R.F. NOTE #17

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R.F. Structure with Insulator

After a considerable amount of time spent in irresolution and procrastination, a decision has been made, finally ?, to support the dees on alumina insulators and thus permit the moving short circuit to be in air.

Oh, fingers never breathed freer
Than when bathed in Michigan air.
And surfaces never felt cooler
In this free environment, so rare.

These past few days have been spent in calculating this system, hopefully, with accuracy, and in detailing mechanical designs. Now it is possible to calculate everything below the plane where the dee ties onto the 4.125 OD stem with great accuracy because we deal with concentric lines, and even though there are many places where the impedance changes discontinuously, the program gulps these up effortlessly. But it is very difficult to calculate the dee. So, in the program, we section the dee into eight parts and approximate each part with rectangular transmission lines and each part then is multipled by a form factor.

Fortunately we have a nice 1/2 scale model dee-stem structure which will permit us to determine fairly accurately what these form factors should be. So the 1/2 scale model was carefully set up and the resonant frequencies as a function of the length from the median plane (M/P) to the shorts was measured. Transformed to full scale the results appear in Fig. 1. Then by trial and error, and error correction, form factors were found for the program that gave a good fit with the measured results. The dashed curve in Fig. 1 shows the computer calculations, obviously in good accord.

So then we use these dee data to calculate the actual full scale system, with insulator, and many impedance changes along the stem, instead of the constant impedance of the model stem. After many changes of parameters, using an inter-reactive programming technique the final results appear in Table 1, and the frequency vs. distance is displayed in Fig. 2.

Note that the top frequency for $\lambda/4$ mode operation is about 32.5 mHz and that above that frequency we have a $3\lambda/4$ mode with consequently larger power requirements to achieve the 100 KV. But since we are working with a power low we can, even on this $3\lambda/4$ mode achieve 50 KV with 50 KW.

Now I wish to document what dimensions were used in the calculations, and say a little about other things. Of course the computer program and "run" does this, but, I know people don't want to look at another's program. So in Fig. 3 and Table II, I endeavor to show this documentation and I hope any interested reader will understand it.

Explanation of Fig. 3 and Table II.

N stands for either a point where a voltage and current can be specified, or for a length of transmission line. In Fig. 3, the schematic shows three transmission lines leading from the top of the dee stem (I am considering the lower stem and half dee). This is point N=8. In Table II, as in the program, if A(N)=0 then N is a point!, else it is a line. The insulator is in line 13 and the moving short in line 16.

The circle to the right shows that a transmission line between N-1 and N has outer diameter A(N) and inner diameter B(N) in inches, and for the connections between point 8 and the various parts of the dee I use the approximation of rectangular transmission lines multipled by a form factor to generate the curve in Fig. 1. A(N), B(N), G(N), H(N) are the dimensions in inches I have guessed at. The form factors were such as to multiply my calculated Z_ϕ for these lines by 30%. If G(N)=0 then the line is 0 else ◻.

In Table II, ΔL is the length of L(16), i.e. from point 15 to the moving short. L(N) is the distance from point N to the M/P. Z_ϕ is the characteristic impedance in ohms. W_i is the power in sector N on the inner conductor and W_o the power on the outer conductor. These powers are for different frequencies. In each case I scan down my power per section over the frequency range 7.5 to 32.5 mHz and choose the <u>largest</u> power for that section. The reason for doing this is to guide the people who design the water cooling.

C(N) is the lumped capacity between the dee and dummy dee. In order to get the fit of Fig. 1, I had to multiply my calculated values by .8. As a check to see that you understand Fig. 3 and Table II, note that exactly 32 inches below the M/P the stem changes from 4.125 inches OD to 7.25 inches OD, leaving only .75 inches between the inner and outer conductors for length N(11).

Thus, hopefully, we have condensed several pages of computer printout into 3 figures and 2 tables readily understood!

