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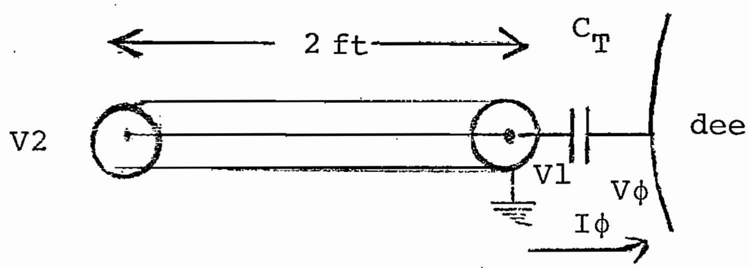
Fine Tuner

As of 7/10/78 a design existed for the fine tuner involving having a bellows, a moving foil, a hydraulic piston and a follow pot mounted under and above the dees. D. Burleigh didn't like it, complaining that these items were very inaccessible. Unfortunately he was right. So after much head scratching and the contribution of good ideas from Lawton, Blosser and Burleigh, we have come up with a "clean" design that gets around Burleigh's objections, and might even work. Figure 1 shows the design.

In the course of deciding on this design, it seemed appropriate to inquire anew into how much $\Delta F/F$ the fine tuners should be required to accomplish. Going back to RF Note #3, we note that an arbitrary choice of $\Delta F/F$ of 0.1% was stated as being satisfactory and since at that time the lowest frequency was 30 MHz this led to a $\Delta C/C$ of 0.2% or 1.5± 1pf for each half dee. But now things are different. Our lowest frequency is 9 MHz. Also, measurements on the 50 MeV machine show that the existing fine tuners achieve ± .25% $\Delta F/F$. R.F. Note #17 says that the equivalent C of a dee + stem is 587 pf at 10 MHz, so that if we wish to achieve $\Delta F/F$ of .25% or $\Delta C/C$ of .5% then each tuner must be capable of $\pm$ 1.5 pf. Thus we select the fine tuners to have 2 ± 1.5 pf, or a maximum of 3.5 pf. This can be accomplished with the design of Fig. 1. Let us now calculate what the current and voltages are.




To a very good first order, since V1 will be less than 1/10 of $V\phi$, the current $I\phi$ will be

$$I\phi = V\phi\ \omega\ C_T = 1\sqrt{2}\times10^5\times2\pi\times9\times10^6\times3.5\times10^{-12} = 28 \text{ amps rms.}$$

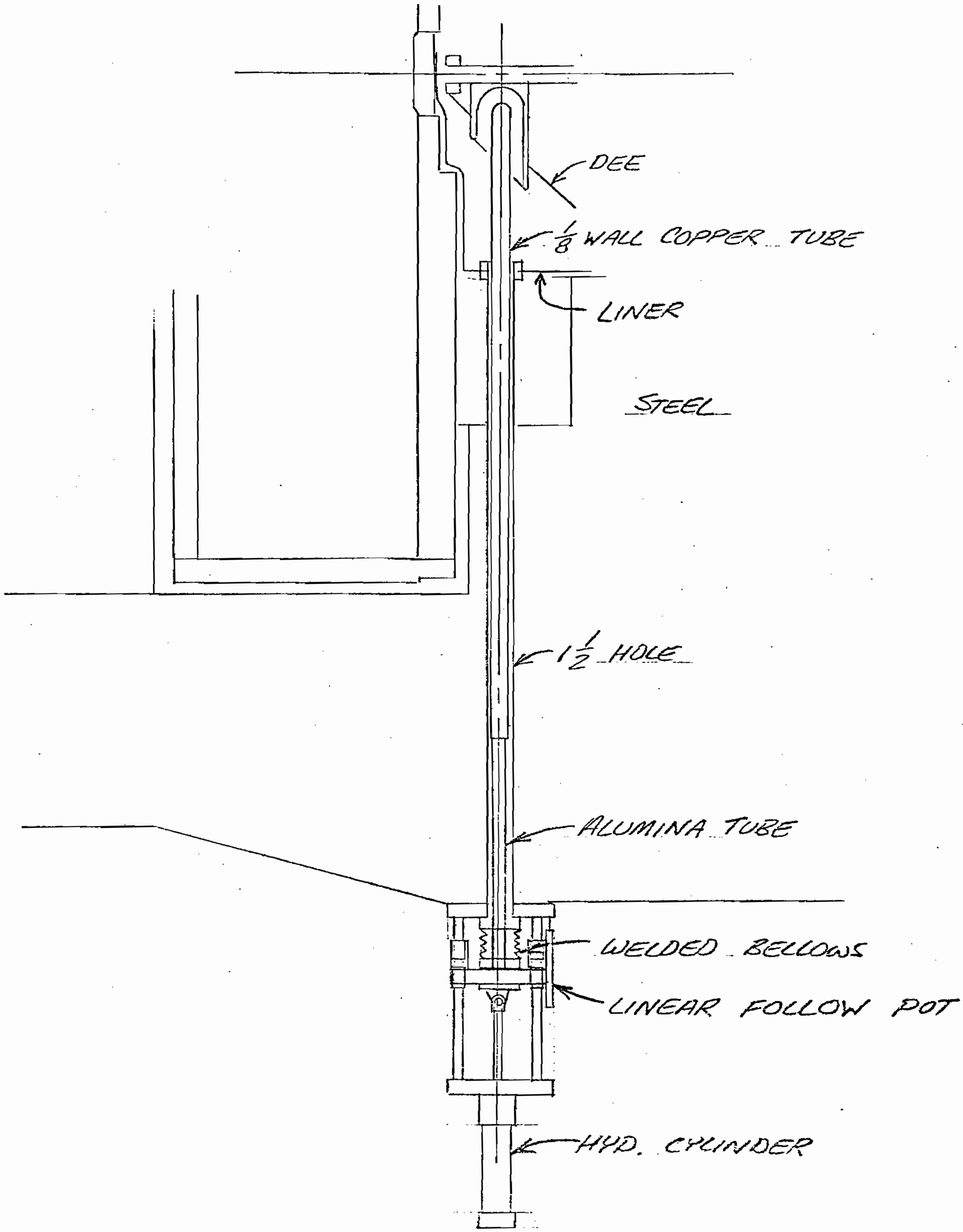
This current enters the line of $Z_0 = 138 \log \frac{.5 + 3/16}{.5} = 19\Omega$.

