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RF Book

R.F. Note 77

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EVEN NEARER

1. Preamble

We are trying to get the RF System on in 3ϕ mode at 78 kV on each dee at 24.423 MHz so that the first internally accelerated beam will be deuterium. In trying to do so as quickly as possible we have made a few mistakes that have retarded our forward motion. The first mistake was entirely my fault! First, in air, we tuned up each transmitter with the other two detuned, then, again at 1 atmosphere we tuned up for three phase operation. We could indeed get nice three phase operation, but when the phases were approaching exactly 120^{o} apart a 10% amplitude oscillation of about 10 Hz set in. We don't understand this. At this time I thought we were below 20 kV so that no sparking should occur. There were many unexplained anomolies, but instead of trying to understand them we pressed on and decided to go to vacuum.

We couldn't get a vacuum and finally decided that two upper dee stem insulators were cracked. On dissassembling these two dee stems (B&C upper) we found that the insulators were indeed cracked, and the evidence was sufficient to allow us to conclude that a free living RF arc had existed on the top of the corona ring and had caused thermal stresses in these insulators and cracked them. The reason the third insulator (A) didn't crack, it is postulated, is that it had at least 4 times as much air cooling the outside as did the other two, due to our having inserted polypropylene screens in them.

How come? My theory is that an air arc developed at the maximum gradient place (either the center region or at the dee to liner edges(½ inch)). The heated air blew these arcs across the dee, up the dee stem, and finally settled them in a stable place on the corona ring, sort of like what happens in a Jacobs ladder. This couldn't happen at the lower stems. I am fairly confident that this is a correct explanation.

Now we are very wary of testing in air.

The second mistake occurred as we were reassembling everything. Bother the details here: hydraulic oil fluid of maybe 1 quart accidently leaked down onto the dee liner and the 1/4 inch crack between the liner and the coil cryostat while the cap was halfway up. Damnation! The outlook was bleak--and soon to become bleaker. This finishes the preamble.

2. One at a time dee tests to calibrate the dee voltage monitors.

We pumped down and got an indifferent vacuum of 4×10^{-5} Torr. We detuned B&C stems by 14 inches and brought A dee up to an Xray calibration voltage of 35 kV. Similarly, we got B dee to 32 kV. C dee ran into a brick wall at 20 kV. Even so, we were able to get approximate calibrations for our dee voltmeters(actually these are voltages proportional to the short currents).

Meanwhile we were operating under a multitude of handicaps. The damned transmitter servos weren't working properly, due in the main, to shaft slippages and poor design (my fault again).

Various phase detectors were't working properly due to offsets here and there, poor design, misconnected or poorly connected cables etc. One of the greatest design errors was that the range of the anode fine tuners was excessively small (my fault again). Also the various protective features (-dV/dt, excessive reflected power, stem short sparks) didn't work and were disconnected. The only protection circuit that worked was the override circuit on A transmitter that prevented excessive screen current from tripping us off.

Even so, we successfully completed these calibrations and proceeded on.

3. Three Phase Operation.

With the "Residual Gas Detector", an invaluable instrument, we were able to determine that the principle leak component was water. So, to get a decent vacuum, M. Mallory arranged to pump liquid nitrogen up the bottom dee cryostat lines to trap the water, and, soon, we got down to 3.5×10^{-5} Torr and could turn on.

We have established various recipes for being able to turn on, and although later we will undoubtedly have ones that taste better, it turns out that it is fairly easy to "get on" even with a poor recipe. Suffice it to say that we "got on".

Our number one operator was at the controls, and after considerable fiddling around, no doubt using ESP, he finally got 3ϕ operation at a low voltage. Unfortunately, the vacuum would go bad after 10 to 100 seconds and we would turn off and wait a minute or two for it to recover. Interestingly, although a phase relationship of -130 & +110 as between B & A & B & C was possible, -120 & +120 was almost impossible to achieve, and when we came close the same 10 Hz amplitude modulations previously mentioned occurred.

The dees preferred to operate with two in phase and the other 180^{o} out of phase. They obviously don't like 3ϕ, but with such a competent and insisting operator as our No.1 we were able to, in the main, after our stupid loops had settled down (about 2 seconds) to achieve a semblance of 3ϕ operation.

Then he tried to raise the voltage. For 15 minutes we were stuck. Then it slowly rose. And suddenly, on Sunday night at about 9 p.m., he broke through and we were able to get up to about 50 kV, with all loops closed and reasonable, but not accurate, 3ϕ operation. Wunderbar! The vacuum stayed quiescent at 3.5×10^{-5} Torr. Now I knew that the RF system would eventually be successful!

We had some trip offs due to inexplicable interlockery and quit for the night so that we could watch the end of game 6 of the World Series--but since it was rained out, we were able to wash our socks and get a good nights rest for a change.

Monday we came on again to try to explain these trip offs. Soon, another manifestation appeared. We got sparks in B Transmitter accompanied with final anode power supply crowbars.

This is serious. Visual inspection revealed that the sparks were to the anode fine tuner, which was known to be good for 30 kV at least. How come?

A little thought revealed the answer to this manifestation. Anode B was detuned in such a manner that even though its forward power was zero, the other two dees could drive power into it and cause it to have an arbitrarily high anode voltage. 100kV would be a snap--leading to a tube spark and crowbarring. Toshi will corroborate this with TRED2 soon. So we are learning about what a complicated thing 3ϕ operation is and about how unforgiving it is about mistunings. Still, we feel that all problems can and will be solved, and that in spite of what it thinks it wants to do, we (I) can force it to do what we (I) want it to do. Amen.

On 10/29/81 we pulled a lower stem and found the water leak. It will be fixed, the various protective circuits restored, the transmitter tuners stabilized, a "3 dee amplitude" knob installed and other good things done.

We will install anode RF spark gaps, set to 20 kV, to shut off all transmitters if one has more then 20 kV delivered to it (this is done via the photosensitive transistor spark detectors). We will replace the air transmitter fine tuner capacitors with vacuum capacitors, but this won't happen for another month (presumably after "beamtime").

And then, each night, we kneel down and pray that the big pumpkin will come at night and fix everything up right!