R.F. Note 72

April 21, 1981
J. Riedel

K800 RF SYSTEM again

In the last rf note we presented a possible design for the K800 rf resonators, with qualms because of certain deficiencies with the 1/2 scale model. The model was improved and finally we got some believable results. The measured Q at the low end of the frequency range agreed with the calculated value to within 10%.

The program was modified to give the same F vs L and voltage distribution as the model up to 80 MHz and we felt we could now proceed with confidence to compute an optimized design. Meanwhile we used the resistive paper technique with a new twist to determine the electric fields in the insulator and thus the losses. The new twist was to mask off the area where the insulator was and spray it with aquadag (graphite in a water suspension) until the resistivity there was 1/10 of what it was elsewhere. The results were quite dramatic: the equipotentials always went perpendicularly through the insulator so that the electric field was always parallel to the surfaces.

The losses in an insulator are

$$W = \frac{\omega K K_o}{2Q} \int_v \frac{V^2}{d^2} dv$$

and the design of Fig. 2 of R.F. Note 71 resulted in a power concentraton of 5 watts per square inch where the insulator connected to the ground surface. This much power is considered excessive, so the insulator was moved further from the M/P and was wholly within the 26 inch hole. The insulator was lengthened and the cone angle increased and the power was thus brought down to .5 W/in^2. We were happy for only a few days. R. Burleigh contacted WESGO and was informed that that insulator couldn't be made. Further, any cone probably would cost 10 times as much as a cylinder, for to make a cone they started with a thick walled cylinder and ground it into a cone after firing.

We regrouped and planned a different line of attack. We would use a cylinder! In fact, why not the K500 insulator. This has the advantage that we know it can be made, and also we can start testing right away with one of the K500 spares. This insulator is 15.75" OD by 9" long by 3/8" wall thickness. We tried a few designs and temporarily have settled on version E.

One concern was that the resistive paper technique solves LaPlaces equation in only two dimensions, whereas for the three dimension case we know the fields will be higher. Consider concentric cylinders where E_r = V/r ln b/a whereas for a plane E = V/(b-a). Fig. 1 is a plot of K = (b/a - 1)/ln b/a which is the field enhancement at a due to taking the third dimension into account.

Note that for small b/a the correction is small but for large b/a it is dominating. Still, for the region where the insulator is, where b/a = 1.6 a correction factor of 28% applied to our resistive paper work was probably satisfactory.

To check this, Dave Johnson, using a library program called Poisson, was able to solve for the fields exactly. Fig. 2 is the computer plot of the equipotentials in an r, Z plane for a figure of revolution about the axis and Fig. 3 is for a simple x, y case, corresponding to our resistive paper results. If the correction factor of Fig. 1 is applied to Fig. 3, Fig. 2 results. Voila!

For this particular case the maximum gradient was 14 kV/inch for 100 kV across the insulator. This results in

$$W = \frac{2\pi \times 2.2 \times 10^{7} \times 10}{39.37 \times 2 \times 2 \times 10^{4} \times 36\pi \times 10^{9}} \times \left(\frac{1.4 \times 10^{4}}{1}\right)^{2} \times .375 = .57 \text{ W/sq in}$$

having to be carried off on the air side of the insulator. The calculation was done at 22 MHz which, as will be shown below is the worst case. Even with this modest power it will be advisable to blow air by the insulator, as the Q goes to pot very quickly with temperature. At 300°C the Q has halved.

Another possible problem with the insulator design is sparking in air. From Fig. 2 one learns that where the gradient in air is the highest, namely at the corona ring, the gradient is 70 kV/inch for 100 kV on the corona ring. This is a safe operating gradient, the limit being 76 kV/in.

So we are happy with this design and present it. Fig. 4 shows the geometry to just below the insulator. Below the insulator, in the region where the short moves, the outer conductor is a hexagon fitting about an inscribed circle of 28 inch diameter. Table I lists relevant results for a few frequencies, and Fig. 5 is a graph of F vs short position and V DEE vs Frequency. This latter curve is from Resmini who claims that to keep the turn number reasonable we wouldn't want to work at a higher voltage than shown in this graph. This is nice, as it results in the highest voltage at the insulator being 107 kV (at 18 MHz).

