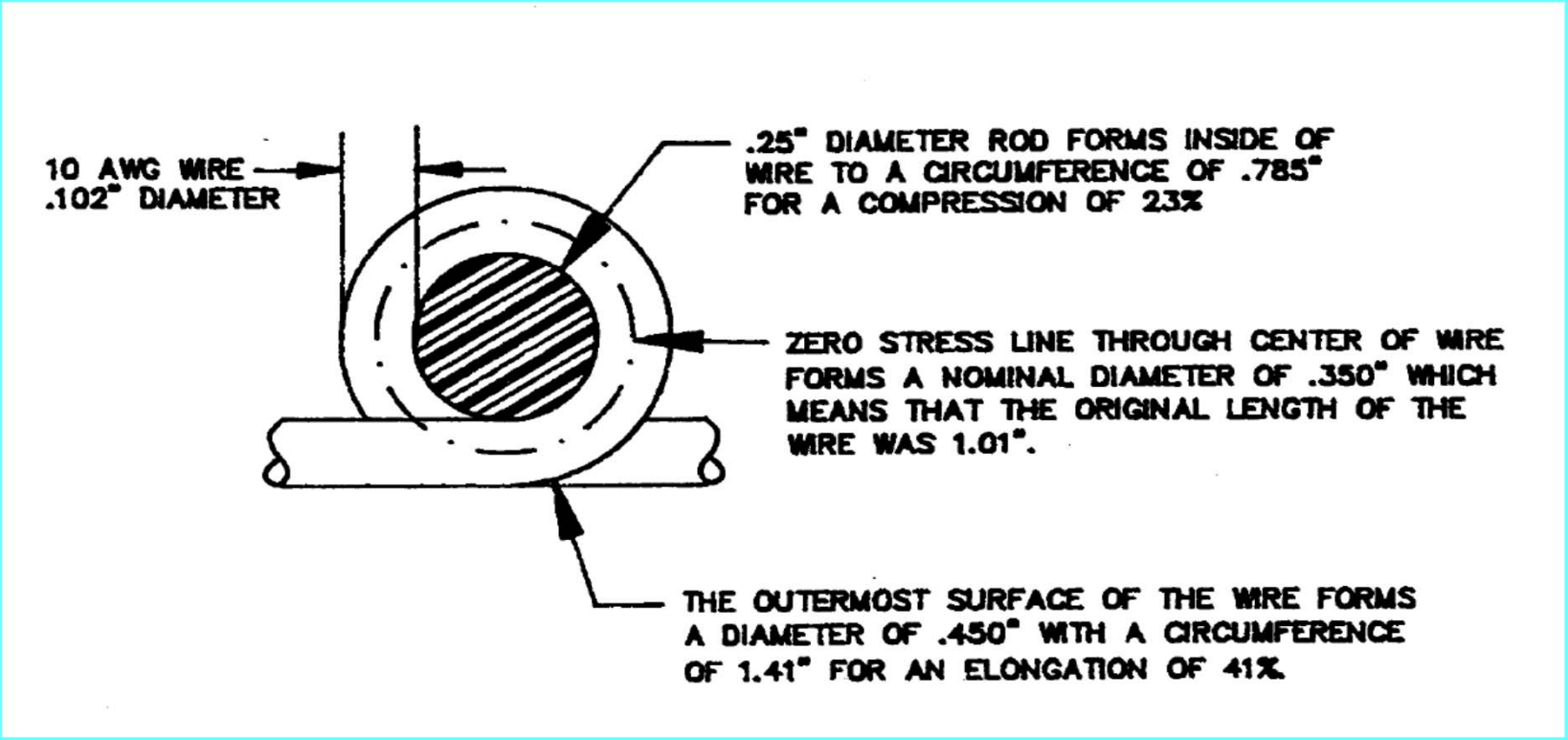
The first telegraph line in the United States was completed in 1844 and ran from Baltimore, Maryland to Washington, D.C.

Morse had hired the ingenious construction engineer Ezra Cornell to ***lay the pipe carrying the wire***, but one of Morse's partners, Congressman F. O. J. Smith, purchased ***wire with defective insulation***. With the project on a rigid deadline, Cornell suggested that the fastest and cheapest way of connecting Washington and Baltimore was to ***string wires overhead on trees and poles***. The line was completed in time for a dramatic and ***spectacularly successful link between the Supreme Court chamber of the Capitol building and the railroad station in Baltimore***.

Telegraph stations and the poles supporting telegraph wires were first constructed along railroads, since the ***right-of-way to that land had already been granted***. The first messages sent via telegraph concerned the movement of trains, but soon the telegraph was used to share news and business information. ***Compared with sending written messages by horse or train, the telegraph was a virtually instantaneous form of communication***. Telegraph lines were quickly stretched across the United States and Europe and were installed in Asia, Africa, and Australia by the end of the century; ***telegraph cables were also laid across the Atlantic Ocean***. Telegraph companies became one of the largest business endeavors of the nineteenth century, and Samuel Morse reaped the monetary benefits of his invention. The telegraph was continually improved and used through the first half of the twentieth century.



Making the case for finely stranded wire



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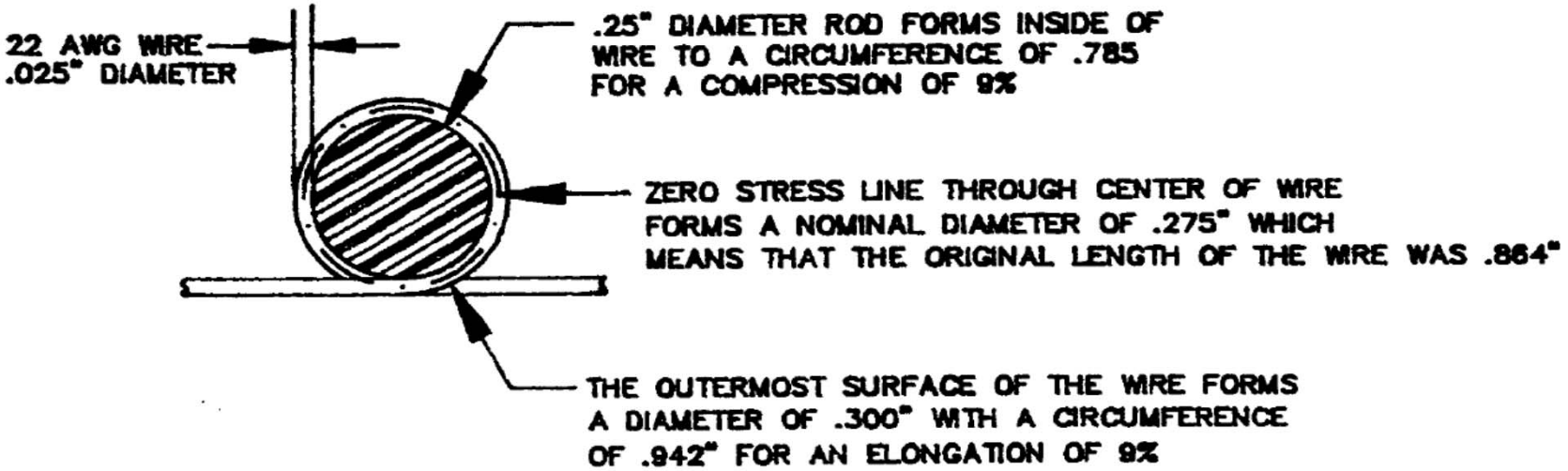
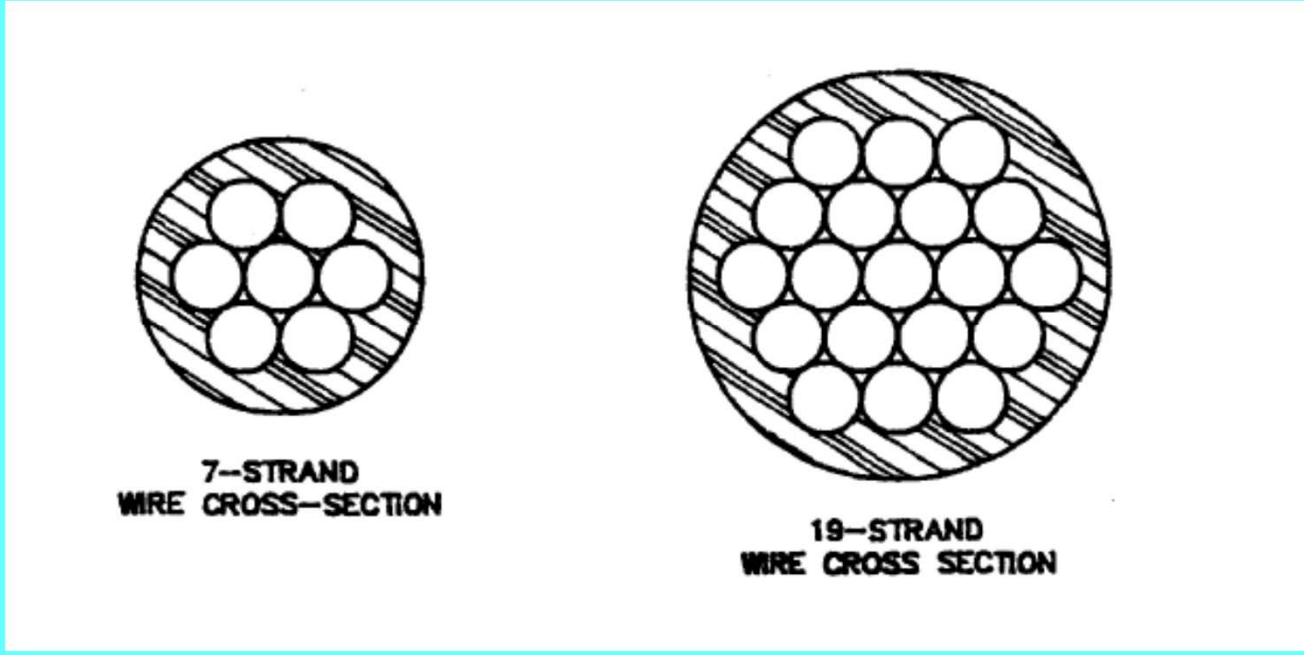


Making the case for finely stranded wire



You know you're having a bad day when . . .

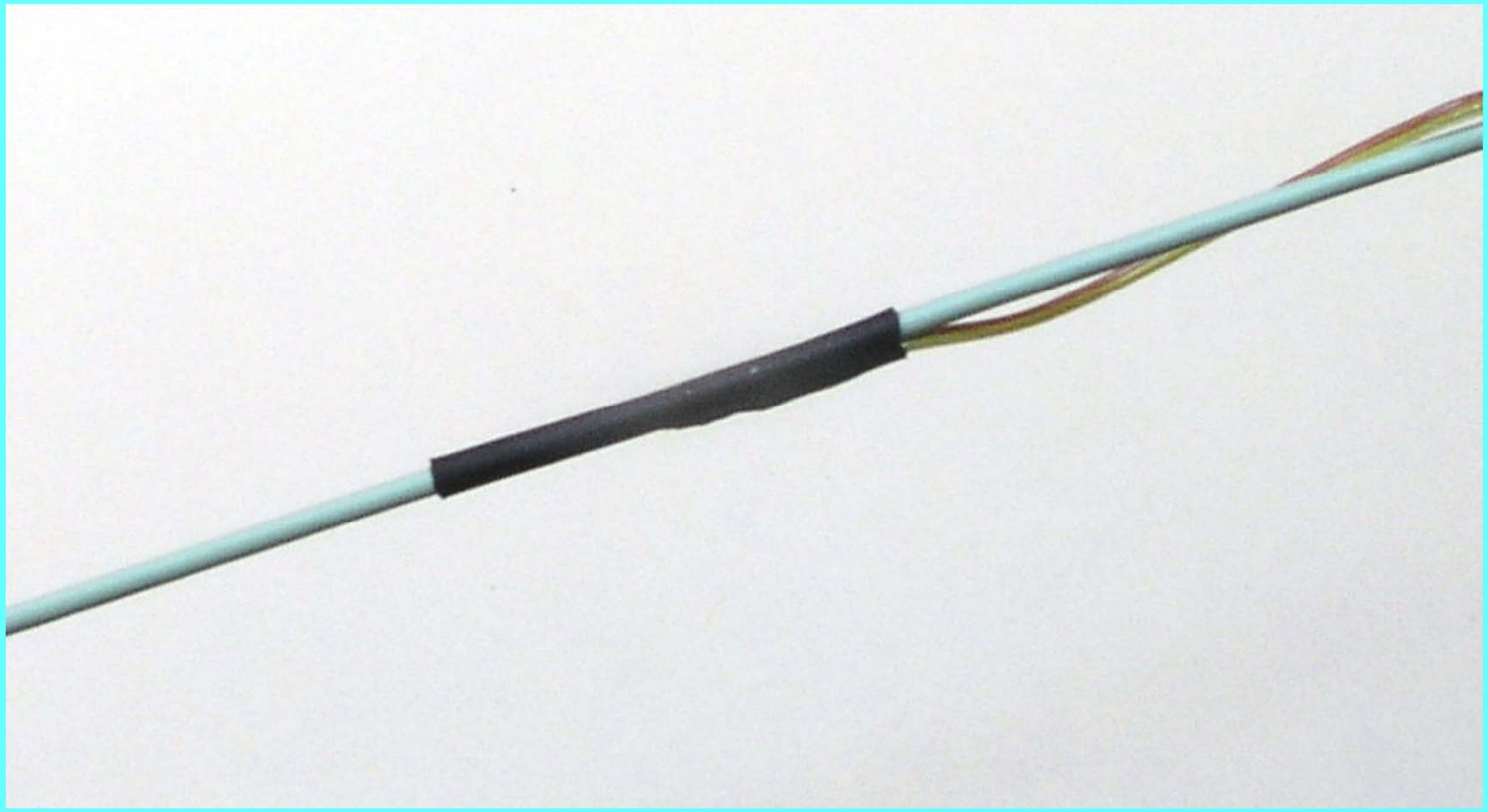
The American Standard Wire Gage . . . How big is it?

