R.F. Book

R.F. Note #61

18 February 1980
J. Riedel

K=800 1/2 Scale Model

In the last R.F. note we presented the results of various calculations for a possible R.F. system for the K=800 superconducting cyclotron. These calculations were based on a computer model of the dees copied from the K=500 model. On re-reading the program and R.F. Note #17, I note that I made a force fit with the program and the model so that agreement was met. Specifically, when I split the dee in half, instead of multiplying each dee $Z\phi$ by two I found that the fit occurred when I multiplied the $Z\phi$'s by 1.33. This is what I have done with the K=800 calculations.

This "form factor" really only affects the high frequency results. However, it is at the high frequency (27.5 MHz) that we are in trouble in three respects: Is 60 inches from the median plane short enough to make 27.5 MHz possible? Are the current densities at the short realistic? And is the powwer correct? Small changes in the form factor greatly influence the results.

Therefore I feel that it is mandatory to make a scale model of the dee! At first I thought that the sole purpose of this model was to find an appropriate computer model of the dee so that then I could optimize the design by changing the radii of the stems. But in the liesure of this year's Arkansas winter, while trying to find a design which would minimize -L and ΔL (see RF Note #58), I came up with possible designs for the stem which will also need modeling (or a much more sophisticated computer program). Actually this is quite feasible because we do have cylindrical symmetry here so that a program like the one in use at Los Alamos can be used to achieve great accuracy. Figure 1 shows the kind of geometry I am thinking of.

The idea of using this elongated 24 inch diameter line just before the short arose as follows: first I found that by placing a lumped capacity to ground at the point where the stem emerges from the iron (61 inches from M/P) -L and ΔL could be shortened by as much as 48 inches for modest values of ΔC ($\sim$300pf). Then I considered various ways of making this a switchable ΔC. All the possible designs turned out to be mechanical monstrosities, though feabible, especially so since H.B. doesn't seem to shy away from Rube Goldberg type designs. Figure 2 shows sketches of two of these designs.

Anyway, I decided to try a non switching design and found that if, immediately before the short, I used a 24" inner cond. in a 26" outer conductor, we were able to tune over the range 9 to 27.5 MHz with -L = 175", L=81 making this section 20" long and L=104". W27.5 = 214KW. No further optimization was done because I realized my program was inadequate to properly take into account such large discontinuities in $Z\phi$.

At MSU

At MSU the weather is about the same as in Arkansas, but the mood is more austere, conducive to more rigorous thinking; and, besides there is more interaction with others, a measure which lubricates the thinking process. Due to a question by H.B. I consulted my program and found that the equivalent dee capacity for MV800 was 280 pf, almost twice that for the K=500 system (MSUDS, RF Note #17). This is almost certainly too much. When I arbitrarily reduced this capacity by 1/3 I found that the 27.5 MHz power was reduced to 160KW or by about 30%, and the short current was also reduced proportionately. Thus it became very obvious that it was of prime importance to know what the equivalent circuit of the dee really was.

Conclusions: Therefore, I recommend we proceed as follows:

1. Build a 1/2, 1/3 or 1/4 scale model dee + uniform lines with a movable short. The lines should model full scale dimensions of 12 inch inner diameter of outer conductor, 6 inch outer diameter of inner conductor, and lengths from median plane of 200 inches, however the actual diameters can be modified to fit closest to commercially available pipes. This model will be excited at instrumentation levels to measure F, Q, and Rs vs L to compare with the results of MV800. MV800's dee parameters will then be modified so that the calculated results agree with the measured values. This completes the purpose of MODEL 1: namely, to find the correct computer model of the dee.

2. We ammend MV800A by putting into it the proper parameters for the dee, and, proceeding with confidence that below and above the dee we are able to calculate exactly what happens, arrive at reasonable dimensions for the discontinuous line geometries shown in Figure 1. Then we change the model (the lines and moving short only) and remeasure the performance. Hopefully, the results will agree with the computer calculations. If not, we scratch our head and modify what needs to be modified until agreement is reached. This means that either the computer model is modified, or the real model is modified. I agree that if either modification is required I should be chastised, fined and disposed of for incompetence.

