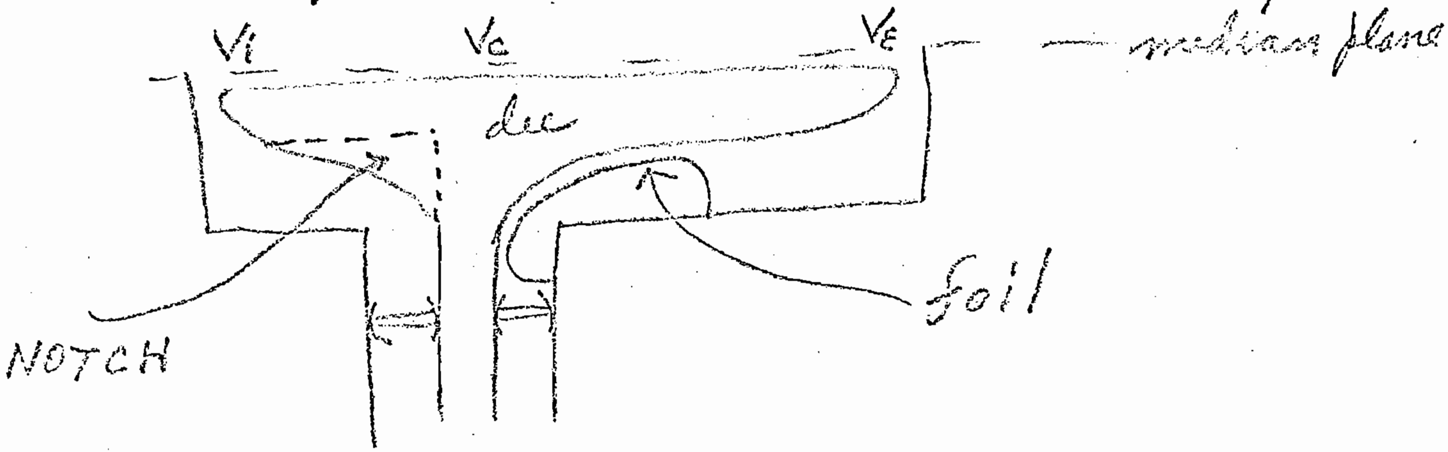
214-0006-01-01_00 MSU RF SYSTEM

Note #5

by J. Riedel March 11, 77

A. Model Measurements.

When the 1/2 scale model was measured using the low capacitance modified vector voltmeter probes (c = 1pf) the highest frequency was found to be 183 mHz with Blosser's beautiful dees. The radial variation of voltage was measured, foils were added as indicated in the sketch below and the variation remeasured, and finally a notch was cut out of the injection side of the dee. The results are summarized in table 1.



	V_E	V_C	V_I
original model	1	.4	.48
with foil	1	.45	.58
foil + NOTCH	1	.47	.63

TABLE 1

With the foils and the notch the frequency was changed and the distribution measured for each frequency, the results appearing below.

	Freq	L in	V_E	V_C	V_I	
	160	1	1	.47	.63	
	134 26	4	1	.64	.75	81
120	80 54	13	1	.86	.9	
	53.4	27.5	1	.94	.96	
	26.6	79.5	1	.98	.99	

