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RF #37

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Water Load for Testing Anode Power Supply

We have placed an order for our anode power supply. This supply will deliver 150 kW at 20 kV to each of three parallel outputs, individually current monitored. A part of the specification is that the supply be factory tested into a dummy load for as long as is necessary for thermal equilibrium of all the components to be achieved. This usually takes about four hours.

Now the standard method of building such a dummy load is to assemble 450 kW of air cooled resistors. Large companies, like GE or Westinghouse, have such large resistor banks left over from previous uses but smaller companies must build them and the cost, using commercially available resistors, would probably be around $50 k.

We propose to build these loads using water as both the resistive element and the coolant. Figure 1 shows the construction. Each load wants to look like $(2 \times 10^4)^2/150k = 2700\Omega$. Let us assume that a temperature rise of 50^oC in the water is o.k. then we will need a water flow of

$$\frac{1.5 \times 10^5 \text{ watts}}{50^oC \times \frac{250 \text{ watts}}{^oC \text{ GPM}}} = 12 \text{ GPM for each}$$

This would be city water which we would throw away.

In Berkeley and Princeton, city water had a resistivity of about $10^4\ \Omega$ cm, but I am informed that East Lansing water is about $2.5 \times 10^3\ \Omega$cm. I can well believe it because of what it does to my coffee and my scotch. It is good for bathing only. Nevertheless we can use it for this job: in fact, since LA city water is probably $10^4\Omega$cm $\pm\ 5 \times 10^3\Omega$cm we should design a water load that can be adjusted to have the proper resistance for water that may vary from $2.5 \times 10^3\Omega$cm to $3 \times 10^4\Omega$cm. (A range of more than 10 to 1) This can easily be done.

The resistance of the water load will be $R = \frac{R_o L}{A}$ to first order, where R_o is the resistivity discussed above, L the length in cm., and A the area of the conducting path, in cm^2. With electrodes of 4" diameter, separated by 50 cm in a 6 inch diameter pipe, the resistance will be for $R_o = 2.5 \times 10^5$, $\frac{2.5 \times 10^3 \times 50}{(3 \times 2.54)^2 \Pi} = 700\Omega$

for $R_o = 3 \times 10^4$, $\frac{3 \times 10^4 \times 50}{(3 \times 2.54)^2 \Pi} = 8000\Omega$

somewhere in between lies our desired number of 2700 Ω. How to achieve it?

We use two methods. First, by moving the two electrodes towards the center we can reduce 8000Ω to about 2700 for water of 3×10^4 Ωcm in a 6" pipe. Second, by adding the reduced diameter lucite pipe at the center we can raise the resistance from 700Ω to 3000Ω for, 2.5×10^3 Ωcm water. In this way we can obtain the proper resistance.

Now it is appropriate to calculate the amount of hydrogen released by disassociation, and the amount of copper deplated. The amount of hydrogen released is

$$H = \frac{5 \times 10^{-5} \text{ moles}}{\text{amp. sec.}} \times \frac{22.4 \text{ l}}{\text{mole}} = \frac{1.1 \times 10^{-3} \text{ liters}}{\text{amp sec.}}$$

so each hour we will release

$$H = \frac{1.1 \times 10^{-3} \text{ liters}}{\text{amp sec.}} \times 7.5 \text{ amps} \times \frac{3600 \text{ sec}}{\text{hr}} = \frac{30 \text{ liters}}{\text{hr}}$$

which should not bother anyone. But no matches, please.

The amount of copper deplated can be calculated from the fact the 10^4 amps deplates 60 gms/sec, which results in deplating 3.5×10^{-5} cu in/sec. So far a 20 sq in electrode, we will remove 5.5 mils per hour, obviously not significant.

Any other problems? Maybe. If the water is highly aereated, the bubbles coming off as it heats up could lead to sparking. However I and others have used loads like this in the past successfully and therefore I predict that it will work fine, unless East Lansing's City water does me in.

Problems With the 50 MeV Cyclotron R.F. System and the Valued Use of a Spectrum Analyzer

Recently (12/7/78), on the occasion of the cyclotron's being asked to run at21 MHz, various problems developed, manifested primarily by the anode enclosure light sensitive spark detector repetitively crowbarring things off. In inspections of the anode circuitry even one with jaundiced eye could see that the transmitter was sick: the blockers were spark stained, and the anode insulators were discolored and also spark stained. Why? The most obvious answer was that, at a certain time while the anode voltage was raised, the tubes broke into a self excited parasitic oscillation at some high frequency which resulted in very high rf voltages appearing at the external anodes.

After some head scratching it was decided to replace the blockers and tubes with freshly scrubbed one, and then, in a flash of inspiration, to try our newly acquired spectrum analyzer to look at the anode voltage.