What is MV800A? MV800A only concerns itself with F1 or F2 (27.5 MHz & 9Mhz). At F1 we divide the 1/2 resonator into 19 discrete pieces as pictured in Figure 3, with the short exactly one inch from the discontinuity at position 18. To do this we have to use an iterative routine to adjust section 16 (the low Z section, which is really a capacitor for the F2 case) such that resonance occurs. The criterion for resonance is twofold but equivalent; the phase of the incident voltage vector at 19 is 90^o and $\Sigma 1/2\ CV^2 = \Sigma 1/2\ LI^2$. These partial energies are arrived at by exactly calculating the integrals of the ΔE's from one line section ot the next.

And then, as in MSUDS, HFRF, and MV800 the dissipated power for each section is exactly calculated and the sum presented. This disposes of MV800A. Let us hope that MV800B doesn't ever have to exist.

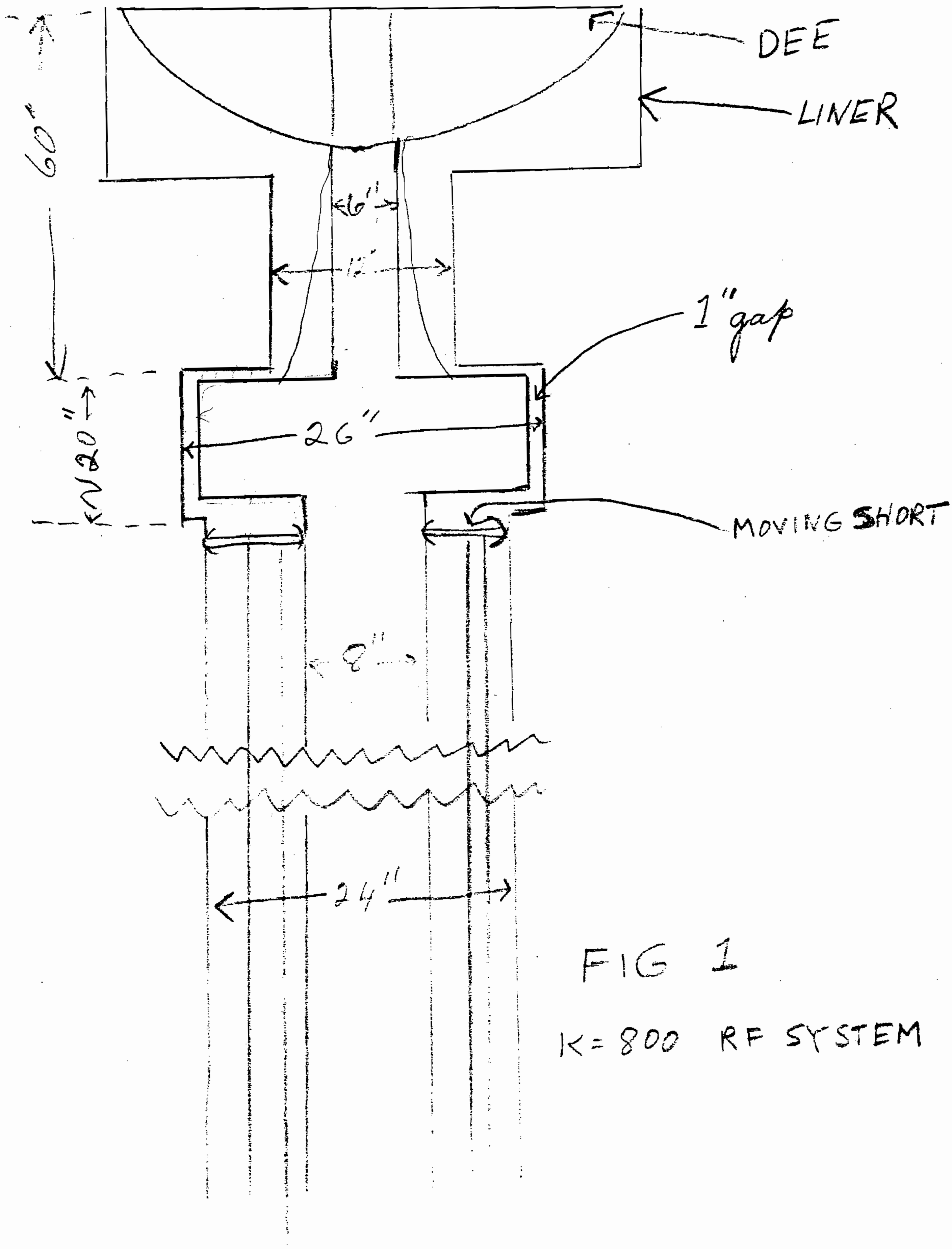


FIG 1

K=800 RF SYSTEM

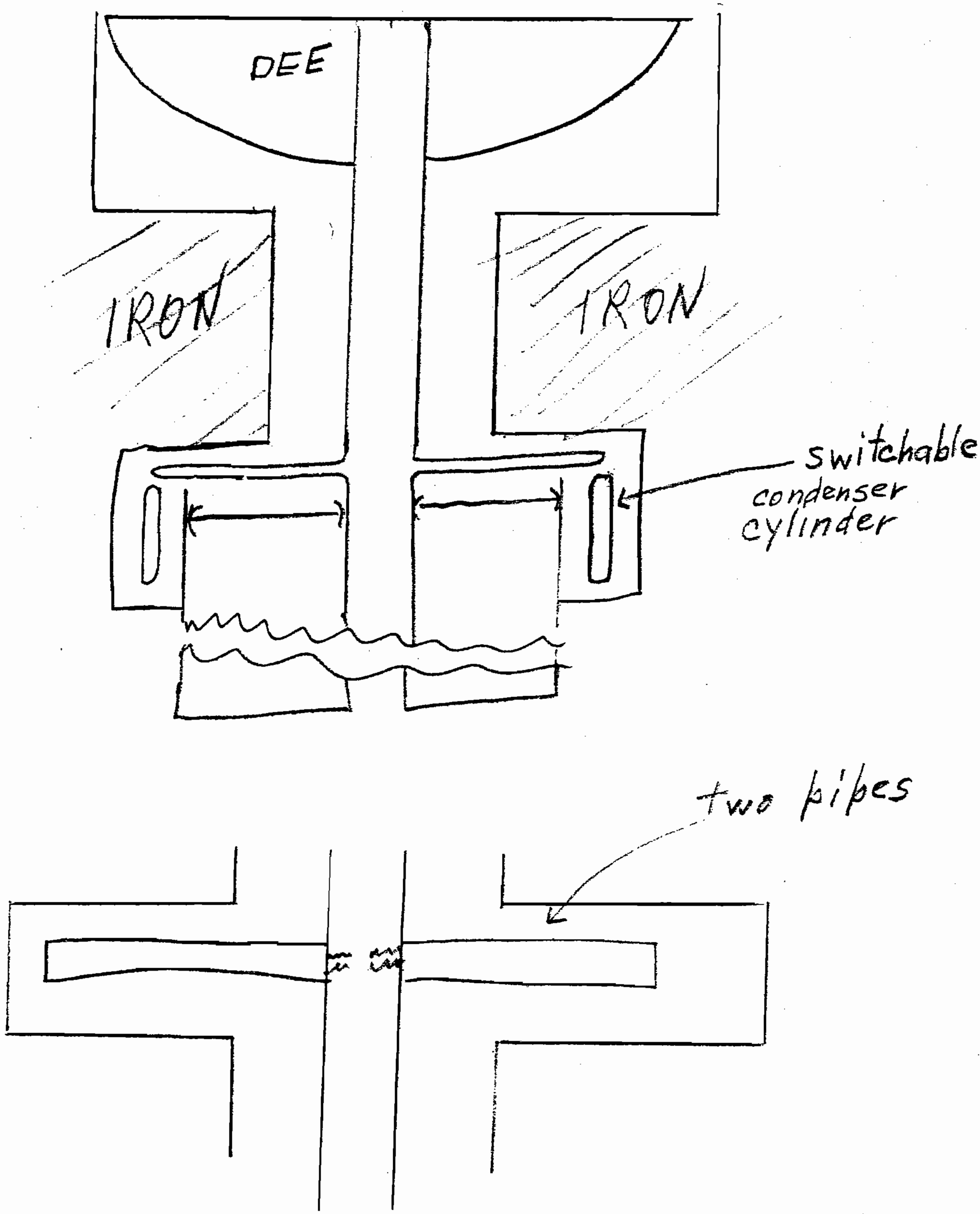
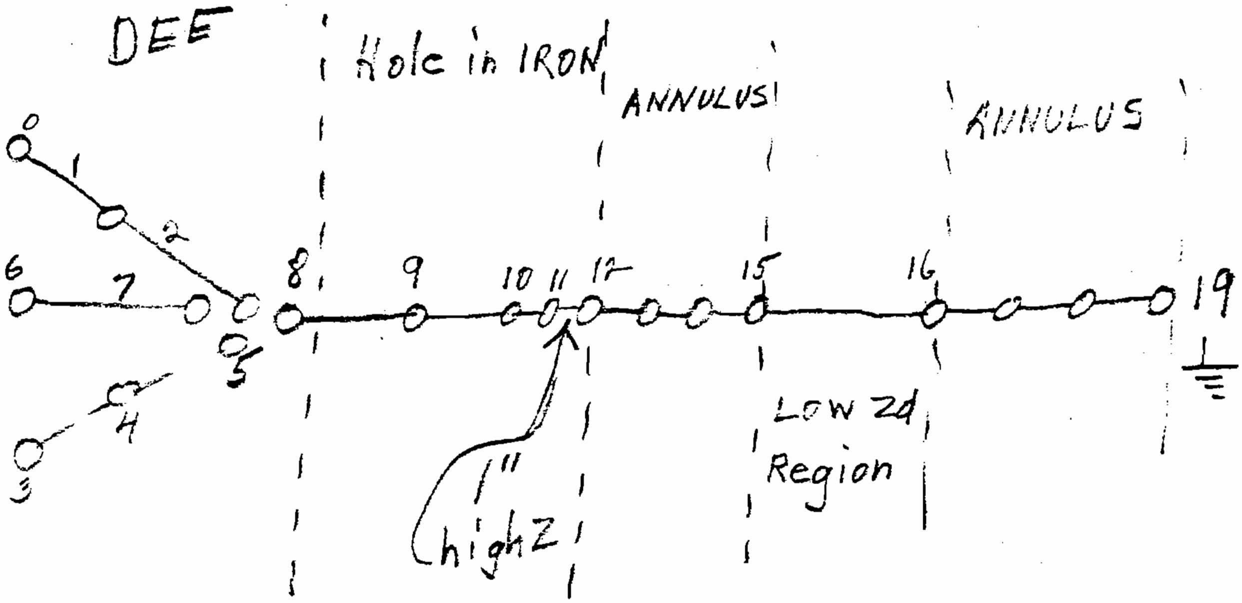
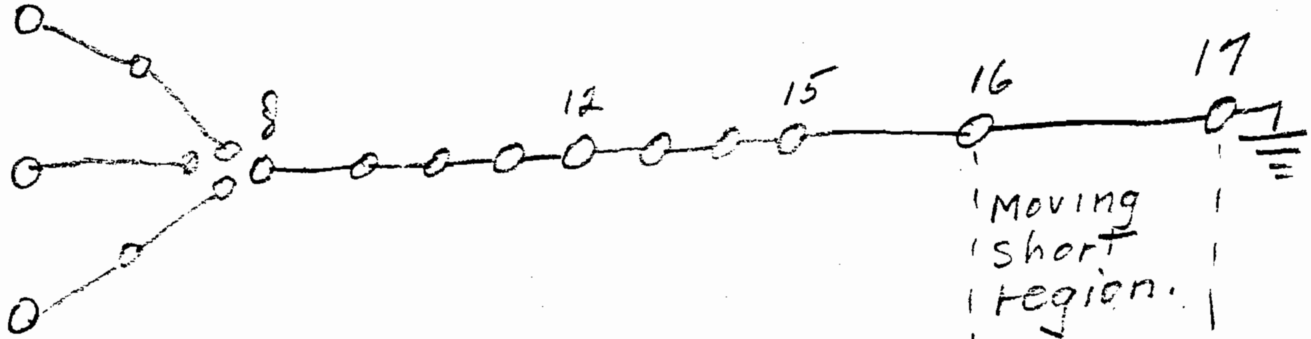


FIG. 2.



