R.F. Note #92

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12/22/83

K800 Transmitter

DRIVER

The new driver circuit was completed and tested on 12/10/83. It is the circuit described and the calculated results are presented in RF note #82. It works fine, although with only 39.25" instead of 42 inches of travel for the stub tuner it could only get down to 9.15 MHz. This driver is able to comfortably provide up to 300 volts peak drive voltage to the grid of the RCA 4648 final amplifier over the entire frequency range 9 to 28 MHz, whereas 225 volts peak should be enough to produce 250 KW output.

FINAL

The anode circuit of the transmitter at present is the design of W. Worsham. Mechanically, it is very elegant. Electrically it is a loser. Since this design has never been presented in an RF note and shall do so here. Figure 1 shows the mechanical design, and figure 2 the equivalent circuit. Figure 3 shows the measured modes, for one set of parameters. It is patently impossible to avoid exciting these modes when harmonies of the fundamental cross them.

When we were satisfied with the new driver we turned the final on and drove it, first at 27.5 MHz. The sixth harmonic, at 165 MHz, was ten times larger than the fundamental. Then a strong line at 400 MHz appeared on the SA. We edged downwards and successively excited 5th, 4th, and 3rd harmonic modes until we got to 25.5 MHz where we were clean by virtue of tricky adjustment of the two condensers. Then we were able to deliver 250 KW into the water load at 83% effeciency. After about 10 minutes the main breaker opened and we quit for the day.

Thus we were able to prove that the tube is O.K., and that apparently the 1.3 GHz parasiter inherent to the tube causes no trouble, at least at 25.5 MHz. The tube performance: 20 KV B+, 1.2 KV Sc Volts, -200 Vg, 225 volts peak drive was almost exactly what program "TUBE" calculated.

1.3 GHz PARASITIC

Previously we tried to suppress this parasitic. We are poorly instrumented for microwaves. We have a tecktronix plug in spectrum analyzer good to 2 GHz, and a GR oscillator covering to 1.5 GHz. We also have NE2's. These are tiny neon bulbs, the neon at about 100 μm pressure and have the property that they break into a visible glow discharge when 90 volts appears across them and thereafter regulate the voltage across them to 60 volts. We stick them onto various surfaces in the anode box. With these three instruments we were able to learn the following.

1.) With the P.S. at 5 KV and Vsc at 1 KV we reduce the grid bias, and observe that the neon bulbs start glowing and the SA produces a line at 1.3 GHz when the Ip > .5 amps. If we lower the grid bias a little more the signal squigs at frequencies from 100Hz to 1 KHz. This is due to the fact that large chunks of screen current flow, reducing the screen voltage so that oscillations disappear until the screen voltage recovers. I presume everyone knows what squeeging is.

2.) Meanwhile we had acquired some Q1 ferrite sticks (μ=10, L=6", w=1/2", t=1/8"). We pasted 8 of these to the screen by pass condenser radially and absorved that now we could go to 1.5 amps before the parasitic manifested itself.

3.) We now acquired some eccosorb material. This is 1/4 inch thick foam polybutanol with carbon particles imbedded in it. Covering the emtire surface of the screen bypass condenser with this stuff killed the parasitic (up to 10 amps dc at least). Unfortunately the Q of the fundamental was reduced by a factor of five and thus it would burn up. We proved this by putting 800 volts peak on the anode from our 100 watt amplifier, and, indeed, it started smoking after only 10 seconds.

4.) We could also kill the parasitic by covering the anode housing with this stuff.

So it was obvious that all we had to do was to install this stuff on various surfaces in such a way as to kill the 1.3 GHz parasitic but protect it from the 9 to 27 MHz rf. This can easily be done by installing 13 inch long $\lambda/4$ resonators vertically on the anode housing and putting the eccosorb material in them. At 1.3 GHz, $\lambda/4$ = 2.27". A resonator was built and tested and it was determined that with H=.5 inches the proper length (edge effects) was 2.1 inches. Fig. 4 shows four of these mounted in the anode box.

Meanwhile, we await a tuned absorber form Emerson and Cummings. With this material we may not have to build the resonators to hide the absorbers. All in all, I feel that the 1.3 GHz parasitic can either be ignored or licked. It did not bother us at 25.5 MHz as predicted by RCA. However there is a long history of lurking latent problems suddenly becoming manifest and kicking you in the "you know where".

