214-0017-01-01_00

9/23/77
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Dee-Insulator Design & Other

1. Gleanings from Q. Kerns of FNAL

Quentin Kerns, the electronics genius from FNAL and previously Berkeley visited the laboratory on 9/21/77, and we were able to learn a great deal from him. He explained the design of the main ring FNAL rf cavity insulators. The latest version uses 99.5% purity alumina cylinders, 15" OD by 9" long and operate at 60 KV peak, one side in air, the other in vacuum, at 50 MHz, but with a 25% duty factor. These insulators previously failed due to overheating when only 95% purity alumina was used. The difference in Q was a factor of 8 between the 95% and the 99.5% purity alumina, so it seems that if the 95% alumina was marginal, then successful operation at 84 KV and 100% duty factor would be equally marginal at 50 mHz. However, these insulators were 1/2 inch thick, and the losses are proportional to frequency. So at 15 mHz, using a 3/16" thick insulator, we extrapolate to marginal operation of 200 KV cw, and then we can blow air on the insulator. So it seems that the insulator should not fail due to dielectric heating. There are, however, three other possible failure modes. The most serious is the ohmic heating of the metalized surfaces bonded to the ceramic. These surfaces (not pure copper), with an unknown resistivity will heat up due to the large currents required to flow over them. This is the main reason why as large a diameter insulator as otherwise feasible should be used, thus reducing the current density. The way to hopefully reduce this problem to oblivion is to water cool the copper as close to the insulator as is feasible. A third possible mode of failure would be due to multipactoring on the vacuum side. Multipactoring phenomena on metallic conductors is fairly well understood, but with insulators the situation becomes more complicated due to the fact that a certain patch of insulator surface when emitting more electrons than bombard it, becomes positively charged, thus attracting ever more electrons. However, this multipactoring problem becomes, if anything, less, with the high gradients we will be using.

The fourth and most disastrous failure mechanism is sparking, either on the vacuum or air side. On the air side it is necessary to use corona rings to reduce the maximum gradients to less than 30 KV/cm, and to shield the ceramic to metal contact region. This should be possible with a proper design. Even so, a cosmic ray shower, or inadvertent dust particle may trigger a spark, and it is then necessary to monitor the occurrence of such a spark and immediately shut off the rf so that no damage occurs. This puts the onus on the rf engineer, but is solveable. Similarly, a spark on the vacuum side must be speedily detected and the rf turned off.

The simplest and most universal method of detecting such a spark, either on the vacuum or air side is by employing a -dV/dt detector. A -dV/dt detector to cut off the rf drive was already in the design, but Kern's work on this subject points up the desirability of making the frequency response of the voltage detector at least 1 MHz and the -dV/dt detector very sensitive. He mentioned the number $\Delta V=5\%$ of V. It is believed all this is possible so long as no one coughs.

The other important design feature of the insulator imparted to us by Kerns was that the insulator should always be in compression, even when the vacuum side is down to air. So we will design this feature in. (Tsch.)

Turning to other things, Kerns overcorroborated my opinion that power supply manufacturers wouldn't understand how to design the output circuitry of the final power supply and that we must stipulate that either an empty space be left for it, or that they build it exactly to our design.

In regard to the "conceptual design" employing single side band and quadrature outputs from the synthesizer he wasn't enthusiastic at first. But when it was explained that the overriding purpose was to permit all servo loops to be functional over a thousand to one dee voltage range he saw the light and agreed. He had previously built limiting non-phase shifting amplifiers over a broad band range and admitted it would be easier at a constant 2MHz frequency. Further, we discussed how to build a fast voltage detector and he showed me an example superior to what I had planned. We were discussing the fundamental reasons why phase detectors were intrinsically faster and more accurate than amplitude detectors: namely by virtue of their ability to achieve the same up-rate as down-rate because of coherent detection, and the diodes being turned "on" each cycle independent of the amplitude of one of the signals. Then it dawned on us that, with the aid of the single sideband signals, and knowledge of the phase, coherent amplitude detection was also possible. So, perhaps we will have a better and certainly faster amplitude detector.