Sections used for 27.5 MHz in MV800A



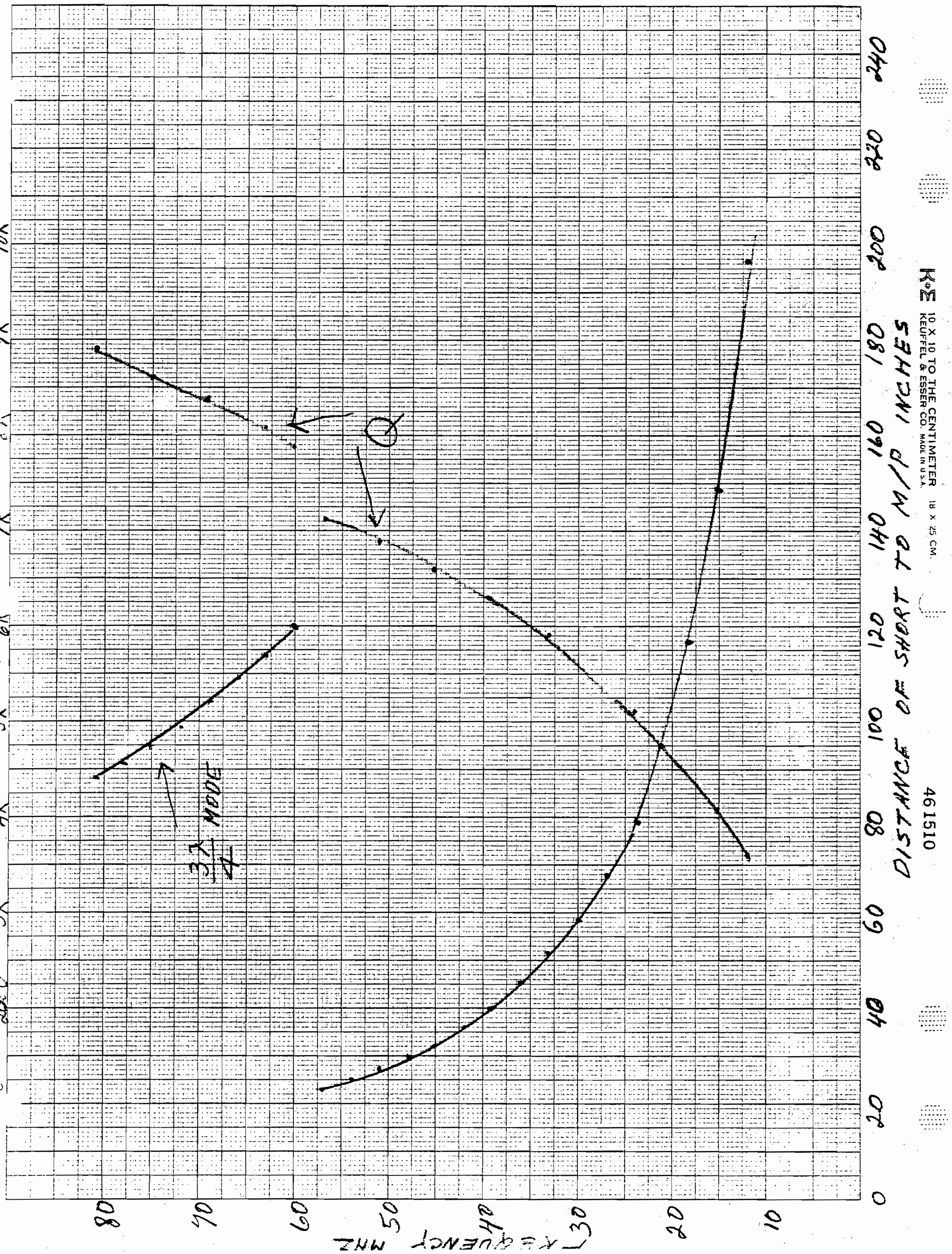
Section used for 9 mHz.