K500 Transmitter

The K500 transmitters have had their problems, and some still remain. After we got the right bicycle chains on them they have given no more problems. We still experience not very frequent failures of the fingers, but we think that if we replaced these fingers with the carbonated silver tips a la Phillips, as we are going to do for the dee stem outer conductors, this problem will disappear.

Early in the testing of the A transmitter we had a problem with parasitics, but after we tore it apart and cleaned all the surfaces and put it back together again, this problem no longer existed. And it is a fact, not previously mentioned, that, into a dummy load, we smoothly operated over the entire range 8.3 to 35 MHz with no evidence of harmonic excitation anywhere. This was before the capacitor fine tuner was installed. When the fine tuner (the nth fine tuner after many false starts) was installed then we were able to see harmonic excitation unless we adjusted the stem short so that the fine tuner operated in a restricted portion of its range. Adding a discrete fine tuner doubles the number of modes in the system. That is why I propose to make the K800 transmitter to be described below.

K800 FINAL AMP PROPOSAL

The present design of the anode circuit is, in my opinion insuperable. Many frequencies would be denied to us, and at any frequency tricky adjustments of the two condensers would be required. The extra complications when we are required to drive a dee instead of a water load, attendent on slight mistuning of the dees seem insurmountable to me.

Therefore, I say scrap it! Some may think that this is just another manifestation of the pitty NIH syndrome. Maybe it is, but I think I have given this design a fair shake, waiting to test it, etc. We can spend a few more months pinpointing which frequencies have to be avoided. Then we have to modify it anyhow since I notice that there is no provision for grounding or biasing the transmission line. I have spent many agonizing hours coming to this decision and feel compelled to present the following arguments.

1.) A pure L in parallel with a pure C have only one resonant mode. Unfortunately each L also has C's and each C has L's. Usually with discrete L's and C's the higher modes are very high and thus cause no problems.

2.) If two C's are paralleled another mode is introduced because of the inductance involved. That is why we had to cut out the bolt in capacitors of the driver grid sockets, and also why in paralleling the two driver tubes we deliberately added an inductance and then damped this extra mode out with a resistor. We had to do the same with the two monitors.

3.) The criterion is clear: use the absolute minimum number of components! A capacitor loaded transmission line is the simplest we can achieve, given a tube with its capacity. Then achieve resonance by varying the length of the transmission line. There are higher order modes, $3\lambda/4$, $5\lambda/4$, $7\lambda/4$ etc., but these move with the short and are unlikely to coexist with the fundamental. Since there are an infinity of such modes, though, eventually there will be coexistence, i.e., one of these modes will be an exact multiple of the fundamental. If this multiple is < 20 then they will be driven by the small conducting angle of a high effeciency tube, resulting in high voltages leading to sparking, or to reduction of the tubes effeciency; sometimes to excessive screen currents.

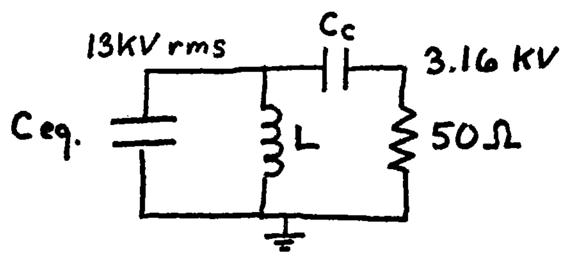
To make a check on the above statements we successively removed the two tuning condensers and the output coupler from the K800 anode ckt and measured the modes. Between the fundamental, now at 32.7 MHz and 160 Mhz the number of modes had been reduced to 4 (from about 20). Modes at 91.3, 97.0, and 101.4 were low impedance modes and can be ignored. So there was only one troublesome mode left. This was at 153 MHz and its shunt impedance was

5 times higher than the fundamental. So we would have had trouble at 30.6, 25.5, 21.86, 19.13, 17.00 and 15.3 MHz. This mode needs to be identified, and trapped out. If we only have one such bad mode we can lick it.

It is proposed that we adopt one of the designs proposed in RF Note #80, with certain modifications. In that note we were to use a moving short in a region where ID=6", OD=30" and the OD was a duodecigon (12 sided polygon). At a meeting on 12/13/83 it was decided that the mechanical people (H.B.) would choose the cross-section geometry for this region, considering all polygons from 3 to ∞ sides. Then Vincent will use "TRANS" to optimize the other dimensions, striving to make the total length short enough such that push rods can be used, although bicycle chains are OK, and minimize I max and energy storage.

