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J. Riedel

R.F. Note #89

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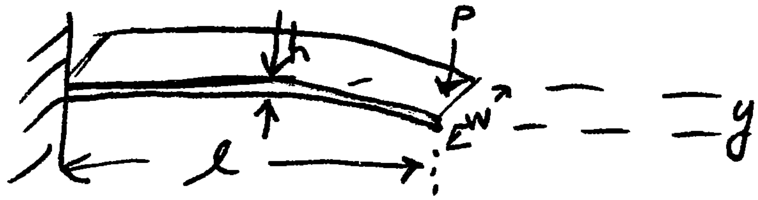
ON FINGERS



ℓ = length of cantilever beam, inches
h = thickness, in.
w = width, in.
P = force lbs
E = mod. of elasticity lbs/in.^{2}
I = moment of inertia of cross section = $\frac{Wh^3}{12}$
y = deflection at open end, in.
s = stress at fixed end, lbs/in.^{2}

art Hepler. mech. Eng.

Equations

$$y = \frac{P\ell^3}{3EI} = \frac{4\ P\ell^3}{Ewh^3}$$

$$s = \frac{6P\ell^2}{wh^2} = 1.5\ E\ \frac{h}{\ell}\ y$$

Parameter	ℓ in.	h in.	E lbs/in^2	Yield lbs/in^2	σ	α
our fingers (Be Cu)	.6	.01	19 X 10^6	1.4 X 10^5	110	1
new Glidcop	.95	.01	13 X 10^6	7 X 10^4	204	.9
new Be Cu, cu plated	.95	.01	19 X 10^6	1.4 X 10^5	110	1

where σ = thermal conductivity, BTU/hr/ft^2/^{o}F/ft
and α = electrical conductivity in comparison with Cu.

The other interesting equation is:

$\Delta T = \frac{H\ \ell^2}{2\ \sigma}$ where ΔT is the temperature difference from the contacting tip to the water cooled base, and H is the heat generated per unit square by the rf current. Since α is about the same, we will neglect it in the following comparisons.

For equal lengths and thicknesses we find that the ratio of the allowed deflection (to the yield point) for Glidcop and BeCu is 1.5 in favor of BeCu.

Because of the better thermal conductivity of Glidcop, the ratio of temperatures is 1.85 in its favor.

To get the same deflection at their yield point, we find that:

$$\frac{\ell 2}{\ell 1} = \sqrt[3]{\frac{E2}{E1}\ \frac{P1}{P2}} = .88 \left(\frac{P1}{P2}\right)^{1/3}$$

thus the pressure ratio for the same deflection is 1.5 in favor of BeCu, while the length ratio is .88 and thus the ΔT ratio would be reduced to 1.63 in favor of Glidcop.

For the K500 Cyclotron stem outer conductor panel fingers we have sufficient evidence to conclude that heating is not the cause of the problem. As a result of the above comparisons I conclude that for the K500 panel problem, copper plated beryllium copper fingers with either silver or graphite silver tits about .1 inches long would be better than using Glidcop! So there!! The above analysis is all very well for making comparisons, but it would be well to actually calculate the ΔT for our existing fingers.

$$\Delta T = \frac{H\ell^2}{2\sigma} \qquad .\ell = .6", \qquad \sigma = 2 \text{ watts/cm}^2/^{o}C.$$

The total outer conductor current at 30Mhz and 100KV would be 2600 amps, or 433 amps per panel. Our resistive paper work showed that the current density in the center of the panel was twice what it is at the edge, so the current density in the center is $\frac{433 \times 1.5}{8} = 81$ amps per inch, or 31.9 amps/cm.

The surface resistivity is 2×10^{-3} ohms per square, so the power density is

$$H = 31^2 \times 2 \times 10^{-3} \text{ watts/cm}^2 = 2 \text{ watts/cm}^2$$

$$\text{and } \Delta T = \frac{2 \times .6^2 \times 2.54^2 \times 4}{2 \times 2} = .8\ ^{o}C$$

So the superior thermal conductance of Glidcop is of no significance, and the fingers are not being destroyed by heating.