The maximum current density at the short is 4000 amp/6π = 212 A/in = 83.5 amps/cm, about the same as for the K500 design. So IF the K500 works satisfactorily then the K800 will too. Enough of the resonator; we will let it sit and stew for awhile. Undoubtedly we will change it.

Transmitter Status and Plans

Pieces for the transmitter anode box have arrived and we expect it to be assembled with a screen bypass condenser installed

F	L	V_{EXT}	V_{INJ}	V_{cent}	W_{KW}	Q	Rs	I_{max}	V_{ins}	C_{eq}	C_{coup}
27	62	200	209	179	181	5100	110	4000	74	275	2.5
26	64	200	208	180	174	5300	114	4000	72.5	284	2.55
24	68	198	204	182	155	5700	125	3800	89	302	2.65
22	72	186	191	173	126	6100	136	3500	99	322	2.76
20	78	173	177	163	99	6500	150	3100	105	343	2.9
18	86	158	161	151	74	6900	167	2600	107	365	3
15	103	133	134	128	44	7430	196	2000	103	400	3.4
12	133	103	104	101	22	7700	231	1300	88	442	3.9
9	190	100	100	180	18	7600	270	1100	92	500	4.8

TABLE I

Where L is in inches
V in KV
Rs in $K\Omega$
I in Amps.
C in pf.
F in Mega Hertz.

$\Delta L = 128'' =$ range of short.