The fingers are to be carburized silver tips about .1"diam and .1" long, each tip being on the end of a silver plated BeCu leaf spring about 10 mils thich, 1/8" wide and 1" long. We will start without a fine tuner, but the design should be such that a distributed fine tuner capacitor of 10±5 pf can be added.

Let me now discuss the tuning requirements and why it is desireable to minimize energy storage. As far as the transmitter is concerned, when it is delivering power to a properly tuned dee via a 20 foot long transmission line that is terminated by the dee the equivalent circuit is as below.



The Q of this circuit is $\frac{\varepsilon}{w}$ where ε is the circulating energy and w is the delivered power, set at 200 KW. $\varepsilon = Vo^2 wCeq$. In rf note #80 Ceq could vary from 100pf to 800pf, thus ε varying from 3 MVA at 28 MHz to 7 MVA at 9 MHz. This corresponds to Q's from 15 to 35.

Now the normal $\Delta F/F$ due to normal $\Delta T/T$ is about .1%. Obviously with low Q's like 15 or 35, .1% mistuning will hardly affect the amplitude, but it will cause a phase shift between the tube current and the rf voltage of about 10%. Well, the fast phase loop can take care of this, and the tube effeciency is only slightly lowered. This is why transmitter fine tuning is probably not necessary. The plan would be to adjust the transmitter shorts at low power with closed loop. Then before going to high power open the loops so that the shorts do not move during a long run.