Fig 3

Addendum

We have modified MV800 so that it calculates everything for the full scale dimensions of the first version of our model (uniform 12 inch and 6 inch pipes). Figure 4 shows the short position and Q vs F. For a half scale model the Q will be down by $1/\sqrt{2}$. Table I shows the calculated voltage variation along the dee and upper stem. The positions where the voltages are calculated are as shown in Figure 3, bottom. V9 is a point on the stem 20 inches from the M/P.

When the model is assembled we will install 8 voltage monitors and measure the ratios of monitors 1-9 to 0, the extraction radius. At the present time I am proposing to excite the dee to about 2 kV with our 50 watt amplifier and use vacuum tube diodes as peak detectors to make the measurements. Before that time, though, we will make a test of the adequacy of this method.


DISTANCE OF SHORT TO M/P INCHES
FREQUENCY MHZ
Q
3λ/4 MODE
Q
0
20
40
60
80
100
120
140
160
180
200
220
240
10
20
30
40
50
60
70
80
2000
3K
4K
5K
6K
7K
9K
10K
10 X 10 TO THE CENTIMETER 18 X 25 CM.
KEUFFEL & ESSER CO. MADE IN U.S.A.
461510

	V1/V0	V2/V0	V3/V0	V4/V0	V5/V0	V6/V0	V9/V0
9	1	1	1	1	1	1	.95
12	1	1	1	1	1	1	.95
15	1	1	1	1	1	1	.95
18	1	.95	1	1	1	.95	.9
21	1	.95	1	1	.95	.95	.85
24	.95	.95	1	.95	.95	.95	.8
	.95	.9	1	.95	.9	.95	.75
30	.95	.9	.95	.95	.9	.9	.7
	.95	.9	.95	.95	.9	.9	.65
36	.95	.85	.95	.95	.85	.9	.6
	.95	.85	.95	.9	.85	.85	.5
42	.9	.8	.95	.9	.8	.85	.45
	.9	.8	.95	.9	.8	.8	.38
48	.9	.75	.9	.85	.75	.8	.3
	.9	.7	.9	.85	.7	.75	.275
54	.85	.7	.9	.85	.7	.75	.15
	.85	.65	.9	.8	.65	.7	.07
60	.85	.6	.85	.8	.6	.65	0
	.8	.6	.85	.75	.6	.65	-.09
66	.8	.55	.8	.75	.55	.6	-.17

TABLE I

March 5 '80

H. Blosser & F. Resmini from J. Riedel.

Having some time while waiting for the test stand to be reassembled I decided to get ahead of myself and create MV800A as per ref note #18. It took 8 hrs of writing and debugging but it's done and attached are the results. I believe this shows what the K=800 rf system will look like.

Note: lengths 13, 14 & 15 and 16, 17 & 18 at 27.5 MHz are annuluses where the two annuluses are split into 3 pieces each. For 9 MHz the short annulus power (29) is calculated exactly

$$W = \frac{I_f^2 R_\phi}{2\pi} \ln \frac{r_2}{r_1} \; ; \; R_\phi = 2.63 \times 10^{-7} \sqrt{F} \text{ ohms per square.}$$

The big deal here is that ~~the~~ the low impedance length L(16) was found to be 16" using an iteration technique at 27.5 MHz, then that length was used to find L(18) at 9 MHz.

The capacity of L(16) reduces the total length at 9 MHz to 166 inches, increases the power at 27.5 MHz from 190 to 217 KW and increases the 9 MHz power from 120 to 182 KW.

So I think the only problems with K=800 RF system will be the moving short contacts in vacuum and how to assemble it all. After all, I think the outer conductor will have to be a pipe!

12:09 MAR 05 MV800A...