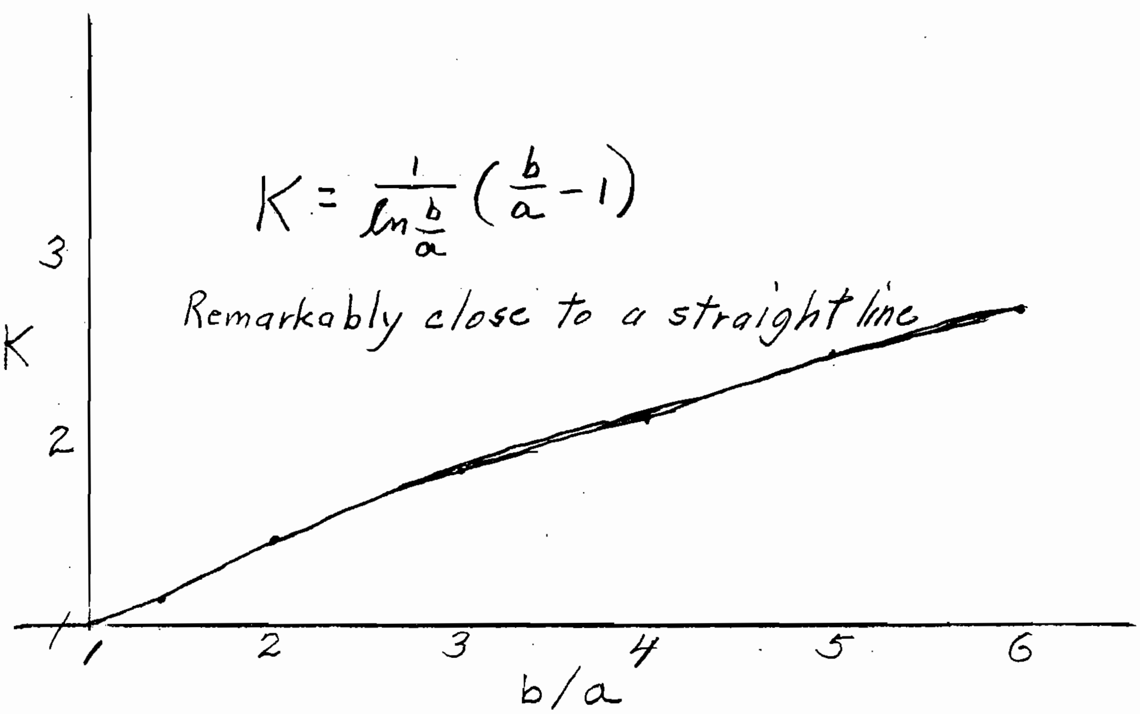


FIG 1

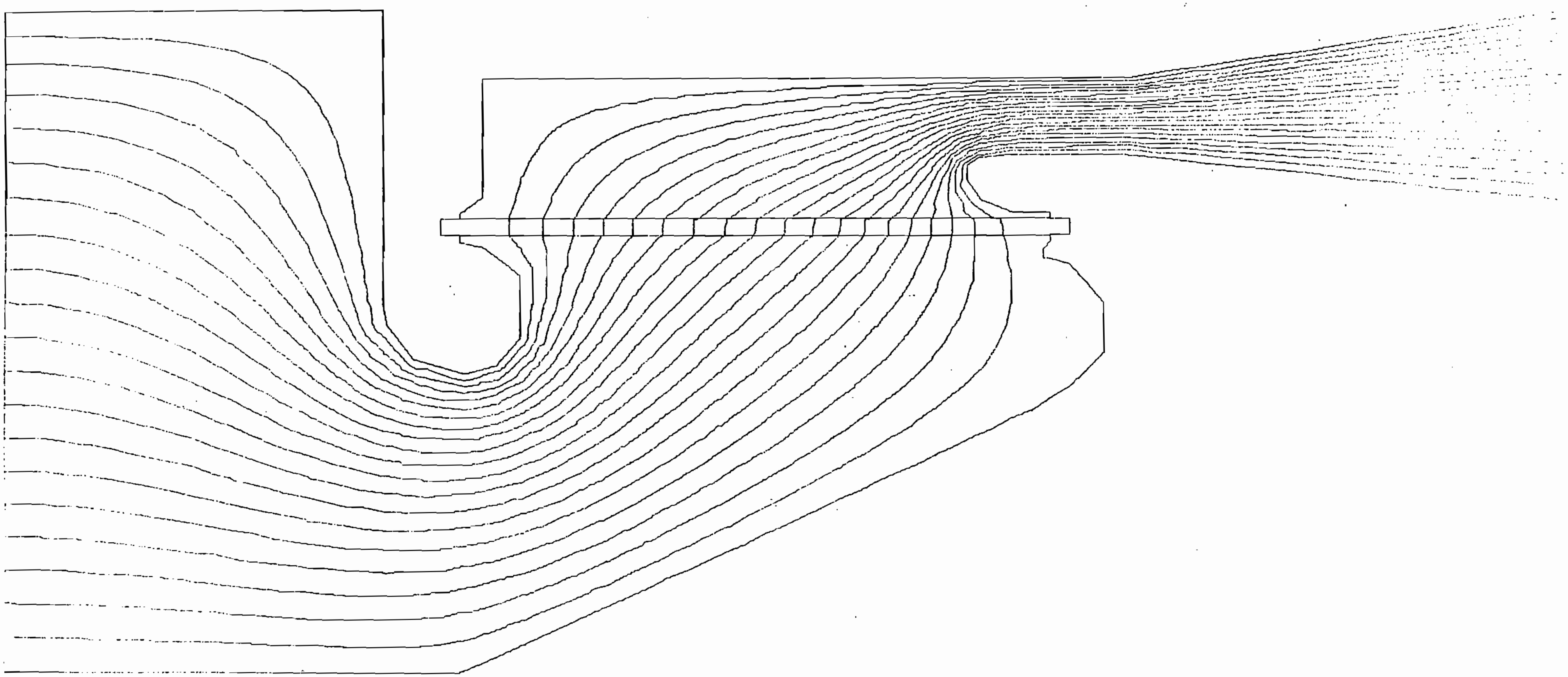


FIG 2

PROB. NAME = DEE STEM r,Z CYCLE = 160

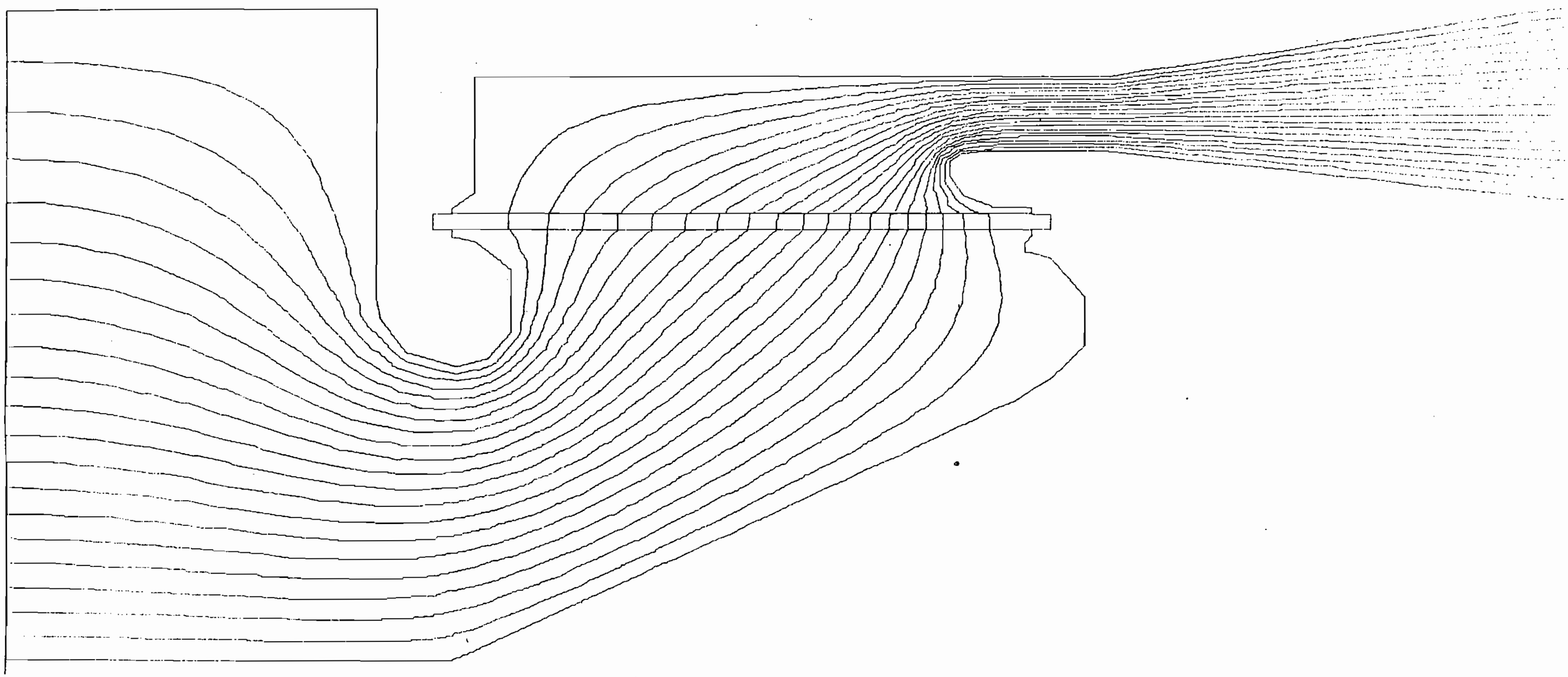


FIG 3

PROB. NAME = DEE STEM X,Y CYCLE = 160

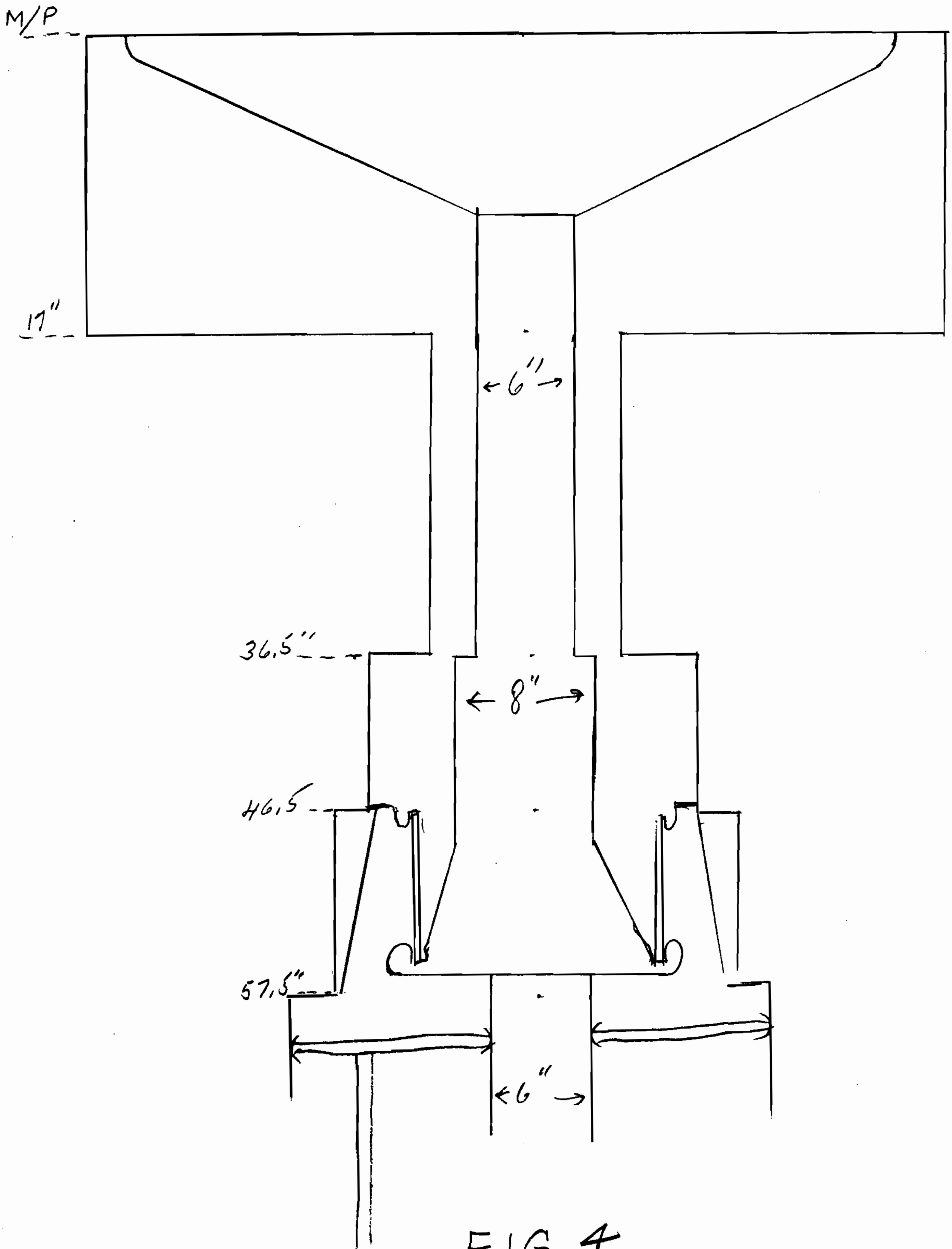


FIG 4

K+E 10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 1510

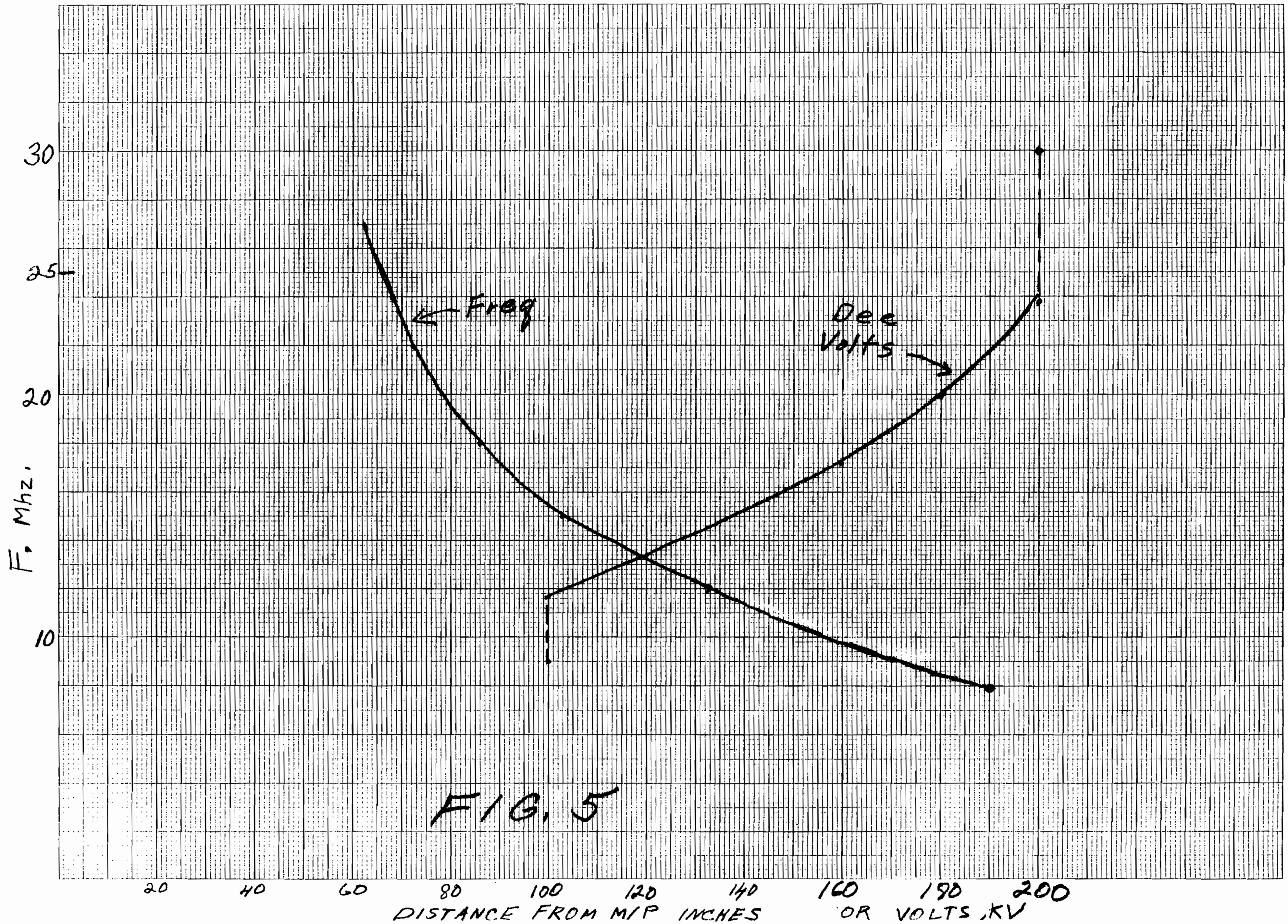


FIG. 5

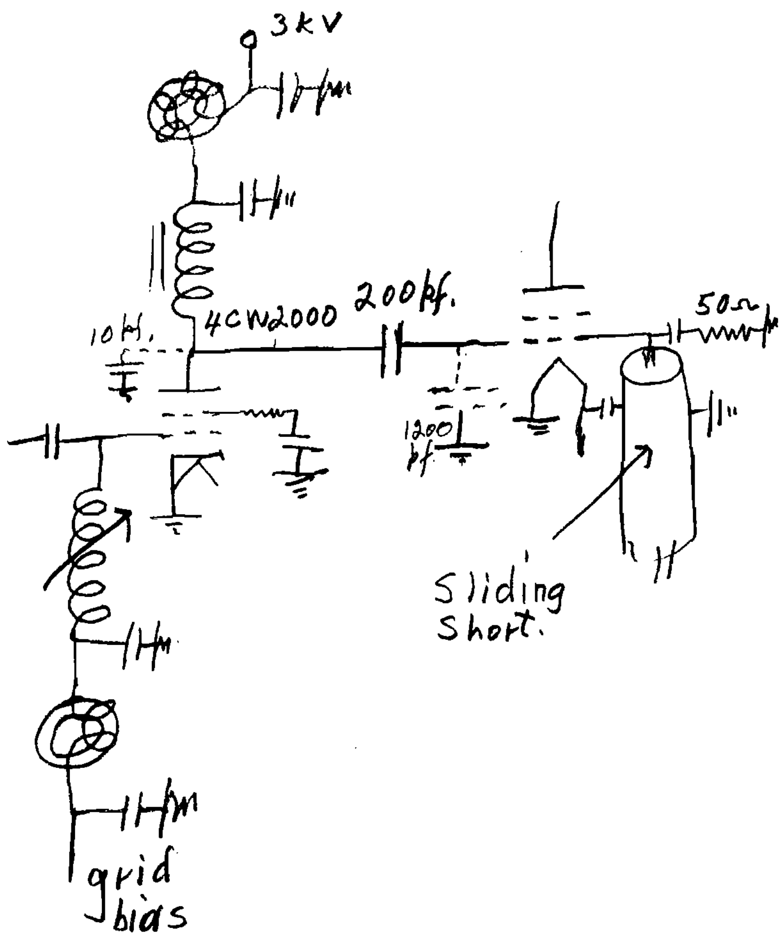
by June 1, 1981. The filament P.S. should also be assembled by this time so that we can not only check out the grid circuitry, but test the tube and generate a real set of data sheets. Meanwhile, I