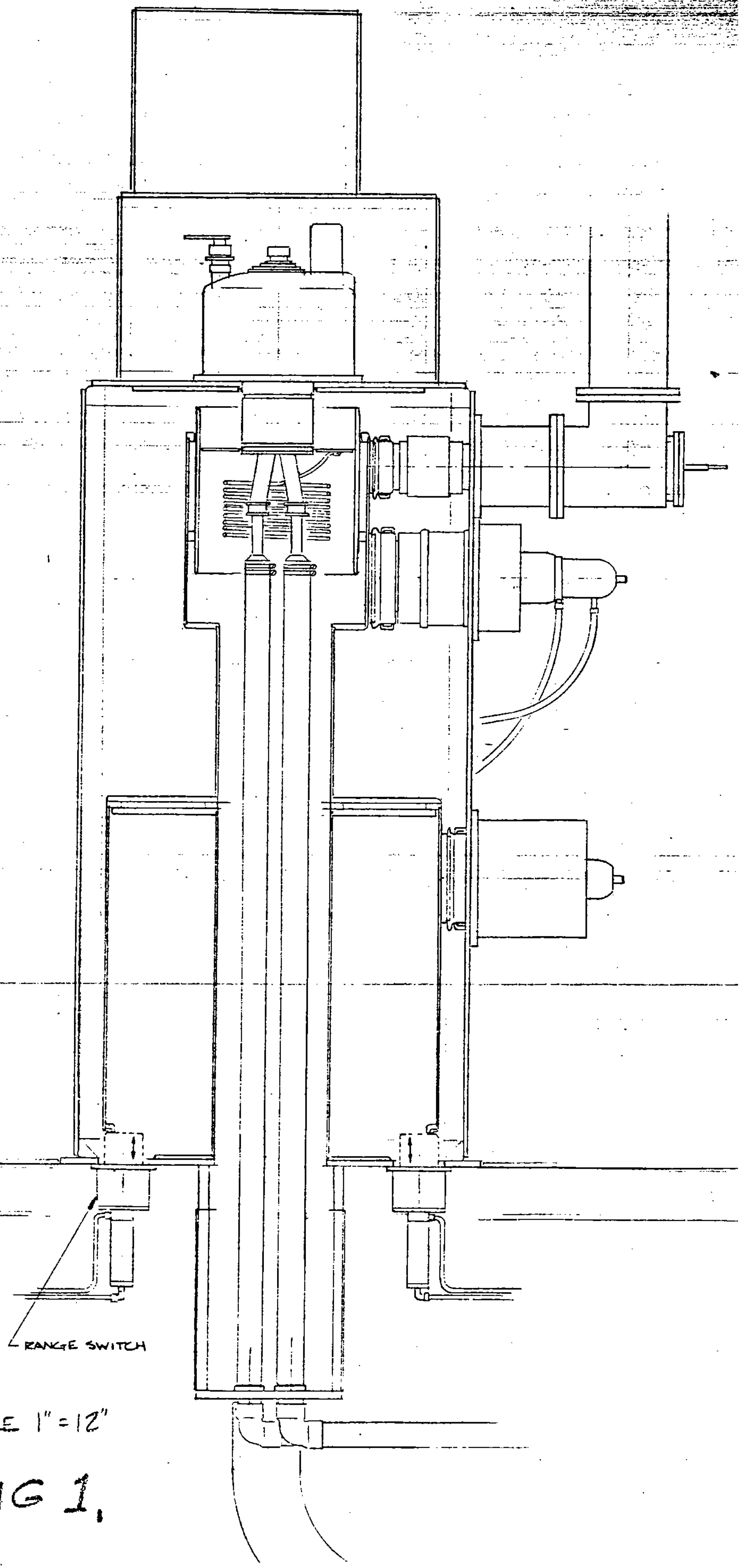
TRAPS

Traps are used to snare animals, and in rf are used to lower the impedance of an undesireable mode without burning up from the fundamental power. For example, to trap out the 153 MHz mode one first finds out where the voltage maxima are and where the current maxima are.

Say we couple into a voltage maxima with a capacitor, put an L in series to resonate at 153 MHz and a series R to absorb power at 153 MHz and not burn up at 30 MHz. We thus have a series LRC circuit, where $\omega L = \frac{1}{\omega C}$ at 153 MHz, and at 30 MHz we have $X=\omega L$. So that we do not have to tune it too carefully we make Q=20 at 153 MHz.

So we make $C=5\times10^{-13}F$, $L=2\times10^{-6}$, Q=2, R=100Ω at 153 MHz. At 30 MHz, R≈50Ω and for 13 KV rms, $W=I^2R=\left(\frac{V_o}{\omega C}\right)^2 R=$ 84 watts.

Thus this trap looks like 50 ohms at 153 MHz, but looks like 2×10^6 ohms at 30MHz.



SCALE 1" = 12"

FIG 1.