Wire Table

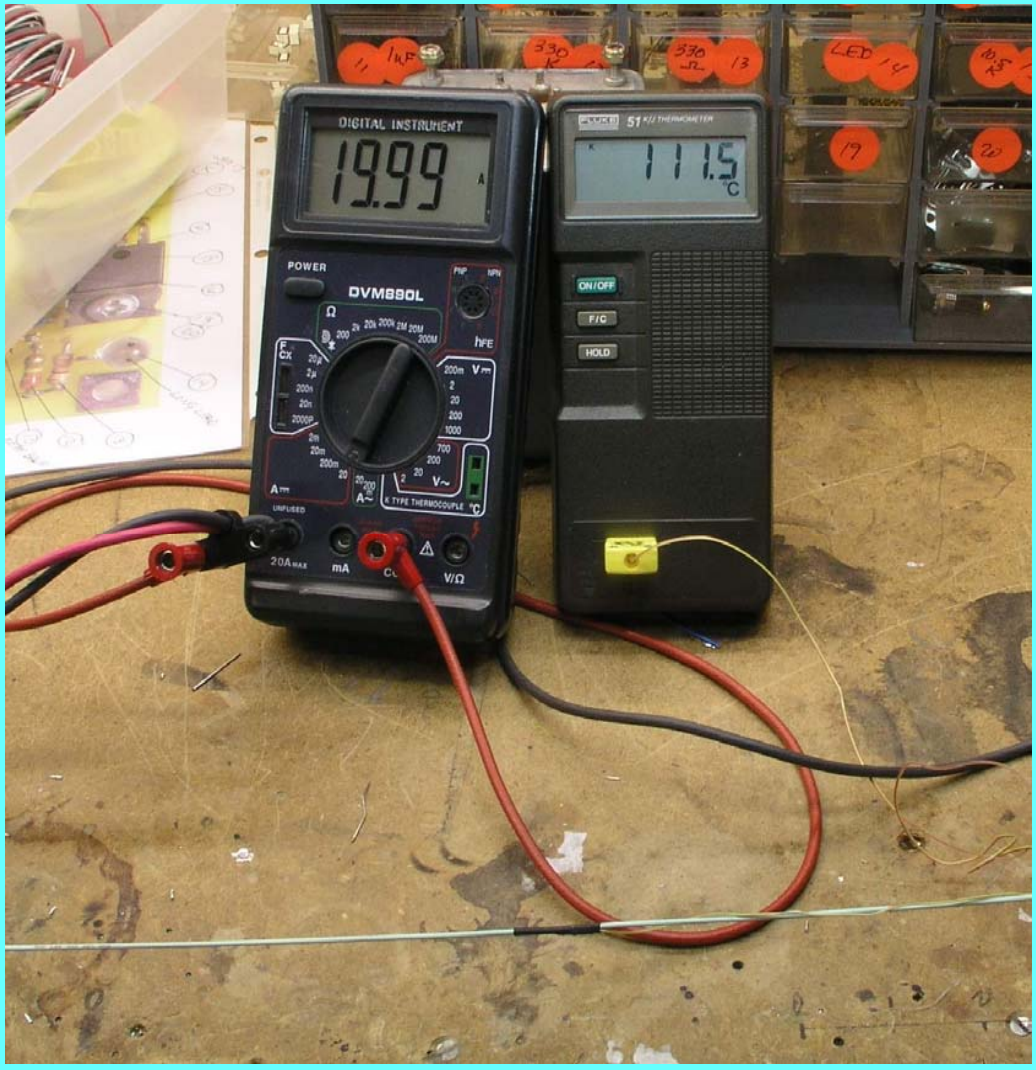
AWG No.	Dia-meter Mils	Area Circular Mils	Ohms per 1000 Feet	Feet per Pound	10 Deg C rise current	CMA per Amp
0000	460	211,600	.049	1.56		
000	410	167,800	.062	1.97		
00	365	133,100	.078	2.48		
0	325	105,500	.098	3.13		
1	289	83,700	.124	3.95		
2	257	66,400	.156	4.98	100A	664
3	229	52,600	.197	6.28		
4	204	41,700	.249	7.91	72A	579
5	182	33,100	.313	9.98		
6	162	26,250	.395	12.6	54A	486
7	144	20,820	.498	15.9		
8	129	16,510	.628	20.0	40A	413
9	114	13,090	.792	25.2		
10	102	10,380	.999	31.8	30A	345
11	91	8,230	1.26	40.1		
12	81	6,530	1.59	50.6	22A	296
13	72	5,180	2.00	63.8		
14	64	4,110	2.53	80.4	15A	274
15	57	3,257	3.18	101		
16	51	2,583	4.01	128	12.5A	206
17	45	2,048	5.06	161		
18	40	1,624	6.39	203	10A	162
19	36	1,288	8.05	256		
20	32	1,022	10.2	323	7A	146
21	28	800	12.8	400		
22	25	642	16.1	514	5 A	128
23	23	509	20.3	648		
24	20	404	25.7	817		

Figure 8-3. Wire Table for American Standard Wire Gauges

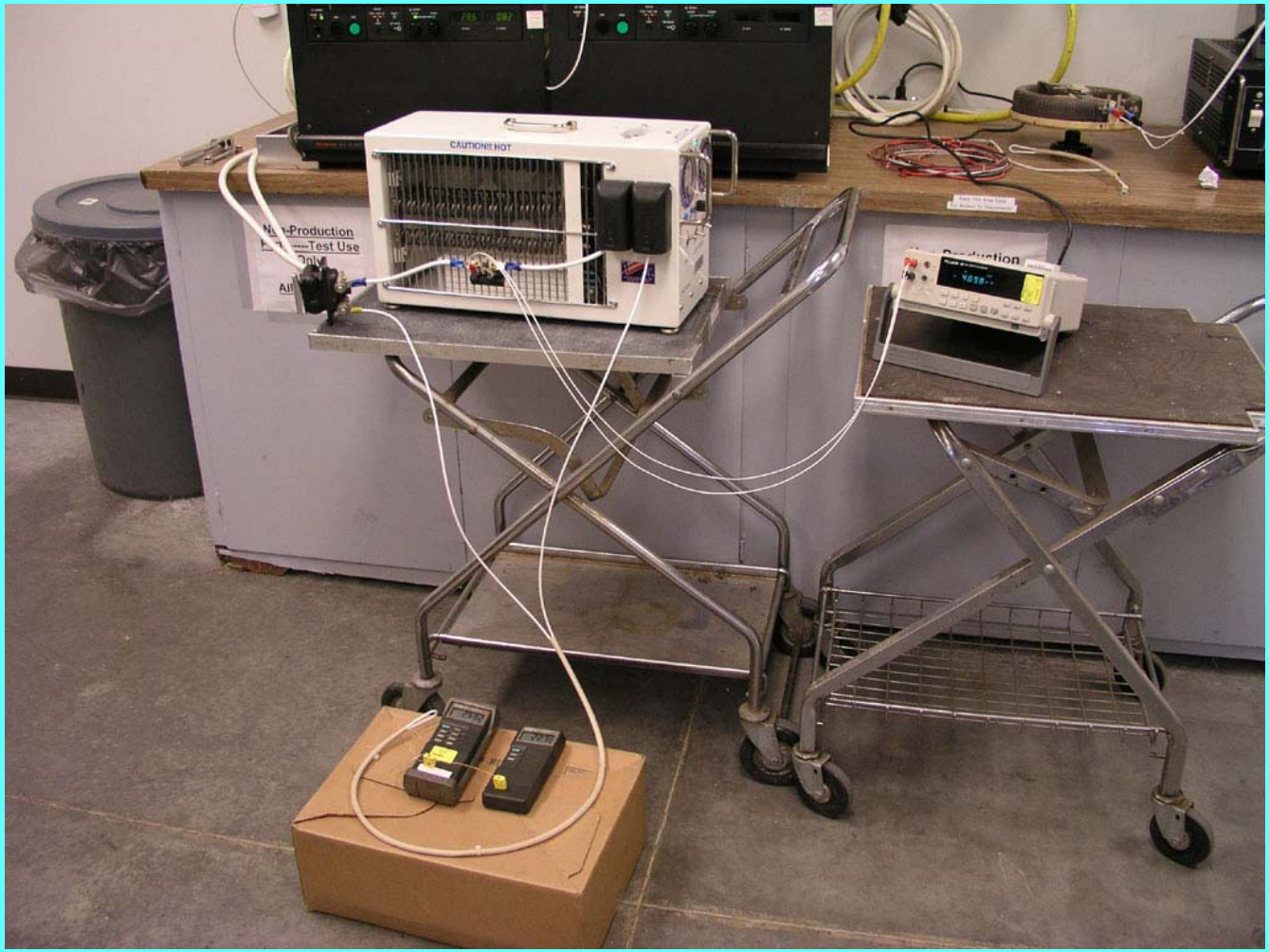
- **How much current does it take to BURN a 22AWG wire?**
- **Let's put a thermocouple on a piece of 22AWG wire and load it up . . .**



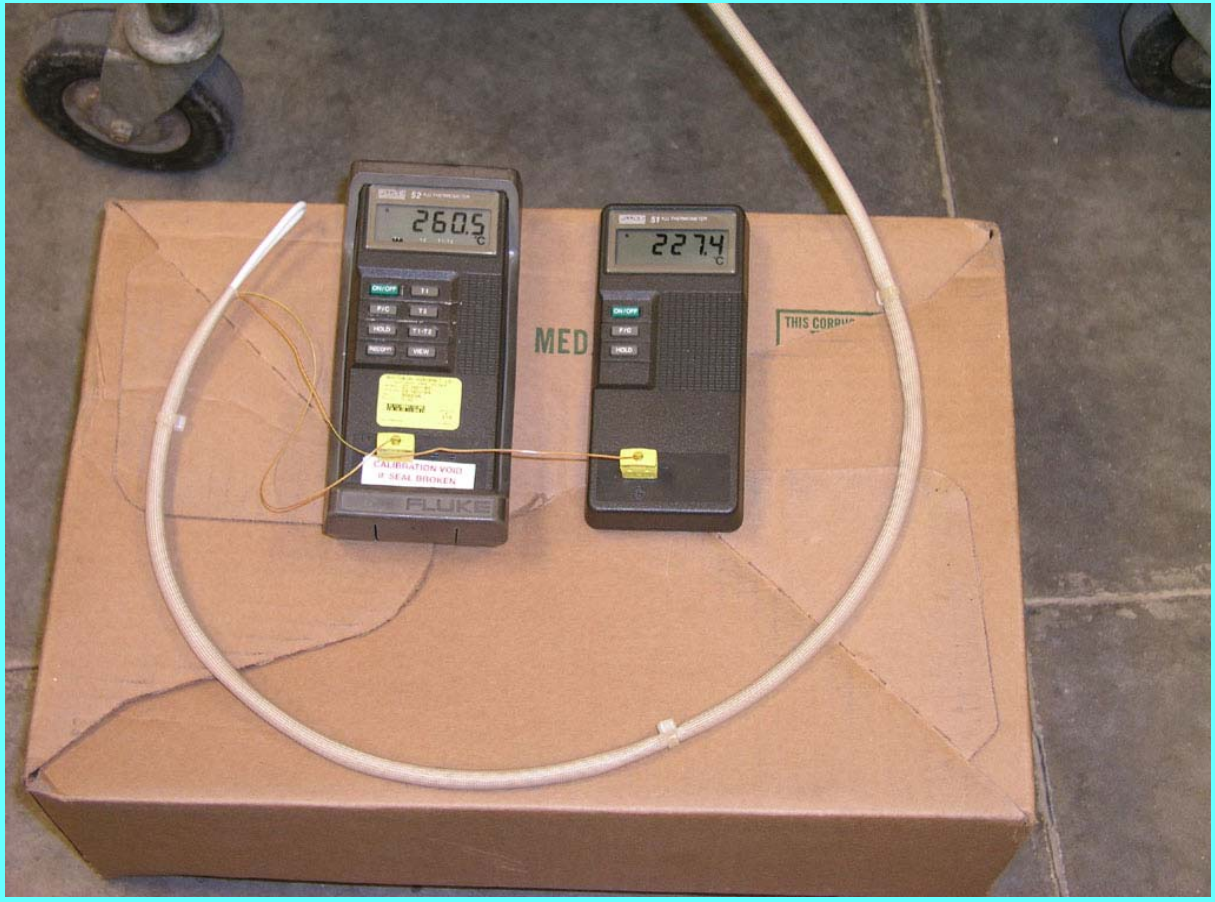
- **This 22AWG wire has been carrying 20A at room temperature for over 20 minutes.**
- **The outside (insulation temperature) is 112C**
- **The wire is rated to operate at 150C**
- **If the wire is not “overloaded” for operating temperature, why might we still want to make it bigger?**