feel so confident about the transmitter that I say we can simply relable the K500 drawings for the transmitter stem and sliding short.Instead of ordering 1, order 4, three for the K800 transmitters and one for the permanant test stand. In any case it would be desirable to have at least 1 stem on hand by November 1, 1981. The 300 kW dummy load will be here by then and we can test the transmitter. Fig. 6 shows how I presently plan to drive it. It will be as easy as eating duck soup to build this driver by November 1, 1981.

Aydin P.S.

The 1.2 MS P.S. for the transmitters is scheduled to arrive on 8/1/81. This is bad timing, because we will be very busy at that time trying to turn the K500 on. Normally, power supplies are delivered a year or so later than scheduled, but if nature is as perverse as usual, this time the P.S. will probably come on time. The problem is that we are not prepared to acceptance test it under full load. We don't have a 1.2 MW load, and until the LCW system for the K800 addition is realized even if we did have a load, testing would be difficult, even if possible. The K800 LCW system probably won't be available until a year from now. For about $20,000 we could have a 1.2 MW water load in four months. But if, instead, we build the 4 transmitters, one working into the 300 kW RF water load, these transmitters can constitute the total dummyload and we save $20,000. We'll chew our cud on this for awhile.

R.F. Test Stand

Fig. 7 shows how I think the rf test stand might look. We use the same aluminum box as we used for the K500 test stand, only we either copper plate the inside, or build a copper liner in it. It is to be single ended so that we can find enough vertical height for it without using the pit. The overall height, including fully extended push rods would be about 30 feet. So I visualize the tank being about 3 feet above the floor in the high bay area and the top of the extended push rods riding 33 feet up in the air. Expedition and simplification would result if we decide that it is a two frequency test stand, built in such a way that it might take a day or more to change from one frequency to the other. Thus we don't use a carriage or push rods. But then, I guess we want this permanent test stand to be able to test the moving short too. Unfortunately, then, this means we must design and build the moving short. So, although I would like to see this stand in existence by 2/1/81, I suppose that date is unrealistic, as are, in fact, all the other listed dates.