The results were dramatic. At low voltage one could see the fundamental, a small second, third and fourth harmonic, and a large fifth harmonic which grew rapidly as the voltage was raised. Whereas the first, second, third and fourth harmonic signals were stable, the fifth harmonic signal was pulsating with about a 10% modulation. Then as the rf voltage was raised one could see the 5th harmonic take off, exceeding the fundamental. Obviously a bad situation. So the frequency was lowered to about 20 MHz. Now the forth harmonic dominated. But by twiddling the "NEUTRALIZING" knob, it could be eliminated, and satisfactory operation at high voltage achieved.

So much for that! Obviously the operators should always have a spectrum analyzer looking at the anode box when they tune up to a new frequency. Also, obviously, the anode box is in serious trouble. Let us hope (maybe pray) that the anode boxes for the 500 MeV do not have similar problems.

F.M. Noise and Detection

At about the same time, the dee voltage wave form (usually compose of 60, 120 and 360Hz modulation of about .1%) started exhibiting some 1 to 2 KHz modulation, which resulted in beam quality deterioration. A solution was quickly found: the operators switched from the Rhodes and Swartz Synthesizer to a crystal oscillator. Now, how does one find out what was wrong with the synthesizer? Head scratching, again. Then I got a chance to do something which I had long wanted to do: measure F.M. noise.

So the apparatus shown in Fig. 2 was assembled. The 1000 feet of RG59U was carted from the archives. Along side it was a 1000 ft spool of RG8U, but it weighed about 200 lbs. When I was younger I would have carted it off instead and thus not have had to put up with the factor of 6 attenuation in the 1000 ft of RG 59U, and the attendent impedance mismatches resulting from using a 75Ω cable in an otherwise 50Ω circuitry. A mere case of debilitation with age, that's what it is. Even so, it worked. At first we were able to see 5 parts in 10^5 of 60 Hz and its harmonics FM modulation. But when we monitored the crystal oscillator and saw almost the same, suspicion about the validity of the measurements arose. So we put a cheater (2 prong to 3 prong adaptor on the scope a c plug and then we were finally able to see the 1 KHz FM modulation of 1 part in 10^5 from the synthesizer. As experienced at Princeton, these types of cyclotrons connot tolerate 1 part in 10^5 frequency modulation of the rf.

