R.F. Book

R.F. Note #52

August 13, 1979
J. Riedel

Status Report on Resonator

First, let us correct two mistakes made in RF Note #51, reporting on TEST 4. The current that the stem fingers must carry is 70 amps per centimeter, not inches. The second mistake lay in the statement that the stem fingers were O.K. True, they did not burn up, but on closer inspection with a 20 power microscope, about half the fingers showed evidence of sparking and would have failed had we run longer. Now it is possible that this sparking was due to a crudy copper stem and or to build-up of molycoat on the fingers. So there is a chance that when the surfaces are silver plated the fingers will work o.k. Since there was also damange on some of the outer conductor fingers, the panels must also be silver plated. One to two mils is the recommended plating thickness.

Without the molycoat (molybdenum di-sulfide) galling will mean frequent replacing on the fingers.

D. Lawton has a back up design which I officially label "door spring contacts". These are about 1/4" diameter springs using tightly wound silver plated beryllium copper wire of about 20 mils diam. There will be 12 of these captured in curved slots so that they can't dominoe as they are pressed into an elipsoidal shape via 12 pneumatic pistons. The contact force per wire will be approximately 2 pounds per wire. This pressure would be relieved when the short is moved. Altogether, this seems such an obviously superior design to the fingers that if we have enough time, I would recommend that we implement it as soon as possible and not wait until we burn up the fingers again.

Present plans are to have the test resonator reassembled and ready for rf tests by the end of September.

Waterload

On 8/6/79 we tested the 150KW 2.6666 x 10^3 ohm water cooled Cerment resistor acquired from Yellville, Arkansas, and it passed with grade A+. At first we had 30 GPM and a temperature rise of 15°C. Then we throttled the flow down to 15 GPM and the temperature rise was 30°C. So we proceed with confidence to build 3 more to send to Transrex in Califorinia so that in October they can use them as dummy loads to prove out the performance of the 450 KW power supply they are building for us. It's amazing that Yellville, Arkansas,almost in the middle of no where, is the only place which makes resistors like these. Wonders never cease!

Transmitter

The cause of the transmitter stem finger failure is attributed to poor soldering. The transmitter was repaired, reassembled and on 8/10/79, tested for about 4 hours at 30 mHz and a stem current 50% higher than our normal maximum current. Quickly we burned up the 10 KW rf waterload resistor in the anode box, but we proceeded without it and no problems with the transmitter manifested themselves, except I thought the air flow was too low. The exit air temperature was about 45°C and I have asked D. Lawton to find out where the major restriction on air flow is and do something to double the air flow. The best way is to measure the pressure below the short, in the anode box and in the grid box.

Amplitude Regulation

In the Marine Corp during WWII, it was trite to say that there were four ways of doing things. The Marine Corp way, the Commander's way, the right way, and My way. Now I always worked very hard to make the last two ways equivalent; but the problem always was to correctly define the right way. As I grow older, thus losing various abilities, hopefully I am gaining some wisdom and thus improving my ability to define the right way. And I have learned that rather than thrash around using trial and error methods, it is best to exactly calculate a calculable problem and prove in advance that your solutions will work.

Therefore, in regard first to the dee amplitude regulator I have decided to calculate the open and closed loop response of this servo. Also, rather than use the bang-bang overriding circuits mentioned in RF Note #49 I have decided to do this right too, so that in case of excessive screen or plate current, water temperature etc, analog servo control will take over and limit these excesses.

The reason I shied away from implementing this "right" way of doing things before was that, as a result of my experience at Princeton University, at the critical time of first beam, there was no time to optimise the rf system by trial and error methods. The same will be true here. So at first turn on the damn RF system must already be complete. Computer simulation is the only answer, and I am confident that I can do it!

First, a small dissertation on servoe loops for the neophite; and of course we are all neophites in this business. To the uninitiate an analog servo loop seems simple. Figure 1 shows the facts.