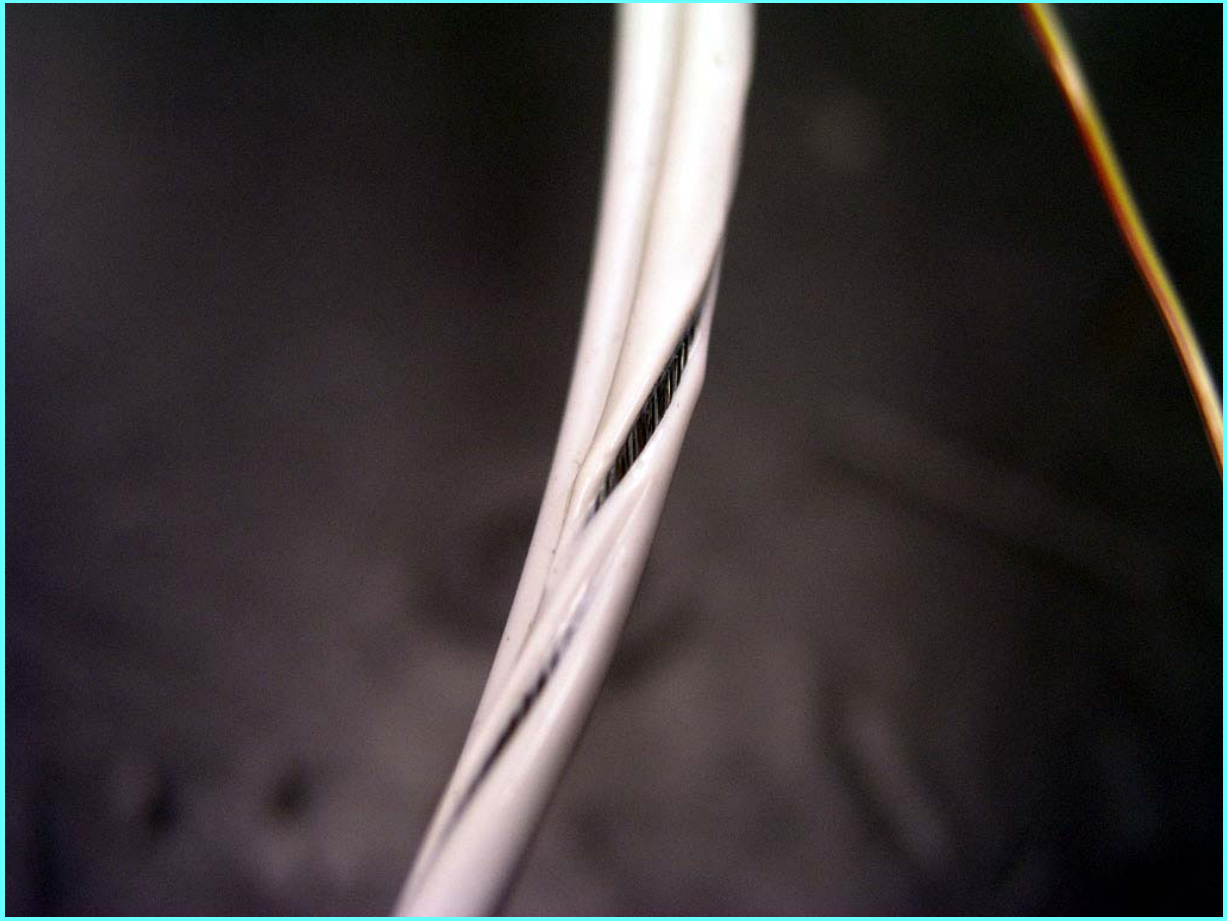
- **Temperature Rise Setup**
- **Power supply and load bank were set up to apply 83A current to sleeved bundle of two 10AWG wires**



- **82A, 2 strands of 10AWG under Silicone Impregnated Fiberglas Temperature Rise Stabilized at ~ 20 minutes**
- **Temperature under a tye-wrap rose to 260C**
- **Temperature between tye-wraps was 227C**



- **Damage to wire after 40 minutes @ 83A Under Fiberglas Silicone Sleeve**



- **Copper is copper is copper . . . No practical temp limits. Size driven by allowable voltage drop. Temperature limited by insulation ratings and ambient temperatures.**

Insulation qualities determine suitability to task.

- **Temperature rating**
- **Resistance to environment . . . Oil, hydraulic fluid, ozone, water, etc.**
- **Mechanical robustness**
- **Flammability**
- **Weight**
- **Minimum thickness to task**
- **Suited for bundling with other wires and components servicing a variety of tasks**

The American Standard Wire Gage . . . How big does it need to be?

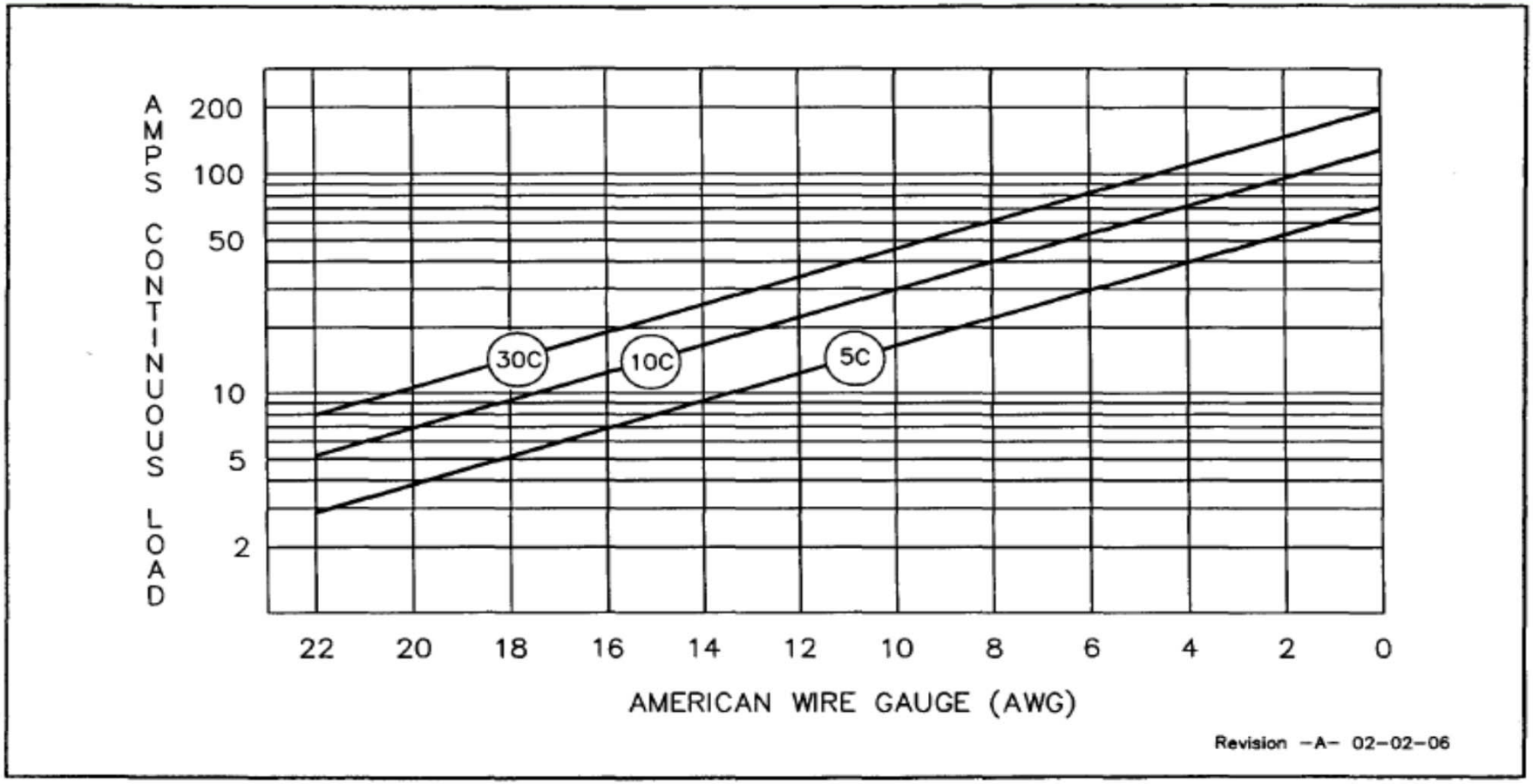


Figure 8-4. Wire Current Capacity Versus Wire Guage and Temperature Rise.

Effects of temperature coefficient of copper on temperature rise:

$R_t = 0.010\ [1+.0039\ (T_{conductor}-20)]$

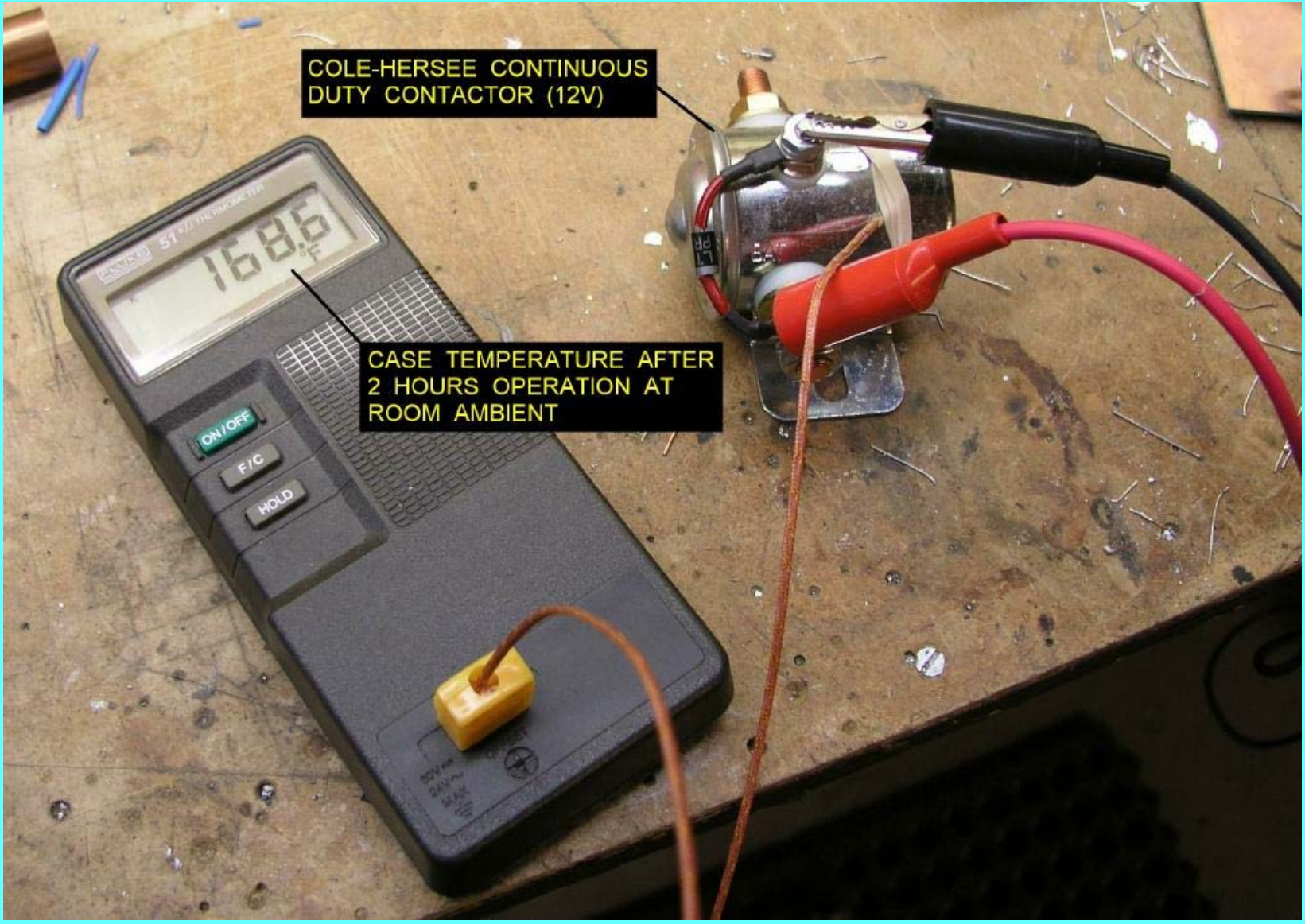
WireOhms/Ft = 10 mOhm/Ft@20C [1+.0039(WireTempDegC - 20)]