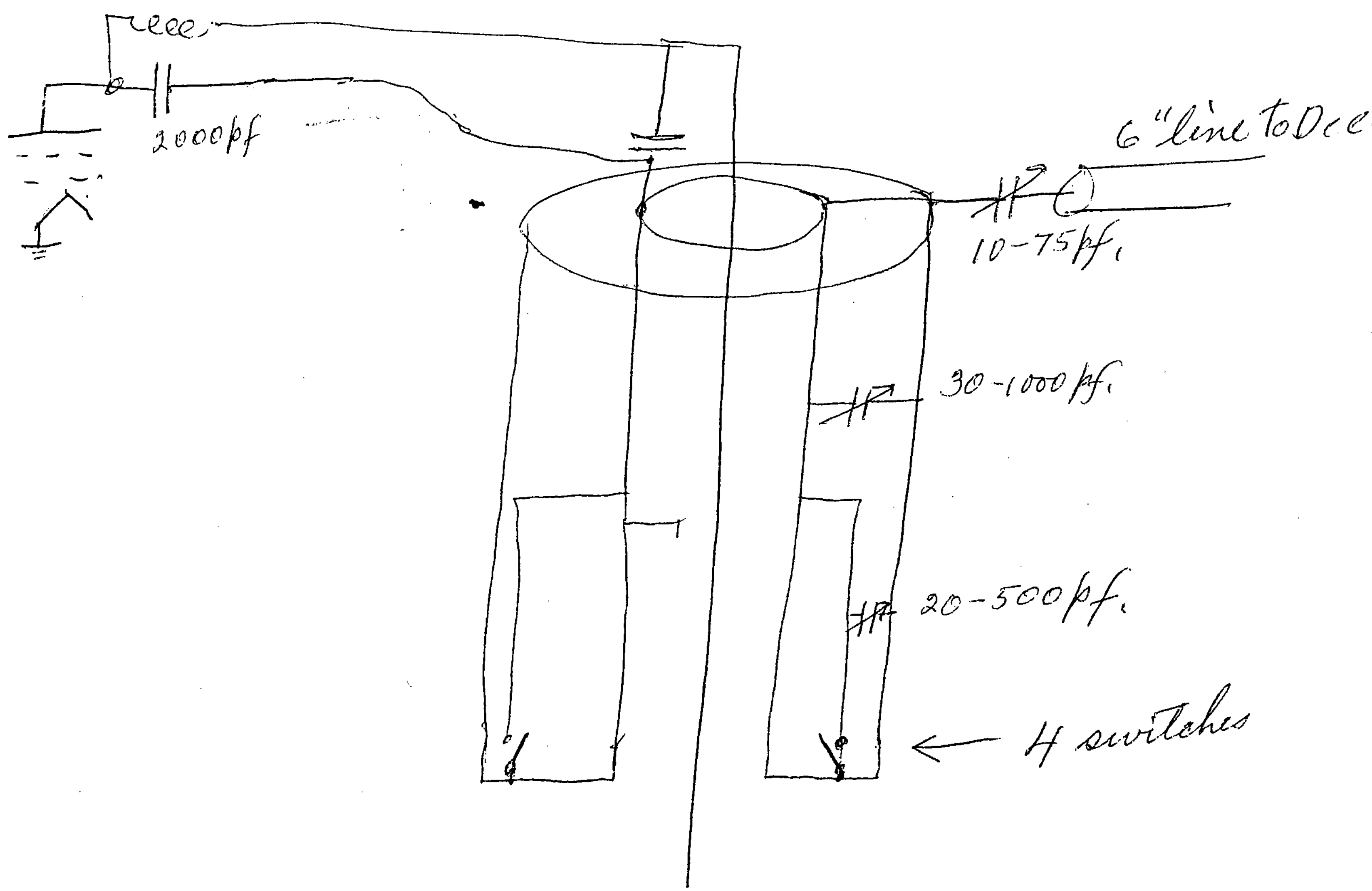


FIG 2.