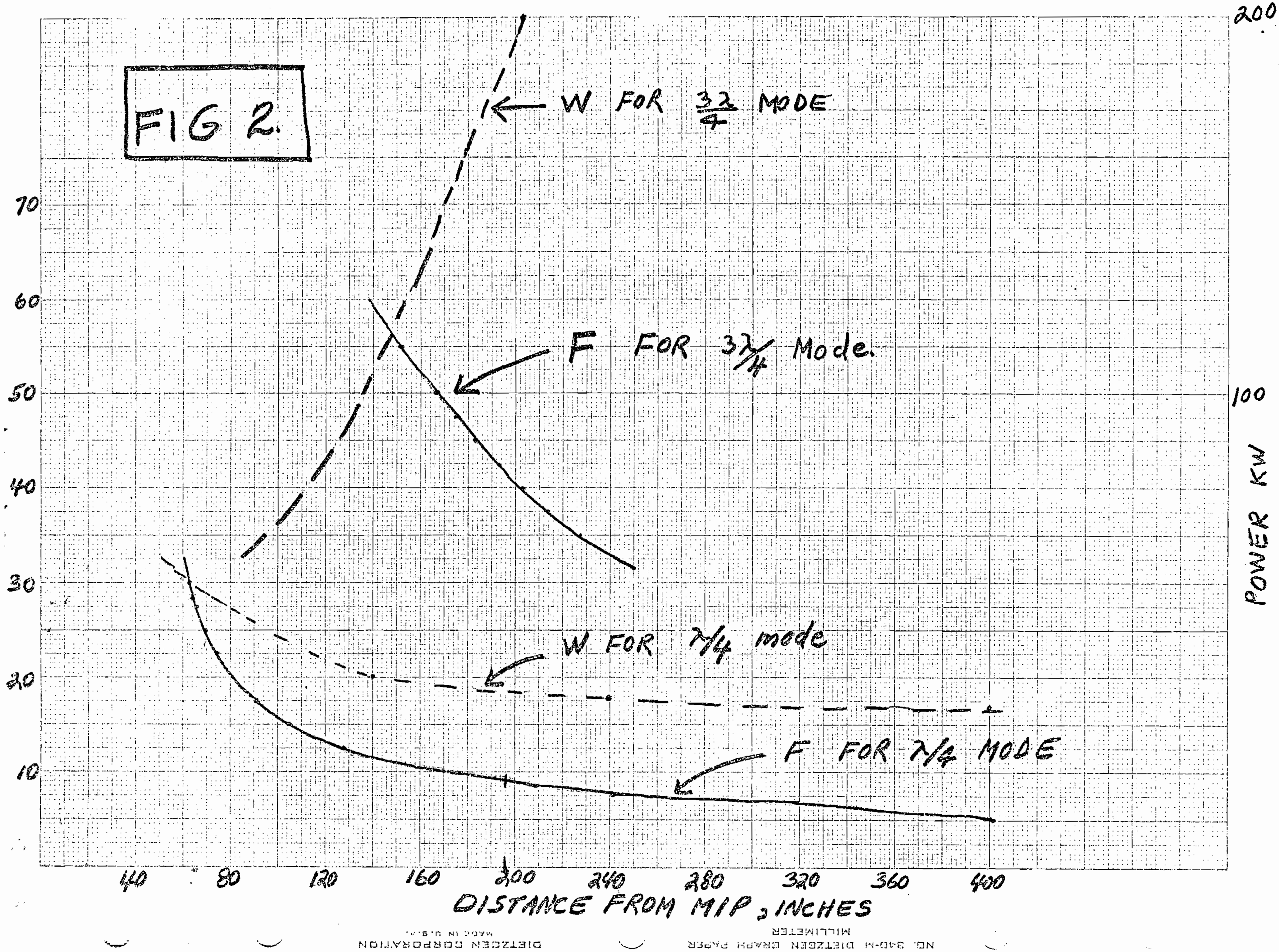
Accuracy Considerations

I believe the low frequency lengths are fairly accurate. However I would not be too surprised to find that the highest λ/4 frequency might be only 31 mHz -- or then it might be 35 mHz. The power requirements are probably within the 30% overestimate we are allowing for in our transmitter and power supply specifications. As for the rest: let us pray. Fortunately, now that we are in air, future improvisation is not too difficult.

Further Considerations

Note that now the current at the short is up to a maximum of 2600 amps rms and the heat generated per square inch at the inner radius is 50 watts! Therefore, in addition to the water cooling near the fingers, we should have some air blowing by. I suggest a blower (~100 CFM) at the bottom blowing air through the fingers and by the insulator and emitting through holes at N=12, blowing on the correction coil leads.

FIG 2.



W FOR 3λ/4 MODE
F FOR 3λ/4 Mode.
W FOR λ/4 mode
F FOR λ/4 MODE
70
60
50
40
30
20
10
200
100
POWER KW
40
80
120
160
200
240
280
320
360
400
DISTANCE FROM MIP, INCHES
DIETZGEN CORPORATION
MADE IN U.S.A.
NO. 340-M DIETZGEN GRAPH PAPER
MILLIMETER

69
61
130

TABLE I.

F MHz	ΔL INCH	L INCH	W KW	V_{INS} KVP	I RMS A.	Q --	R_S KΩ	E MVA	C_{EQ} Pf.	C_C Pf.
7.5	181	241	34	95	1200	4500	144	155	661	7
10	106	167	36	91	1400	5100	138	184	587	6
15	45	69	40	80	1900	5800	123	236	498	4
20	21	81	44	65	2200	6000	111	269	428	3
25	9	70	48	47	2500	5900	103	285	362	2
30	3	63	52	28	2600	5400	96	285	302	2
32.5	0	61	53	18	2600	5200	92	281	275	2
35	167	227	230	7	2600	8800	21	2045	1860	4

Symbology:

ΔL = length of last section to the short

L = distance from M/P to the short

W = power of 2 stems and 1 dee

V_{INS} = peak voltage entering insulator

Q = 2π x Energy stored per cycle/energy lost per cycle

R_s = shunt impedance = V^2_{rms}/W

E = circulating energy megavoltamperes

C_{EQ} = the capacity which stores the total energy at 100 KV peak volts

C_c = the value of the coupling capacitor from the transmitter feeder

241
181
50

144
138
50
188

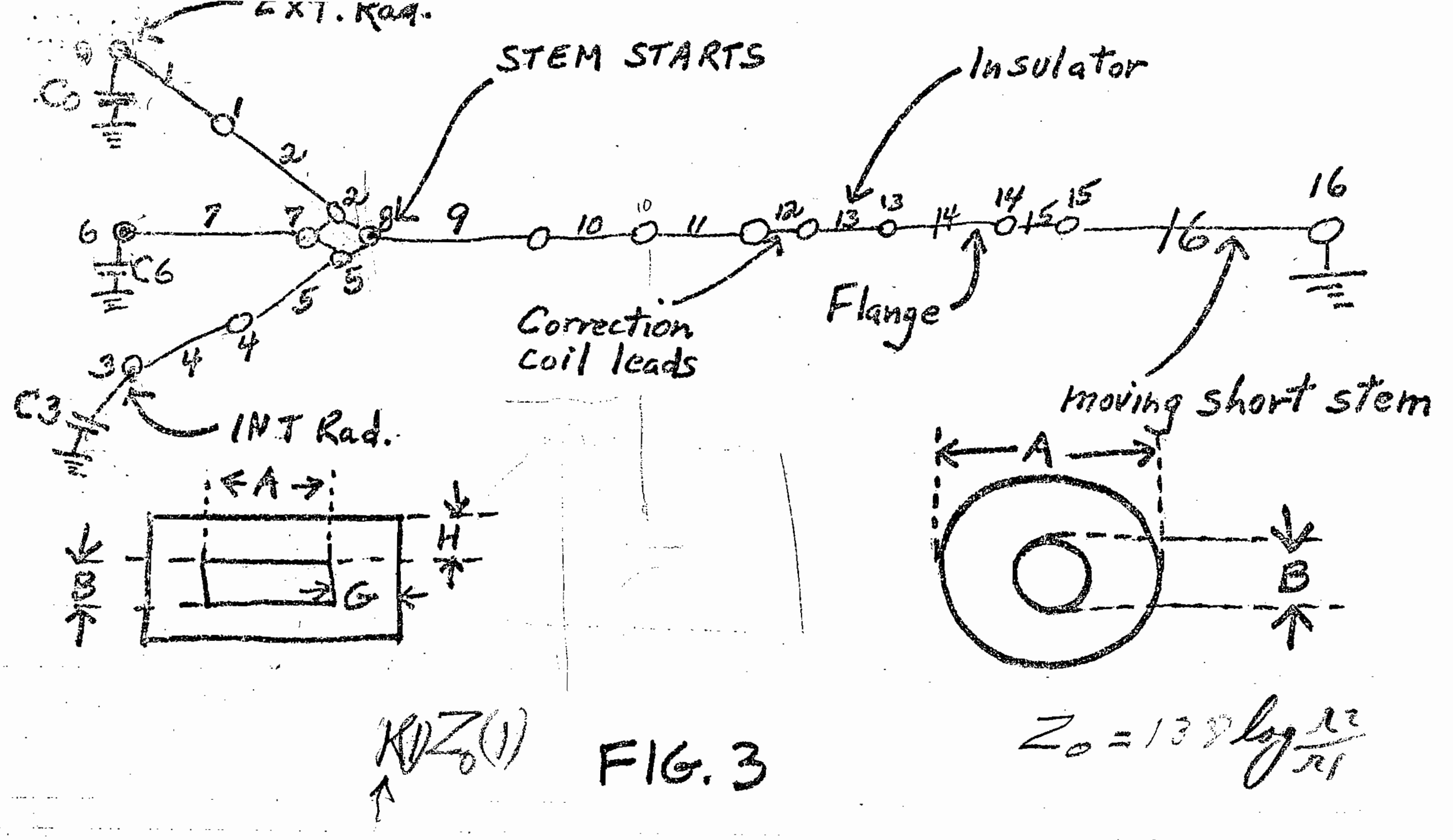


FIG. 3

Table II.

N	ΔL	L	Z_o	A	B	G	H	W_i	W_o	C
0	0	0	0	0	0	0	0	0	0	14.4
1	10	10	58.8	4	4	2	6	400	100	0
2	10	10	46.9	8	6	4	3	430	120	0
3	0	0	0	0	0	0	0	0	0	7.2
4	8	8	58.8	4	4	2	6	1000	300	0
5	8	8	46.9	8	6	4	3	1400	500	0
6	0	0	0	0	0	0	0	0	0	4.8
7	10	10	43.3	8	6	3	3	~~70~~	~~30~~	0
8	0	0	0	0	0	0	0	0	0	0
9	11	21	45.1	8.75	4.12	0	0	3500	1600	0
10	11	32	45.1	8.75	4.12	0	0	4500	2000	0
11	11	43	11.3	8.75	7.25	0	0	4300	1900	0
12	3	46	11.3	8.75	7.25	0	0	1200	1100	0
13	10	56	35.5	21.7	12	0	0	3000	1500	0
14	1	57	18.3	21.7	16	0	0	180	150	0
15	3	60	77.0	21.7	6	0	0	1500	500	0
16	0*	0*	81.2	16	4.12	0	0	15000	5000	0

*see Fig. 2 and Table I