PROGRAM MV800A SEE RF NOTE # 58

FOR 27.50 MHZ THE RESULTS ARE

N	Z	L	DEG	DEG	R/M	V	I	W	E
0	0.0	0	0	0	0.0	2.0E+05	3.5E+02	0.0	
1	54.5	11	8	17	1.4E-02	1.9E+05	7.6E+02	1.3E+03	
2	41.7	11	13	22	5.7E-03	1.8E+05	1.3E+03	1.7E+03	
3	0.0	0	0	0	0.0	2.0E+05	71.	0.0	
4	40.0	11	1	10	7.9E-03	1.9E+05	6.2E+02	3.2E+02	
5	42.9	11	11	20	6.1E-03	1.8E+05	1.1E+03	1.3E+03	
6	0.0	0	0	0	0.0	1.9E+05	1.1E+02	0.0	
7	43.3	10	2	10	6.4E-03	1.8E+05	5.5E+02	2.0E+02	
8	0.0	10	0	0	0.0	1.8E+05	3.0E+03	0.0	
9	41.5	27	43	58	4.3E-03	1.4E+05	3.6E+03	2.0E+04	
10	41.5	44	58	72	4.3E-03	7.8E+04	4.1E+03	2.8E+04	
11	32.3	61	67	81	3.9E-03	3.0E+04	4.4E+03	3.1E+04	
12	52.5	62	85	86	2.4E-03	2.5E+04	4.4E+03	1.2E+03	
13	9.2	62	66	68	1.3E-03	2.4E+04	4.4E+03	1.3E+03	
14	7.1	62	62	64	1.0E-03	2.2E+04	4.5E+03	1.0E+03	
15	5.7	62	58	60	8.2E-04	2.1E+04	4.6E+03	8.6E+02	
16	5.2	78	58	71	1.5E-03	1.3E+04	5.1E+03	1.4E+04	
17	65.8	79	88	89	2.9E-03	6.0E+03	5.1E+03	1.9E+03	
18	5.7	79	82	83	8.2E-04	4.8E+03	5.1E+03	1.1E+03	
19	7.1	79	85	86	1.0E-03	3.3E+03	5.2E+03	1.4E+03	
20	9.2	79	87	89	1.4E-03	1.3E+03	5.2E+03	1.8E+03	

W/DEE KW	E/DEE MVA	Q	R SH	C EQ PF	C COUP 3 DEES
217	1069	4909	91	309	2701

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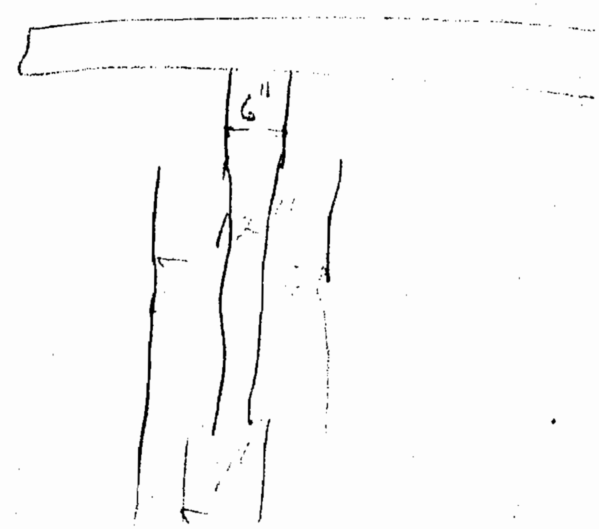
these results are for one stem
so power in the short at [illegible] MHz
is W18 + W19 + W20 ≈ 15 KW
Peak current is 5200 Amp rms
density = 20 amps/[illegible]
a little more than [illegible]



FOR 9.00 MHZ THE RESULTS ARE

N	Z	L	A	B	G	H	K	O	C
0	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	14.4
1	54.5	11	6.00	4.00	2.00	6.00	1.53	3.02	0.0
2	41.7	11	10.00	6.00	4.00	3.00	1.24	3.02	0.0
3	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	3.0
4	40.0	11	10.00	6.00	2.00	6.00	1.34	3.02	0.0
5	42.9	11	11.00	4.00	4.00	3.00	1.25	3.02	0.[illegible]
6	0.0	0	0.00	0.00	0.00	0.00	0.00	0.00	4.8
7	[illegible]	[illegible]	[illegible]	6.00	3.00	3.00	[illegible]	[illegible]	0.0