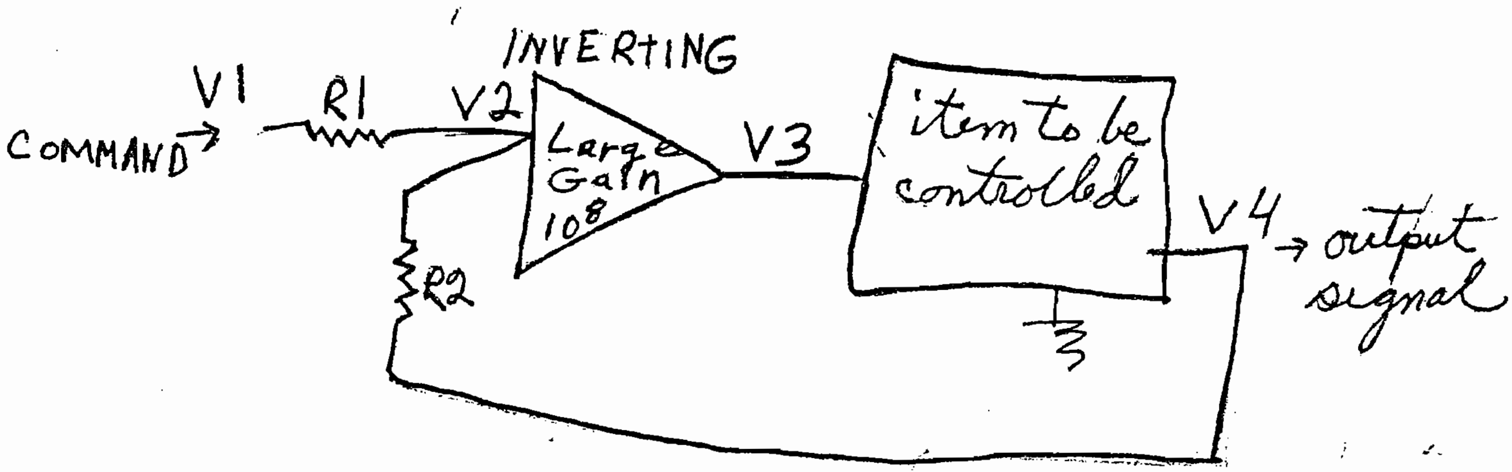


Figure 1

Let R1 = R2 and V4 = V1 when regulation exists. If V4 is lower than it is supposed to be then V1 - V4 into the 10^8 gain amplifier will cause V4 to increase. Conversely if V4 is higher than it is supposed to then V1 - V4 into the amplifier will reduce it. So, obviously, V4 will obey the command! However, some 60 or 80 years ago Nyquist and Böde showed that things weren't this simple, and that if things called "transfer functions" in the open loop weren't done right the system would oscillate. The criterion for oscillation to exist in an open loop measurement is simple. If the gain is more than 1 and the accumulated phase shift is 180 degree, then the closed loop will oscillate! This is equivalent to saying that in a Nyquist diagram (a polar plot in the complex plane) the locus must not enclose the -1 point. In a Böde plot, which method I choose to use, the criteria is that the gain must be at least .5 before the phase delay reaches π. A sure way of insuring this is to have the open loop gain fall off at no greater than 6 db/octave (factor of ten per decade) until the gain is well below unity.

And then the closed loop response reveals the results, and it will bode ill of one to exceed the open loop response criteria!

Fig. 1 shows the circuit diagram of the computer model of the amplitude servo. T1 is the time constant of the dee, with break frequencies ranging from 3 to 9KHz. T2 is the time constant of the driver, an alarming .5 µs. L is the cable length between the voltage monitor and the regulator, T3 is the lead network across the servo amplifier to compensate for T1, and T4 is the integrating time constant of the peak detector, hopefully leas than .1 μs. $G\phi$ and $F\phi$ are the dc gain and unity gain frequency of the servo opamp, presumed to have exactly 6 db/octave fall off to $F\phi$.