INPUT CIRCUITRY
FOR DRIVER IS
identical to K500 Des.

FIG G

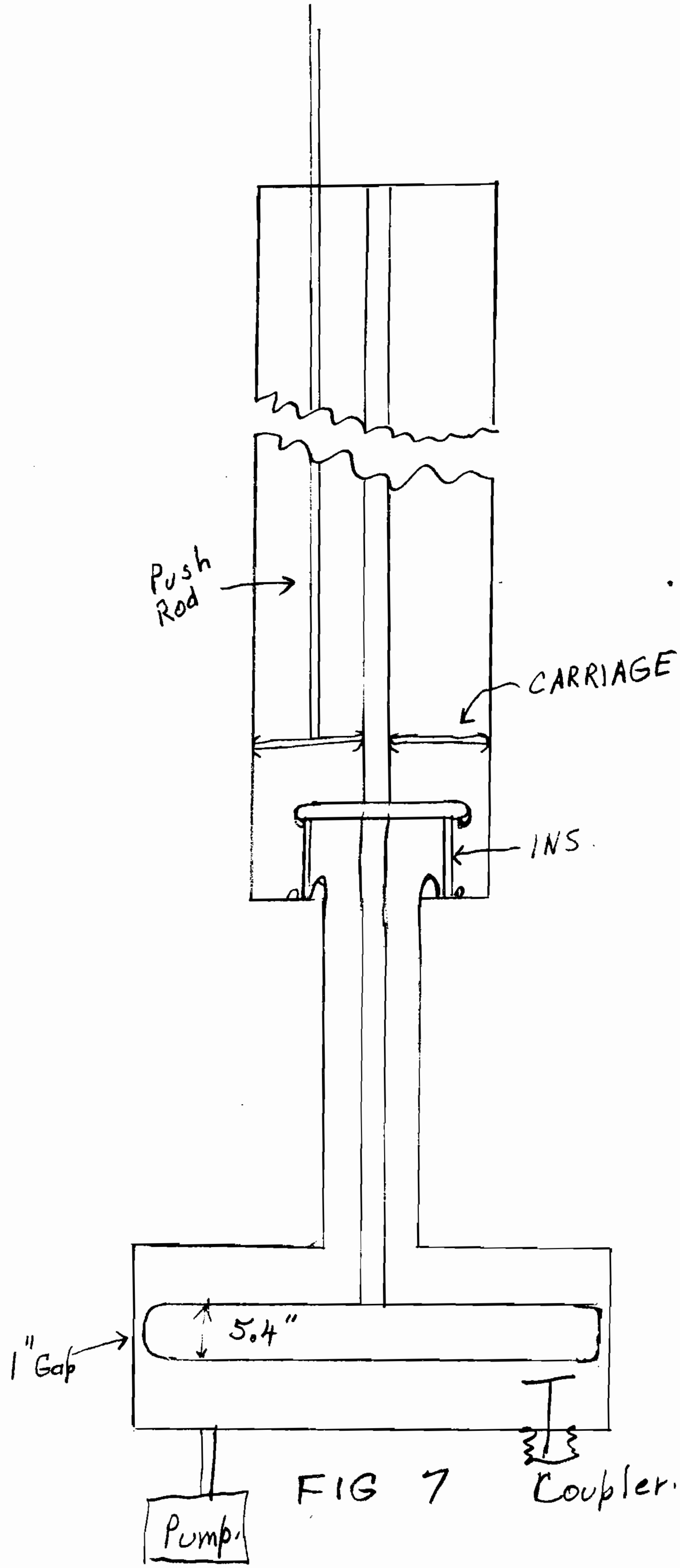


FIG 7