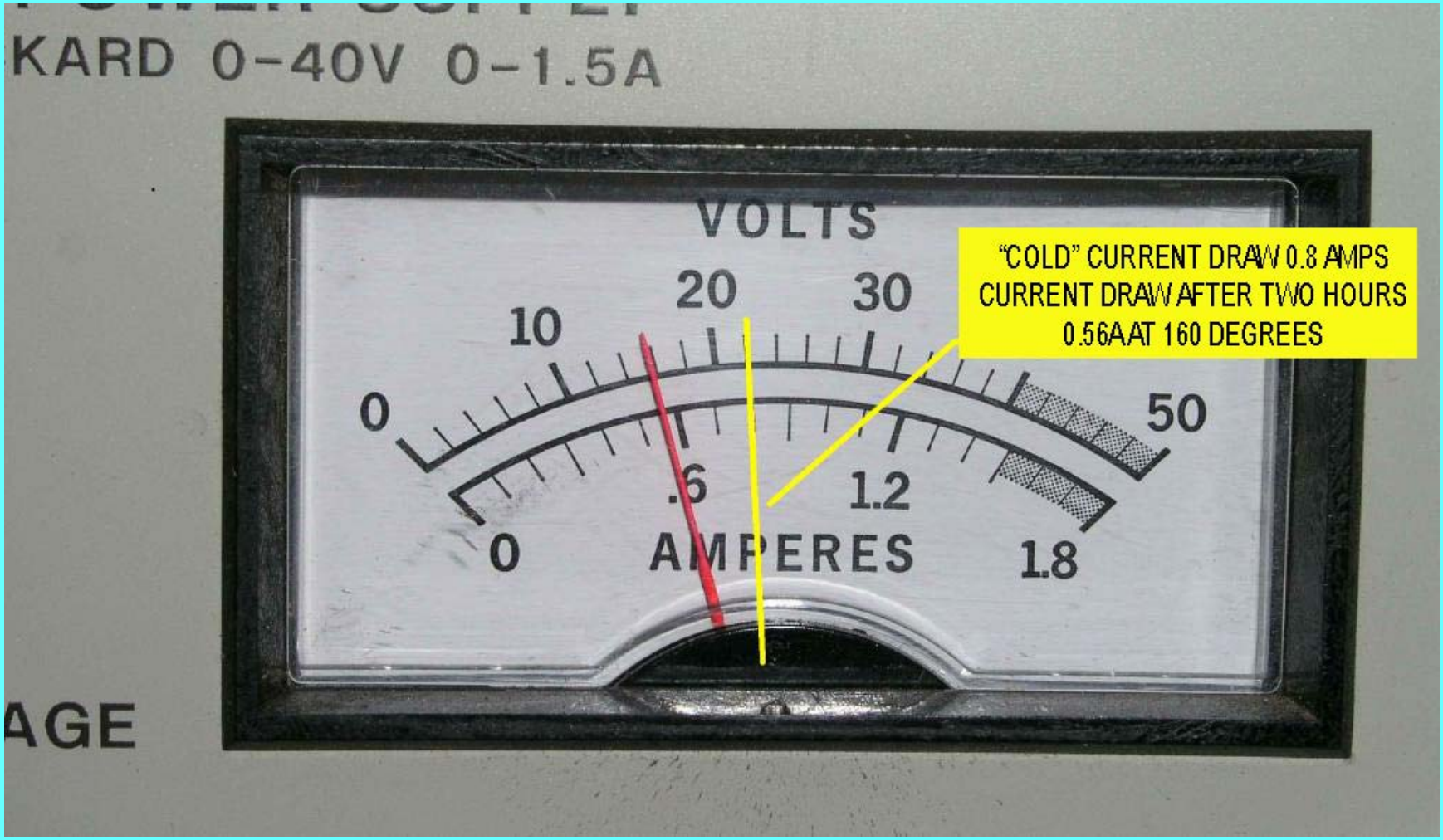
$\Delta T_{conductor} = R_t I^2(\rho_{conductor\text{-}surface})$

Trise = Watts * DegC/Watt

$\Delta T_{conductor} = 0.010\ [1+.0039\ (T_{conductor}-20)]\ I^2(\rho_{conductor\text{-}surface})$

Note that the effect of conductor temperature ($T_{conductor}$) has a positive feedback effect on temperature rise ($\Delta T_{conductor}$) . In the experiment where insulation temperature of the wire was measured at 223 ºC the multiplier on Rt was [1 + .0039(223-20)] = 1.79 This shows that temperature rise on a wire not only goes up with square of current but that more than 79% of that rise was due to temperature coefficient of copper alone!


COLE-HERSEE CONTINUOUS DUTY CONTACTOR (12V)
CASE TEMPERATURE AFTER 2 HOURS OPERATION AT ROOM AMBIENT
168.6
ON/OFF
F/C
HOLD


KARD 0-40V 0-1.5A
VOLTS
0
10
20
30
50
0
.6
1.2
1.8
AMPERES
"COLD" CURRENT DRAW 0.8 AMPS
CURRENT DRAW AFTER TWO HOURS
0.56AAT 160 DEGREES
AGE

Steinair, the builder's source for the "good stuff"

WIRE

- **Mil-Spec (22759/16 and M27500) Quality aircraft wire. Tefzel coated, tin plated conductor, currently multiple colors/sizes. ALL WIRE IS BRAND NEW, NOT Surplus! Contact us directly for Bulk pricing (500'+ minimum), orders are discounted.**

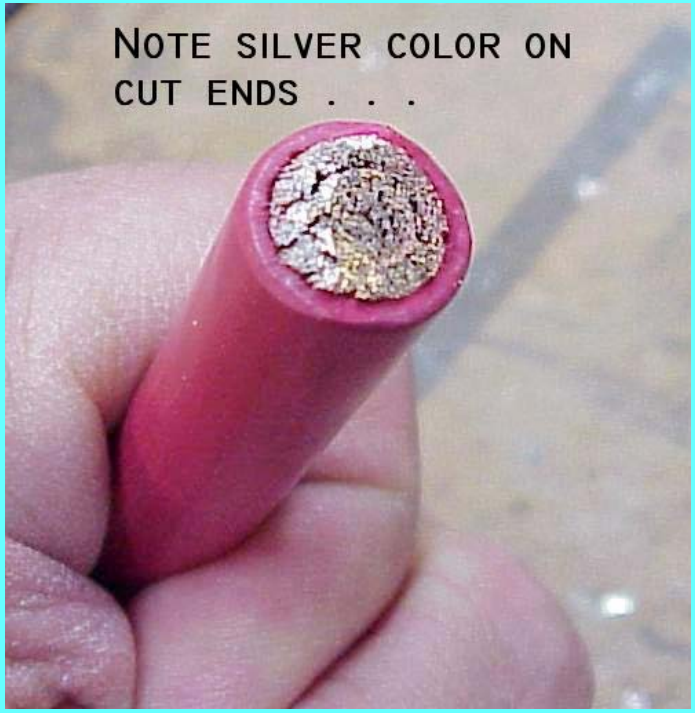
- **We stock nearly 1/2 Million feet of Mil Spec Tefzel Wire in over 37 different color combinations, so if you don't see something you want, give us a call and we might just have it! We also are glad to "re-spool" wire to your required lengths, and because we now purchase wire in 10,000' - 20,000' spools we can get you LONG continuous lengths.**

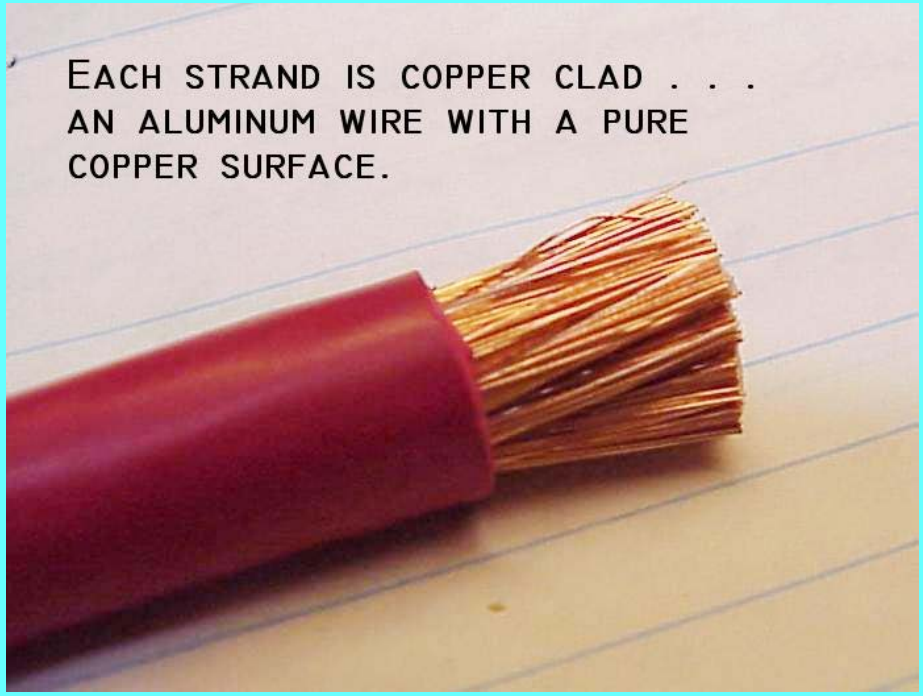
- **If you desire to have wire coiled onto a spool, there will be a $2.50 spool charge for the physical spool.**

Http://www.steinair.com

- **Early attempts to use aluminum wire in aircraft was a dismal failure. The strands were big, prone to crack, and bare aluminum. Very hard to achieve rugged gas tight joints.**

- **Fine-strand, copper clad aluminum wire fixes all these problems an yields a wire that can be treated pretty much like pure copper.**



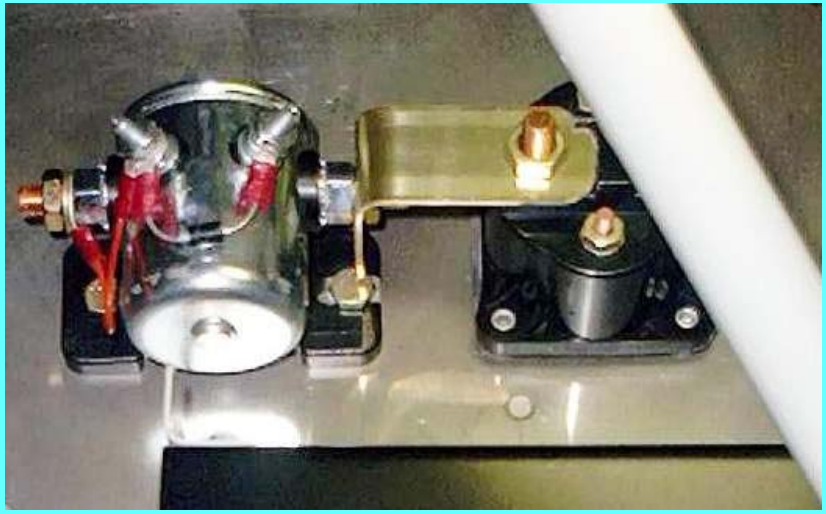


Fat wire options: Copper clad aluminum solders just like pure copper.