Minimum Capacity
Anode Inductance LOW
K800 Final Anode

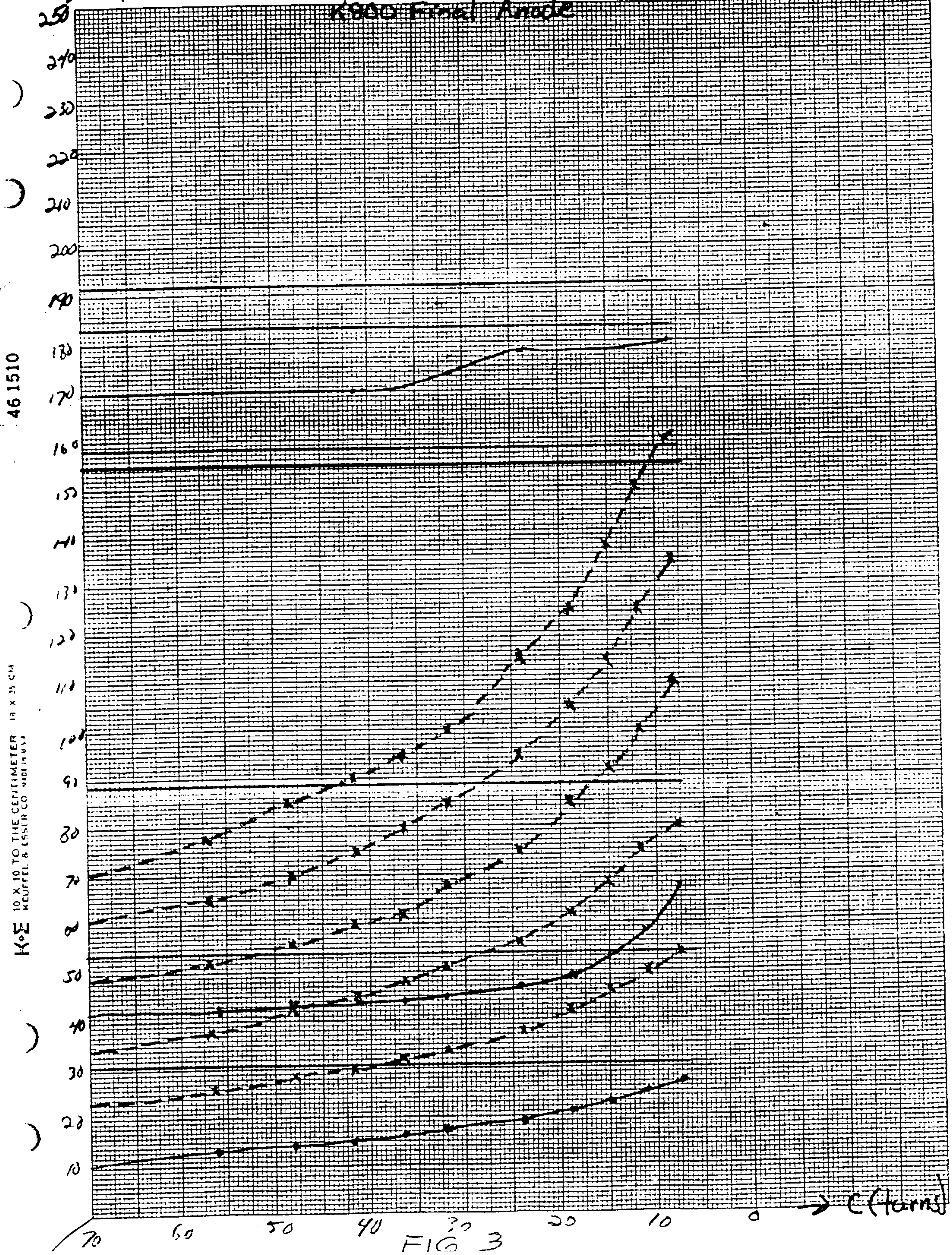
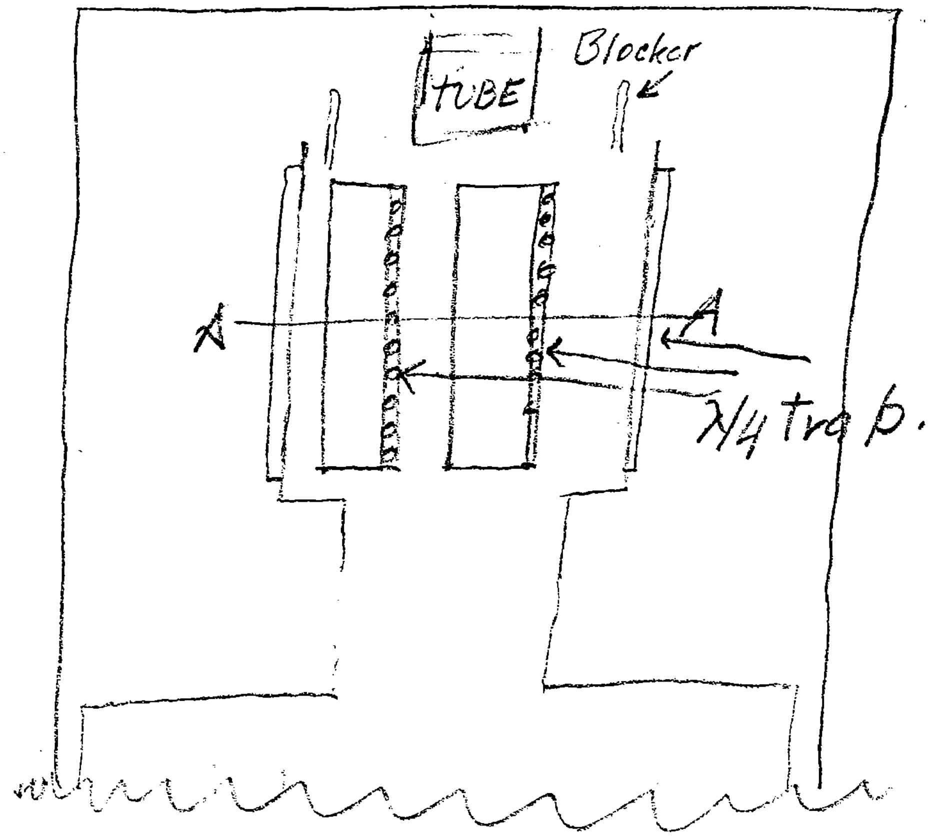


FIG 3



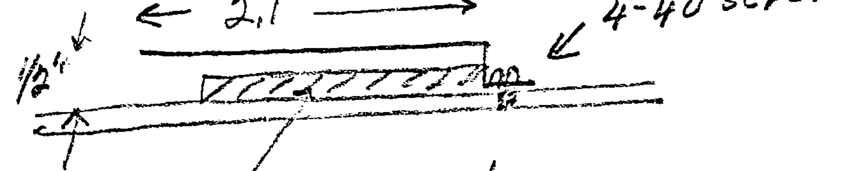


Fig4.