The goal is to acheive an open loop gain of 1000 at 360 Hz so that the presumed 1% unregulated amplitude ripple at 60 and 360 Hz will be reduced to .001% by the regulator. This means (using Bode's criteria) that we must have unity gain and less than 180° lag at 360 KHz. The cavity starts putting in a 90 degree lag at 3 KHz and the op amp puts in a lag of 90 degrees starting at .01 Hz. The cavity lag is eliminated with lead network across the op amp.

It was soon learned that a cable length of 100 meters (dee to control room and back) was intolerable. 10 meters is o.k. This means that A, the regulator must be located in the vault and B, the 50 feet of cable necessary to use our current monitors on the short are excessively long.

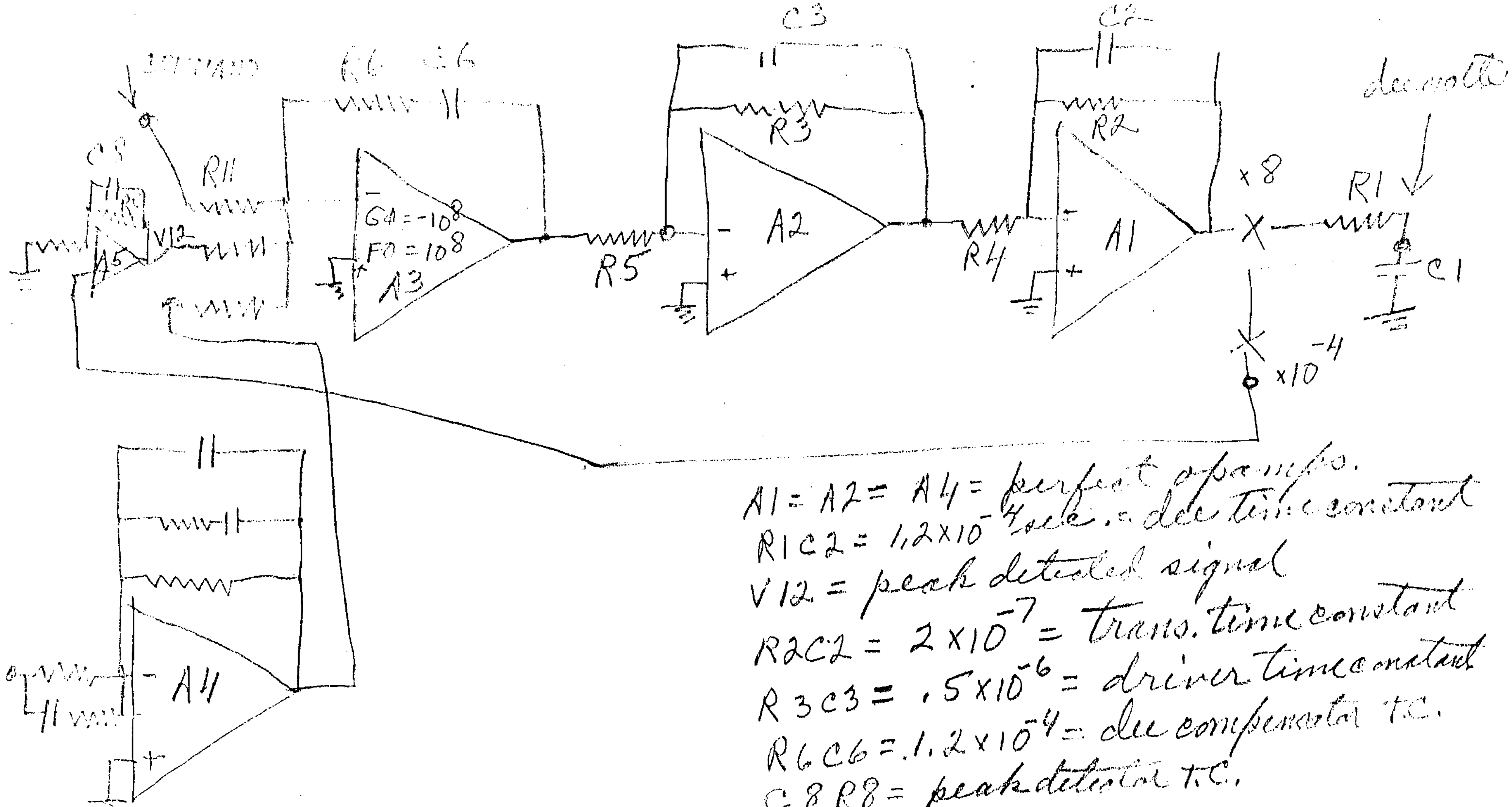
During the next two weeks further computer simulation will be done and a final design for the regulator will exist.