- **Welding cable is exceedingly robust and very flexible.**
- **May be considered for all fat wires in an aircraft.**
- **4AWG welding cable may be used between to wire battery(+) and battery(-) terminals irrespective of the wire sizes used elsewhere in the system of fat wires.**

- **Braided strap fabricated from gazillions of fine wires is still the conductor of choice between firewall ground stud and engine crankcase.**

Fabricate short, high current jumpers between equipment items with studs from copper or aluminum.



Routing wire bundles in airplanes

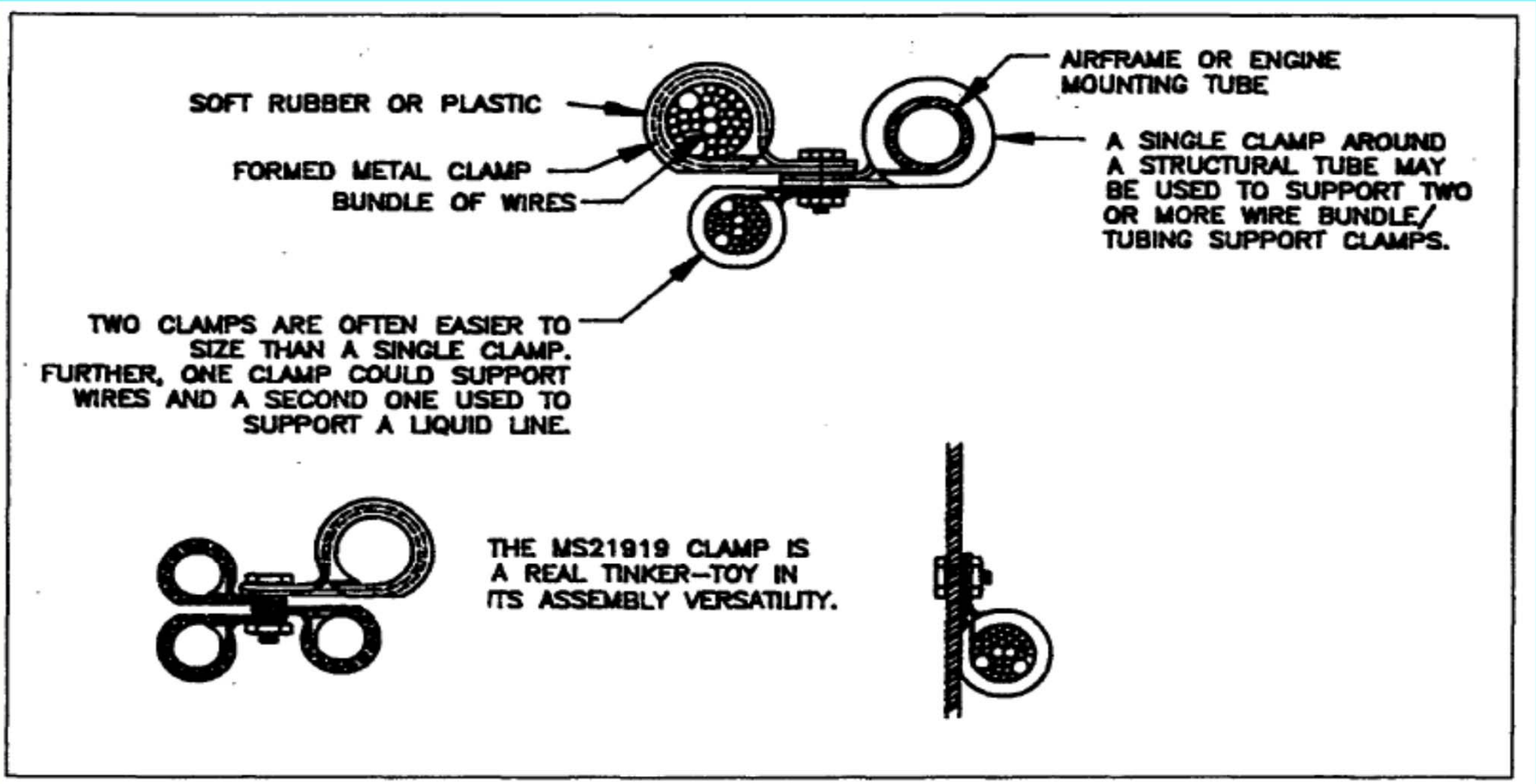
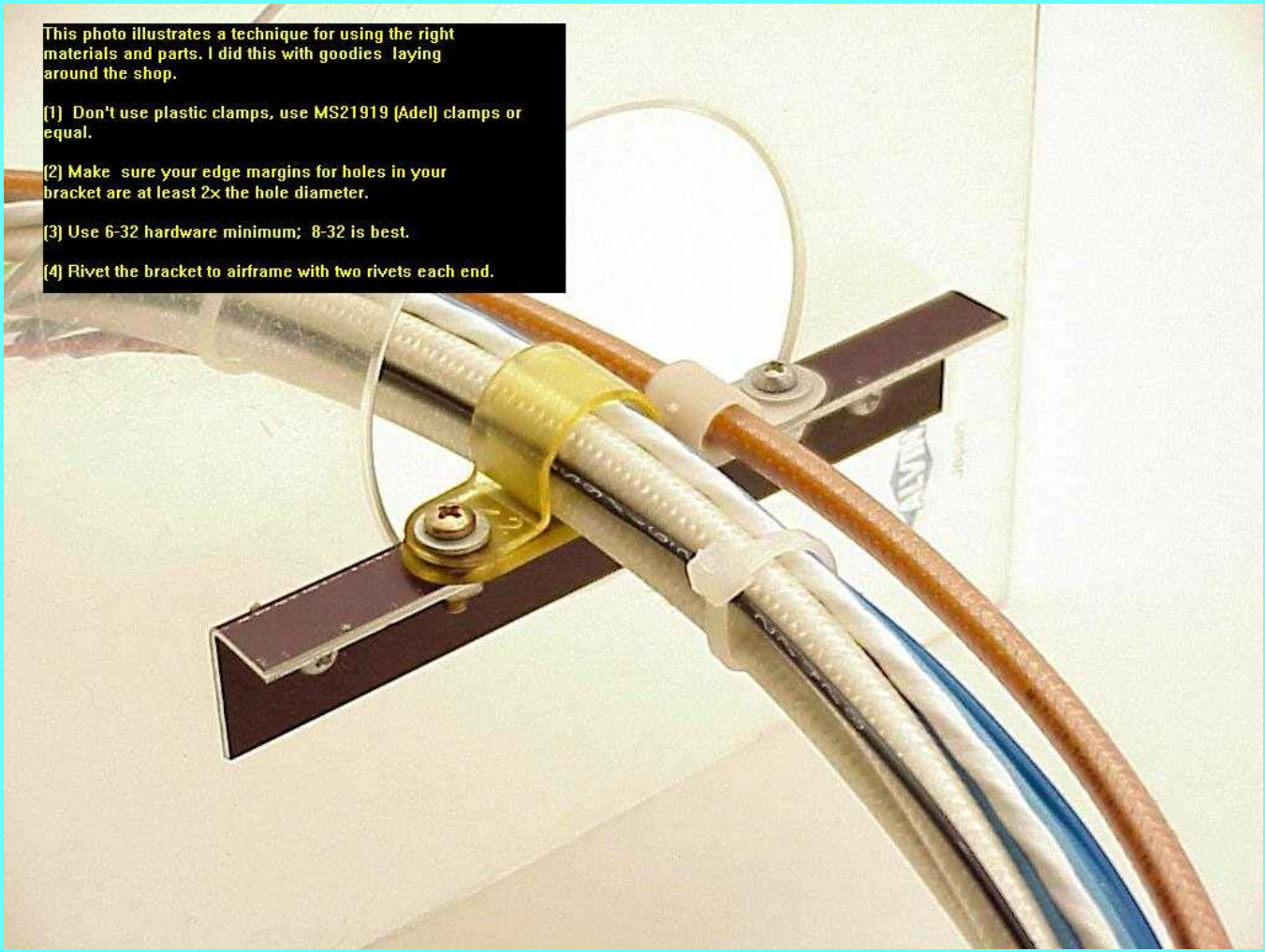


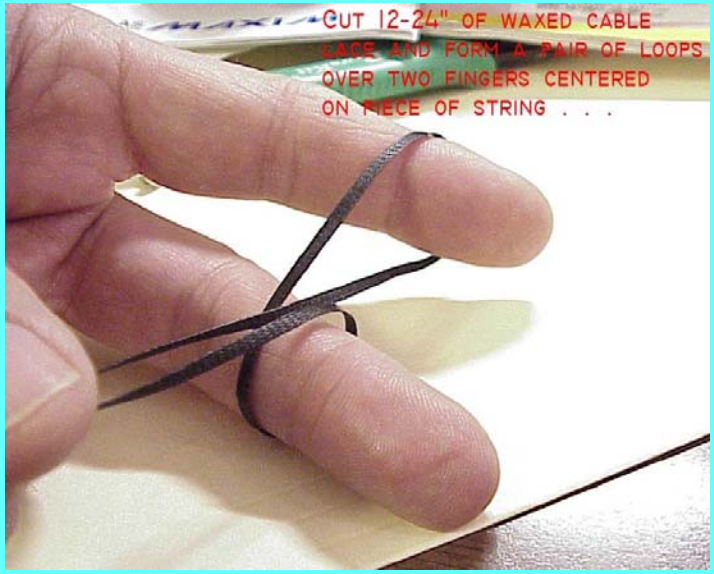
Figure 8-7. Applications of the MS21919 Padded Clamps.

You know you're having a bad day when . . .