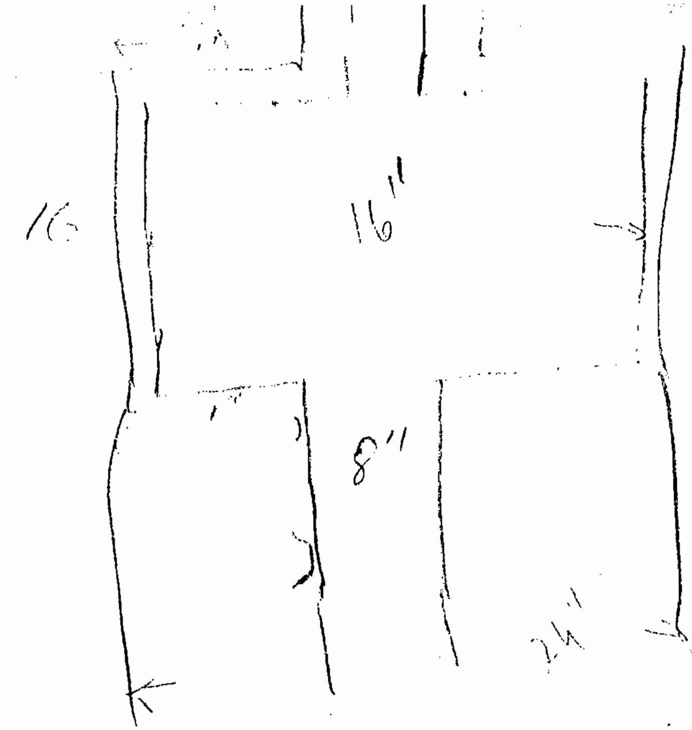
1.5	27	12.00	6.00	0.00	0.00	1.00	4.66	0.0
1.5	44	12.00	6.00	0.00	0.00	1.00	4.66	0.0
2.3	61	12.00	7.00	0.00	0.00	1.00	4.66	0.0
2.5	62	24.00	10.00	0.00	0.00	1.00	0.27	0.0
9.2	62	7.50	5.50	1.00	*****	1.00	0.55	0.0
7.1	62	9.50	7.50	1.00	*****	1.00	0.55	0.0
5.7	62	11.50	9.50	1.00	*****	1.00	0.55	0.0
5.2	78	24.00	22.00	0.00	0.00	1.00	4.31	0.0
5.8	79	24.00	8.00	0.00	0.00	1.00	0.27	0.0
5.8	166	24.00	8.00	1.00	0.00	1.00	24.01	0.0

Z	L	DEG	DEG	R/M	V	I	W	E
0	0	0	0	0.0	2.0E+05	1.2E+02	0.0	
5	11	3	6	8.2E-03	2.0E+05	2.5E+02	81.	
7	11	4	7	3.3E-03	2.0E+05	4.3E+02	1.1E+02	
0	0	0	0	0.0	2.0E+05	24.	0.0	
0	11	0	3	4.5E-03	2.0E+05	2.1E+02	21.	
9	11	4	7	3.5E-03	2.0E+05	3.8E+02	88.	
0	0	0	0	0.0	2.0E+05	38.	0.0	
3	10	1	3	3.7E-03	2.0E+05	1.9E+02	14.	
0	10	0	0	0.0	2.0E+05	1.0E+03	0.0	
5	27	17	21	2.5E-03	1.9E+05	1.3E+03	1.4E+03	
5	44	21	26	2.5E-03	1.9E+05	1.5E+03	2.1E+03	
3	61	21	25	2.2E-03	1.8E+05	1.9E+03	2.8E+03	
5	62	38	38	1.4E-03	1.8E+05	1.9E+03	1.2E+02	
2	62	8	8	7.6E-04	1.8E+05	2.0E+03	1.5E+02	
1	62	6	7	5.8E-04	1.8E+05	2.2E+03	1.3E+02	
7	62	6	6	4.7E-04	1.8E+05	2.4E+03	1.2E+02	
2	78	6	10	8.6E-04	1.8E+05	4.2E+03	3.8E+03	
8	79	66	66	1.6E-03	1.7E+05	4.2E+03	7.4E+02	
8	166	66	90	1.6E-03	1.4E-03	4.6E+03	7.3E+04	

ANNULUS= 5865.64

W	E/DEE MVA	Q	R SH	C EQ PF	C COUP 3 DEES
	1169	6418	109	1033	7547

0 HALT



ΔL = 166
79
87