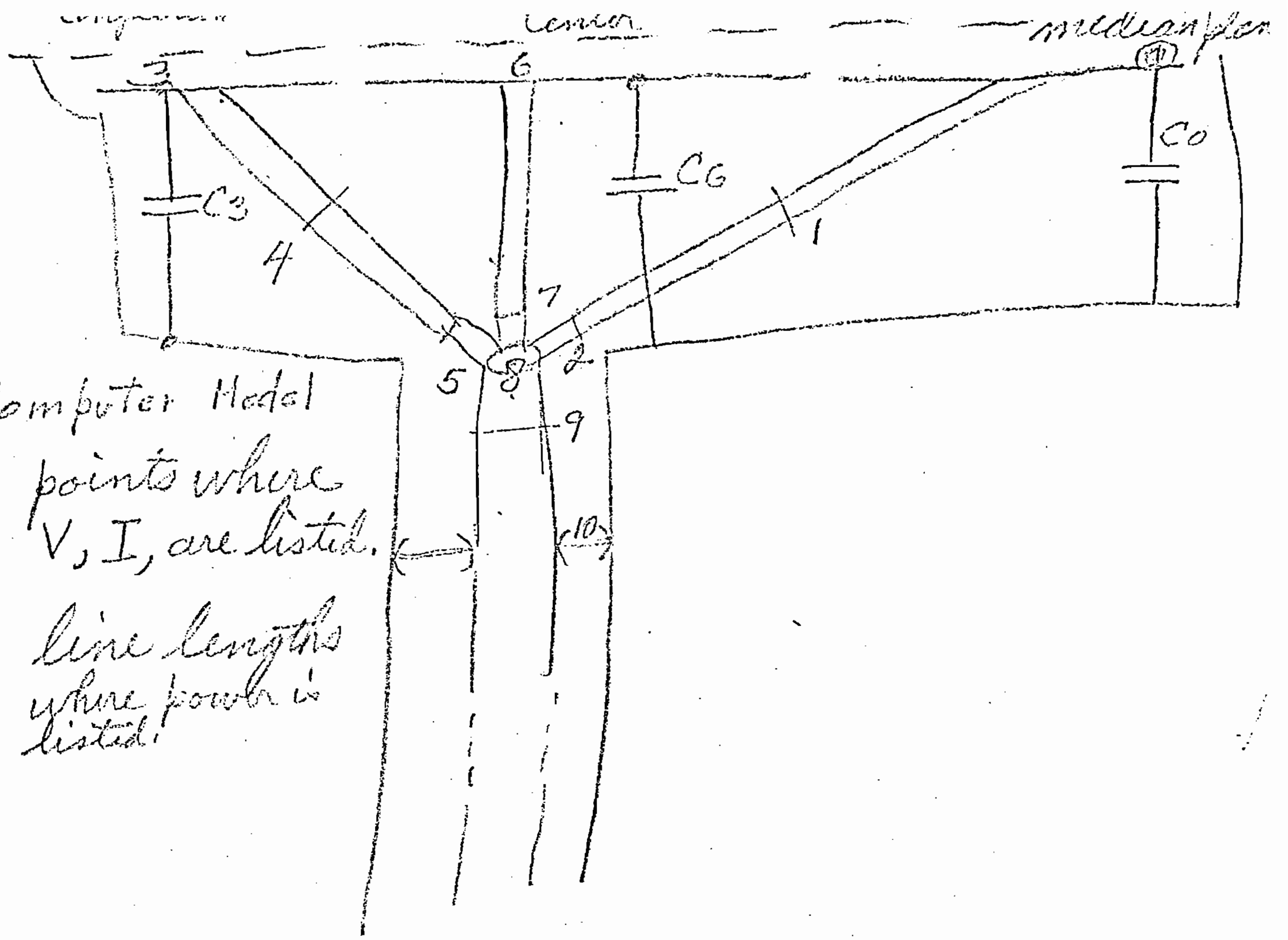
TABLE II

L = length to end of inner conductor, not to median plane.

The foil was then removed to determine its effect on the low frequency. The low frequency increased by 4% this concluded the model testing.

3. Computer Model

A computer program called MSUDS exists which can calculate the dee-stem resonator and present the results. Because this program is written in BASIC it is simple and straightforward, very flexible and easy to modify. The model ~~that~~ the computer presently uses is shown in figure 2.