New Dee Voltage Monitor

There are two undesirable aspects with the present current pick-up loops mounted on the moving short carriage: The amplitude varies by 1 to 8 over the frequency range, and because the cables measuring this current must pass through the push rods the minimum distance to the regulator mounted at the amplifier would be 50 ft. This, as pointed out in the note on the voltage regulator, is excessive for stability of the closed loop. So we have decided to mount a voltage divider on the spinning surrounding the dee insulator.

The voltage at the point of the insulator nearest the dee varies 2 to 1 over the frequency range, and at the other end of the insulator it varies 4 to 1. So at the chosen point it will probably vary 3 to 1, which is less variation than the current pick-ups provided.

The geometry here is very complicated and the difficulty in solving Laplaces equation in three dimensions to ascertain the proper size for the pick-up electrodes is formidable. Fortunately, however, as a result of long experience, we feel we can outguess Laplace, especially so when we only need to pick-up more voltage than necessary, and then we can throw some away by adding capacity.



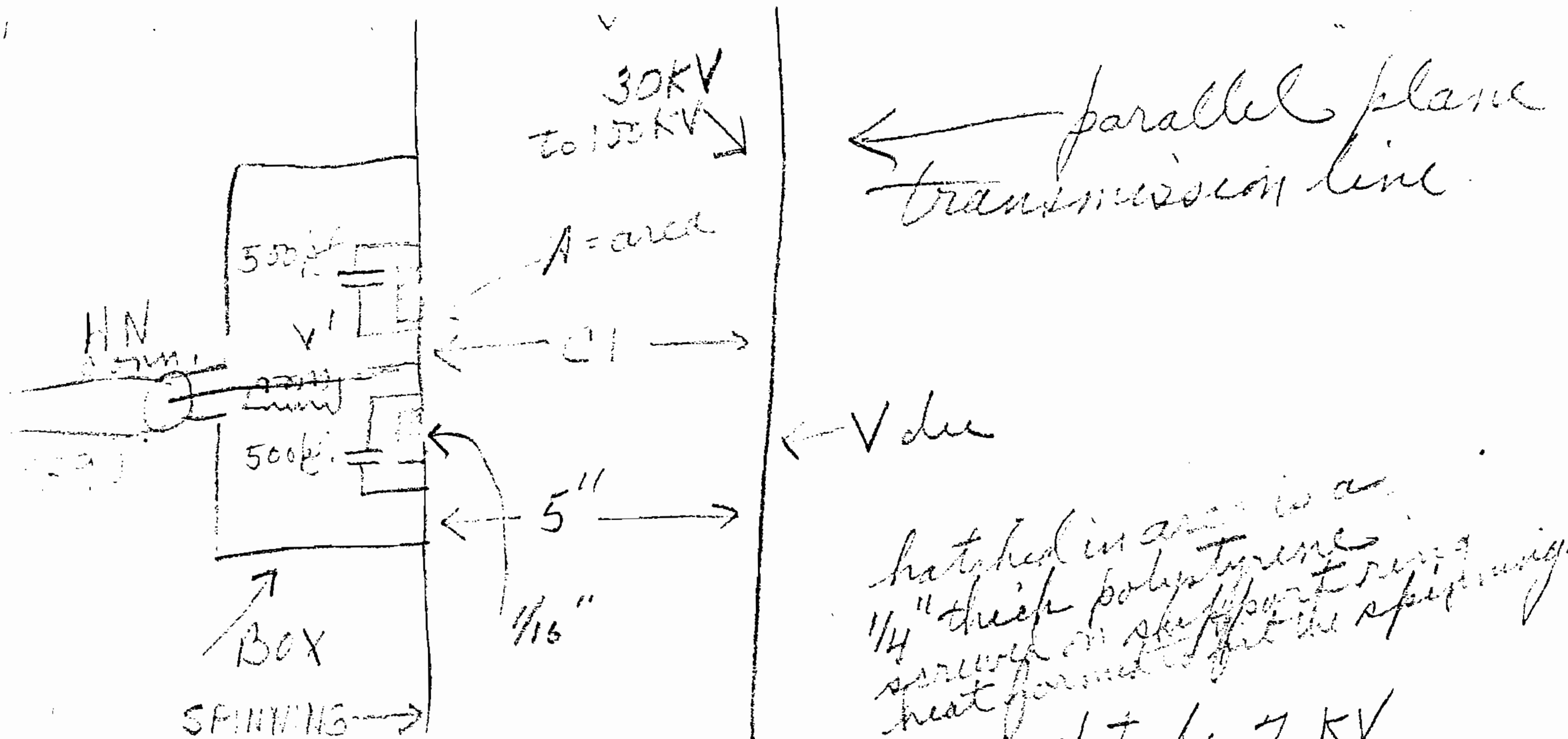
A1 = A2 = A4 = perfect op amps.
R1C2 = 1.2×10^{-4} sec. = dee time constant
V12 = peak detected signal
R2C2 = 2×10^{-7} = trans. time constant
R3C3 = $.5 \times 10^{-6}$ = driver time constant
R6C6 = 1.2×10^{-4} = dee compensator t.c.
C8R8 = peak detector t.c.