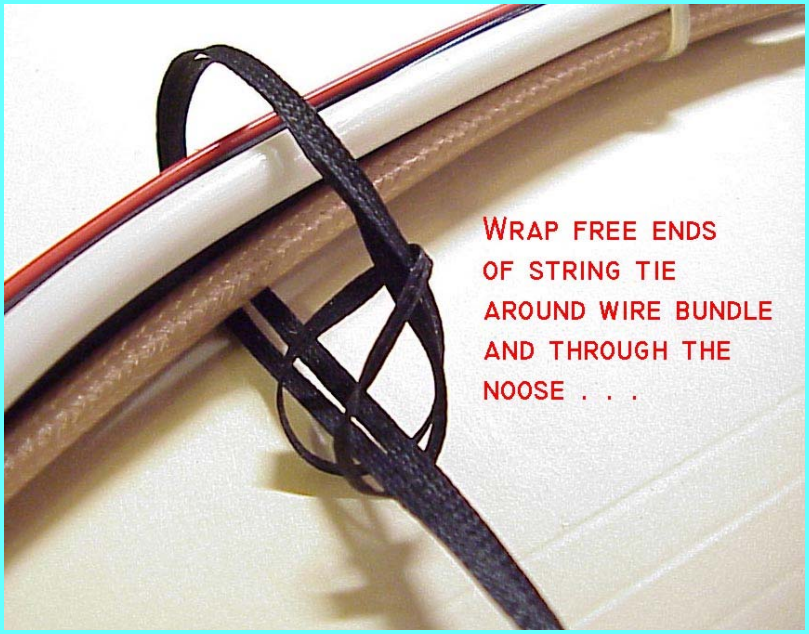
Routing wire bundles in airplanes

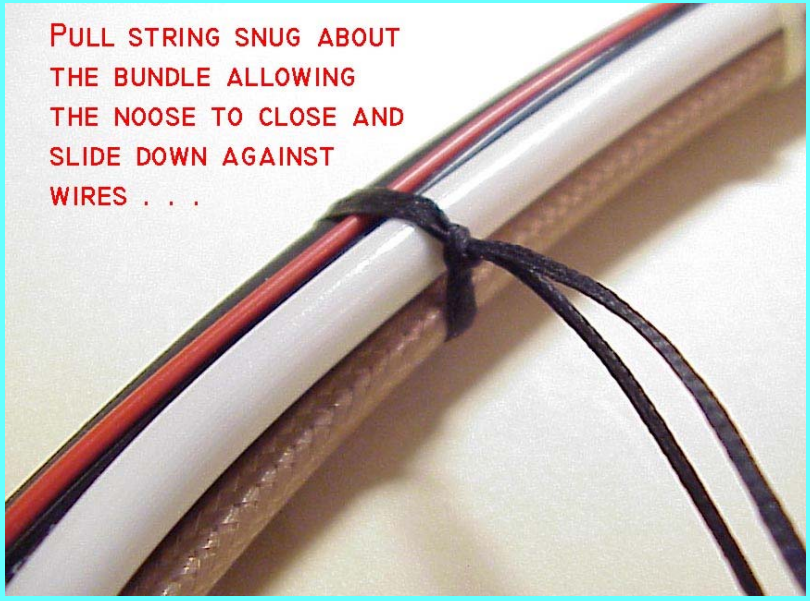


Routing wire bundles in airplanes

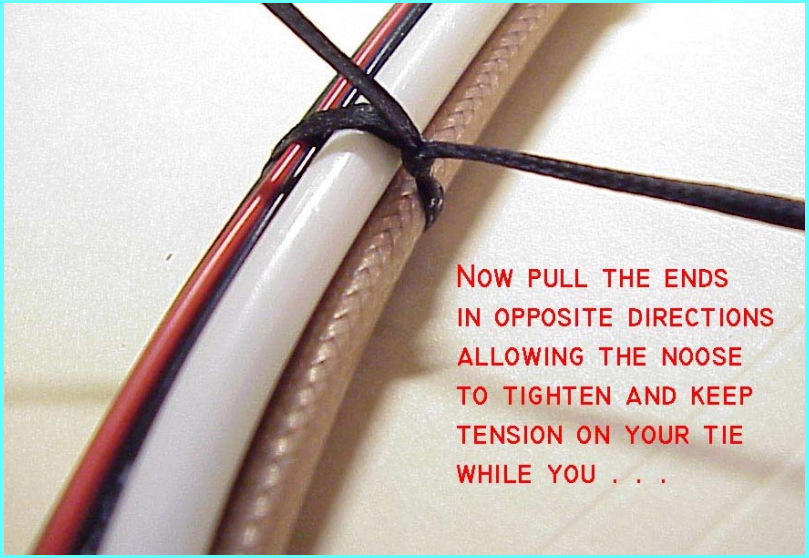


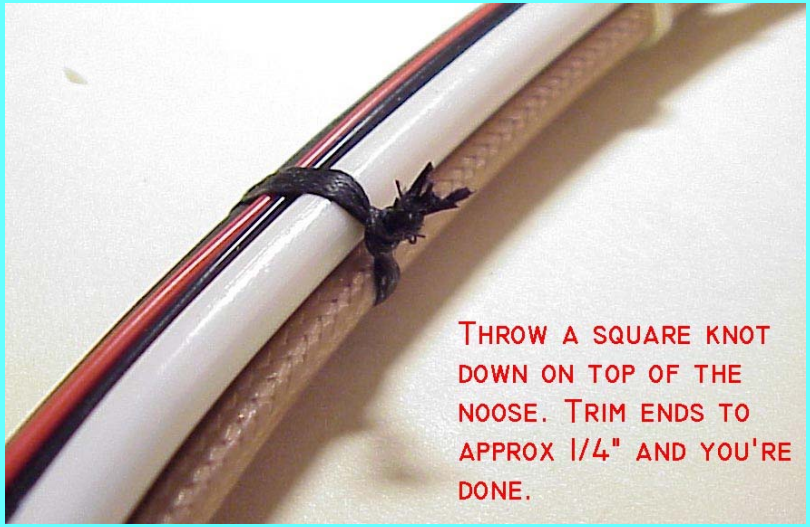
Routing wire bundles in airplanes



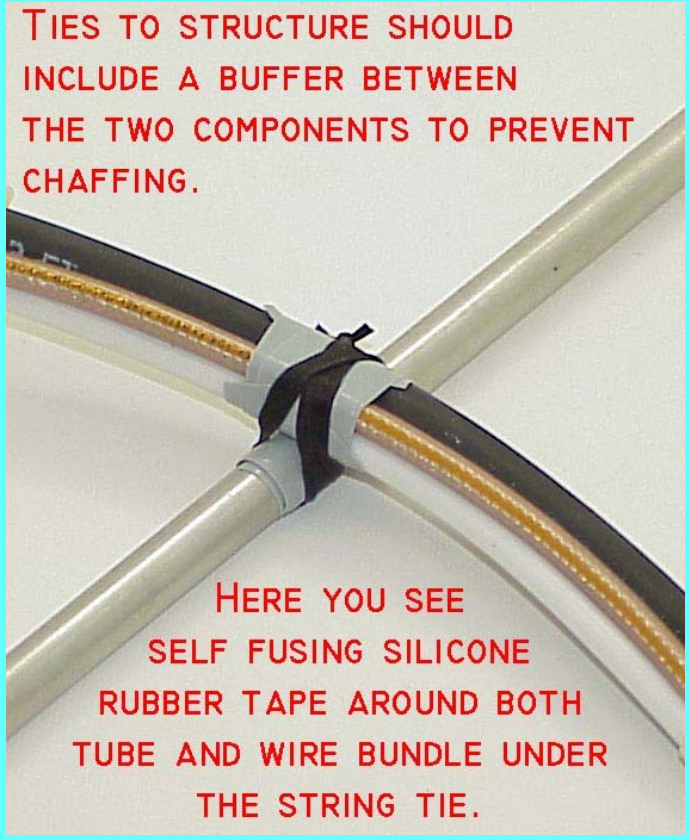


Routing wire bundles in airplanes

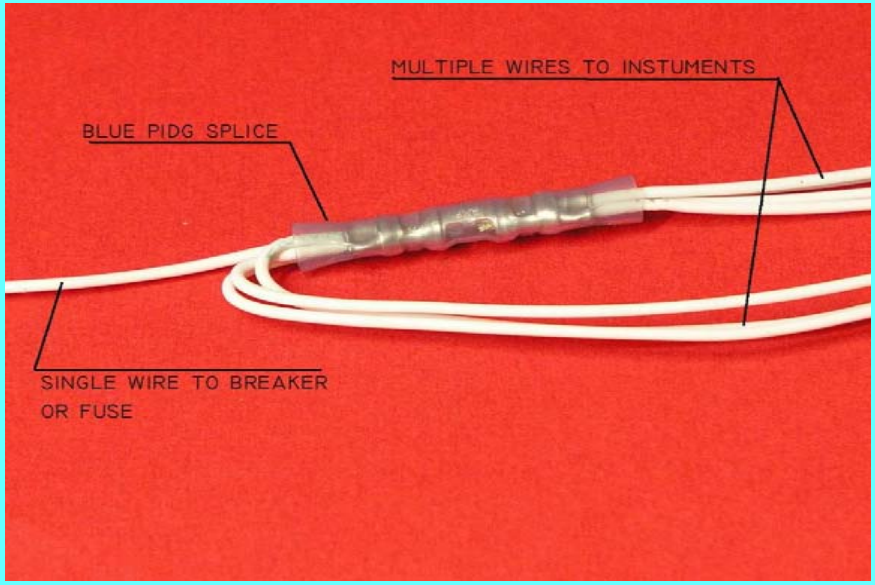


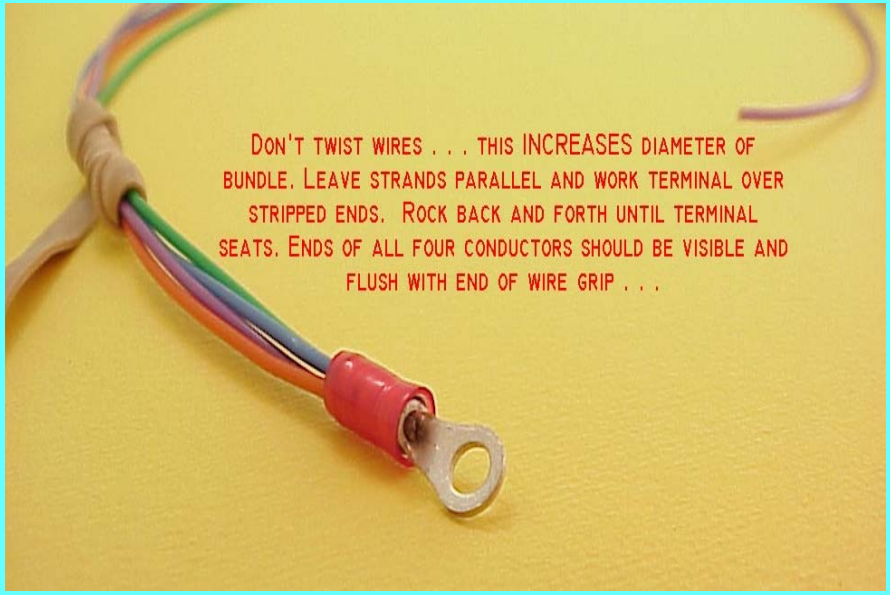


Routing wire bundles in airplanes

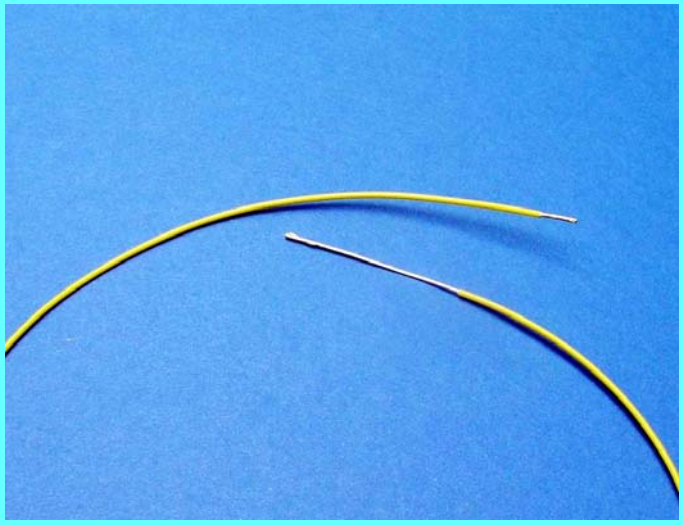


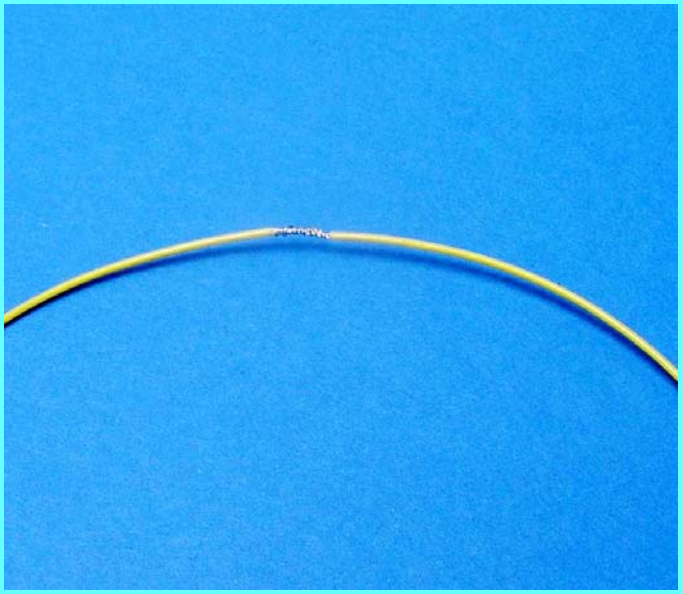
Routing wire bundles in airplanes

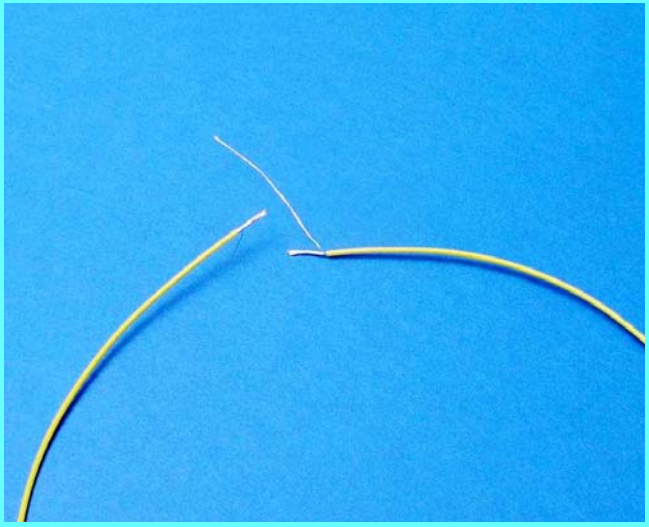


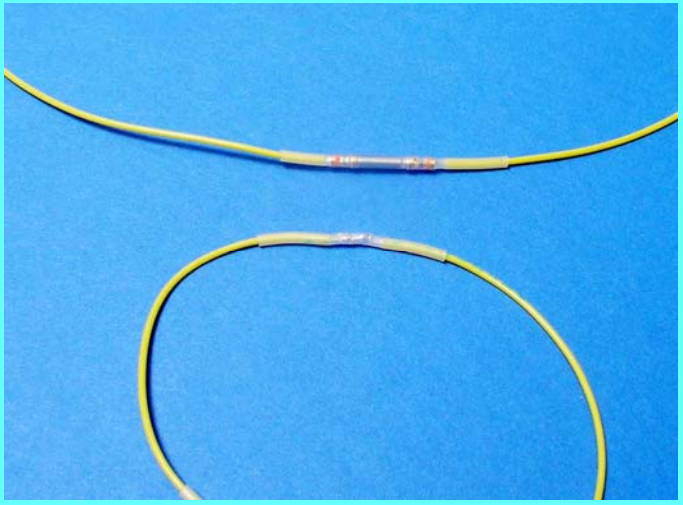


Routing wire bundles in airplanes

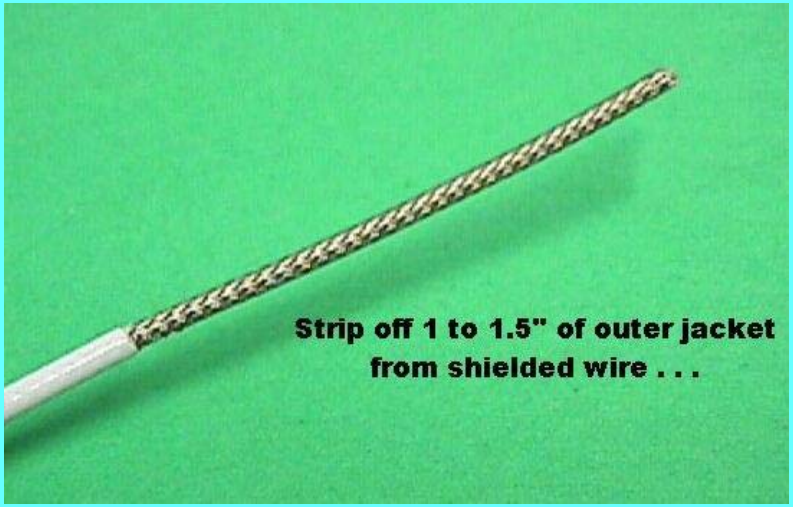