Computer Model

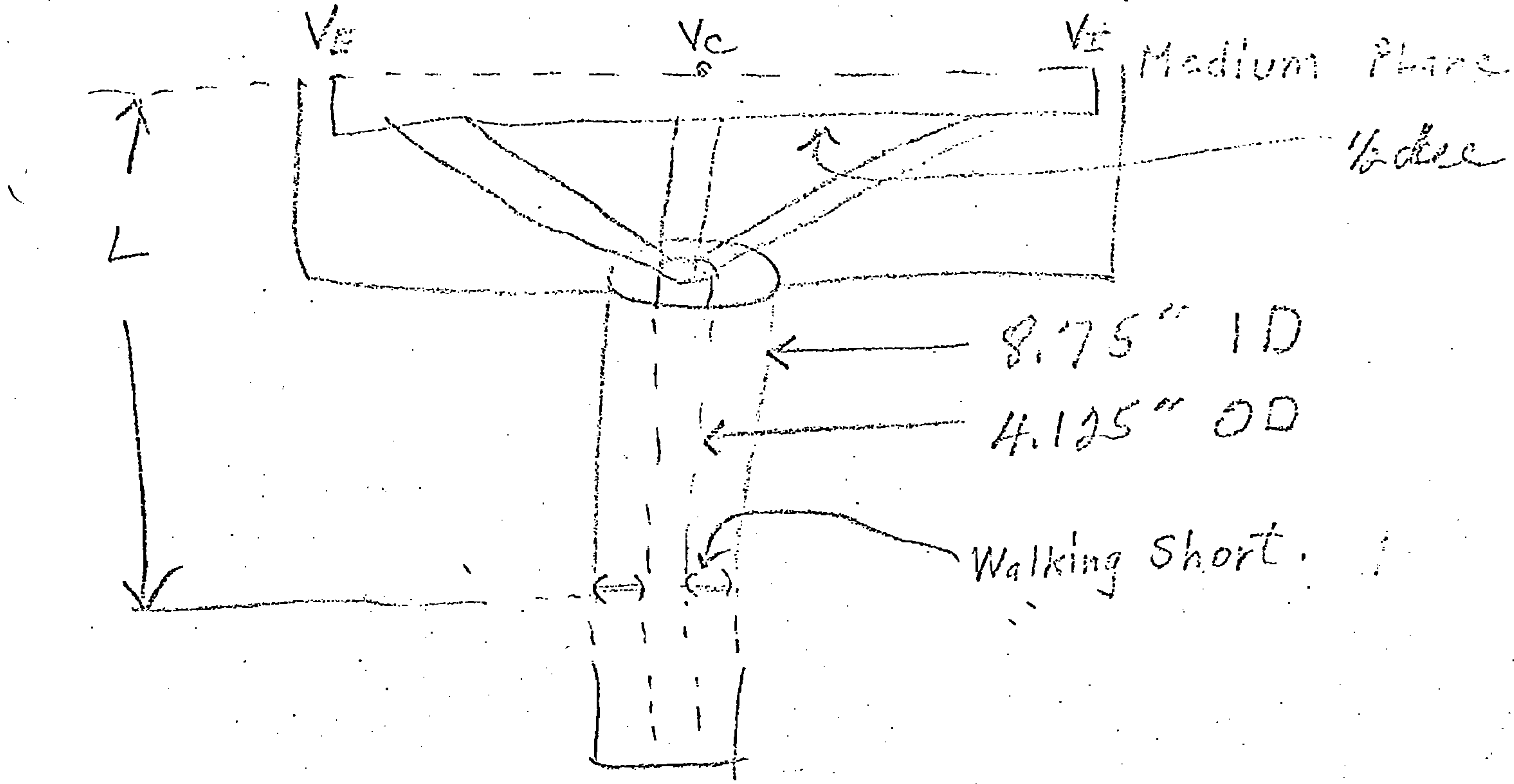
10 points where V, I, are listed.

7 line lengths where power is listed.

values for C_0, C_3, C_6, Z_1, Z_2, Z_4, Z_5, Z_7 were estimated and the results calculated. These values were then modified until conformity with the 1/2 scale model measurements was achieved, so that reasonable confidence could be placed on their aptness. The equivalent capacity of the entire line was easily checked by confirming that the calculated length L/O agreed with the model measurements. Table III gives a summary of the full scale results.

The apparent in this table is the fact that the radial variation of the voltage is very sensitive to capacities C_0, C_3, C_6 and the impedances of the lines

MSU CYC RF SYSTEM SUMMARY



Conditions as of 12:13 March 12, 1977

F MHz	V_E kV P	V_C kV P	V_I kV P	L "	L '	I_{MAX} A, RMS	W/□in MAX, W	W/½dee kW	Q	E MVA
13.33	100	98	99	182	15	1600	14	31	2900	92
26.67	100	97	98	74	6.2	1800	25	25	4000	100
40.00	100	92	94	41	3.4	2000	38	25	4600	114
53.33	100	80	88	25	2.2	2100	50	24	4900	119
66.67	100	62	78	18	1.5	2100	55	24	4900	115
80.00	100	44	58	13	1.1	2000	57	23	4400	103

Definitions:
V_E = Extraction voltage, peak
V_C = Dee Center voltage, peak
V_I = Injection Voltage, peak
L = Length in inches and feet to short from median plane
I_{max} = stem current at the short, rms
$W_{\square in}$ = watts per square inch at the short,
$W_{½dee}$ = Power consumed by one stem, half dee,
Q = Loaded quality factor = [illegible]
E = [illegible] energy in stem/dee [illegible] MVA.

connecting these to the stem. Of course, of primary importance in these voltage ratios is the length of the two lines.