A4 not designed yet.

$\frac{R2}{R4} = 4.0$, $\frac{R3}{R5} = 35.7$
= gain of final and driver

FIG 2 - Amplitude servo simulator.

It is claimed that a sufficient model for the geometry is as below:



when V dee = 100KV we wish V' to be 7 KV

therefore $C1 = 7/10^5 \times 10^{9} = 7 \times 10^{-14}$ pf. ~ 10^{-13}

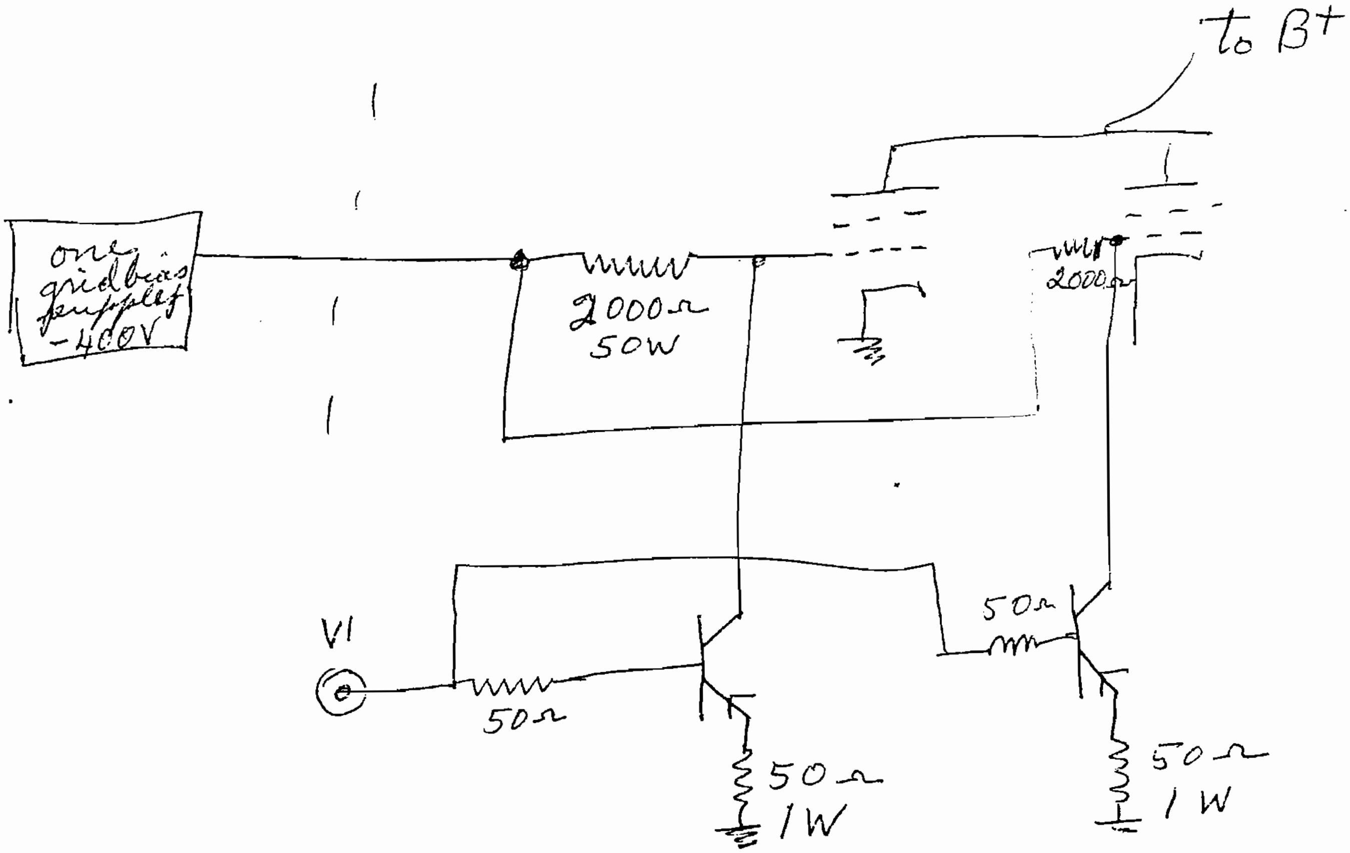
now $C1 = \dfrac{A}{4.5d}$ in pf, sq.in. and in.

so $A = 5 \times 4.5 \times 10^{-1} = 2.25$ sq. in.

or a circle of diameter 2 inches. We have used Riedel's math to arrive at this number! This is a circle cut out of a cylindrical wall. The spacing is 1/16". Let us mount one on each spinning, we have two per dee. D. Lawton will have no difficulty executing this.

Using the 50 MeV transmitter as a shunt B^+ regulator

The grid circuit will be modified as follows:



The transistors are PNP-450 volt, 50 watt. A 5 volt signal at V1 will depress the grid bias to 200 bolts, thus turning on some 8 amps. This final P.S. will feed both the 50 & 500 MeV transmitters through separate current transducers. W. Harder will make these changes so that tests can be made August 27.

Meanwhile, J. Jenkins is modifying the "turn on" module to provide pre and post gates to make V1.

Longer Range Considerations

Turn On Method. After a few years of operation, when the dee surfaces have been quelled into submission, perhaps normal turn on methods will suffice. But at the start, and I am now only involved in "the start", I plan on proceeding as follows: Dees B & C will be detuned and we thump away at Dee A until we can achieve stable operation at 100 KV for a few hours. Then we detune A&C and prove B. Then, similarly we detune A&B and prove C. Now, with phase and amplitude loops "OPEN", as before, we thump away at all three until we can achieve, say, 20 KV on each dee. Now we close the phase and amplitude loops and slowly raise the voltage of all three dees. When a spark occurs, which it will, we pulse RF drive off for 1 second and pulse on all dees again. If sparks repeat themselves for N times(N between 5 and 20) we reduce the voltage demand to 20 KV, hopefully then come on and slowly raise the voltage again. Slowly means maybe 10 seconds. If sparking continues, we "open the loops", come on at 20KV and scratch our heads before proceeding. Remember, no one has yet found out how to make a 3ϕ rf system work!

This time, while in Arkansas, I plan on doing a great deal of fishing, and as I sit,watching my bobbing cork and sipping from a bottle of mountain dew, no doubt I will come up with better ideas.