Then we turned to the sliding finger contacts on the moveable short circuit, now in air. Kerns "felt" that it would be desirable to remove the contact when moving the short. He also suggested that the outer conductor be split in tridents, and at the splits shielded insets could accommodate the glass rope, or perhaps even metal lead screws to move the short. It is an interesting idea which we will pursue. On his return to FNAL, Kerns agreed to send us detailed drawings of the insulator and corona shield, and a bidders list for power supplies.

2. The Hi Q Model Tests

On my return the Hi Q Model, designed to study the problem of 3ϕ operation, was complete. The circuits were capable of being tuned, by moving the stem shorts, from 39 to 120 MHz. The Q was approximately 3000 as compared with the calculated value of 5000. Kerns reported that this sort of discrepancy had been his experience too. He attributed it to a skin resistance lower than what would be calculated from the resistivity of copper. So we will use a 50% bugger factor in our power estimates!

The 15-year old Moog servoe hydraulic valves didn't work as well as they had previously, but after being exercised awhile, they improved. It immediately became obvious that I had made a mistake: the motion to cover the resonance was hardly detectable. The capacitors were too large. Even so we accomplished a lot. The position servoes worked, albeit imperfectly, the phase detectors worked. The drive coupling capacitors could be adjusted to achieve zero standing wave ratio in the drive lines. Incidentally, when talking to Kerns about buying or inventing directional couplers, he recommended the method employed here, of simply putting in three or four amplitude detectors in the line and adjusting the coupling capacitor for unity standing wave ratio. After the initial measurements over the frequency range, the computer could simply set these capacitors from a look-up table, as the necessary precision requirement is only about 20%.

So we have a little setback here. The capacitors are to be replaced with a parallel plate capacitor capable of accomplishing ±0.1% frequency change when the moog pistons exercise a motion of ±0.2". Mr. Francis and Mr. Lawton will execute these simple changes during the next week, and Francis will then demonstrate ? the feasibility of 3ϕ operation!

3. Synthesizer

The specifications for the synthesizer were composed in Arkansas and are ready to be typed up. The following manufacturers are to be asked to bid on making it and if anyone can think of some vendor to add to this list, please inform us.

Hewlett Packard
General Radio
John Fluke Instruments

4. Transmitter

Now that the frequency range has been reduced to a top frequency of 35 MHz (or 30), the 4CS100,000D output tube, the same as presently used on the existing cyclotron, will be satisfactory. A calculation of drive requirements shows that perhaps only a drive voltage of 200 volts rms will be required. One 4CW800B can thus supply the drive requirements, and it in turn can be driven by a 100 watt solid state broadband commercially available amplifier.

5 ~~4~~. Galling Tester

It seems that, perhaps, a galling tester is no longer necessary. D. Cole has, finally, come up with something. He has determined (ce vrai?) that the coefficient of friction of a rhodium plated polished silver surface on his best electro-polished copper surface is .5, compared to a value of .1 on a crocus cloth mechanically scrubbed copper surface. So it would seem that yearly mechanically polishing the copper surface (to remove oxide build-up) would suffice.

6 ~~5~~. The Moving Short

R. Burleigh has come up with a magnificent design for a walking short in vacuuo. Unfortunately it was very complicated and expensive to build. So before he left, two weeks ago, we agreed to throw out the walking part of it and go for push rods enclosed in long bellows. Now that the short will be in air, a question arises as to whether the still very complicated short itself should be used. The reason for most of the complications in the nanopole construction was to accommodate ±1/8 inch variations in the spacing between the inner and outer conductors of the stem line. Now hear this: I personally have seen many examples of burned up sliding shorts and the grizzly consequences thereof; and in every case these disasters were due to, initially, just one of the many fingers making only indifferent contact! I could go on and on on this subject, but at the moment, after due deliberation, I believe Burleigh's complicated design should be adopted. However I am willing to leave it as it is and not put the extra complications in it attendent on relieving the force when moving the short. We can replace the fingers yearly if they show signs of wearing out.