The half scale model stems scale to 9.8" OD, 4.65" ID and it is interesting to note that the computer model for these stem dimensions compared to our planned values of 8.75 OD, 4.125" ID give the following ratios for the indicated parameters: (a * is for the scaled model).

length to short at 13 mHz $= \frac{4.40m}{4.55m} = \frac{1^*}{1.03}$

power at 13 mHz $\frac{25^*KW}{31KW} = \frac{1^*}{1.24}$ [illegible]

From table III we see that there are at least three possible problem areas,

1. at the high frequency, with a total current at the short of 6000 amps rms we have a current density of 154 amps/inch on the inner conductor, a very high number.
2. This results in a power density in copper of 60 watts per square inch.
3. The so far best achievable ratio between Vi and VS is 1/.6.

[illegible] damage.

C. The walking short

Although it seemed that the moving anulus and the fingers of the walking short should be made of copper plated molybdenum, this idea has been abandoned because the thermal conductivity of Moly though good, is still a factor of three worse than copper and would result in a 500°C temperature rise in the one inch long fingers. Therefore D. Burleigh has come up with a promising design using copper fingers. The plan is to use about 100 fingers, each with two hemispherical contacts of approximately 10 mils diameter. These hemispheres would be first gold plated (~ .1 mils) and then receive a rhodium flash (.01 mils). When pushed into the hard copper (possibly silver plated (.1 mil)) of the inner and outer conductors with an area force just shy of the elastic limit for hard copper (about 15000 PSI) it is hoped that each contact can pass 10 amps rms at 80 mHz without problems.

The water cooling to the anulus and the hydraulic fluid to the pistons would be fed via 3/16" diam thin walled SS tubing wrapped around ~~=~~ and living between the inner and outer conductors. (As the walking short traverses its 15 or so feet these would drastically flex.) Also, the anulus would not (hopefully) rotate as this would interfere with a simple position indicator – Bob Cook would say "made in two".

[illegible] Chamberlain.

In principle everything about the ... short can be calculated except what happens at the contact. Since our current densities per inch or centimeter on contact are a factor of 2 or 3 higher than anyone has successfully used (to my knowledge), it seemed to behoove us to test this. Now tests of finger contact have been made in many laboratories over the years so it is appropriate to ask: "why should we try to reinvent the wheel?" Well, the reason is that, first no one has had to ~~test to~~ these current densities and secondly, no one has employed the area contact pressure ~~that~~ we envisage using. R. Kerns at FNAL in a report on measurements that he had made some ... years ago gave me my clue as to how to proceed. He looks at the contact area with photomultipliers, ~~[illegible]~~ and as the current is increased there will come a time when light is detected. ~~[illegible]~~ after light is produced in the contact the contact will eventually be destroyed, and reliable operation will only be achieved at current densities well below this amount. Con't pg.

Lp

D. Contact finger test

We are constructing a test apparatus to investigate the current carrying ability of one contact. Our goal is to test this contact to the point where light begins to be emitted, and we are providing for the possibility of passing up to 30 amps at 80 mHz thru it. To start, however, we will provide for 30 amps at 30 mHz. The set-up is as below.