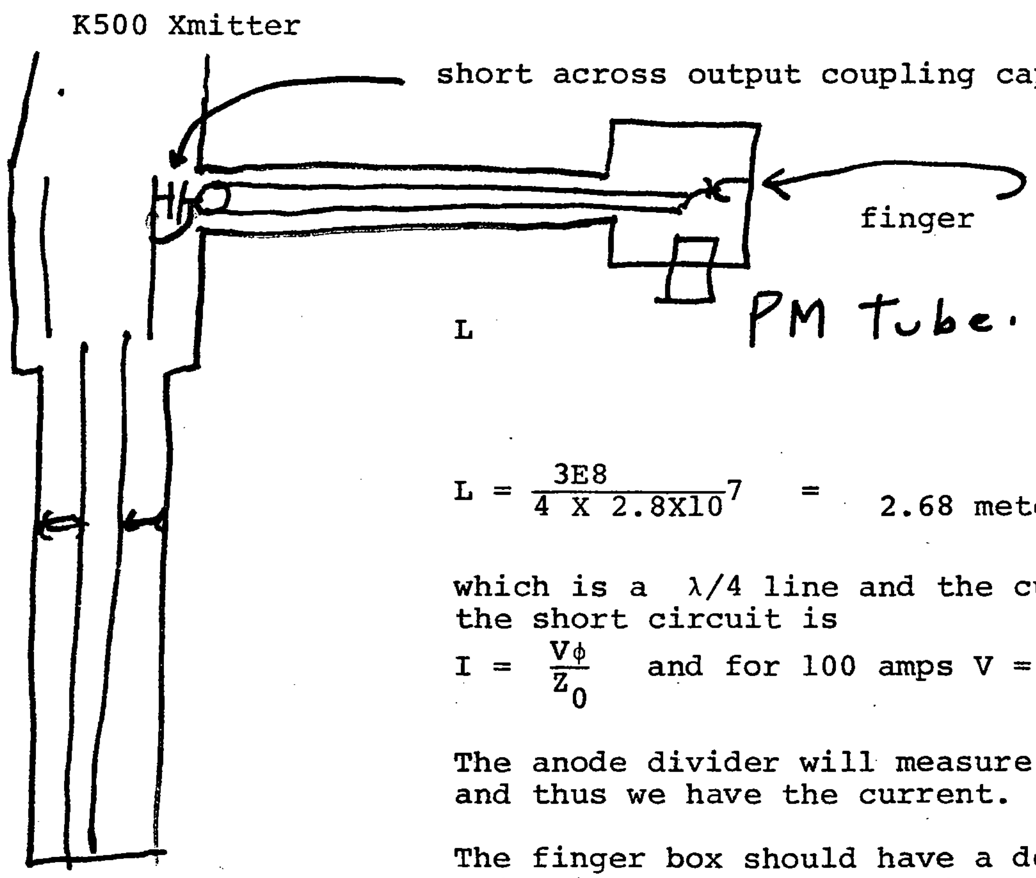
<u>Silver on Cu, Silver on Silver, or Graphite Silver on either Cu or Silver?</u>

In R.F. note #9, written, lo, these many years ago, we described some tests with a finger. Unfortunately, the documentation shows clearly only that silver plating the contact resulted in it's being able to carry 40 amps without damage, (vs only 5 amps for copper) but it is unclear whether the opposing surface also had to be silvered. However, it was because of this test, which finally used silver on silver, that we contracted for the expense of silver plating the inner conductors of the K500 stems. Please note that we have not had a single failure of these inner conductor contacts!

There is no doubt but that it would be safest and best, therefore, to plate all surfaces on which finger contacts are made. However, in view of the cost of plating the panels (estimated to be between $10,000 and $20,000), it behooves us to make another test, especially so since it is very simple and easy to make this test.

The finger tester should be capable of destroying any finger and therefore I propose that it be capable of forcing 100 amps at 28 MH_Z through the finger. Again, I want to use a photomultiplier tube to look at it to detect the very first signs of damage.

The set up will be simple, as picture below.



$$L = \frac{3E8}{4 \times 2.8 \times 10^7} = 2.68 \text{ meters}$$

which is a $\lambda/4$ line and the current at the short circuit is

$I = \frac{V\phi}{Z_0}$ and for 100 amps V = 7500 volts rms.

The anode divider will measure this voltage and thus we have the current.

The finger box should have a device for adjusting the pressure and measuring it.

We will try all of the titled options.