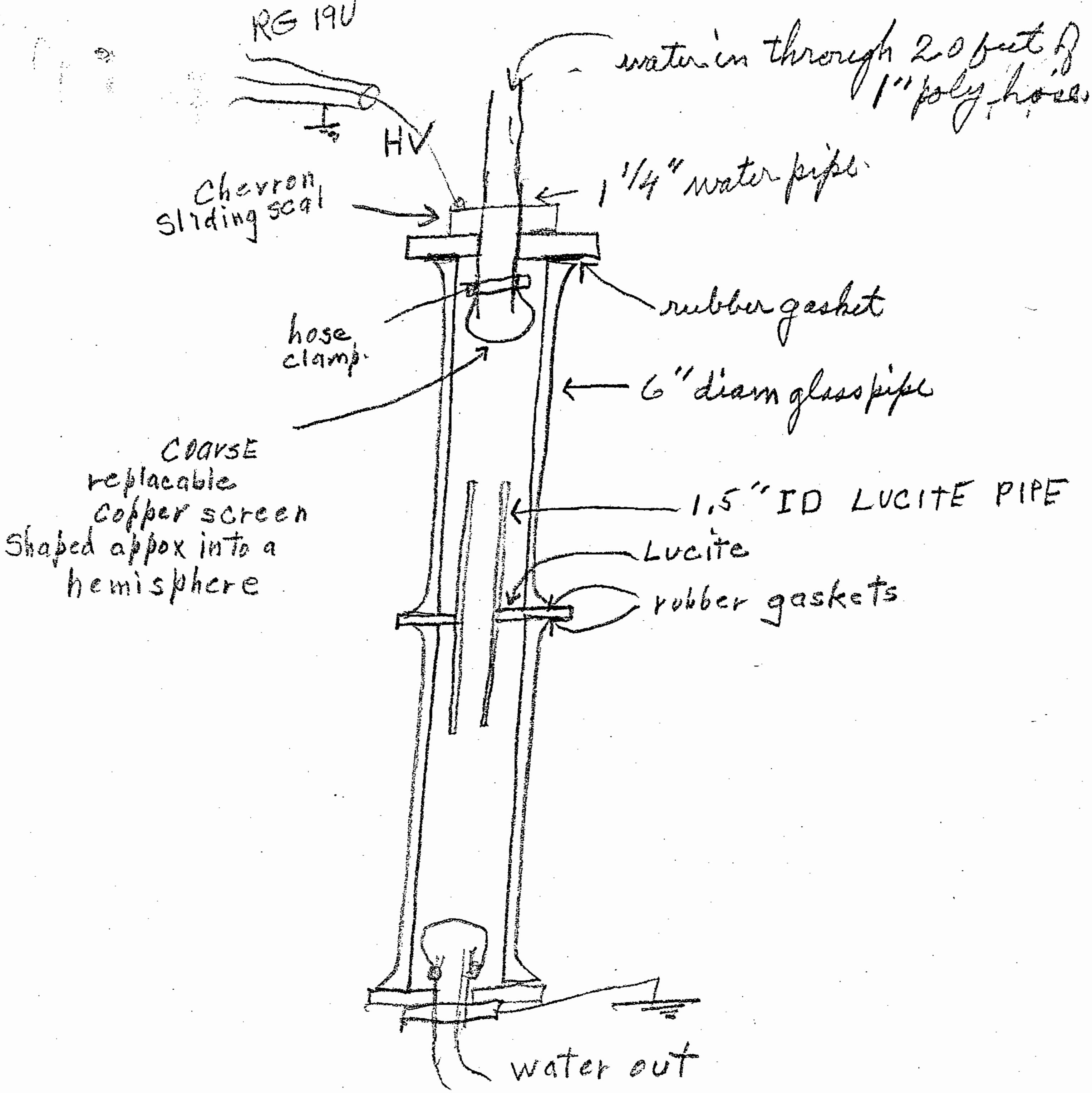
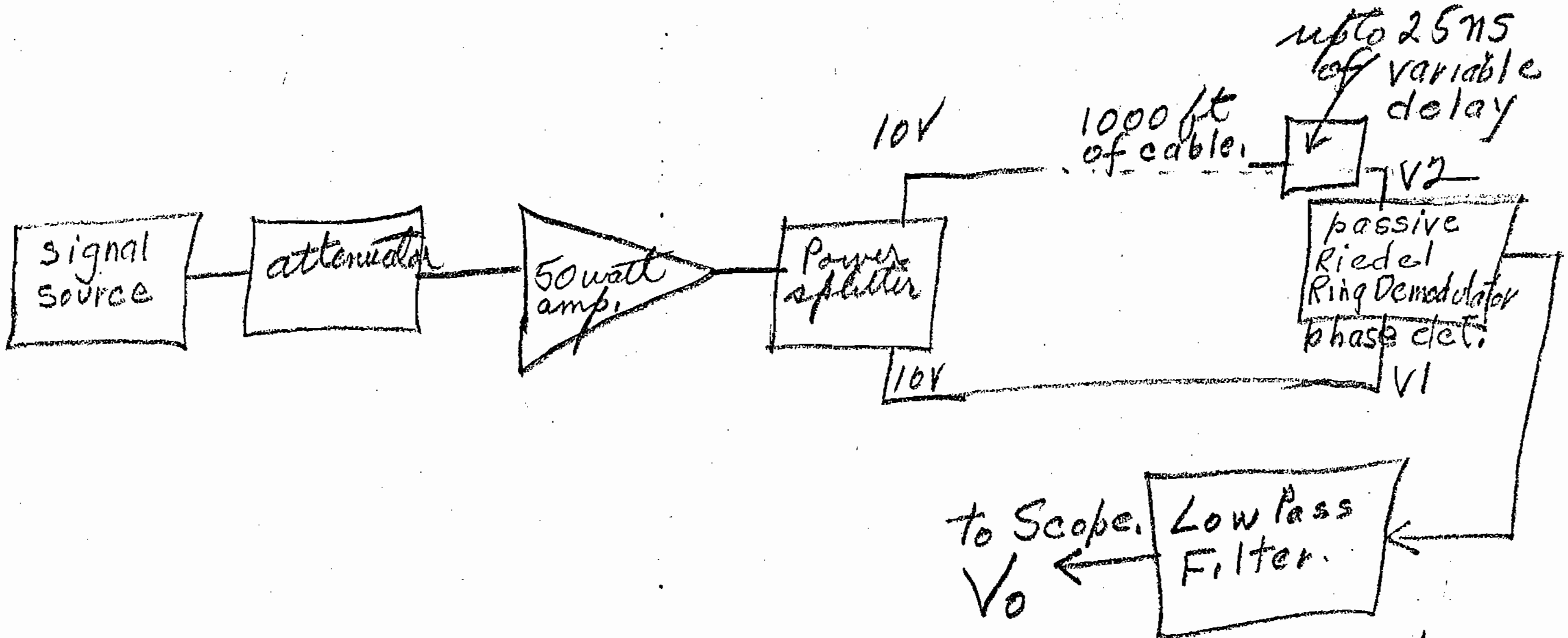

RG 19U
HV
water in through 20 feet of 1" poly hose
Chevron sliding seal
1 1/4" water pipe
rubber gasket
hose clamp
6" diam glass pipe
COarSE replacable copper screen Shaped appox into a hemisphere
1.5" ID LUCITE PIPE
Lucite
rubber gaskets
water out

FIG 1.



with the variable delay box adjusted so that the average Vo is zero, meaning V1 + V2 are 90° out of phase, the sensitivety is a maximum and proportional ~~to~~ ωL, where L is the 1000 ft. At 20 mHz the sensitivity of this analog frequency meter was 1 mv for a $\frac{\Delta F}{F}$ of 5×10^{-6}.

Fig 2.