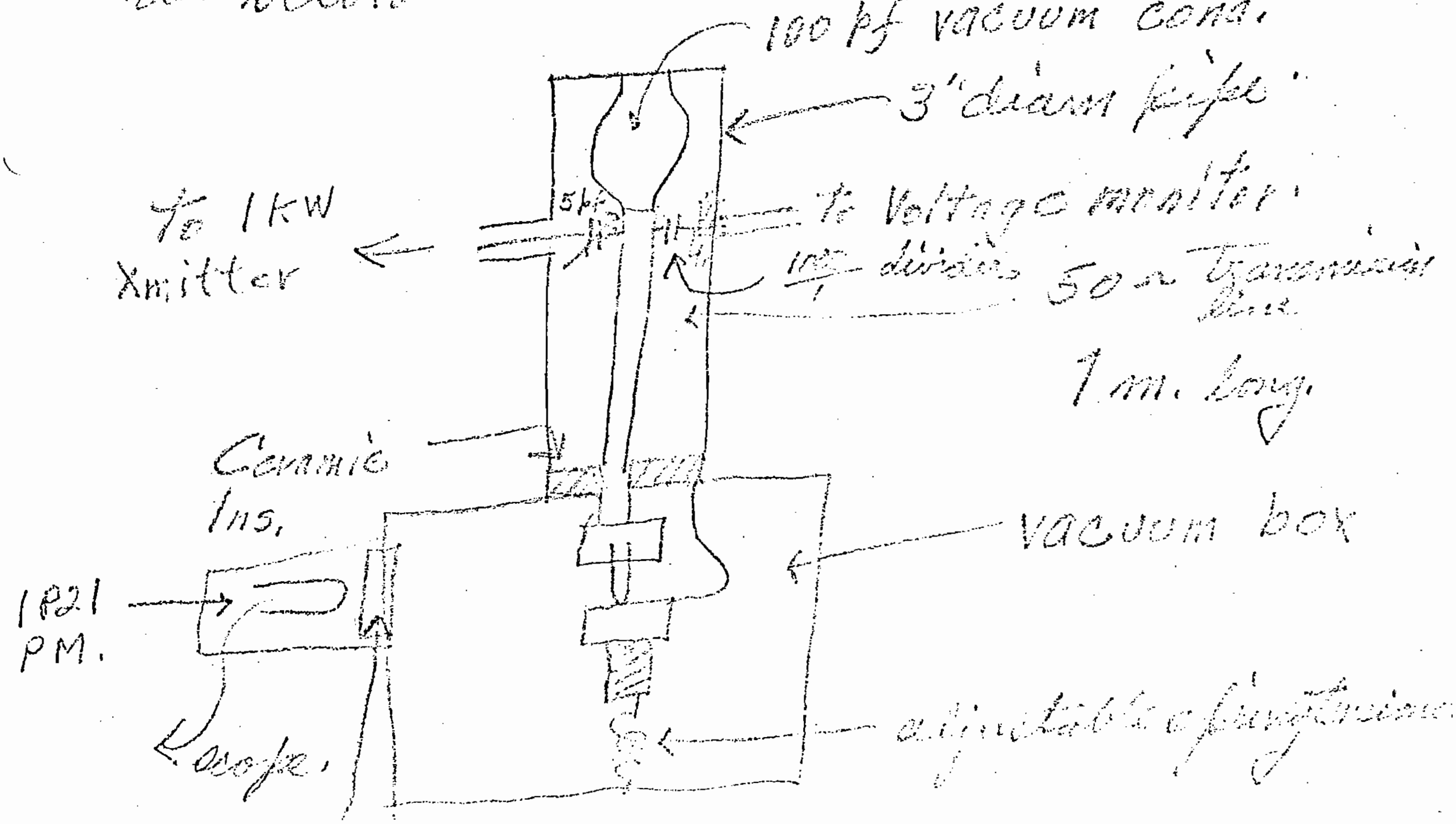


Fig 3.
Finger tester

to achieve 30 amps at 30 MHz the voltage at the condenser will have to be about 1600 volts. Assuming a Q of 5000 the power will be about 100 watts. These tests will be performed in April.

3.2 / 4 R.F. System

If the fingers are incapable of carrying the current, D. Curtis suggested ~~that~~ part of this current could be rendered by placing a capacitor above the fingers. With a $\lambda/4$ system this will do no good, but various possibilities exist if we go to a $3/4\ \lambda$ system.

The idea is to put an enclosed cylindrical box between the inner and outer conductors of the transmission line, making the impedance there about 3 ohms. With 1/8" spacing to the conductors it is felt ~~that~~ 5 KV per gap or a total of 10 KV across the line would be a safe working voltage. ~~[illegible]~~ to MSUDS was modified, becoming BURL, and a system was calculated. The sketch of the configuration ~~and the results~~ appears in Fig 4 and the results are summarized in table IV