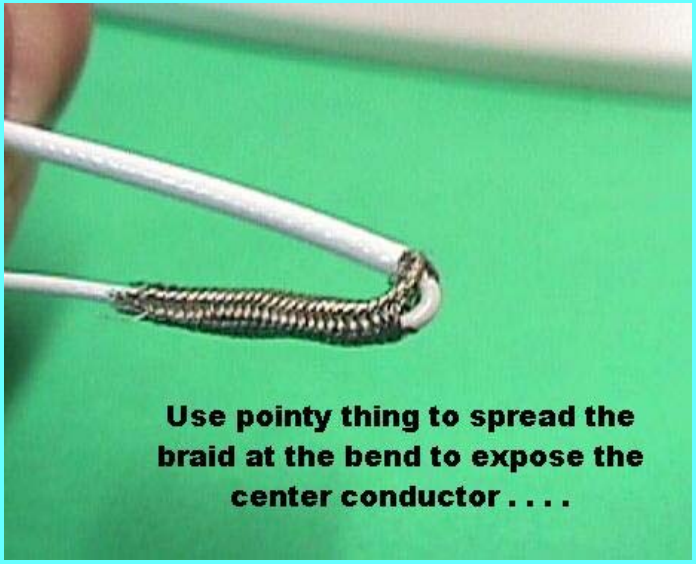




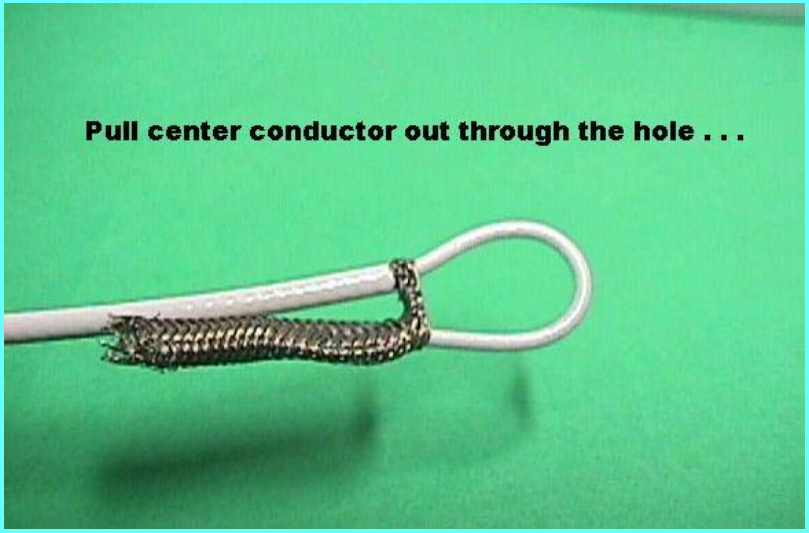


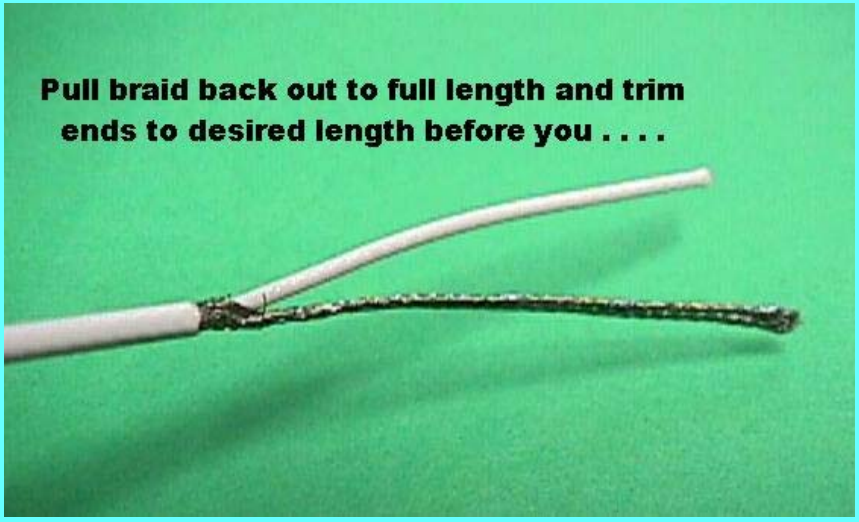
Routing wire bundles in airplanes

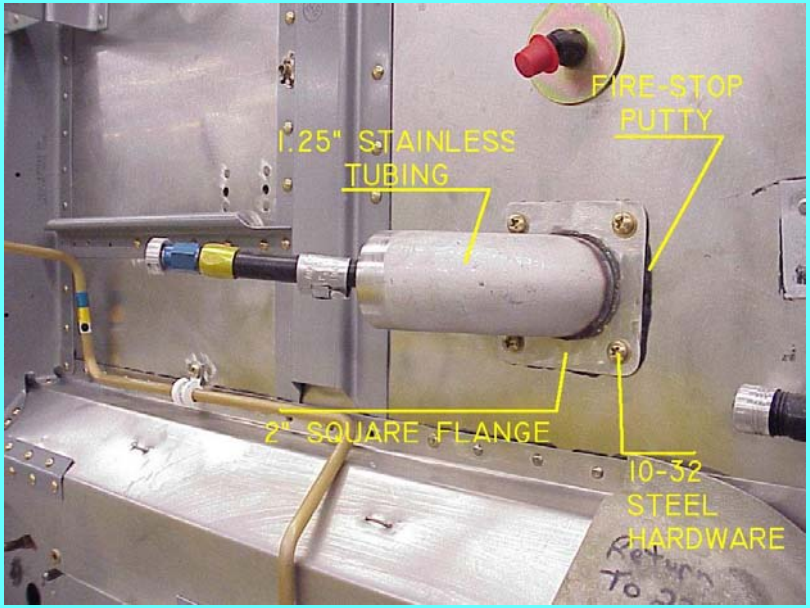


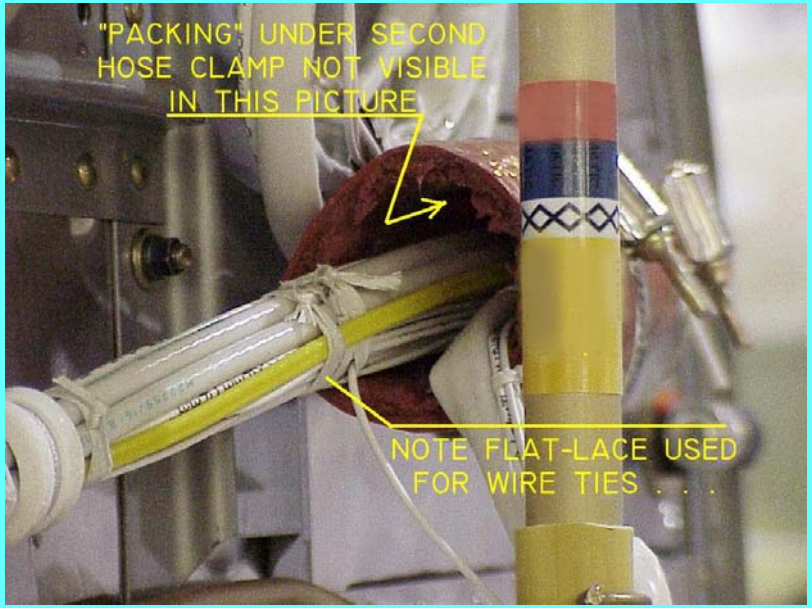


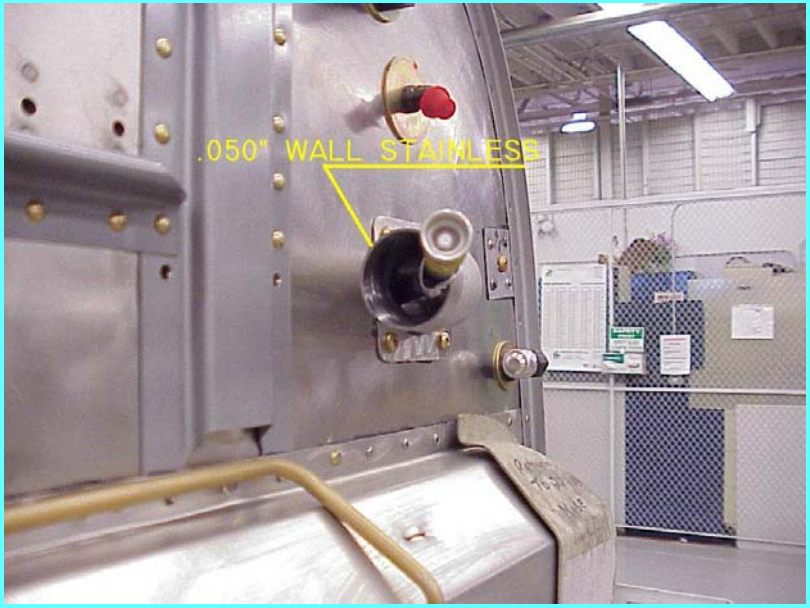
Routing wire bundles in airplanes

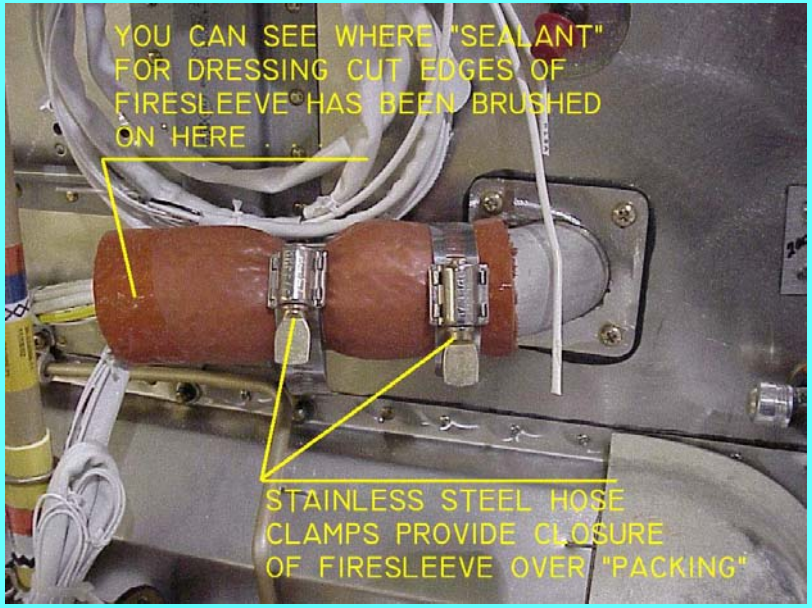


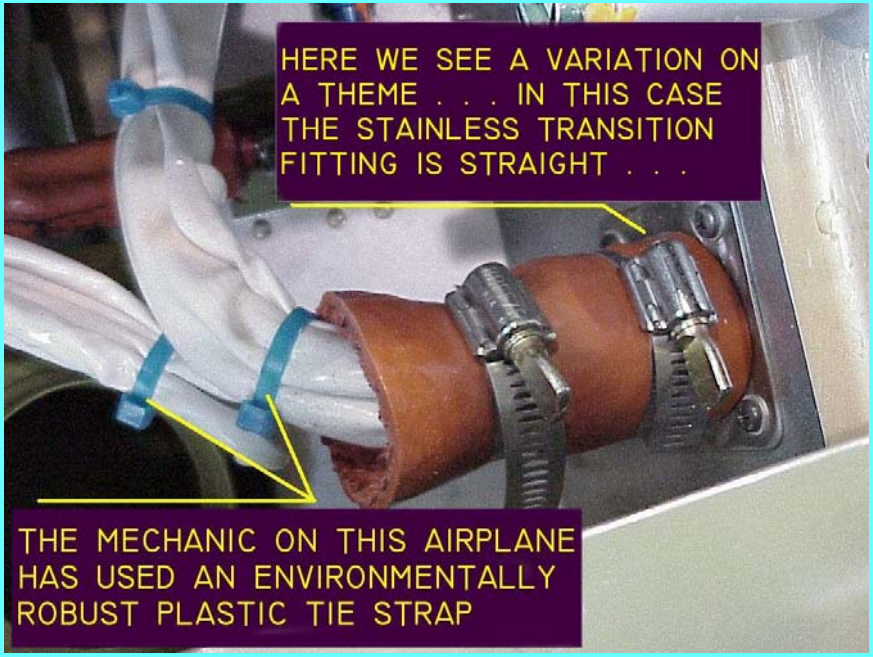


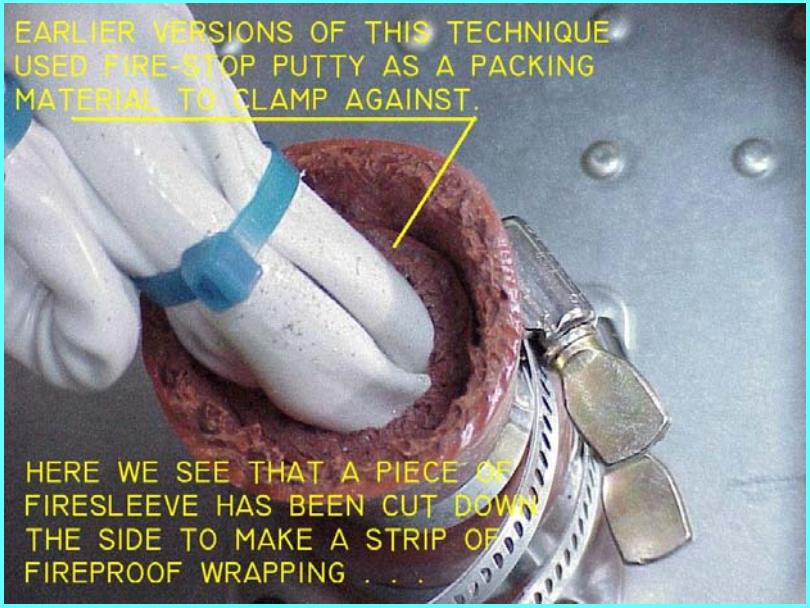

FIRE-STOP
PUTTY
1.25" STAINLESS
TUBING
2" SQUARE FLANGE
10-32
STEEL
HARDWARE

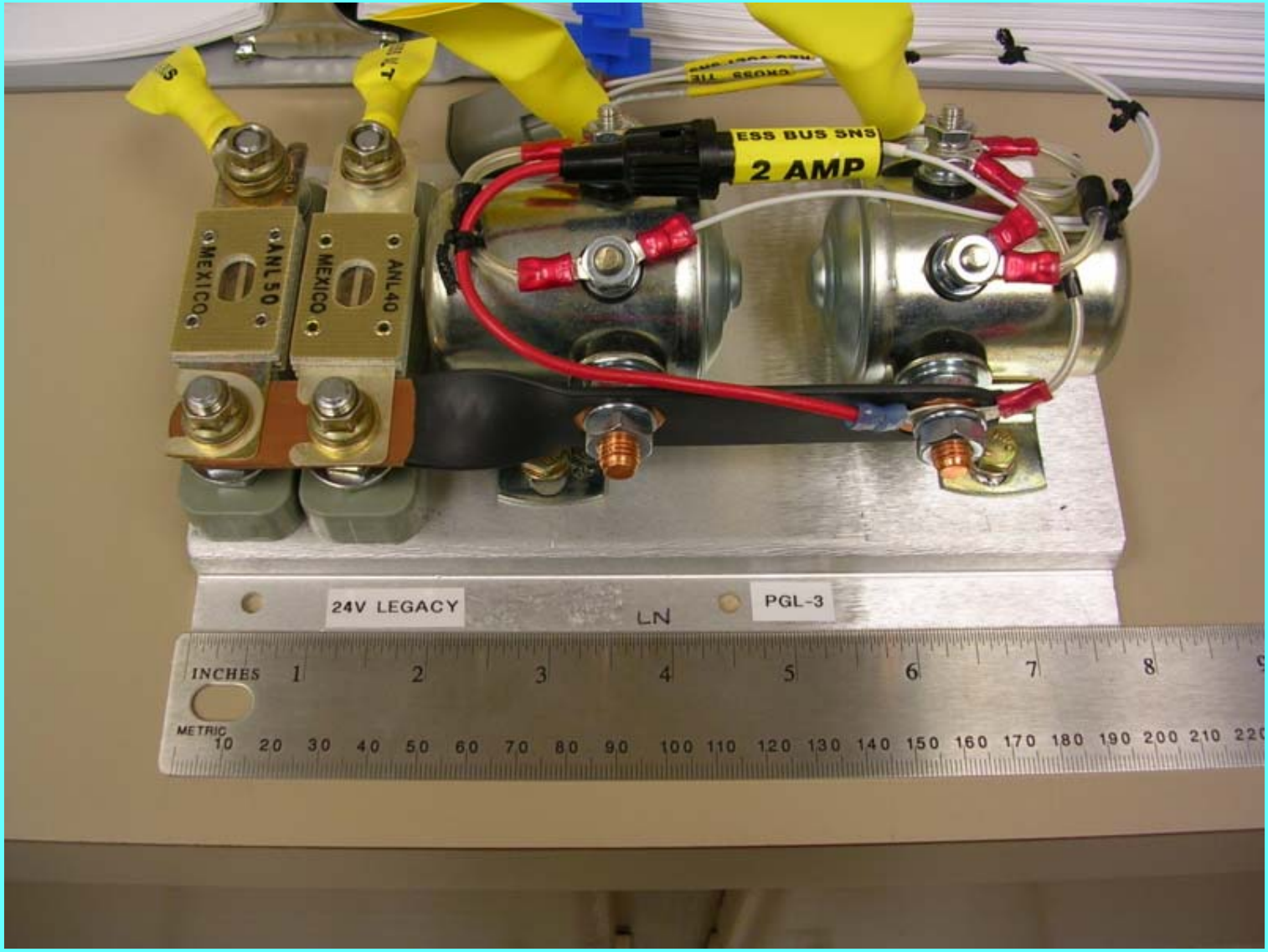

"PACKING" UNDER SECOND
HOSE CLAMP NOT VISIBLE
IN THIS PICTURE
NOTE FLAT-LACE USED
FOR WIRE TIES . . .

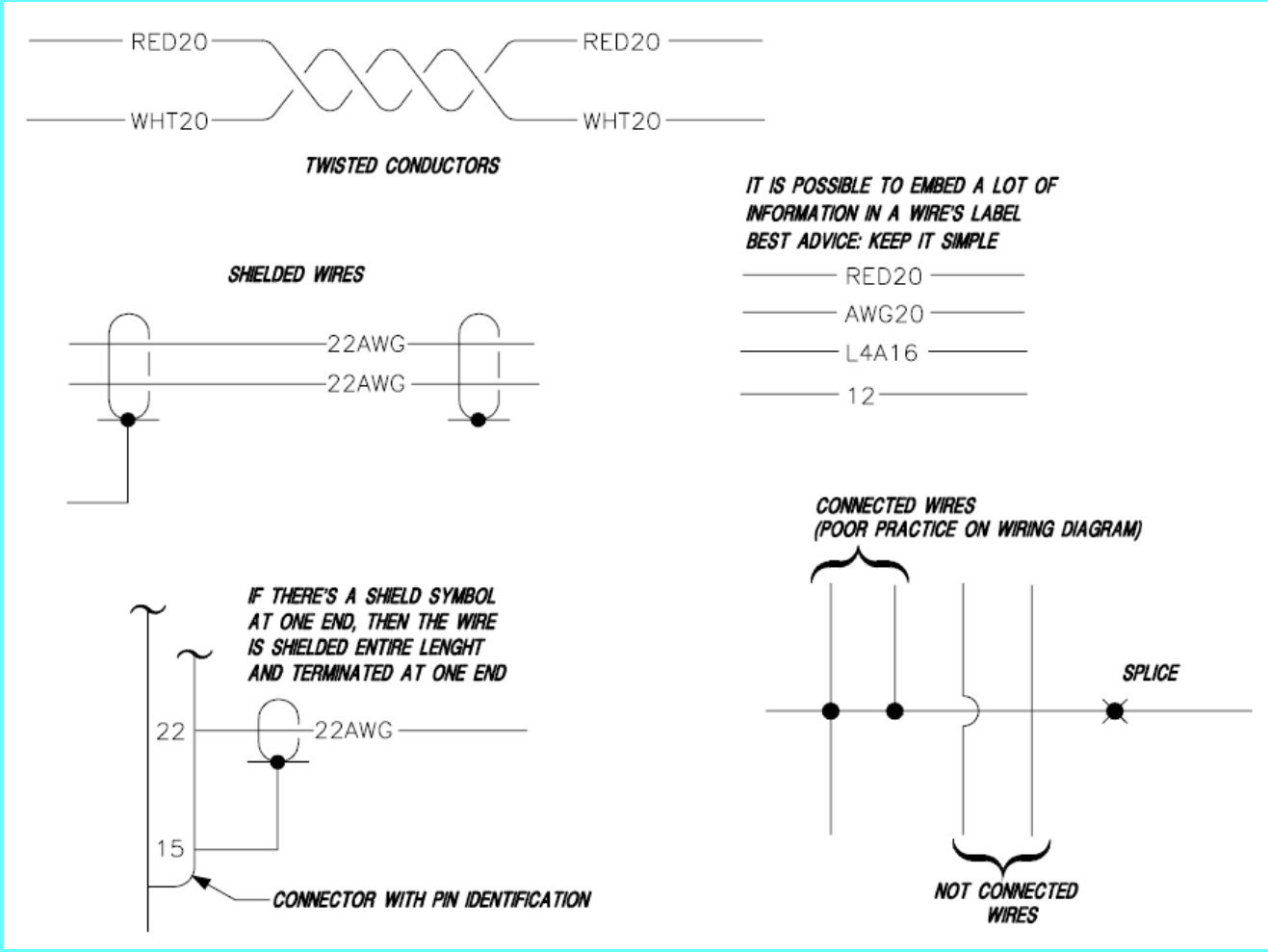

.050" WALL STAINLESS


YOU CAN SEE WHERE "SEALANT"
FOR DRESSING CUT EDGES OF
FIRESLEEVE HAS BEEN BRUSHED
ON HERE . . .
STAINLESS STEEL HOSE
CLAMPS PROVIDE CLOSURE
OF FIRESLEEVE OVER "PACKING"


HERE WE SEE A VARIATION ON A THEME . . . IN THIS CASE THE STAINLESS TRANSITION FITTING IS STRAIGHT . . .
THE MECHANIC ON THIS AIRPLANE HAS USED AN ENVIRONMENTALLY ROBUST PLASTIC TIE STRAP


EARLIER VERSIONS OF THIS TECHNIQUE USED FIRE-STOP PUTTY AS A PACKING MATERIAL TO CLAMP AGAINST.
HERE WE SEE THAT A PIECE OF FIRESLEEVE HAS BEEN CUT DOWN THE SIDE TO MAKE A STRIP OF FIREPROOF WRAPPING . . .


ESS BUS SNS
2 AMP
ANL50
MEXICO
ANL40
MEXICO
24V LEGACY
LN
PGL-3
INCHES
METRIC



- **Schematic symbols for wire and various methods for numbering and joining**