As this current rushes down the line the voltage increases and the current decreases, perforce becoming zero at the end, where V2 is. The appropriate equations for calculating the magnitude of V1, V2 and the I in the line are:

$$V2 = V1 \cos\theta + I\phi Z\phi \sin\theta$$

$$I2 = I\phi \cos\theta - \frac{V1}{Z\phi}\sin\theta = 0$$

where $\theta$ = the electrical length of the line $= \frac{\omega L}{c} = 6.6^\circ$




FINE TUNER

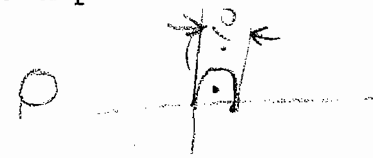
FIG. 1

So $V1 = \frac{I\phi Z\phi}{\tan\theta} = \frac{28x19}{\tan 6.6^{o}} = 4.6$ KV

$V2 = 4.6 \times 10^{3} \times .99 + 28 \times 19 \times 1.15 = 4.62$ KV

and at 30 MHz, for the same maximum tuner capacity, where, since the equivalent half dee capacity is only 150 pf we will have a $\Delta F/F$ of 0.1% the voltages and currents will be:

$$I\phi = \frac{10^{5}x\ 2\pi x 3x10^{7}x3.5x10^{-12}}{\sqrt{2}} = 46 \text{ amps rms.}$$



V1 = 2400

V2 = 2600

Now it remains to calculate the power consumed by the line. This will be highest at 30 mHz where

$$W = \int_0^{\theta} I^2_{(\theta)}\ R_{\theta}\ d\theta = 54 \text{ watts total}$$

25 on center conductor and 25 on outer conductor

Probably no cooling will be necessary, but it is easy to provide on the inner conductor with air, and the outer conductor can easily be cooled by conduction to the water-cooled liner.

Some sparking will occur, but it is believed that these structures will survive the sparks. In the event that they don't, the structure is easily removable for repairs.

Dee Voltage Monitor

The plan has always been to use a capacitor divider under the dee to provide a monitor of the dee voltage, as is being done in the transmitter to monitor the plate rf voltage. However there are two as yet unsolved problems with this method: the 2000 pf capacitor suitable for placing in a high quality vacuum does not exist; it would have to be especially made by depositing silver on mica and secondly a suitable cable to penetrate the vacuum has also not been found; it also would have to be especially made. .11 $.04\ m^2$

So we decide to use loops riding on the moving short. Such a loop monitors $d\theta/dt$, not V as follows:

$$V_{loop} = \frac{\omega\mu_0 IA}{2\pi r}$$

$\cancel{r = \frac{2\pi V}{\omega\mu_0 I}}$ $A = \frac{2\pi r V}{\omega\mu_0 I} = \frac{10 \times .17}{10^{-6} \times 3\times10^{7} \times 2\times10^{3}} = 2.8\times10^{-5}$

where I is the stem current at the short, A is the area of the loop, r the radius at which it is placed. From rf Note #17 we note that as F varies from 30 to 10 mHz the current varies from 2600 to 1400 amps. Thus if the loop is designed to pick up 5V rms at 30 mHz the diameter of the loop should be 0.1 inches and at 10 mHz it will intercept only 0.9 volts. This undesirable variation in the calibration can be avoided, to first order, by having the loop be rotatable via a fourth push rod. But at least to start with, we will use fixed loops, each independently calibrated.

These loops (two for each moving short carriage) will send signals via high quality doubly shielded 50Ω coax cable to the console racks. I1 signal will feed phase detector $\phi 5$ of drawing 5-RE-1K-E. I2 will feed the amplitude detector in the voltage regulator module. This detector will be typec detector illustrated and discussed on page 4 of RF NOTE #19. I3 will feed a logarithmic peak detector and a - dV/dt detector followed by a one shot to cut off the rf drive for a time console knob settable from 1 to 10 seconds. It is a spark detector. I4 is available for oscilloscope monitoring.

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we decide to make V peak = 20 volts at 30 mHz.

$$20 = \frac{\omega \mu_0 I A}{2\pi r} \qquad r = 6.25 \quad I = 2600$$

$$A = \frac{20 \times 2\pi \times 6.25}{2\pi \times 3 \times 10^{7} \times 4\pi \times 10^{-7} \times 39.37 \times 2600} = 3.24 \times 10^{-5}\ m^2$$

$$= .05\ in^2$$

use:
1 for ampl. $\longrightarrow$ .05"
1 for P.D. → F.T. servo
1 for P.D → $\Delta\phi$ servo
1 for 30 meter

$\Big\}$ .025"