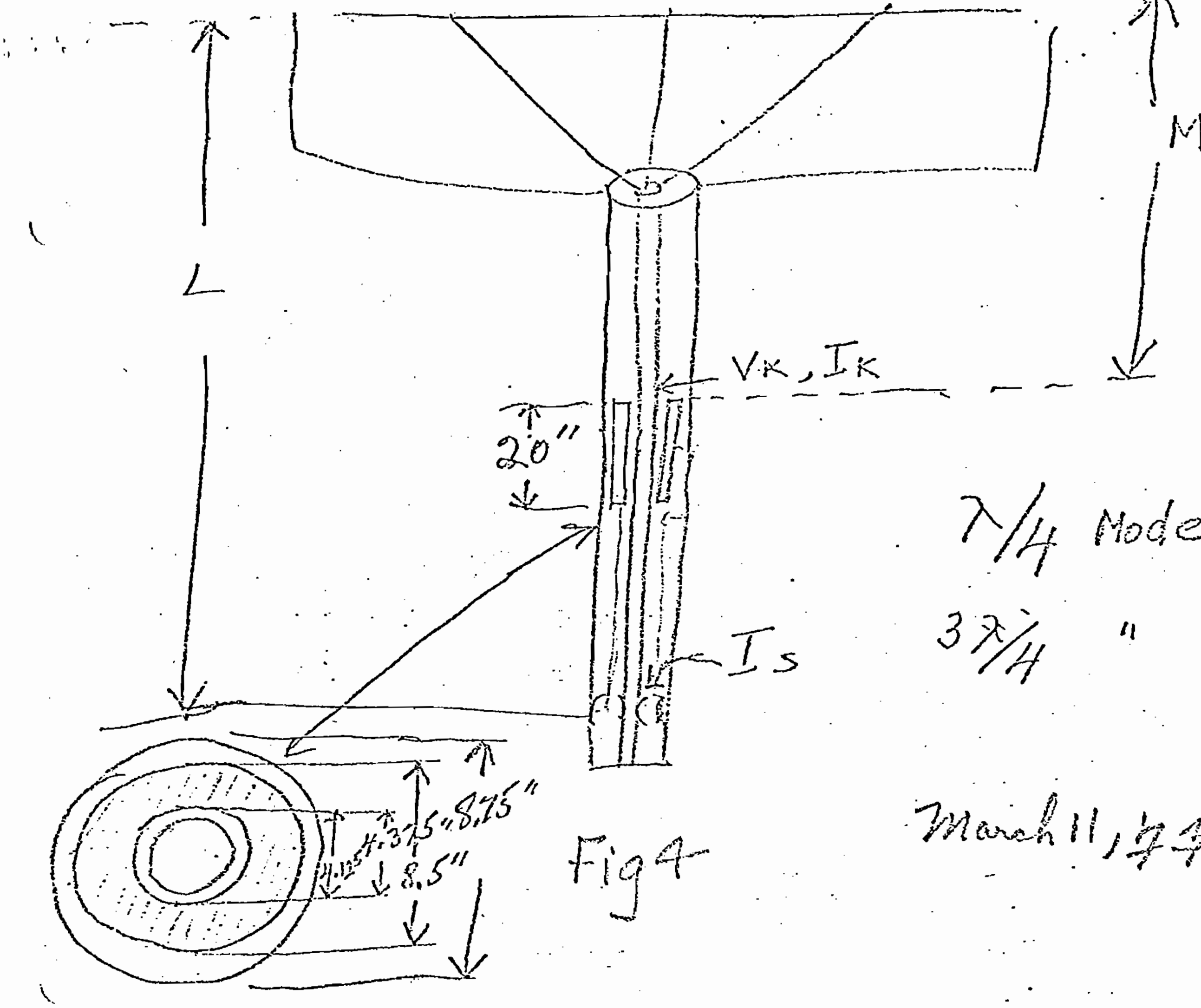


Fig 4

$\lambda/4$ Mode for F<40MH

$3\lambda/4$ " " F=>40M

March 11, 74

F	V_E	V_C	$V_{\#}$	$L_{F.C.}$	Is Arms	I_K Arm	V_K KV	Ws/in²	W/Hzdee	Q	E	M ft.
13,33	100	98	99	17	2000	1600	10	22,4	49	1900	94	14.2
26,67	100	95	97	8,5	2400	1700	10	46	57	1800	104	6,5
40,00	100	90	92	13,5	-550	+500	-10	2,9	43	3400	150	3,1
53,33	100	80	83	11,1	-330	2000	-10	1,22	44	3564	155	3,2
66,67	100	70	72,4	6,8	-300	2300	-10	1,13	52	3700	190	2,3
80,00	100	50	54	5	-440	2700	-10	2,8	70	3730	265	1,6

TABLE 4

Note that for frequencies below 40 mHz we revert back to the $\lambda/4$ mode, but leave the floating condenser in place. This results in lengthening the stem at 13 mHz ~~[illegible]~~ by the 1/2 (meter) length of the condenser action.

This system will work, but the price is about a factor of 3 more power being required. That is for the geometry as listed in fig 4. But since the minimum length to the short is now 5 ft, or well outside the iron, it is possible to make the lines much bigger and it is believed that thus it will be possible to reduce the power by a factor of 2, so that it will be only some 50% larger than for the $\lambda/4$ system. Also, the current densities when switching to the $\lambda/4$ mode will be less, and the mechanical rigidity will be greatly improved. Fig 5 shows the suggested geometry. In April we will calculate for this system.

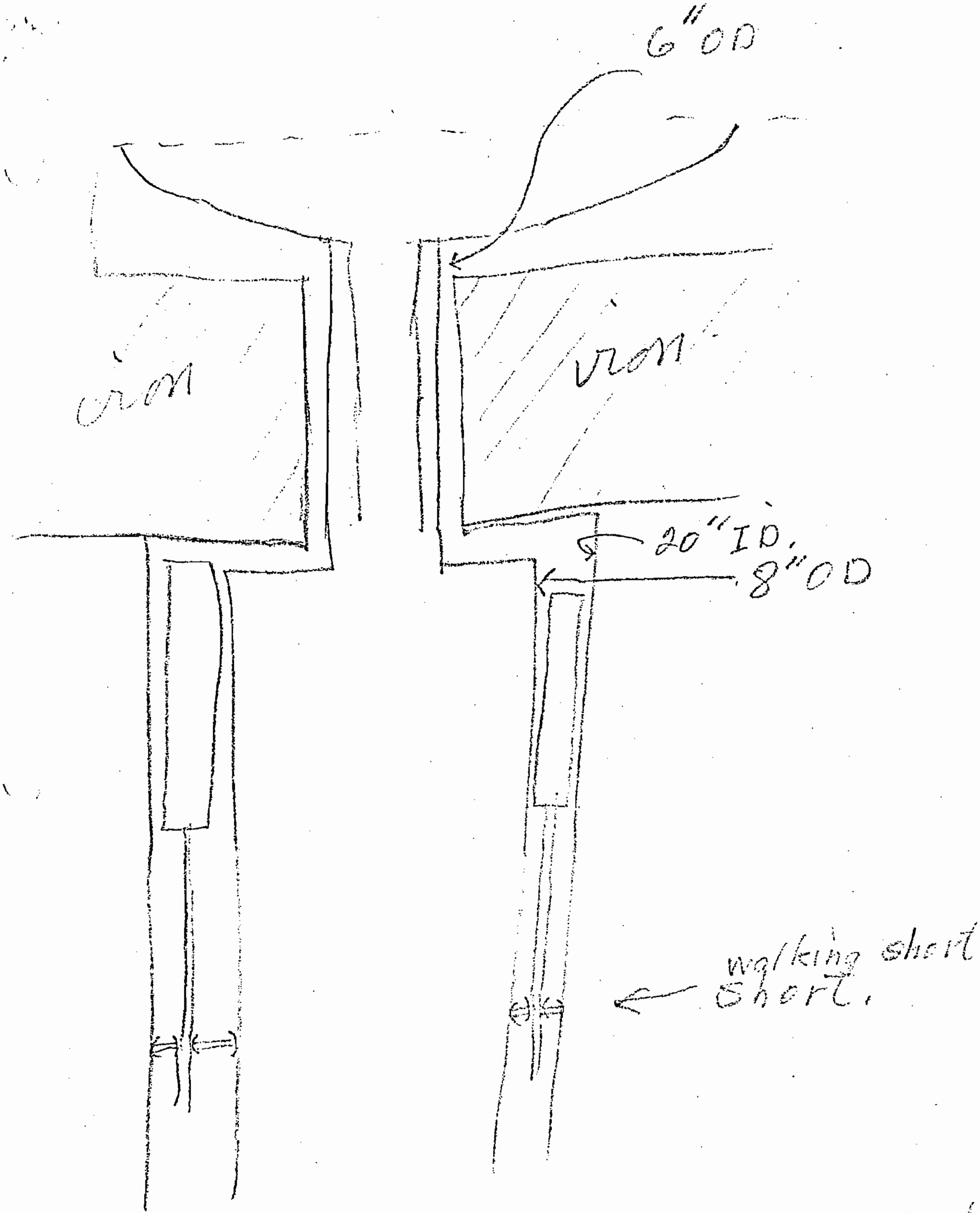


FIG 5

Voila!